Report on Cost/Energy curves calculation

D3.3. of WP3 of the Entranze Project

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ENTRANZE Project

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EEG	Energy Economics Group Institute of Power Systems and Energy Economics Vienna University of Technology
NCRC	National Consumer Research Centre
Fraunhofer	Fraunhofer Society for the advancement of applied research
CENER	National Renewable Energy Centre
eERG	end use Efficiency Research Group, Politecnico di Milano
Oeko	Öko-Institut
SOFENA	Sofia Energy Agency
BPIE	Buildings Performance Institute Europe
Enerdata	Enerdata
SEVEn	SEVEn, The Energy Efficiency Center

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The ENTRANZE project

The objective of the ENTRANZE project is to actively support policy making by providing the required data, analysis and guidelines to achieve a fast and strong penetration of nZEB and RES-H/C within the existing national building stocks. The project intends to connect building experts from European research and academia to national decision makers and key stakeholders with a view to build ambitious, but reality proof, policies and roadmaps.

The core part of the project is the dialogue with policy makers and experts and will focus on nine countries, covering >60% of the EU-27 building stock. Data, scenarios and recommendations will also be provided for EU-27 (+ Croatia and Serbia).

This report presents the Cost/Energy curves calculation for renovated buildings in residential and tertiary sectors, for considered EU countries. An overview of the calculation methodology is given. Cost/Energy curves are presented and assessed in several analysis, with indications for the selection of cost-optimal and nearly zero energy EE and RES technologies/strategies for different building. The report presents also an assessment of curve sensitivity with respect to the economic input data.

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Executive Summary

1.1 Introduction

This report presents the Cost/Energy curves calculation and analysis focusing on renovated buildings in residential and tertiary sector.

Existing buildings refurbishments play a crucial role to reach energetic and environmental targets for Europe. For this, nearly zero energy strategies, cost optimal interventions, and their relations have to be explored also for renovation buildings, both in residential and in tertiary sectors.

The comparative methodology in accordance with Article 5 and Annex III of Directive 2010/31/EU [European Parliament And Council 2010], EU Guidelines [European Commission 2012a] and Regulation (EU) N° 244/2012 [European Commission 2012b] represent a useful example for Member States while drafting their national plans for increasing the penetration of nearly zero-energy buildings. In ENTRANZE project we focus the attention on the renovation of existing buildings. The methodology's main objective is to support Member States in transparently expressing the meaning and ambition level of requirements for nearly zero-energy buildings for different climates and building types. It also may be used by the European Commission as a guiding tool for analysing those plans and requirements.

In the presented cost/energy curve calculation, we adopted a methodology for analysing and presenting data about performance of nearly zero energy buildings, which offers utmost transparency. It can serve as an example for ways to analyse and display the technological and economic features of the "nearly zero-energy area", the "cost-optimal area" and trends resulting from changes in energy and component prices, primary energy factors and progress in the efficiency of components (not considered here) between 2011 and 2020.
Cost/Energy curves are presented and assessed in several analysis, with indications for the selection of cost-optimal and nearly zero energy EE and RES technologies/strategies for different building typologies. The report presents also an assessment of curve sensitivity with respect to the main economic input data.

1.2 Calculation methodology of Cost/Energy Performance

In order to be consistent with the EU process of implementation of EPBD and allow a discussion on the relationship between nearly zero-energy and cost-optimal, our methodology is coherent with the cost-optimal methodology framework.

In accordance with Article 5 and Annex III of Directive 2010/31/EU [European Parliament And Council 2010], EU Guidelines [European Commission 2012a] and Regulation (EU) N° 244/2012 [European Commission 2012b], the Commission established a com-

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parative methodology framework to be used by Member States for calculating cost optimal levels of minimum energy performance requirements for new and existing buildings and building elements. The methodology specifies how to compare energy efficiency measures, measures incorporating renewable energy sources and packages of such measures in relation to their energy performance and the cost attributed to their implementation and how to apply these to selected reference buildings with the aim of identifying cost-optimal levels. The complete process to assess and report on cost optimal levels for energy performance requirements of buildings is described in Figure 20.

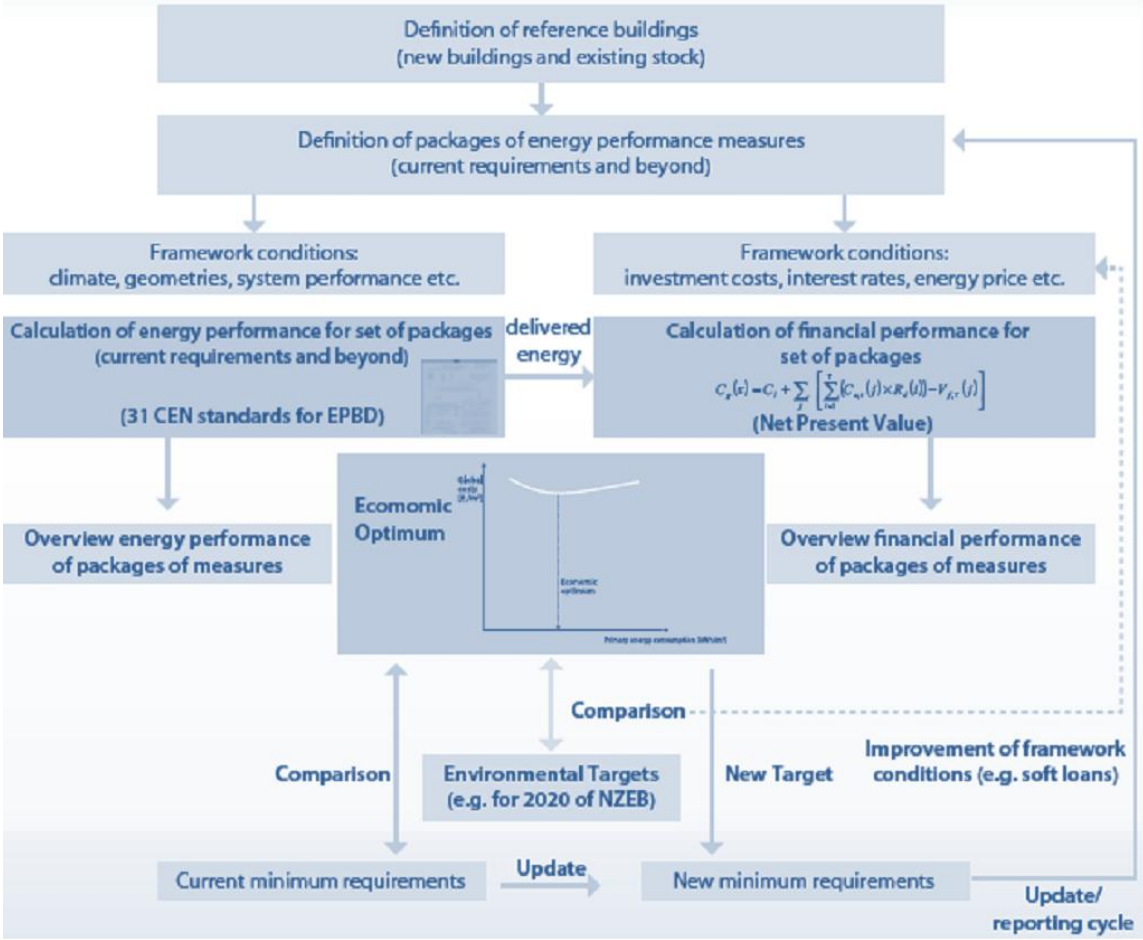

Figure 1. Flowchart comparative methodology. Reproduced from [BPIE 2010]

The detailed calculation methodology for energy performance and global cost proposed by the EU Regulation N° 244/2012 [European Commission 2012b] and the Commission's Guidelines [European Commission 2012a], can be summarized *via* the following Figure 2 and Figure 22. Note that the time interval on which the balance is calculated (e.g. a day, a month, a year) should always be explicitly stated. In our case we perform a yearly energy balance.

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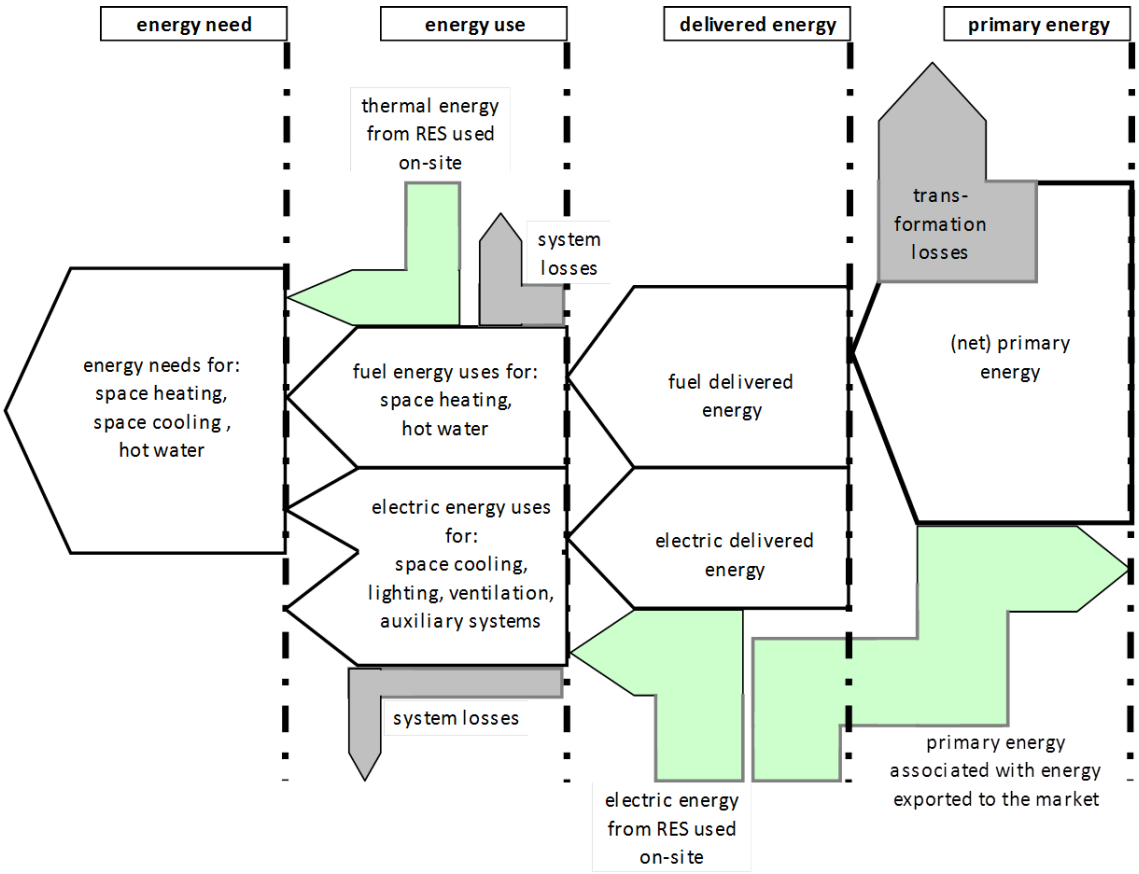

Figure 2. Scheme of calculation of the (net) primary energy demand resulting from the application of measures and packages of measures to a reference building.

In particular, about the energy performance calculation, we are performing the following steps:

1. Selection of efficiency technical solutions and their grouping into typical **packages** (since very often these technical solutions are not used as stand-alone measures but in combination with other measures), based on the definition of the reference base case.
2. Calculation of **energy needs** for heating and cooling and energy use for lighting for main models of buildings (building variants) for which simulations are performed where the selected energy efficiency envelope technologies and combinations thereof are implemented; we carried out this quantitative assessment by dynamic simulations (by using the EnergyPlus software).
3. Generation of all **building models**, which can be also indicated as “building families” by variation of energy efficiency measures for envelope and system technologies for each building variants: “building families” are equal to groups of envelope packages (building variants) related to opaque envelop - indicated with (e) in the Deliverable, glazing and air tightness (w), passive cooling tech-

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niques (c) and efficient lighting strategies (L), plus plant variants verifying whose system architecture is coherent.

4. Calculation of **delivered energy** values for each building model; the energy saving assessment are performed by associating appropriate performance co-efficients to each plant type, in accordance with EN standards and other bibliographic references.
5. Calculation of energy uses for **auxiliary systems** are calculated through a simplified dimensioning.
6. In the models where is implemented a mechanical ventilation system (with or without heat recovery) energy uses for **fans** are calculated.
7. Inclusion of energy generation from **RES** systems (such as solar thermal panels, photovoltaic (PV) panels, heat pumps[1] and biomass boilers) by simple estimation methods and calculation of **net** (**over a time laps of one year**) primary energy consumption for the entire building; the delivered-to-primary conversion factors of the different countries/regions are taken into account.

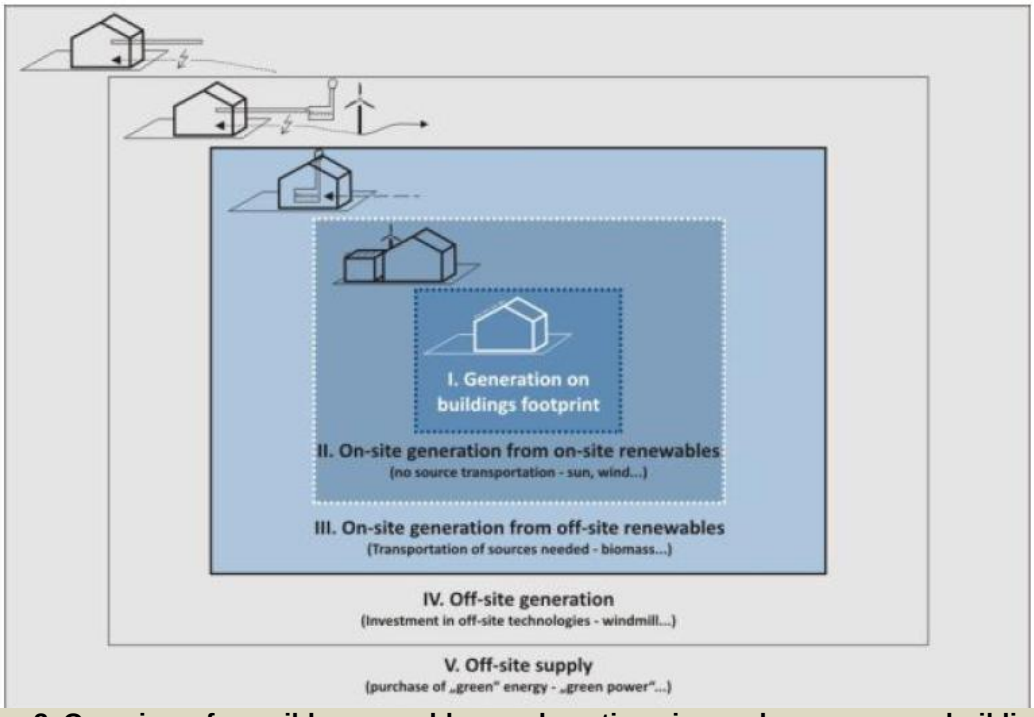

Figure 3. Overview of possible renewable supply options in nearly zero energy buildings, reproduced from [Marszal.2011].

[1] About renewable contributions from heat pumps: heat pump systems were considered as "on-site generation from on-site renewables" with limits and method according to EU Commission Decision 2013//114/UE (1/3/2013).

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The term (**net)** primary energy means – as recommended in 2012/C 115/01, page 10 [EU 2012] – the result of the following steps:

8. Calculation of the **primary energy** associated with the delivered energy, using national conversion factors;
9. Calculation of primary energy associated with energy exported to the market (e.g. generated by RES or co-generators on-site);
10. Calculation of (net) primary energy as the difference between the two previous calculated amounts: (8) - (9).

For the selected climate conditions and building prototypes, the energy needs for heating and cooling, the delivered energy for heating, cooling, hot water and lighting, and finally the net primary energy are calculated for each variant and "building family" .

We consider the "Net ZEB limited" definition, that is we calculate the net primary energy (over a yearly balance, and using symmetric weighting for exported energy from building systems to grid) associated to heating, cooling, domestic hot water, ventilation, auxiliaries, lighting, but we exclude the electric consumption of appliances and other plug loads (although we consider their effects on thermal energy needs). For the sake of comparison, we consider lighting both in non-residential and residential buildings.

The overall methodology includes the following main steps:

- For the main models of buildings (head-models) where the selected Energy Efficiency **envelope technologies** and combinations thereof are implemented, calculation of the energy needs for heating and cooling are executed by using the dynamic simulation software EnergyPlus (in order to correctly take into account dynamic phenomena connected to energy storage and release connected to thermal mass, as required by EPBD and as physically relevant due to variable weather conditions and internal loads).
- Generation of "building families" by variation of Energy Efficient **system/plant technologies** for each head-model and calculation of delivered energy values for each "building family"; the assessment has been performed by associating appropriate performance coefficients to each plant type (including generation, distribution and emission efficiency values).
- For the buildings that include RES plants, calculation of the **amount of renewable energy generated** and calculation of net (over a time lapse of one year) primary energy consumption for all "building families"; the conversion factors of delivered energy to primary energy in the different countries/regions has been taken into account.

- Association of installation **costs** to each technology, including material and labour costs, remove and disposal of existing technologies, business profit and general expenditure.
- Calculation of **global costs**, including capital costs, substitution costs, annual maintenance costs, operating energy costs, over a period of 30 years (subtracting final value), all discounted to year zero (where year zero is either 2011 or 2020). For the sake of comparison, we consider a period of 30 years both in non-residential and residential buildings.
- Note that embedded energy (also called grey energy) is not included in the calculation, which does not exclude the possibility that a MS might decide to include it in the definition and calculation.

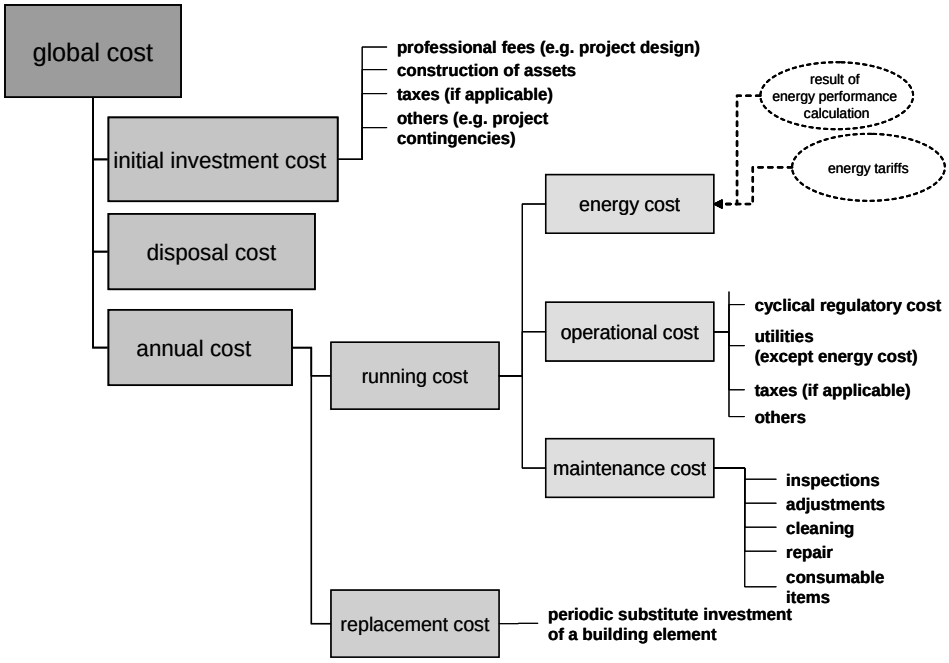

Figure 4. All costs considered in the performed global cost calculations.

Costs of construction not directly related to energy (structure, finishing materials, etc.) are not considering in this analysis We have assumed no subsidies hence PV energy is supposed to be sold to the grid at a price comparable to that of conventional generation sources on the wholesale market. Costs of land, property taxes etc. are not included.

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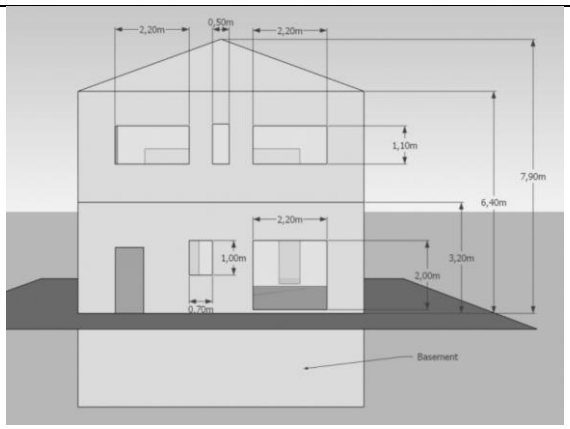
1.3 Reference Buildings

The comparative methodology it has been applied at four category of buildings. The reference building selected are different for use, geometry, envelope and plant system characteristics. For the purpose of the ENTRANZE project we select this four building typologies:

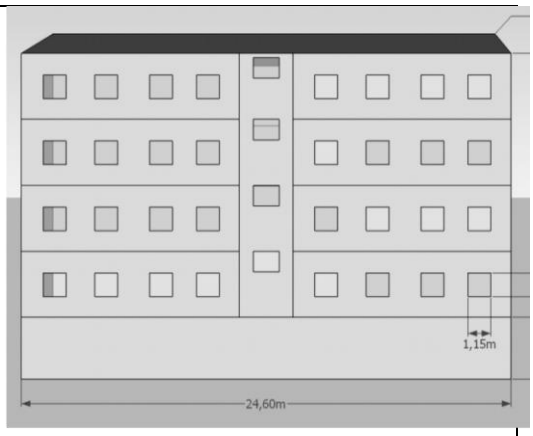
- Single House: composed by an under ground level and two floors over ground level) has a conditioned surface of about 140 m^2 and a S/V ratio of 0,7.
- Apartment Block: composed by four floors and an under ground level. The reference number of apartments is 12 and its conditioned area is around 1000 m^2 and a S/V of 0,33.
- Office: a medium-size and highly-glazed office building, with 5 floors (of 3 m height each) an S/V ratio of 0,33 and a net heated area of 2400 m^2.
- School: a medium-size and highly-glazed school building, with 2 floors (of 3 m height each) an S/V ratio of 0,46 and a net heated area of 3500 m^2

All the considered reference buildings have an ground floor toward an unconditioned basement and the last slab toward an unconditioned space between the last slab and the "slope roof". The office building is an exception, its last slab it is also the roof (plane roof).

Below some indicative pictures of geometrical models.



Single House



Apartment Block

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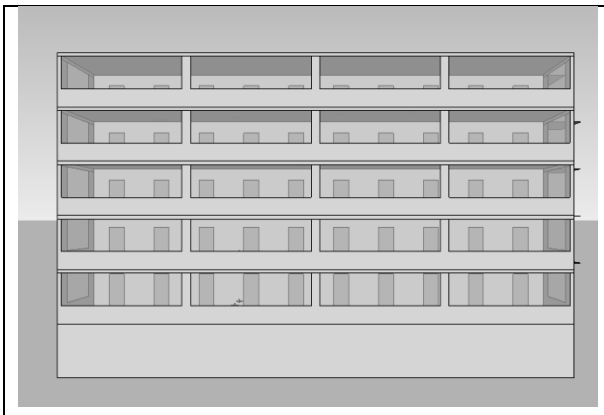
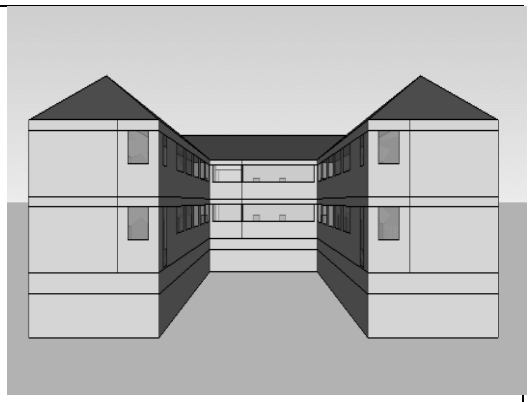
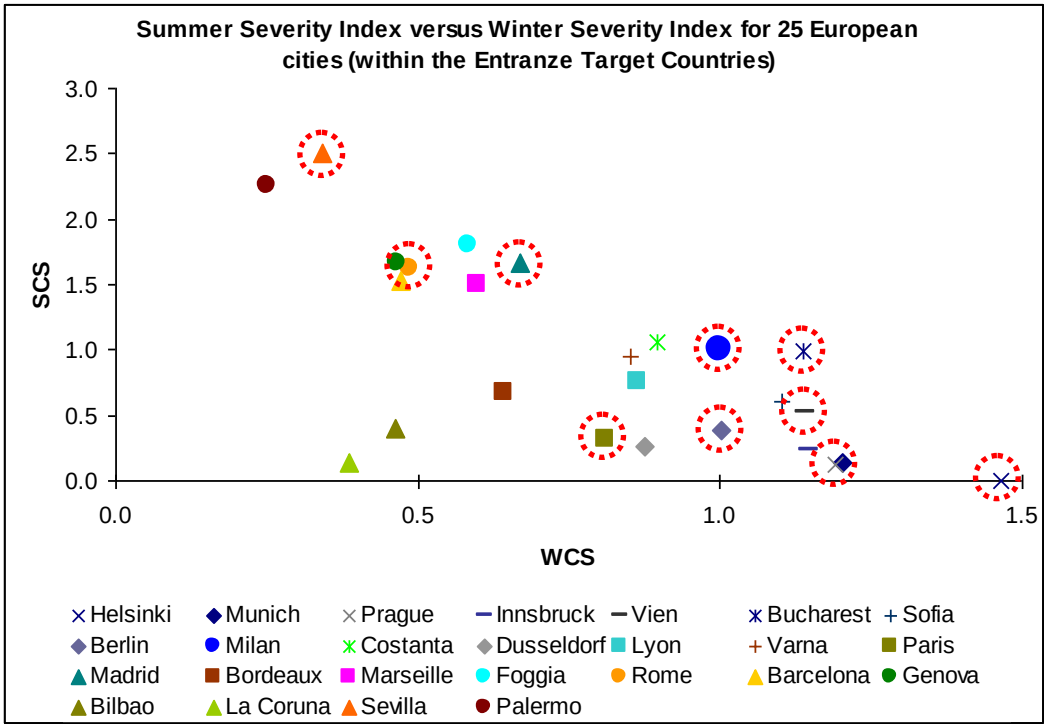
	
Office	School

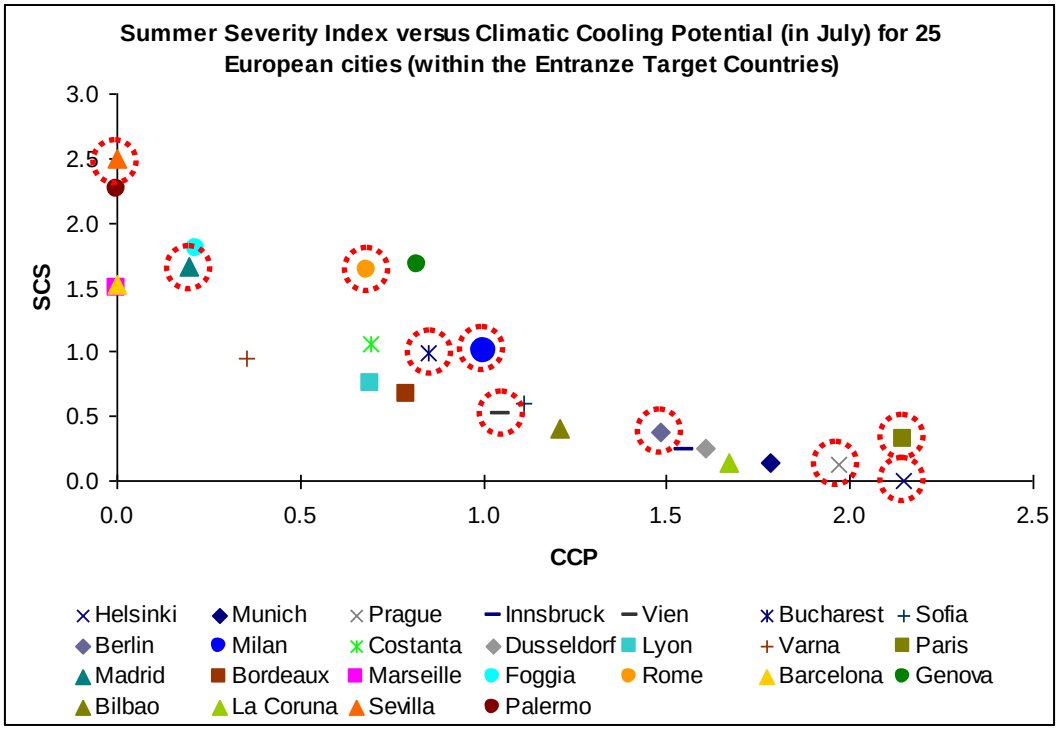
The physical property of envelope components (wall, roof/last slab, basement, windows) and plant system configurations (for heating and cooling) of the building before the renovation works are different for each target country. Each partner had to characterize every type of building in term U-value of opaque and transparent envelope (indicating the layers of wall, roof and basement and the characteristic of window systems) and to indicate the more probable configuration of heating and cooling systems (generator, emission system, regulation, RES technologies etc.).

1.4 Target Countries and climatic contexts

We focused our calculations and analysis on 10 key climatic conditions within the European area of all Entranze project target countries. As reference indicators for climate contexts have been used the Winter Severity Index and the Summer Severity Index proposed by F. Sanchez de la Florthe (2005), as well the Climatic Cooling Potential by Artmann (2007). We calculated this indexes for 25 cities, within the Entranze Target Countries, selected in function of the nominal climatic characteristics, the availability of homogeneous climatic data (IWEC[2]) and their relevance (in terms of urban population).

[2] The International Weather for Energy Calculations (IWEC) are the result of ASHRAE Research Project 1015 by Numerical Logics and Bodycote Materials Testing Canada for ASHRAE Technical Committee 4.2 Weather Information. The IWEC data files are 'typical' weather files suitable for use with building energy simulation programs, derived from up to 18 years of DATSAV3 hourly weather data.





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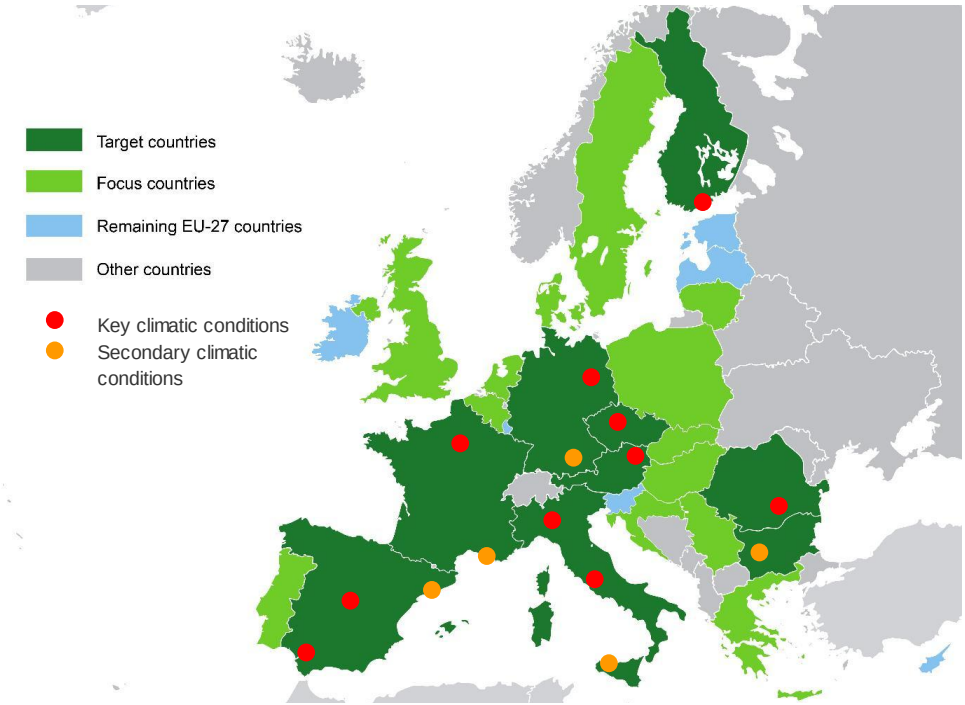
Analysing the obtained data we selected the following locations as key climate conditions:

Context	Climatic characterisation
Seville (ES)	Mediterranean climate (hot summer subtype) with very low climatic cooling potential (extreme summer conditions)
Madrid (ES)	Semi-arid climate with low climatic cooling potential
Rome (IT)	Mediterranean climate (warm summer subtype) with medium climatic cooling potential
Milan (IT)	Humid subtropical climate with medium climatic cooling potential
Bucharest (RO)	Humid continental (hot summer subtype) / Subarctic climate with medium climatic cooling potential
Vienna (AT)	Humid continental climate (warm summer subtype) with high climatic cooling potential
Paris (FR)	Oceanic climate with very high climatic cooling potential
Prague (CZ)	Humid continental climate (warm summer subtype) with high climatic cooling potential
Berlin (DE)	Humid continental climate (warm summer subtype) with high climatic cooling potential
Helsinki (FI)	Humid continental / Subarctic climate (extreme winter conditions)



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1.5 Input for Cost/Energy calculation

A major effort was done in order to collect, for every target country, the initial data necessary to generate the cost/energy clouds and its correlated studies. This phase involved an important number of the expert in every target country for the definition of characteristics of base case buildings. Specifically, all the partner, had to define the technology of envelope elements (layers ad physique properties of walls, roofs, slabs in contact with unconditioned spaces, windows) of existing buildings for every type of building simulated (single house, apartment block, office and school) and the more common and probable strategies and technique of renovation. The same work was conducted for system plants.

Table 1. Example of considered envelope measures families for Single House.

SINGLE HOUSE				VIENNA		PARIS		PRAGUE		BERLIN		HELSINKY	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m^{2}K	e:-	1,25	e:-	1,54	e:-	1,34	e:-	0,93	e:-	0,48
	Roof	U	W/m^{2}K		1,38		1,21		1,33		1,11		0,30
	Basement	U	W/m^{2}K		1,80		1,98		1,24		1,02		0,48
	External Wall	U	W/m^{2}K	e:o	0,30	e:o	0,32	e:o	0,31	e:o	0,28	e:o	0,22
	Roof	U	W/m^{2}K		0,22		0,22		0,22		0,22		0,14
	Basement	U	W/m^{2}K		0,55		0,57		0,49		0,45		0,48
	External Wall	U	W/m^{2}K	e:o+	0,22	e:o+	0,23	e:o+	0,22	e:o+	0,21	e:o+	0,17
	Roof	U	W/m^{2}K		0,17		0,17		0,17		0,17		0,12
	Basement	U	W/m^{2}K		0,33		0,33		0,30		0,29		0,48
	External Wall	U	W/m^{2}K	e:+	0,17	e:+	0,18	e:+	0,17	e:+	0,16	e:+	0,17
	Roof	U	W/m^{2}K		0,12		0,12		0,12		0,12		0,09
	Basement	U	W/m^{2}K		0,23		0,24		0,22		0,21		0,48
WINDOWS	Window Air permeability	U *	W/m^{2}K	w:o	2,62	w:-	3,47	w:o	2,66	w:o	2,67	w:o	2,50
		Solar Trasm.	-		0,62		0,62		0,62		0,62		0,61
		Visible Trasm	-		0,65		0,65		0,65		0,65		0,65
		air infiltration	1/h		0,77		0,77		0,77		0,77		0,77
	Window Air permeability	U *	W/m^{2}K	w:o+	1,71	w:o	2,60	w:o+	1,71	w:+	1,03	w:+	1,03
		Solar Trasm.	-		0,64		0,62		0,64		0,55		0,55
		Visible Trasm	-		0,65		0,65		0,65		0,59		0,59
		air infiltration	1/h		0,58		0,61		0,58		0,58		0,58
	Window Air permeability	U *	W/m^{2}K	w:+	1,03	w:o+	1,71	w:+	1,03	w:+	0,70	w:+	0,70
		Solar Trasm.	-		0,55		0,64		0,55		0,50		0,50
		Visible Trasm	-		0,59		0,65		0,59		0,59		0,59
		air infiltration	1/h		0,58		0,58		0,58		0,58		0,58
COOLING STRATEGIES	Solar shading	-	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m^2		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										
	Solar shading	-	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-
	Night-Cooling	h^{-1}	1/h		4,0		4,0		4,0		4,0		4,0
	Lighting Load	power **	W/m^2		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										

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In addition has been requested at all partner to indicate the typology of thermal bridges to consider in the construction of building energy models.

For every considered technology, the partners, with costs experts' support, built a cost database needed for global cost calculation. The costs was expressed as material costs, labour costs, general expenditure, business profit, professional fees, additional cost for removal and disposal (when request). In this studies we consider the cost linked at work that can have effects on buildings energy demand after renovation. Every cost include all the works necessary to complete the energy efficiency measure as from "art rule".

About primary energy calculation it defined for every target country and energy carrier the respective primary energy factor. The POLES [Enerdata.2007] simulation provide the trend of primary energy factor for electricity till 2030.

In parallel at the simulation task of the energy needs and use by software or simplified methods, all the economical data was collected or modelled:

- Energy prices scenarios for gas, electricity, district heating and biomass. The Poles scenarios provided energy prices trends till 2050 in a reference scenarios and in an ambitious scenarios.
- The price of electric energy produced by a photovoltaic system and exported in the grid.
- The cost of externalities express as €/$C0_2$ necessary to simulate a macroeconomic perspective.
- The value of VAT taxes for every target country.
- The taxes applied at energy prices.
- The nominal interest rate and the inflation rate.

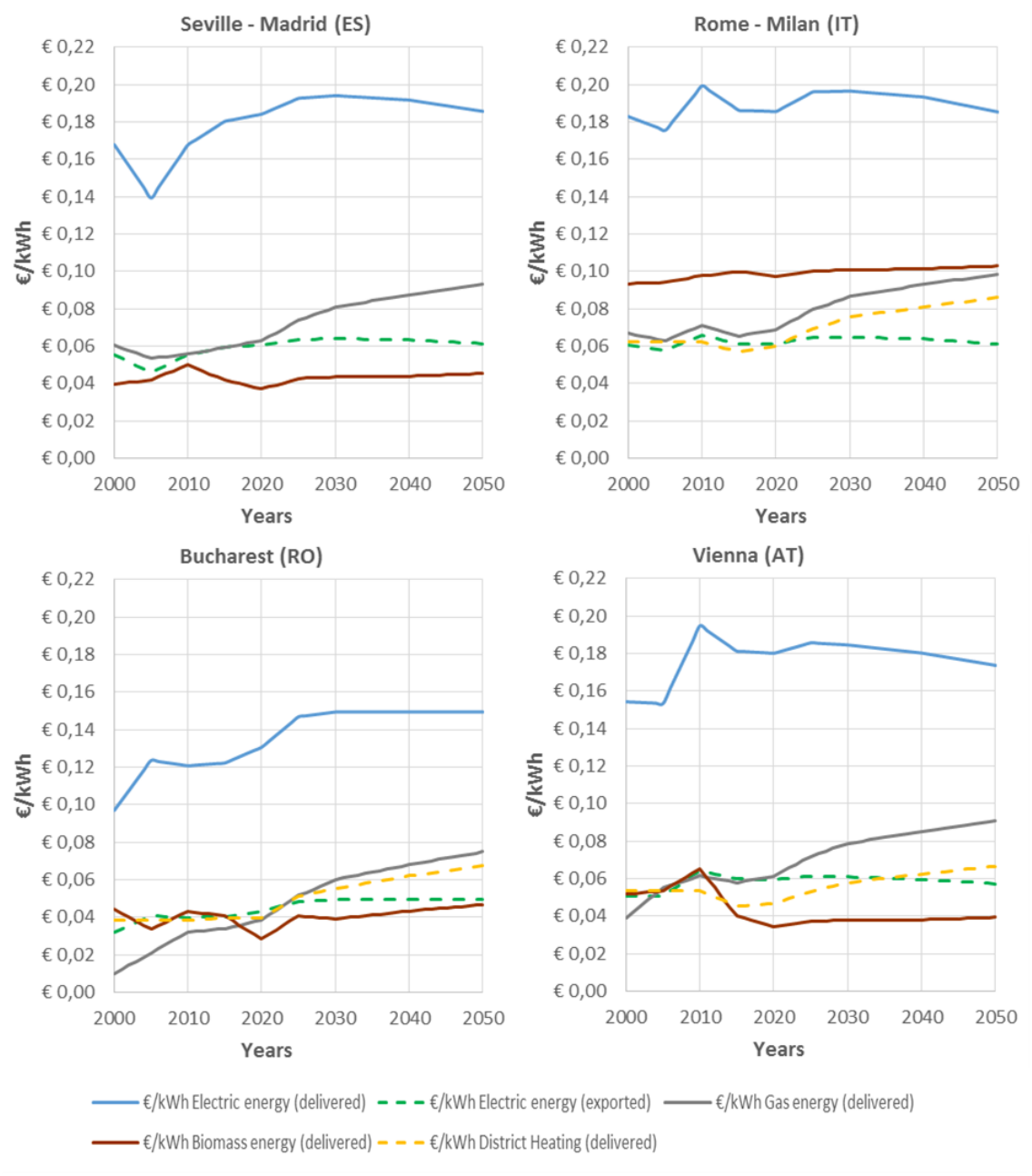

Figure 5. Example of reference energy prices scenarios (Spain, Italy, Romania and Austria).

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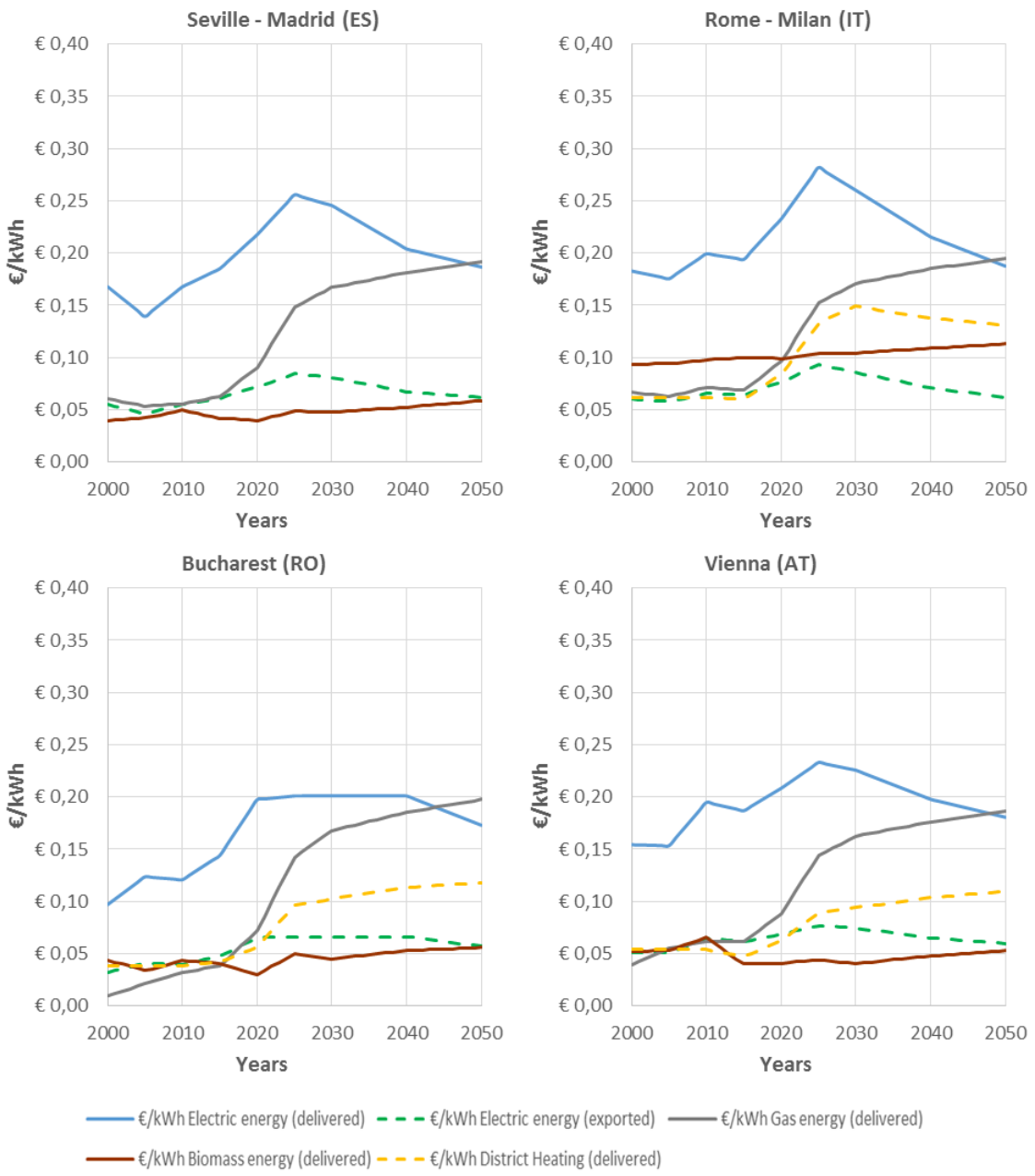

Figure 6. Example of ambitious energy prices scenarios (Spain, Italy, Romania and Austria).

Considering values ranges of this data, we performed a sensitivity analysis respect to the calculation starting year (2011 or 2020), the energy prices scenarios (reference or ambitious scenario), economical perspective in the interested zone (the zone between the right extreme of cost optimal zone and the nZEB zone). All sensitivity analysis were presented in the Annex of this deliverable.

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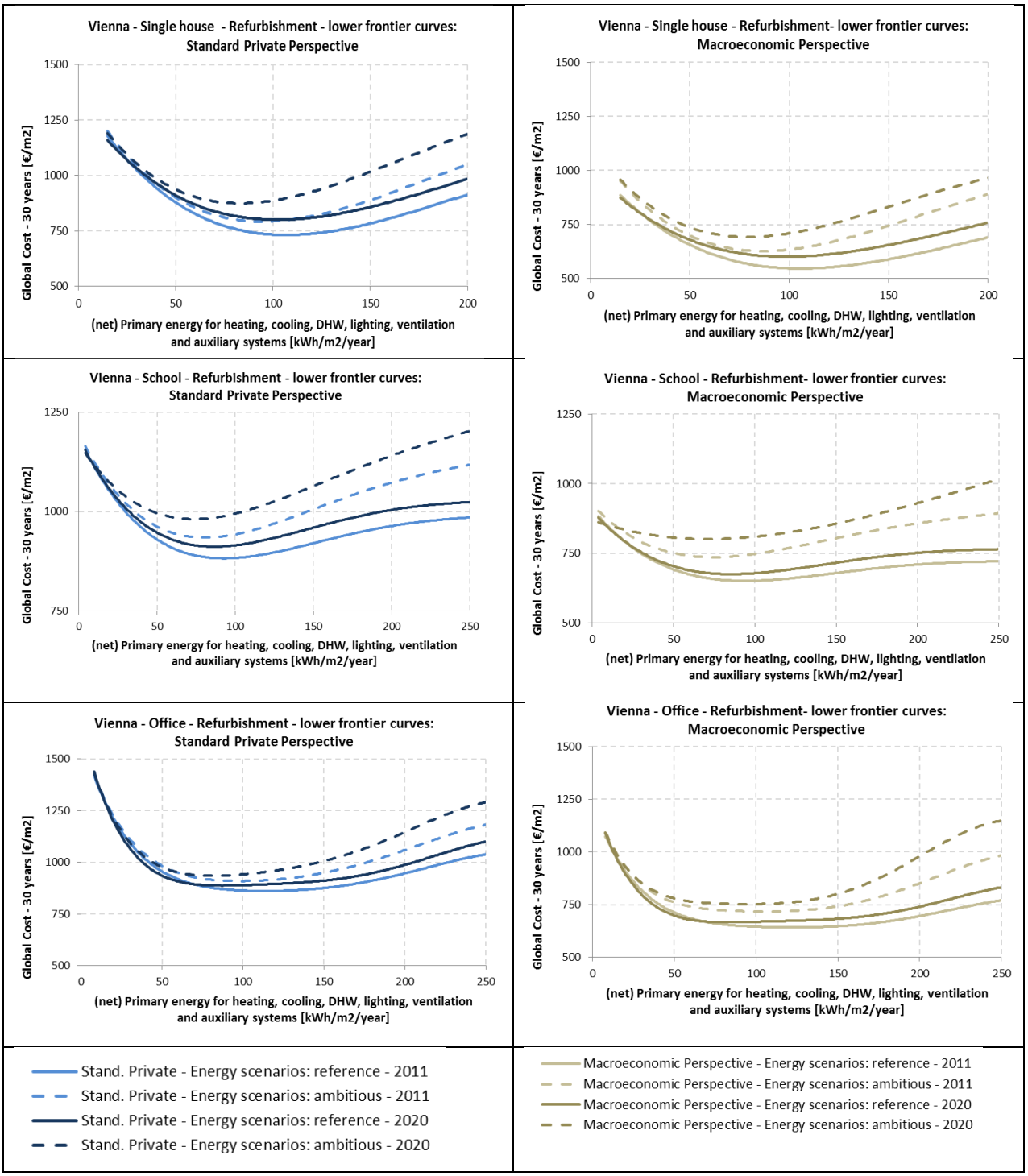

Figure 7. Example of sensitivity analysis on starting year, energy scenarios and economical perspective (Vienna).

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1.6 Main results

For every target country and building type, the main results consist in the definition of possible **targets of (net) primary energy** representative of the "**cost optimal**" (a) and "**nearly Zero Energy Buildings**" (b) solutions for buildings **renovations**. In addition to this two energy/costs targets, we defined two further levels (c and d) of possible renovation expressed as fixed percentages of reduction in (net) primary energy respect to the base refurbishment level with minimum performance thresholds. Particularly the following four targets were considered:

a) Minimum global cost: possible *Cost optima*l target,
b) Minimum (net) primary energy: possible *nZEB* target,
c) 50% of reduction of (net) primary energy respect to base refurbishment level with threshold of 100 kWh/m^{2}y,
d) 75% of reduction of (net) primary energy respect to base refurbishment level with threshold of 50 kWh/m^{2}y.

The four targets allow to evaluate two different approaches in definition of energy performance requirements: an "**absolute**" criterion, based on identification of minimum or best values of global cost and (net) primary energy, and a "**relative**" one, where the energy savings targets are defined respect to the reference base refurbishment levels.

For each targets we selected a **complete refurbishment solution**, which corresponds to one building variants among all calculated ones (in other words to a dot of the cost/energy clouds developed. So the targets building selections are the result of a deep analysis of all cost/energy clouds plotted for every building type and country (see the Annex to this Deliverable). In the next page examples of cost/energy cloud are presented for renovation of single family houses in different climates. The graphs represent all building variants (envelope + systems measures) for each climate condition, the cost optimal target and encouraged range according EPBD, and the corresponding base refurbishment level.

The **base refurbishment level** (BRL) corresponds to the adoption of renovation measures only for aesthetic, functional and safety reasons of the same building components considered for renovation packages. In BRL the old generators and systems is replace with component of the same technology and with efficiency of current state of the market.

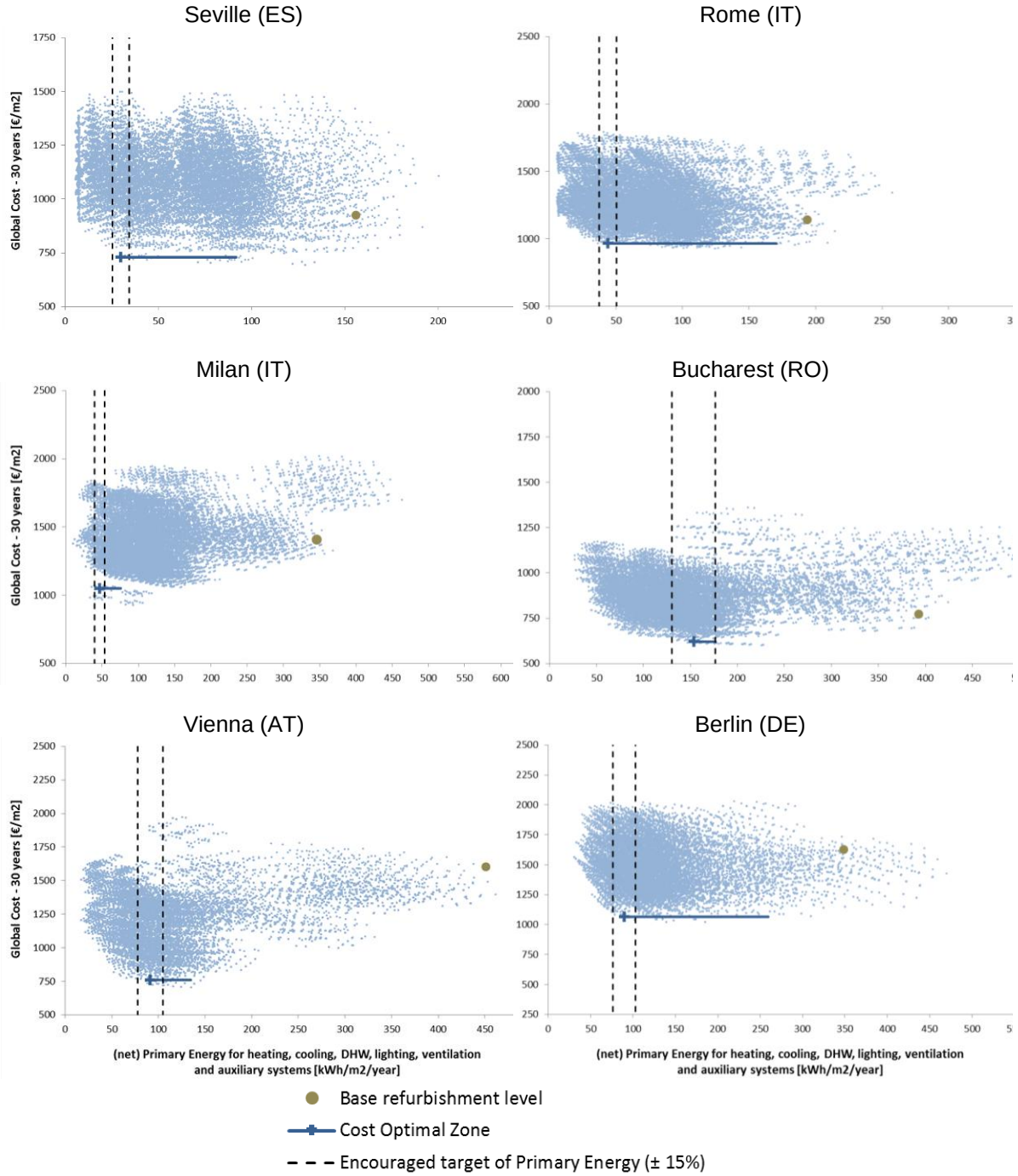

Figure 8. Example of Cost/Energy clouds - financial standard private perspective, reference energy prices (Single Family House).

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For the buildings selection, we considered small ranges around the targets, adopting the following steps.

1. Around every **net primary energy target** (a, b, c and d) we consider a range of ± 5 kWh/m^2/y.
2. In this net primary energy range, we considered all building/system variants whose global **cost increments is lower** than the 10% of the minimum global cost for that target (In this way we considered interesting ranges with various types of solutions and low global cost, closed to the lower frontier of cost-energy cloud).
3. The selected variants are further filtered, considering only the cases with heating plus cooling **energy needs** with a maximum increment of 10 kWh/m^2/y respect to the minimum values of the selected variants (in order to consider in details solutions with low energy needs adopting efficiency measured first).
4. At this point, we select the **best case** with the best value of net primary energy, energy needs for heating and cooling, energy use for lighting, and global cost.

All features (in term of Energy Efficiency Envelope strategies and combinations of systems) of the corresponding four selected buildings are shown and compared for all building types and climate contexts.

The graphs below show an example of results. For what concern the thermal transmittance (U value) of envelope components could be a bit different in the different countries: we have to consider that the renovation levels of different envelope packages are different for every countries for a more consistency of final results, according to information given by Entranze Partners on common refurbishment measures in each country.

As we can see in the following results in some cases different targets can be very close reaching to the same building selection. It could be a robust indication on the possible way to be followed. Of course this depend also by the energy performances of the base refurbishment levels.

We can see in some contexts we don't go below the 50 kWh/m^2/y threshold in net primary energy for apartment blocks. This because we assumed that efficiency strategies in lighting were not implemented in residential building types, and the corresponding energy demand is not reduce respect the base refurbishment level.

In addition for Helsinki (Finland) context, we decided to not improve the thermal transmittance of basement, according local stakeholders indications.

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For apartment blocks we have also more geometric constraints, as a lower roof surface available for renewable solar systems respect to the net overall floor area, respect to single family houses.

Complete descriptions were given for all selected target buildings. For each building type and climate a table shows corresponding values of net primary energy demand and energy needs, renewable energy systems contributions, cooling and lighting strategies, building envelope features and performances (thermal transmittance, air-tightness level, etc.), systems. We present an example of selection table in this chapter, and then all table in the deliverable (see Chapter 5)

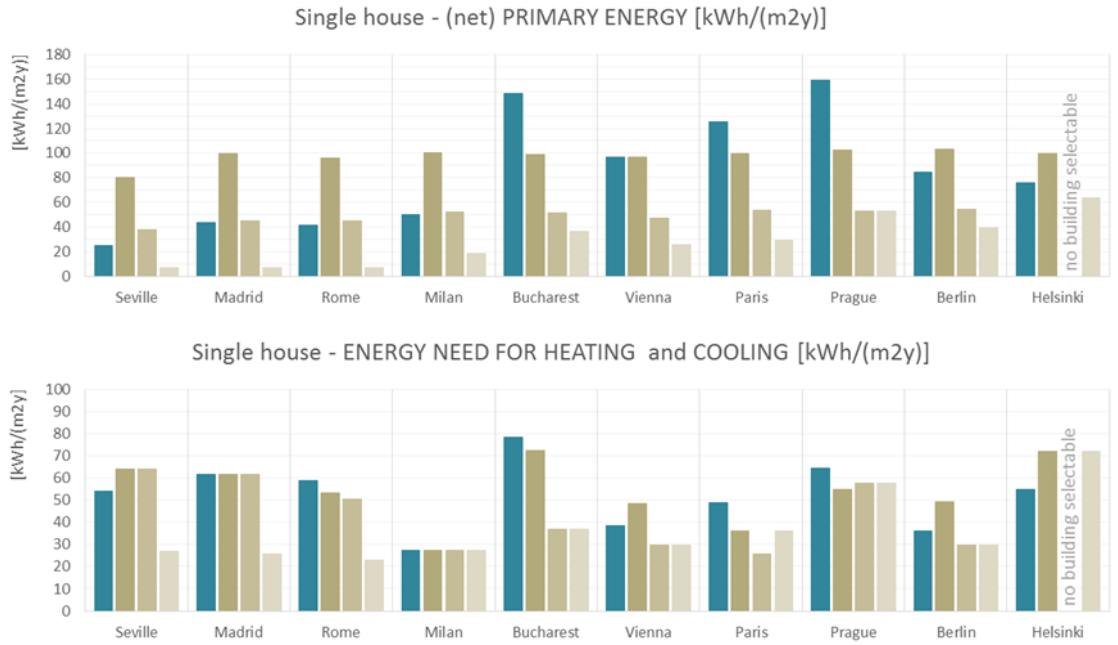

Figure 9. Cross comparison results of (net) primary energy demand and energy needs for heating plus cooling, for single house (All climates)

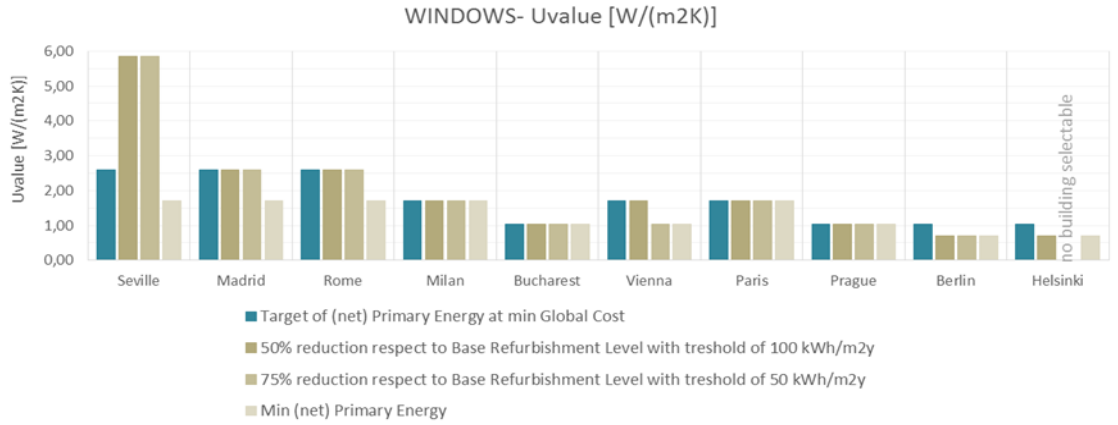

Figure 10. Cross comparison results for WINDOWS of single house (All climates)

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Figure 11. Cross comparison results for opaque envelope components single house

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Vienna SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	21		27		33		33	
OPAQUE ENVELOPE-Package:	++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	15cm insulation -External insulation (EIFS System)	0,22	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,17	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,33	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	+		+		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		n		n	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-
Night Ventilation for Cooling	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0
LIGHTING STRATEGIES :	n		n		n		n	
Lighting Loads	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
	No change	3,5	No change	3,5	No change	3,5	No change	3,5
Lighting Control	description:		description:		description:		description:	
	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	68	connection to a district heating	72	connection to a district heating	58	reversible ground source heat pump	58
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation oly for IAQ	0,05	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05
Heat Recovery	present	0,05	absent	-	present	0,05	present	0,05
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	38,4		48,5		29,6		29,6	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	13,6		13,6		13,6		13,6	
Energy Use for Lighting [kWh/m²y]	13,6		13,6		13,6		13,6	
(net) Primary Energy demand [kWh/m²y]	96,8		97,0		46,8		25,7	
RES contribution [kWh/m²y]	0,0		0,0		40,2		98,1	
Global Cost [€/m²]	791,9		747,3		893,0		1150,7	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	199,5							
Energy Need for Cooling [kWh/m²y]	10,5							
Energy Need for DHW [kWh/m²y]	13,6							
Energy Use for Lighting [kWh/m²y]	13,6							
(net) Primary Energy demand [kWh/m²y]	450,8							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1604,9							

Figure 12. Example of a complete description of selected building for the 4 targets (Single Family House in Vienna)

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In addition to the buildings selection with criteria presented above, we performed a more general analysis to show the ways to reach the cost optimal zone rather the zone with low (net) primary energy demand. This gave more general results on potential of all different measures available, which could represent open indications for policy makers and stakeholders on *cost-optimal* and *nZEB* solutions for renovations.

Larger areas were selected in cost/energy clouds in order to investigate the recurrence of envelope efficiency measures, the plant systems and RES solutions.
A "benchmark" analysis of the renovated building variants characterized by lower net primary energy consumption values and lower global costs over 30 years (considering financial - standard private perspective, with calculation starting year 2011 and 2020) was done.

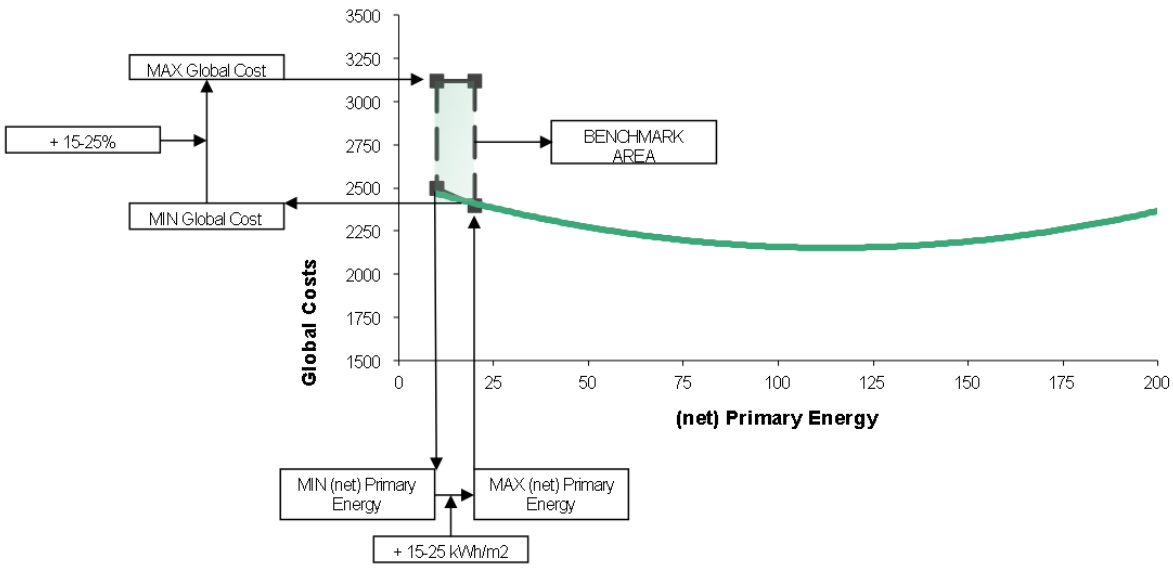

Figure 13. Steps to define the benchmark areas.

The "benchmark area" is determined in the following way:

- Determine the variant with minimum net primary energy (in min.(net) PE Zone) and with minimum global cost (in min. Global Cost Zone).
- Consider an increase of 15 to 25 kWh/m^{2}y (in (net) PE Zone) or of 10 to 15 kWh/m^{2}y (in min. Global Cost Zone).
- At this new level of net primary determine the variant with minimum global cost,
- Increase global cost by 10-25%.

The size of the area is adjusted in order to contain an amount of 150÷200 building variants, suitable for a statistical analysis on their features; these 200 best variants are

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then analysed and the frequency with which certain measures and packages was presented in bar plots.

This analysis gives an indication of the types of technologies that, for each building typology and climate and under the given assumptions for economic perspective, are available for reaching the “nearly zero-energy zone” or the “minimum global cost zone”.

Depending on the specific constraints that the building might experience some of the technology packages might not be available, but other packages are available in the same energy and cost range. For example in dense urban centres ground source heat pumps (GSHP) and /or PV might not be available for some buildings. In that case the remaining available packages will comprise technologies with even higher performance in the envelope (lower energy needs) and plants (lower delivered energy) to compensate the non-availability of PV and GSHP. Other technologies not considered in this analysis and/or that will become technologically and market mature later might also be available.

In the following pages and example of the frequency analysis on suitable measures is presented. In the Deliverable all analysis are shown.

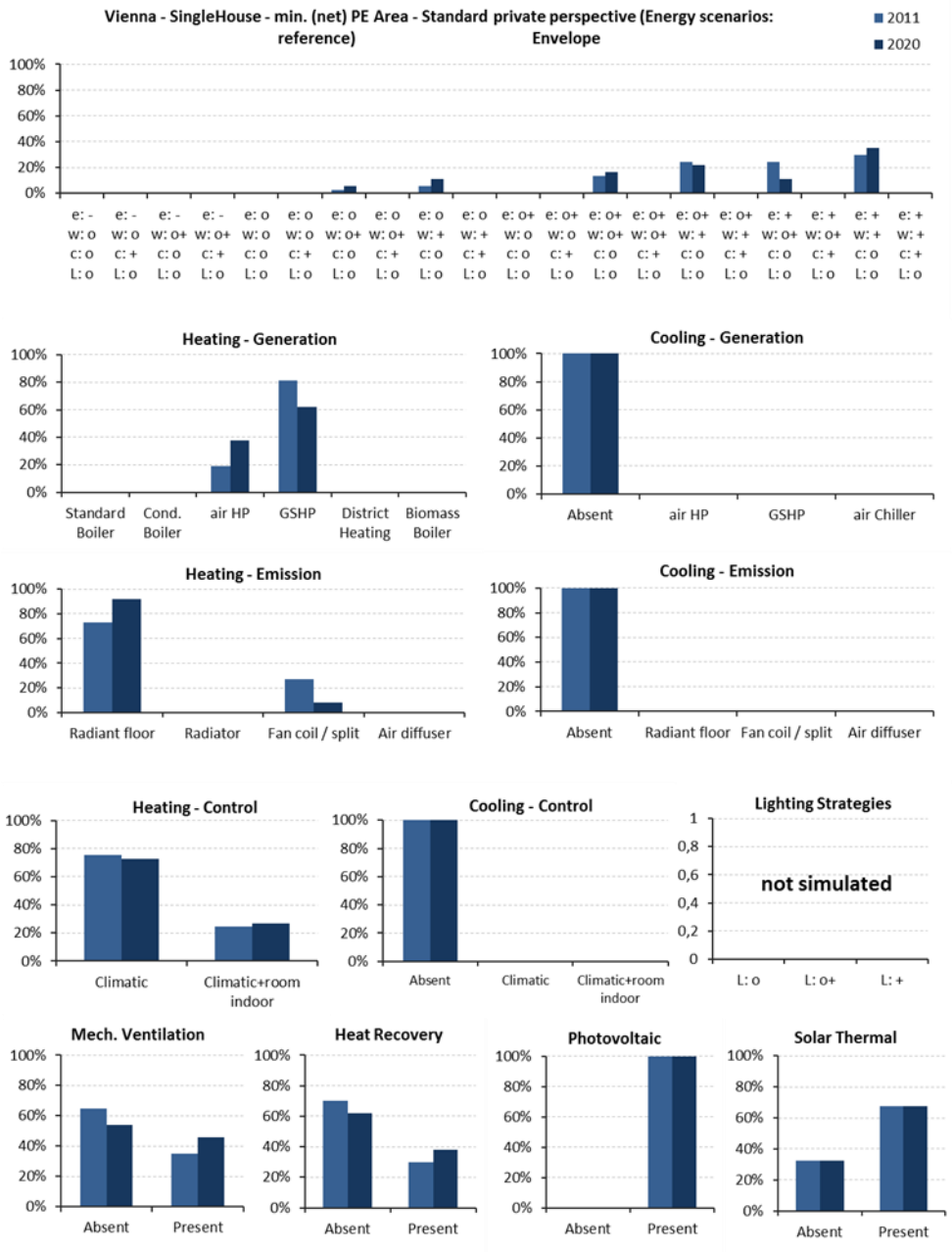

Figure 14. Example of % distribution of envelope and systems measures in the selected area (minimum net primary energy area for Single Family House in Vienna).

In the economic analysis it is evident how energy costs are very relevant in buildings with low performance and how this component is reducible improving the energy performance of the building (reducing energy needs). Obviously, in most cases, the initial investment grows toward the nearly zero energy buildings. The governments could be

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help the owner to realize the renovation of buildings and overcome the difficulties of initial investment with specifics policies, incentives, subsides, tax deduction and so on.

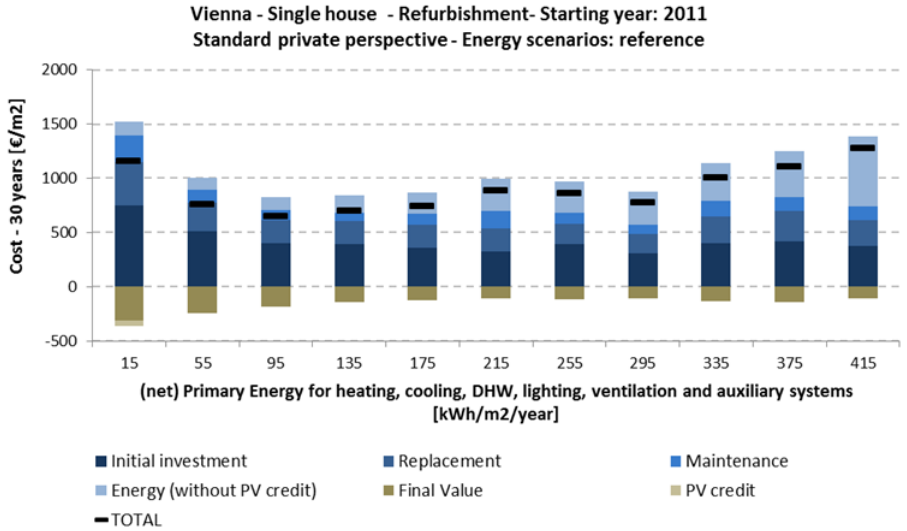

Figure 15. Example of disaggregation of building costs for several building variants positioned on the lower profile of the energy/cost domain.

To reach this results in an easy way, it is important to invest in the insulation of envelope and apply at the building passive or active action to reduce the cooling loads, especially in the country of south Europe, where the energy cost for cooling is becoming always more important, in particular in tertiary sector. The global cost calculation over a period of 30 years allows to demonstrate that buildings with a low energy needs for heating and cooling (EN) and with a higher initial investment costs, in term of global cost, don't cost more than respect to the building with higher EN and less initial investments costs.

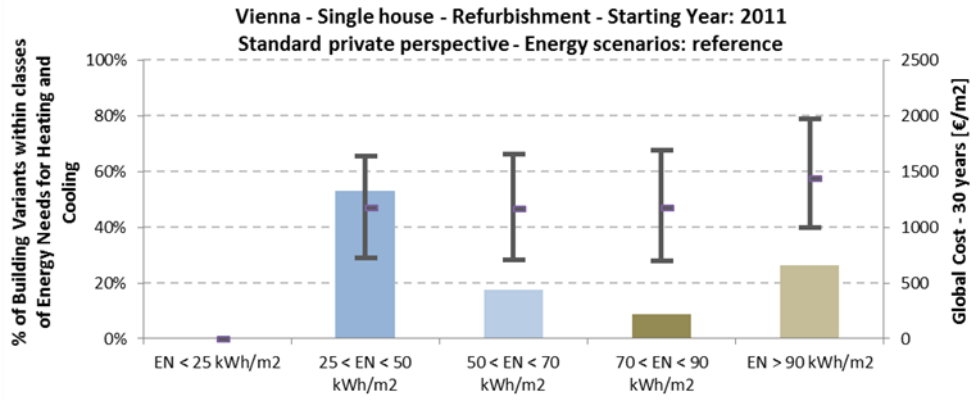

Figure 16. Example of % of building variants by different classes of energy needs for heating and cooling with indication of minimum/mean/maximum global cost

1.7 Conclusion and lesson learned

The quantitative results obtained in this study are obviously depending on the hypothesis made on the typologies of buildings (e.g. window-to-wall ratio, surface-volume ratio, etc.) and can hence result different under different boundary conditions.

One should also consider that in a large scale study as the present one, which used quite conservative assumptions, certain assumptions cannot be as detailed as it would be possible in a national or regional study or in the design of a specific building.

What is extremely important for a proper use of the results is that in this and other similar studies the assumptions, boundary conditions and methodology should be explicitly and thoroughly presented so that results can be compared and lessons learned from them for the design of actual buildings, preparation of legislation, etc.

Keeping hence in mind the crucial importance of the actual boundary conditions that might differ in the considered context and analysis**.**

In general we can see the minimum (net) primary energy (*nZEB*) zone appears characterized by medium-high/high recurrences of efficient/RES technologies in all countries and for both the building destinations.

In the minimum global cost (*cost-optimal*) zone the cross comparison appears more heterogonous for the different climatic regions and for the different building types.

In general the minimum global cost zone is characterized by medium level of efficiency for the envelope strategies, probably due to a more equilibrate balance between initial investment costs and energy savings.

For the single family house it is quite evident that, also within the minimum global cost zone, the penetration of renewable energy technologies is more effective in Mediterranean climates (characterized by higher solar radiation) than the other target countries.

Similar tendency is observed for office buildings, but with less differences between South and North Europe. This is due to a more relevant role played by photovoltaic systems in a building type characterized by higher electric consumptions for auxiliary systems and mechanical ventilation.

Further analysis have been carried out to compare the key energy levels obtained in the different climatic contexts and for the different building types and to evaluate the percentage reduction of net primary energy between the cost optimal target and the base refurbishment level. These results could be relevant also to determine eventual targets consisting in saving percentages in net primary energy respect base refurbishment level.

In the following Table 2 and Figure 17, we can see that net primary energy saving percentages for cost-optimal and nZEB targets are more close in residential buildings than in office and school buildings.

In residential sector, considered apartment building type shows lower energy saving potential respect to single house, due to geometric limits (e.g. lower available roof surface for solar systems respect total floor area respect single house).

In many cases, global cost of selected nZEB solutions (minimum net primary energy) are lower and more advantageous than global cost of corresponding base refurbishment levels (see orange bar and cells in Figure 18).

In general for the buildings selected both in cost optimal zone both in nZEB zone the initial investment cost are higher respect to base refurbishment level. This mean that the building with a minimum global cost (over a time laps of 30 years), in front of an higher initial investment the energy saving plays a fundamental role. The costs to improve a bit the efficiency in a renovated building are covered by the costs of energy saved.

Particularly for school and office buildings, saving percentages in global cost are greater in colder climates, starting from Milano, but also in warmer ones they could be interesting.

Observing the graph below, we can see an inversion of tendency in the percentage reduction of the net primary energy, passing from single house to office. This tendency could be associate to the effect of internal loads: in the target countries where the heating phase is predominant, is simpler to reach important reductions with high internal loads.

Table 2. Saving potential in net primary energy respect to base refurbishment level

net primary energy demand

	Building type	Base refurbishment level	Minimum global cost Target (**)		Minimum net primary energy Target (**)	
Seville (ES)	single family house	156 kWh/(m²y)	-84%	25 kWh/(m²y)	-96%	7 kWh/(m²y)
	apartaments block	127 kWh/(m²y)	-72%	35 kWh/(m²y)	-83%	22 kWh/(m²y)
	office	225 kWh/(m²y)	-36%	145 kWh/(m²y)	-97%	6 kWh/(m²y)
	school	189 kWh/(m²y)	-56%	83 kWh/(m²y)	-96%	8 kWh/(m²y)
Madrid (ES)	single family house	236 kWh/(m2y)	-82%	43 kWh/(m2y)	-97%	7 kWh/(m2y)
	apartaments block	182 kWh/(m2y)	-73%	49 kWh/(m2y)	-84%	30 kWh/(m2y)
	office	298 kWh/(m2y)	-58%	124 kWh/(m2y)	-97%	9 kWh/(m2y)
	school	262 kWh/(m2y)	-69%	80 kWh/(m2y)	-97%	7 kWh/(m2y)
Rome (IT)	single family house	193 kWh/(m2y)	-79%	41 kWh/(m2y)	-97%	7 kWh/(m2y)
	apartaments block	157 kWh/(m2y)	-56%	69 kWh/(m2y)	-80%	31 kWh/(m2y)
	office	296 kWh/(m2y)	-49%	151 kWh/(m2y)	-94%	19 kWh/(m2y)
	school	357 kWh/(m2y)	-58%	149 kWh/(m2y)	-98%	8 kWh/(m2y)
Milan (IT)	single family house	346 kWh/(m2y)	-86%	50 kWh/(m2y)	-95%	19 kWh/(m2y)
	apartaments block	260 kWh/(m2y)	-62%	98 kWh/(m2y)	-85%	40 kWh/(m2y)
	office	400 kWh/(m2y)	-60%	162 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	357 kWh/(m2y)	-51%	175 kWh/(m2y)	-98%	9 kWh/(m2y)
Bucharest (RO)	single family house	392 kWh/(m2y)	-62%	149 kWh/(m2y)	-91%	36 kWh/(m2y)
	apartaments block	307 kWh/(m2y)	-59%	125 kWh/(m2y)	-76%	73 kWh/(m2y)
	office	379 kWh/(m2y)	-48%	198 kWh/(m2y)	-92%	29 kWh/(m2y)
	school	381 kWh/(m2y)	-38%	237 kWh/(m2y)	-96%	15 kWh/(m2y)
Vienna (AT)	single family house	451 kWh/(m2y)	-79%	97 kWh/(m2y)	-94%	26 kWh/(m2y)
	apartaments block	344 kWh/(m2y)	-70%	103 kWh/(m2y)	-85%	52 kWh/(m2y)
	office	525 kWh/(m2y)	-86%	75 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	540 kWh/(m2y)	-86%	77 kWh/(m2y)	-97%	14 kWh/(m2y)
Paris (FR)	single family house	363 kWh/(m2y)	-65%	126 kWh/(m2y)	-92%	29 kWh/(m2y)
	apartaments block	336 kWh/(m2y)	-71%	99 kWh/(m2y)	-84%	54 kWh/(m2y)
	office	493 kWh/(m2y)	-64%	180 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	452 kWh/(m2y)	-51%	222 kWh/(m2y)	-98%	8 kWh/(m2y)
Prague (CZ)	single family house	519 kWh/(m2y)	-69%	159 kWh/(m2y)	-90%	53 kWh/(m2y)
	apartaments block	303 kWh/(m2y)	-46%	164 kWh/(m2y)	-68%	97 kWh/(m2y)
	office	615 kWh/(m2y)	-81%	118 kWh/(m2y)	-96%	24 kWh/(m2y)
	school	579 kWh/(m2y)	-81%	110 kWh/(m2y)	-98%	10 kWh/(m2y)
Berlin (DE)	single family house	348 kWh/(m2y)	-76%	85 kWh/(m2y)	-89%	39 kWh/(m2y)
	apartaments block	319 kWh/(m2y)	-49%	161 kWh/(m2y)	-79%	66 kWh/(m2y)
	office	442 kWh/(m2y)	-85%	68 kWh/(m2y)	-97%	12 kWh/(m2y)
	school	398 kWh/(m2y)	-88%	49 kWh/(m2y)	-96%	16 kWh/(m2y)
Helsinki (FI)	single family house	203 kWh/(m2y)	-62%	76 kWh/(m2y)	-69%	63 kWh/(m2y)
	apartaments block	195 kWh/(m2y)	+13%	219 kWh/(m2y)	-52%	94 kWh/(m2y)
	office	371 kWh/(m2y)	-71%	109 kWh/(m2y)	-91%	35 kWh/(m2y)
	school	339 kWh/(m2y)	-47%	179 kWh/(m2y)	-92%	26 kWh/(m2y)

(**) Percentage variation respect Base refurbishment level

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Figure 17. Saving potential in net primary energy: percentage of saving respect to base refurbishment level.

Figure 18. Target buildings energy and costs variations respect to base refurbishment level (graphs and tables) - in the following pages: (a) min. net primary energy (nZEB) selections, (b) min. global cost (cost-optimal) selection.

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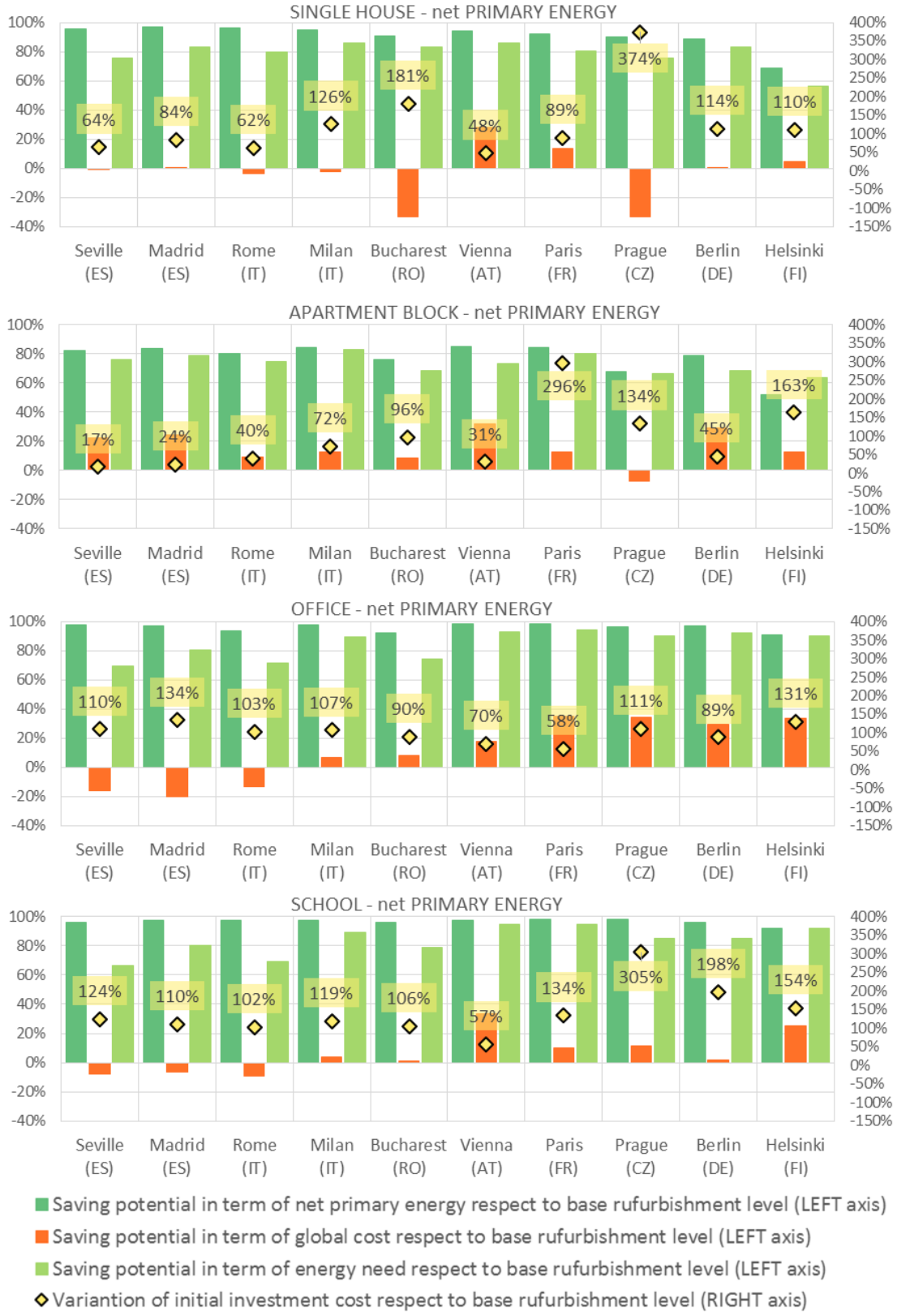
TARGET BUILDINGS ENERGY AND COSTS VARIATION RESPECT TO BASE REFURBISHMENT LEVEL



TARGET BUILDINGS ENERGY AND COSTS VARIATION RESPECT TO BASE REFURBISHMENT LEVEL

In addition the following features can be seen from minimum net primary energy and minimum global costs areas.

- For many climates, cost/energy curves low frontiers are quite flat.
- Higher energy prices scenarios increase the minimum global cost range and lead to a lower value of net primary energy for cost optimal levels.
- Higher prices for CO_2 emissions and eventual costs related to environmental damages and other externalities (taken into account by the macro-economical perspective) could increase the minimum global cost range and lead to a lower value of net primary energy for cost optimal levels.
- About solar RES, photovoltaic systems are very frequent in minimum net primary energy area, while it's less frequent in minimum global cost area. The solar thermal systems don't seem to show so clearly this difference.
- In some cases, we can recognize building variants with worse performance (higher net primary energy demand and/or higher global cost) respect the base refurbishment level. This could be due to bad combination of energy efficiency actions adopted in renovation. This stresses the importance of a good integrated energy design with proper energy calculations and global cost analysis.
- Medium/low temperature emission systems for heating are present both in many variants of minimum net primary energy area both in minimum global cost area.
- In office buildings, efficient lighting strategies appear always as good intervention to reach the minimum net primary energy area.
- In some climate contexts, biomass and district heating systems appear with low frequency in benchmark areas. This could be associated to difficulties to define actual primary energy factor, initial costs for installation (due to different installation conditions) and energy prices (due to private negotiation).
- In benchmark areas generally heat recovery for ventilation appear with low frequency. It produces effective energy savings but with higher initial costs for ventilation systems installations (see examples below with sensitivity analysis about heat recovery systems in cost-energy clouds).In this studies, the penetration of mechanical ventilation with or without heat recovery, is compared with a good user behaviour of occupants. Occupants open windows in good way when air changes need, avoiding excessive openings. This helps to reach natural ventilation solutions in cost optimal and sometimes also in minimum net primary energy area, more often respect mechanical ventilation. The trainer of occupants, in this way, could be a cost effective strategy to reduce the initial investment, annual, and energy costs in a renovation activity, without to reduce the indoor air quality.

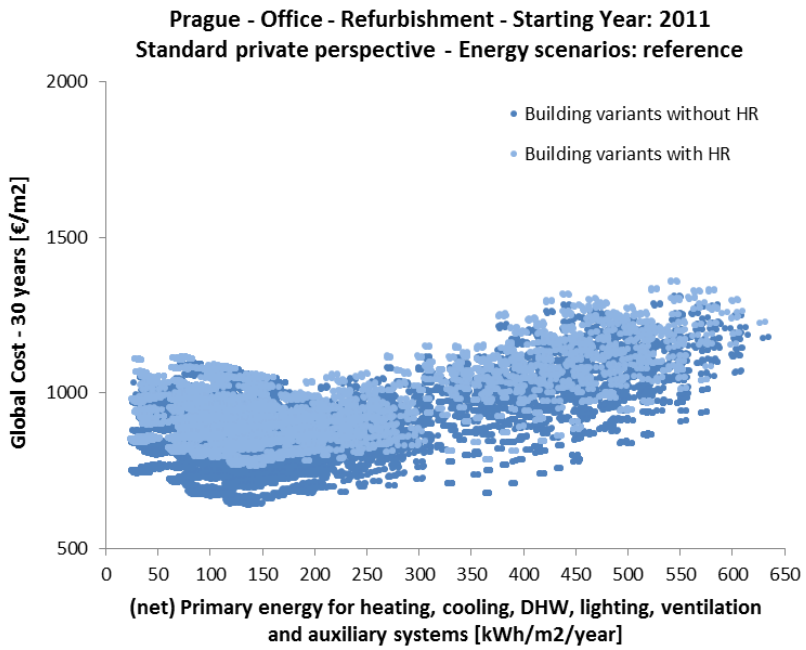


Figure 19. Sensitivity analysis on heat recovery in ventilation - office in Prague.

Applying the European common methodology for cost optimal calculation in a quite large amount of buildings and variants allowed to develop the following comments on the common methodology.

- Cost/energy curves and clouds show important information on net primary energy values and global costs, but can't show explicit information on **energy needs** for different energy end uses. For this further analysis, as some of presented ones, could be useful to study energy needs (for heating, cooling, domestic hot water, energy use for lighting, etc.) in detail.
- On the same graph, cost optimal zone selection can be very widee in terms of net primary energy range.
- The fixed **±15% encouraged target**, by EPBD, for net primary energy respect the minimum global cost area, could lead to very low values for low net primary energy value (e.g. for total net primary energy < 20 kWh/m^2/y). For this field of low values, maybe a fixed threshold of increment/decrement in [kWh/m^2/y] could be defined.
- Global cost over calculation period is an important economic indicator to show the long term behaviour of a building. However not specialist people are used to consider initial investment costs and they don't have sensibility respect global cost values. So it could be important to give references for the obtain results. The indication of **base refurbishment level** could be an useful reference for a direct results evaluation.

- Great care has to be taken to produce **accurate and consistent cost data base** for the considered buildings. Considering building sector and buildings variability, determined costs for a not specific and detailed building project could be difficult and a kind of confidence interval should be determined for the results.
- Cost/energy clouds and curves are very useful to determine net primary energy values and cost optimal targets, also analysing the **sensitivity** respect the main calculation outputs (as energy prices scenarios, primary energy factors, eventual environmental damages cost, etc.).
- Further studies could be useful to consider with more detail also **costs related to environmental damages** and environmental externalities due to energy consumption and emissions. This could bring to very advantageous results for energy efficiency improvements and renewable energy systems development.
- Often, also in the methodology, the attention is focused on low frontier of cost energy curves. Of course this part of the graphs represents the most profitable solutions in terms of global cost. But in general also **higher dots in the graphs** could represent interesting solutions in terms of energy efficiency or environmental value, maybe consisting in technological actions to be advantageously supported with policy and financial solutions.

2. Introduction

Existing buildings refurbishments play a crucial role to reach energetic and environmental targets for Europe. For this, nearly zero energy strategies, cost optimal interventions, and their relations have to be explored also for renovation buildings, both in residential and in tertiary sectors.

In the presented cost/energy curve calculation, we adopted a methodology for analysing and presenting data about performance of nearly zero energy buildings, which offers utmost transparency:

- It is coherent with EN calculation methods, definition of physical variables and terminology.
- It is coherent with the cost-optimal framework methodology.
- It follows a calculation procedure highlighting clearly and explicitly the calculation at various boundary levels (energy needs, energy use, delivered energy, primary energy, net primary energy).
- It provides an example of how to explicitly present all the input variables and assumptions and calculation methodology.
- It can serve as an example for ways to analyse and display the technological and economic features of the “nearly zero-energy area”, the “cost-optimal area” and trends resulting from changes in energy and component prices, primary energy factors and progress in the efficiency of components (not considered here) between 2011 and 2020.

3. Calculation methodology

3.1 Main assumptions at the base of the study

We adopted a methodology to construct building variants including nearly zero energy. For the selected climate conditions and building prototypes, the energy needs for heating and cooling, the delivered energy for heating, cooling, hot water and lighting, and finally the net primary energy are calculated for each variant.

We consider the “Net ZEB limited” definition, that is we calculate the net primary energy (over a yearly balance, and using symmetric weighting for exported energy from building systems to grid) associated to heating, cooling, domestic hot water, ventilation, auxiliaries, lighting, but we exclude the electric consumption of appliances and other plug loads (although we consider their effects on thermal energy needs). For the sake of comparison, we consider lighting both in non-residential and residential buildings. For better precision and following the recommendation of the Cost-optimal framework methodology, the energy need calculation is performed using fully dynamic methods. The overall methodology includes the following main steps:

- For the main models of buildings (head-models) where the selected Energy Efficiency **envelope technologies** and combinations thereof are implemented, calculation of the energy needs for heating and cooling are executed by using the dynamic simulation software EnergyPlus (in order to correctly take into account dynamic phenomena connected to energy storage and release connected to thermal mass, as required by EPBD and as physically relevant due to variable weather conditions and internal loads).
- Generation of building families (group of variants related to opaque envelope (symbol “e” in subsequent graphs), glazing and air tightness (“w”), passive cooling techniques (“c”) in combination with efficient lighting strategies (“L”), plus plant variants) by variation of Energy Efficient **system/plant technologies** for each head-model and calculation of delivered energy values for each building family; the assessment has been performed by associating appropriate performance coefficients to each plant type (including generation, distribution and emission efficiency values).
- For the buildings that include RES plants, calculation of the **amount of renewable energy generated** and calculation of net (over a time lapse of one year) primary energy consumption for all building families; the conversion factors of delivered energy to primary energy in the different countries/regions has been taken into account.
- Association of installation costs to each technology, including material and labour costs, remove and disposal of existing technologies, business profit and general expenditure.
- Calculation of global costs, including capital costs, substitution costs, annual maintenance costs, operating energy costs, over a period of 30 years (subtracting final value), all discounted to year zero (where year zero is either 2011 or 2020).
- Note that embedded energy (also called gray energy) is not included in the calculation, which does not exclude the possibility that a MS might decide to include it in the definition and calculation.

In order to be consistent with the EU process of implementation of EPBD and allow a discussion on the relationship between nearly zero-energy and cost-optimal, our methodology is coherent with the cost-optimal methodology framework.

In accordance with Article 5 and Annex III of Directive 2010/31/EU [European Parliament And Council 2010], EU Guidelines [European Commission 2012a] and Regulation (EU) N° 244/2012 [European Commission 2012b], the Commission established a comparative methodology framework to be used by Member States for calculating cost optimal levels of minimum energy performance requirements for new and existing buildings and building elements. The methodology specifies how to compare energy efficiency measures, measures incorporating renewable energy sources and packages of such measures in relation to their energy performance and the cost attributed to their implementation and how to apply these to selected reference buildings with the aim of

identifying cost-optimal levels. The complete process to assess and report on cost optimal levels for energy performance requirements of buildings is described in Figure 20.

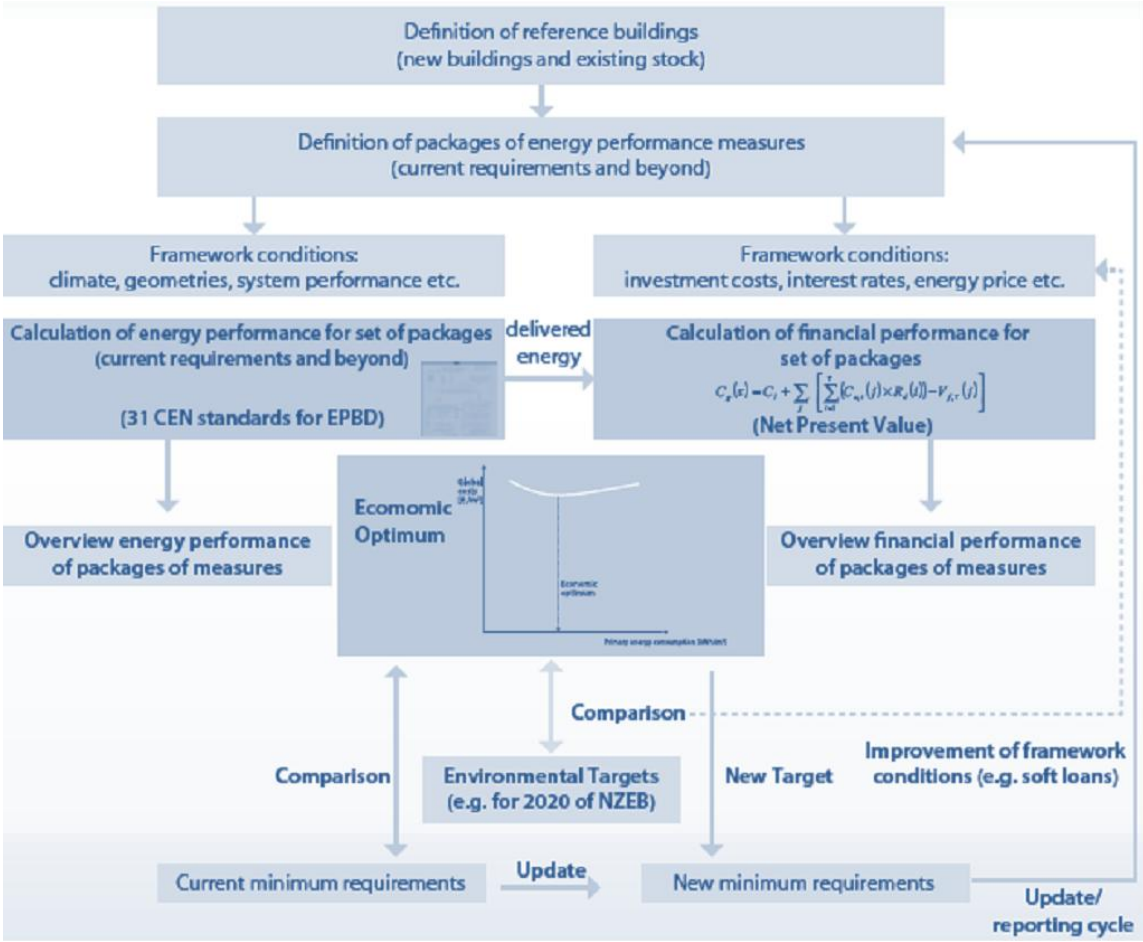


Figure 20. Flowchart comparative methodology. Reproduced from [BPIE 2010]

The detailed calculation methodology for energy performance and global cost proposed by the EU Regulation N° 244/2012 [European Commission 2012b] and the Commission's Guidelines [European Commission 2012a], can be summarized *via* the following Figure 21 and Figure 22. Note that the time interval on which the balance is calculated (e.g. a day, a month, a year) should always be explicitly stated. In our case we perform a yearly energy balance. It is noted that Figure 21 is equivalent to figure 1 of the Guidelines for application of the Cost-Optimal framework methodology with addition of some explanatory note by the authors.

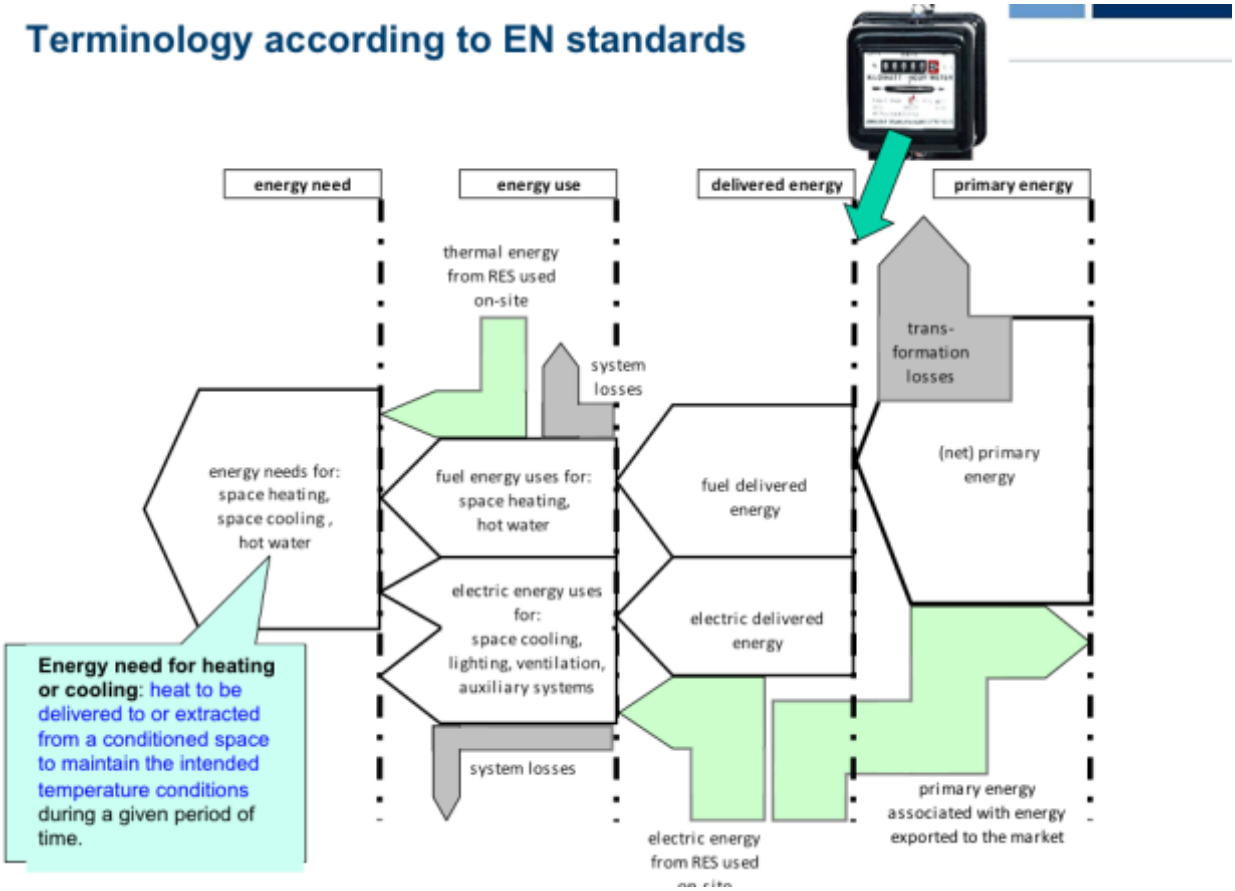


Figure 21. Scheme of calculation of the (net) primary energy demand resulting from the application of measures and packages of measures to a reference building.

In particular, about the energy performance calculation, we are performing the following steps:

1. Selection of efficiency technical solutions and their grouping into typical packages (since very often these technical solutions are not used as stand-alone measures but in combination with other measures), based on the definition of the reference base case (see below).
2. Calculation of energy needs for heating and cooling and energy use for lighting for main models of buildings (building variants) for which simulations are performed where the selected EE-envelope technologies and combinations thereof are implemented; we carried out out this quantitative assessment by dynamic simulations (by using the EnergyPlus software).
3. Generation of all **building models**, which can be also indicated as “building families” by variation of energy efficiency measures for envelope and system technologies for each building variants: “building families” are equal to groups of envelope packages (building variants) related to opaque envelop - indicated with (e) in the Deliverable, glazing and air tightness (w), passive cooling tech-

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niques (c) and efficient lighting strategies (L), plus plant variants verifying whose system architecture is coherent.

4. Calculation of **delivered energy** values for each building model; the energy saving assessment are performed by associating appropriate performance co-efficients to each plant type, in accordance with EN standards and other bibliographic references.
5. Calculation of energy uses for **auxiliary systems** are calculated through a simplified dimensioning.
6. In the models where is implemented a mechanical ventilation system (with or without heat recovery) energy uses for **fans** are calculated.
7. Inclusion of energy generation from **RES** systems (such as solar thermal panels, photovoltaic (PV) panels, heat pumps[3]) by simple estimation methods and calculation of **net** (**over a time laps of one year**) primary energy consumption for the entire building; the delivered-to-primary conversion factors of the different countries/regions are taken into account.

The term (**net)** primary energy means – as recommended in 2012/C 115/01, page 10 [EU 2012] – the result of the following steps:

8. Calculation of the primary energy associated with the delivered energy, using national conversion factors;
9. Calculation of primary energy associated with energy exported to the market (e.g. generated by RES or co-generators on-site);
10. Calculation of (net) primary energy as the difference between the two previous calculated amounts: (8) - (9).

For the selected climate conditions and building prototypes, the energy needs for heating and cooling, the delivered energy for heating, cooling, hot water and lighting, and finally the net primary energy are calculated for each variant and “building family”.

[3] About renewable contributions from heat pumps: heat pump systems were considered as “on-site generation from on-site renewables” with limits and method according to EU Commission Decision 2013//114/UE (1/3/2013).

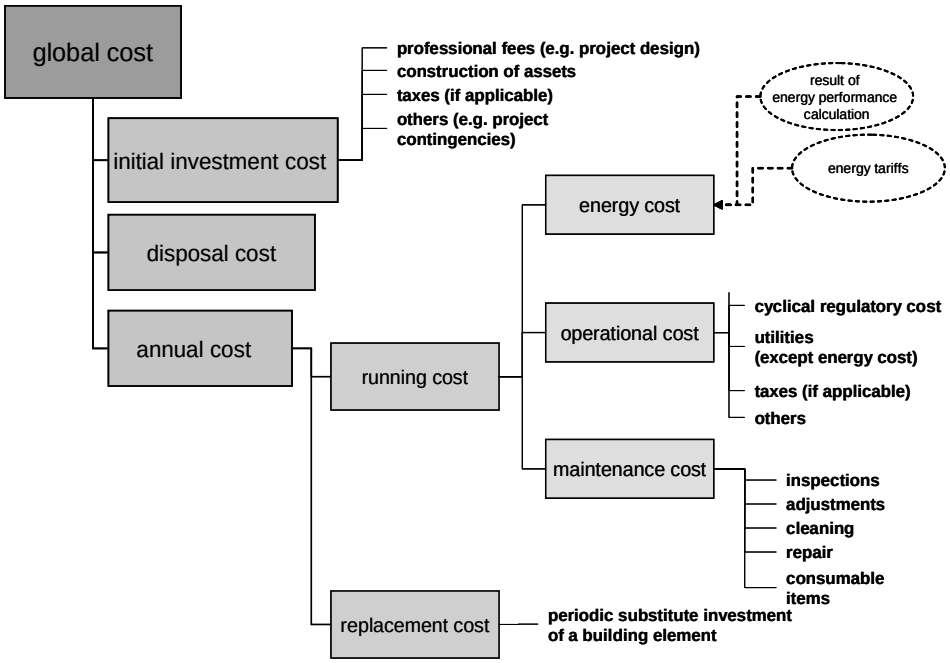

Figure 22. Scheme of calculation of the global cost in terms of net present value for each building variant.

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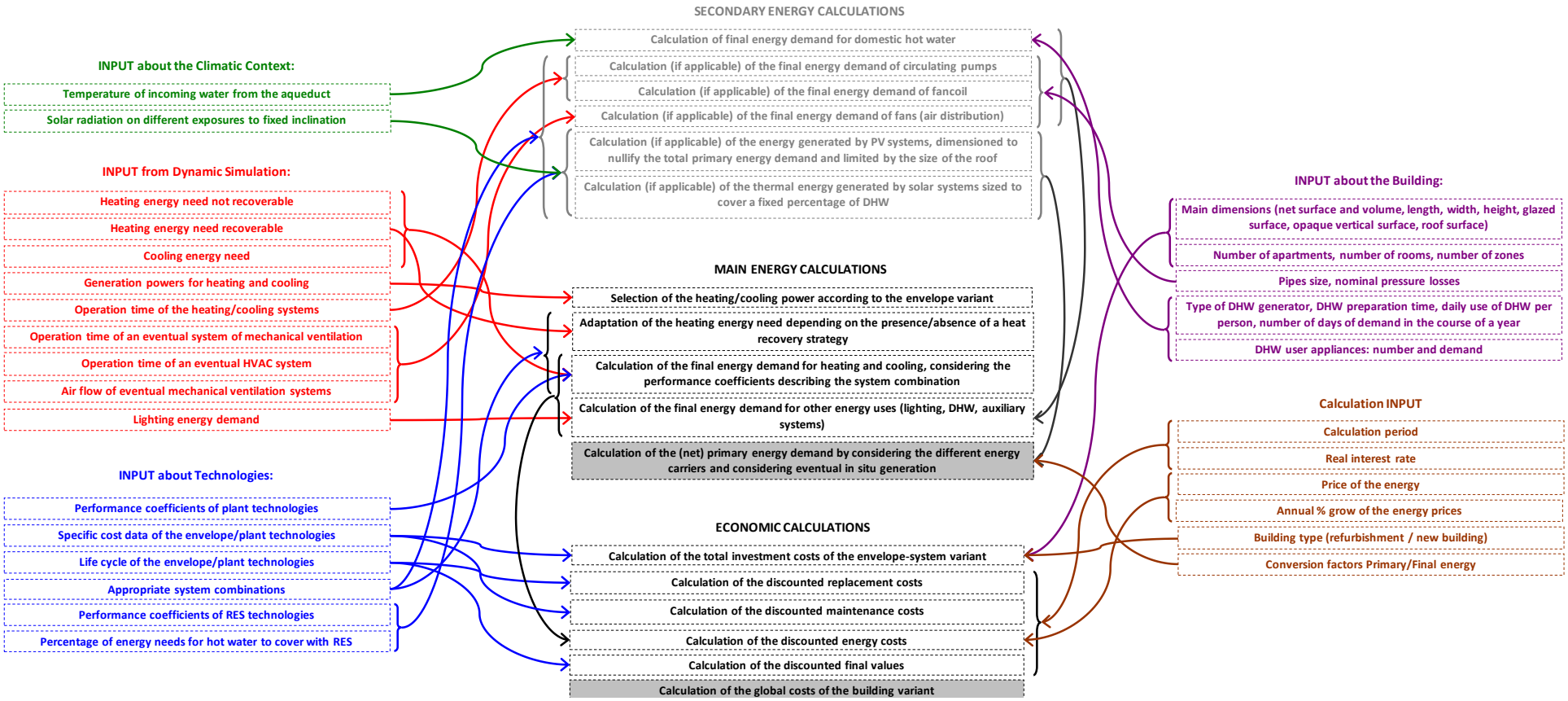

Figure 23: Scheme of the calculation methodology adopted.

3.2 Data input for the global cost calculation

For this analysis two perspectives have been considered: financial standard private, and macro-economic. We show below the values considered for the main parameters of calculation.

In all cases the calculation is done in real terms, so the inflation rate is subtracted from the nominal (market) interest rate.

We only considered one real interest rate of 3% for the macro-economic perspective, corresponding to the suggested value in the cost optimal regulation.

Table 3. Interest, inflation and real interest rates considered.

PERSPECTIVE	INTEREST RATE - Source: EUROSTAT (average of years 2008-2011)							
	ES	IT	RO	AT	FR	CZ	DE	FI
Financial - Standard Private	4.51%	4.61%	8.01%	3.71%	3.58%	4.27%	3.14%	3.51%
	INFLATION RATE - Source: EUROSTAT (average of yers 2008-2011)							
	ES	IT	RO	AT	FR	CZ	DE	FI
Financial - Standard Private	2.25%	2.20%	6.35%	2.23%	1.83%	2.55%	1.68%	2.63%
	REAL INTEREST RATE							
	ES	IT	RO	AT	FR	CZ	DE	FI
Financial-Standard Private	2.21%	2.36%	1.56%	1.45%	1.72%	1.68%	1.44%	0.86%
Macroeconomic	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%

All considered prices are in real terms, base year 2011.

However prices are actualized to the calculation start year 2011 or 2020, respectively for the two calculation series here presented.

Other assumptions for cost determination are as follow.

- Costs according to deliverable D3.1 of Entranze project [Entranze 2013 D31], from specific national cost data collections in the Project
- Costs annual rates of increase according to report “Towards nearly zero-energy buildings- Definition of common principles under the EPBD” (Ecofys, eERG, University of Wuppertal) [Ecofys et al. 2013]
- Annual maintenance cost (percentage of initial cost) according to standard EN15459 (*Energy performance of buildings – Economic evaluation procedure for energy systems in buildings*)
- Components lifespan according to standard EN15459

In global cost calculation also professional fees is considered with the following percentages of the total cost of the packages considered for renovation.

Table 4: professional fees percentages of whole cost for building renovation.

PERCENTAGE OF PROFESSIONAL FEES CONSIDERED [%]								
	ES	IT	RO	AT	FR	CZ	DE	FI
percentage on sum of all total costs for building renovation (applied only at variants analyzed)	11%	11%	10%	15%	10%	10%	10%	10%

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On energy prices, we consider two scenarios from 2011 to 2050, for each country, a reference scenario and an ambitious one, according to deliverable D4.2 of Entranze project and Energy Scenario Development Analysis: Energy Policy Scenarios to 2050 – POLES. Considered scenarios are represented below.

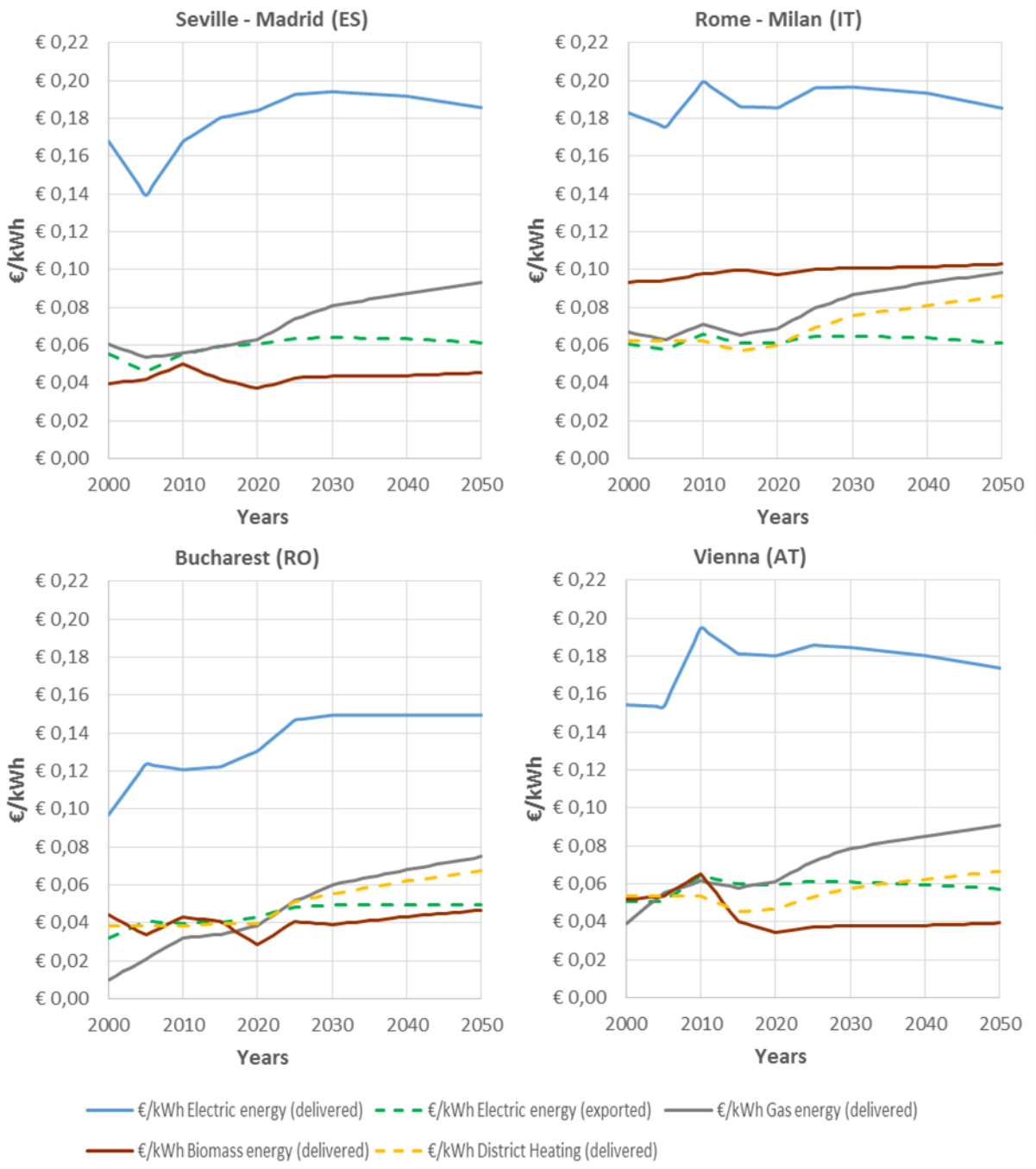

Figure 24: reference energy prices scenarios (Spain, Italy, Romania and Austria).

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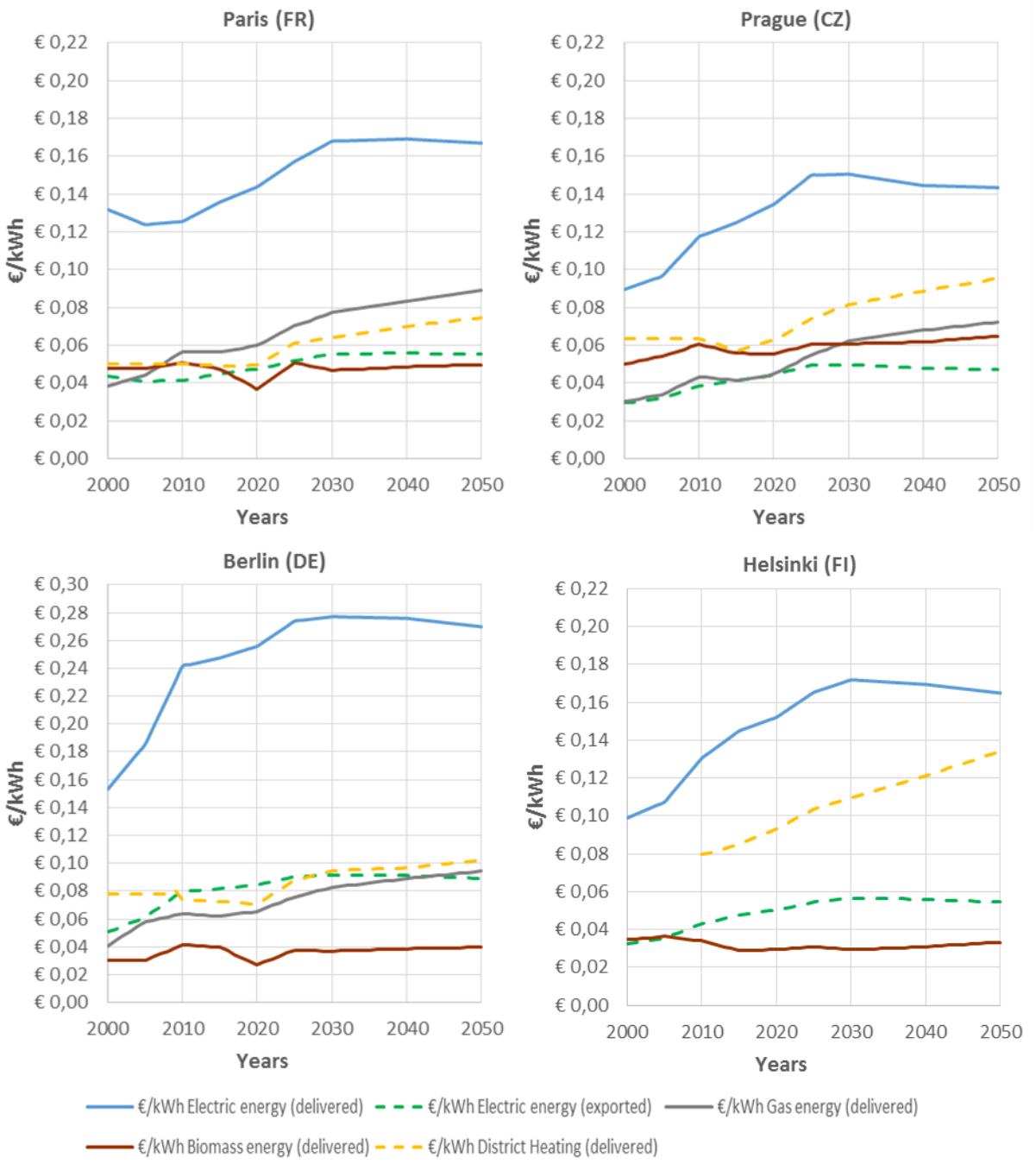

Figure 25: reference energy prices scenarios (France, Czech Republic, Germany and Finland).

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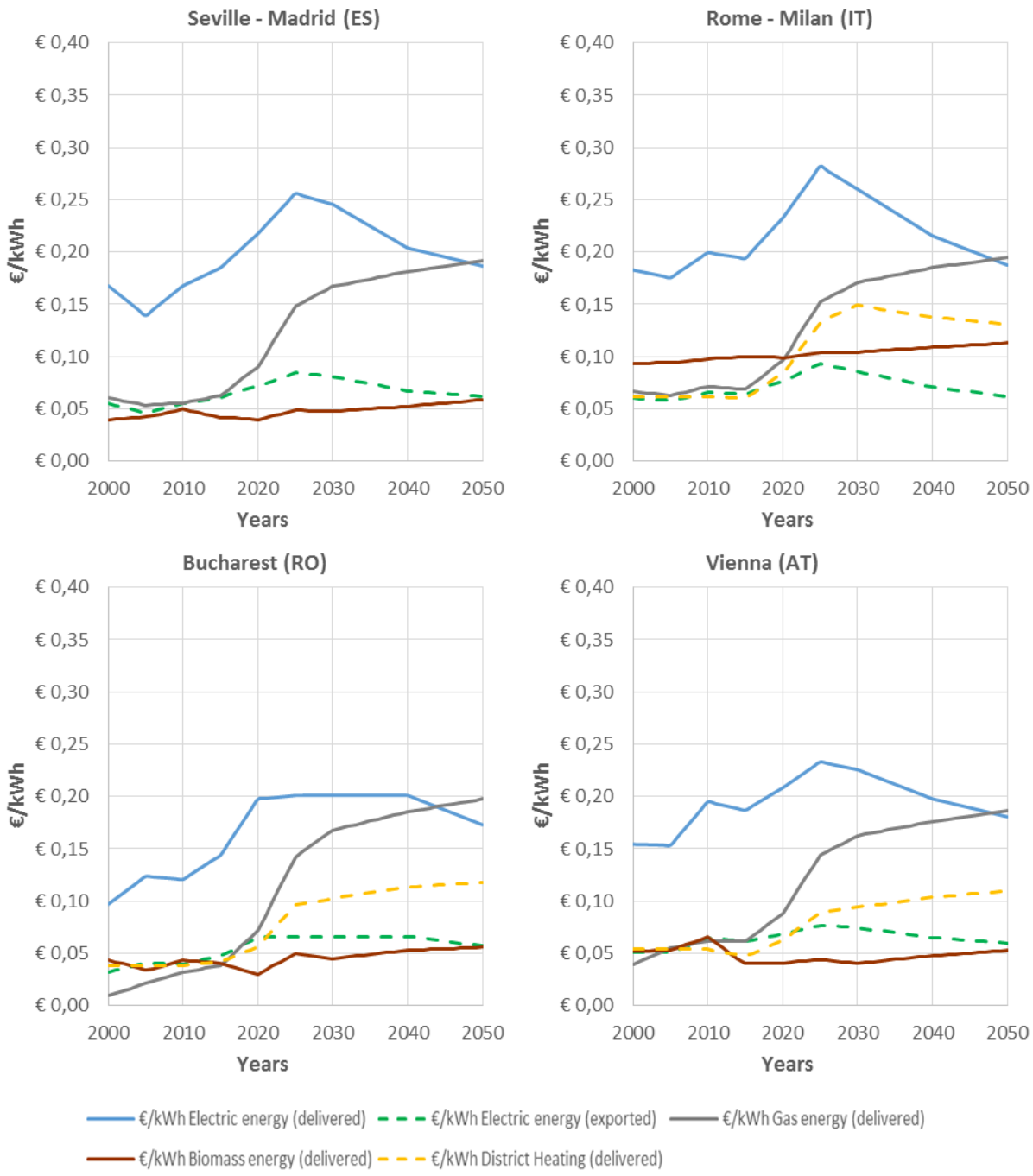

Figure 26: ambitious energy prices scenarios (Spain, Italy, Romania and Austria).

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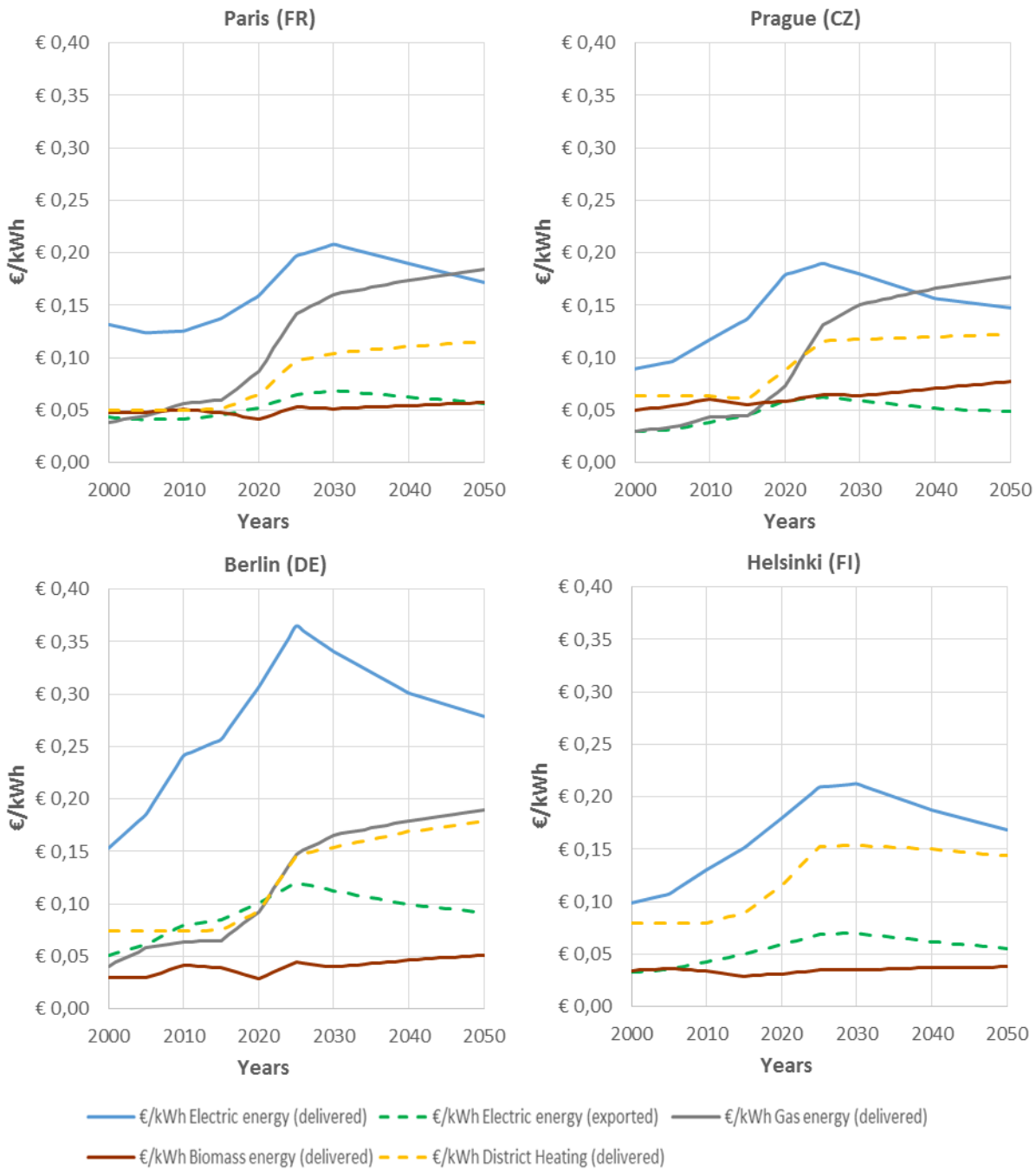

Figure 27: ambitious energy prices scenarios (France, Czech Republic, Germany and Finland).

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In the previous graphs, the dashed lines values are assumed from continuous lines. Particularly according to energy market in each country, exported electric energy prices are assumed about a third of delivered electric energy prices, with the same trends. The trends of district heating prices are assumed similar to gas prices trend or to a mix gas and oil prices trend, depending on specific country. District heating prices are often decided locally in a commercial negotiation.

In order to calculate the primary energy demand from delivered energy with correspondent energy carriers, the following values for primary energy factors (PEF) were assumed for each energy scenarios, according to deliverable D4.2 of Entranze project [Entranze 2013 D42] and Energy Scenario Development Analysis: Energy Policy Scenarios to 2050 – POLES [Enerdata 2007]. Considered scenarios are represented below.

Figure 28: primary energy factors (PEF).

PRIMARY ENERGY FACTORS	kWh/kWh							
	ES	IT	RO	AT	FR	CZ	DE	FI
Electrict - Starting year 2011 - Reference Scenarios	1.89	2.05	2.53	1.65	2.72	3.14	2.45	2.69
Electrict - Starting year 2011 - Ambitious Scenarios	1.89	2.05	2.53	1.65	2.72	3.14	2.45	2.69
Electrict - Starting year 2020 - Reference Scenarios	1.70	1.80	2.18	1.50	2.54	2.65	1.93	2.62
Electrict - Starting year 2020 - Ambitious Scenarios	1.70	1.77	2.07	1.51	2.58	2.62	1.88	2.62
Gas	1.00	1.00	1.00	1.17	1.00	1.00	1.00	1.00
Biomass (Total PEF: renewable + non-renewable part)	1.25	1.50	1.50	1.08	1.50	1.20	1.50	1.50
District Heating	1.20	1.20	1.20	1.00	1.20	1.40	1.20	0.70

Figure 29: carbon dioxide emission coefficients.

gCO_2 /kWh PRODUCED BY ENERGY CARRIER	gCO_2 /kWh							
	ES	IT	RO	AT	FR	CZ	DE	FI
Electrict*	287	423	570	177	77	599	468	199
Gas*	202	202	202	202	202	202	202	202
Biomass	0	0	0	0	0	0	0	0
District Heating**	170	170	170	170	170	170	170	170

* source International Energy Agency
** Data assumed as generation with municipal solid waste

In buildings variants where biomass generation systems are adopted, we used the national total primary energy factors (PEF), which considers both non-renewable and renewable parts, according to [EN 15603].
In this analysis we assumed biomass as “on-site generation from off-site renewables” (see figure below), as more general situation for biomass, for example if we consider also regions where biomass is not available locally (e.g. dense urban contexts).
In this way, in calculations we distinguish between generation from “on-site renewables”, as solar systems, and “off-site renewables”, as in general biomass.
And we avoid to stress to much the cost/energy potential of biomass, also in regions where it’s not really available locally.

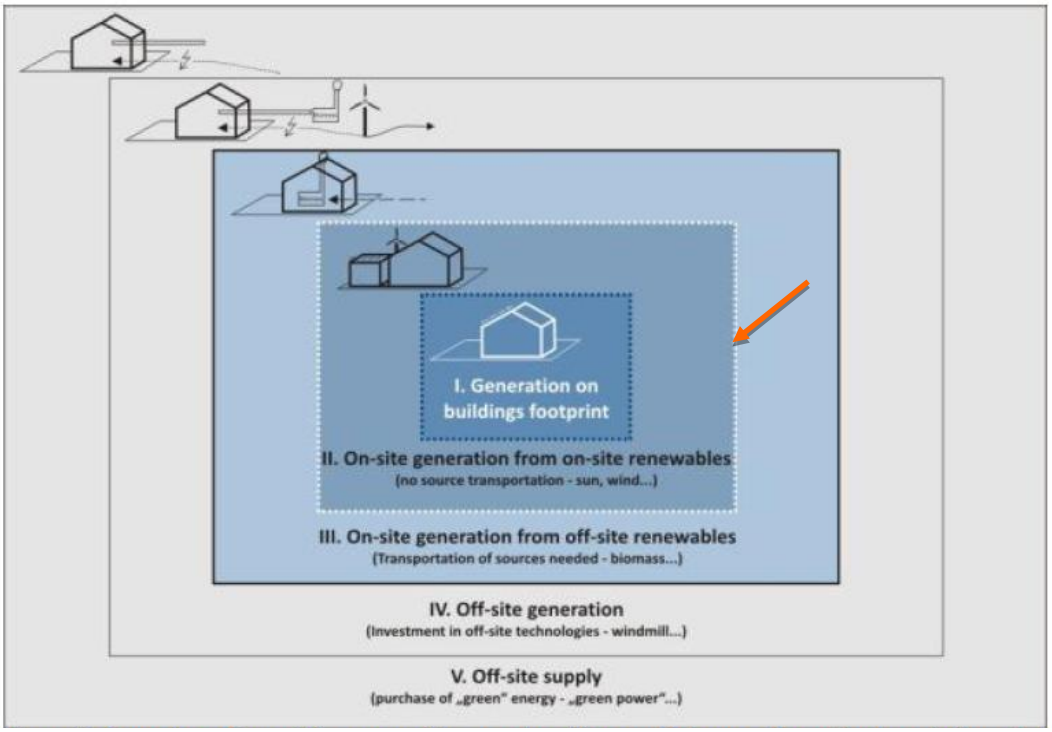

Figure 30: Overview of possible renewable supply options in nearly zero energy buildings, reproduced from [Marszal.2011].

In the following graph, the positions of variants with a biomass generation system are calculated with two different PEF, respectively with only non-renewable part (PEF < 1) and with both renewable and non-renewable parts – Total PEF – (PEF ≥ 1).

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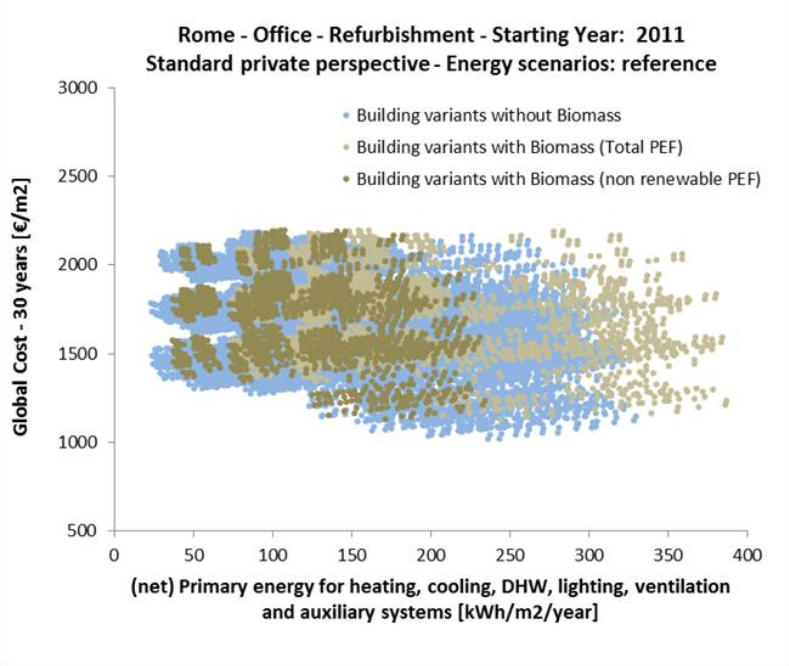

Figure 31: example of sensitivity analysis on primary energy factor (PEF) for biomass, with Total PEF and only non renewable PEF.

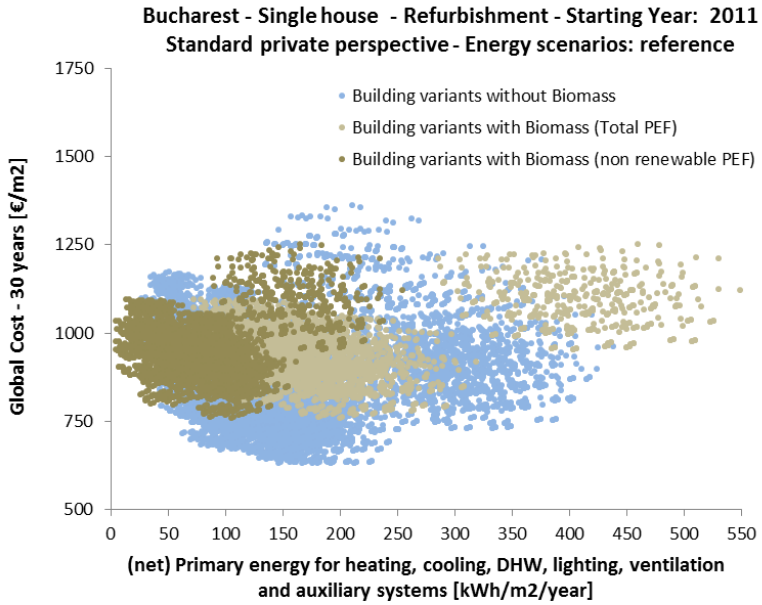

Figure 32: example of sensitivity analysis on primary energy factor (PEF) for biomass, with Total PEF and only non renewable PEF.

About energy contributions from solar photovoltaic and solar thermal systems, we consider the following assumptions:

Solar thermal systems

- Priority to solar thermal collectors to cover about 50% of energy need for domestic hot water, at starting year
- Loss in solar thermal panels efficiency of 1% / year

Photovoltaic systems

- Maximum the 50% of remaining surface of the roof is covered by photovoltaic panels (PV), north exposition exclude (to consider the actual available roof surface taking into account chimneys and other components on the roof)
- PV designed to cover not more than the primary energy demand of building
- 50% of produced electrical energy from PV is consider as directly used in the building
- 50% of produced electrical energy from PV is exported to the grid (in order to consider a form of load matching using the grid. The electrical energy exported to the grid is considered in global cost calculation with a proper cost, approximately a third of the delivered electricity price.)
- Loss in PV efficiency of 1% / year

About renewable contributions from heat pumps; heat pump systems were considered as “on-site generation from on-site renewables” with limits and method according to EU Commission Decision 2013//114/UE (1/3/2013).

3.3 Reference climatic contexts and reference weather data

In order to calculate, with stationary, quasi-stationary or dynamic calculation methods the energy and comfort performances of buildings, climatic conditions are usually represented as sets of data that describe at different degrees of detail, an “average” climate at a certain location. Since there are a number of weather variables that affect building behaviour it is not straightforward to establish a definition of “average” weather.Different definitions and hence different types of data sets are available (IWEC, TRY, TMY, Meteonorm, etc.) based on different weighting of the parameters and other choices. Weather data sets can be in the form of a year of hourly data (8 760 hours) synthesized to represent long-term statistical trends and patterns and are used for hourly calculations of energy and power demand of a building.

As performing building simulations for every Entranze Target Country would have been be time consuming (compared to our resources) it has been decided to select 10 key climatic conditions within this European area. As reference indicators for climate contexts have been used the Winter Severity Index and the Summer Severity Index proposed by F. Sanchez de la Florthe (2005), as well the Climatic Cooling Potential by Artmann (2007). We calculated this indexes for 25 cities, within the Entranze Target Countries, selected in function of the nominal climatic characteristics, the availability of homogeneous climatic data (IWEC[4]) and their relevance (in terms of urban population).

[4] The International Weather for Energy Calculations (IWEC) are the result of ASHRAE Research Project 1015 by Numerical Logics and Bodycote Materials Testing Canada for ASHRAE Technical Committee 4.2 Weather Information. The IWEC data files are 'typical' weather files suitable for use with building energy simulation programs, derived from up to 18 years of DATSAV3 hourly weather data.

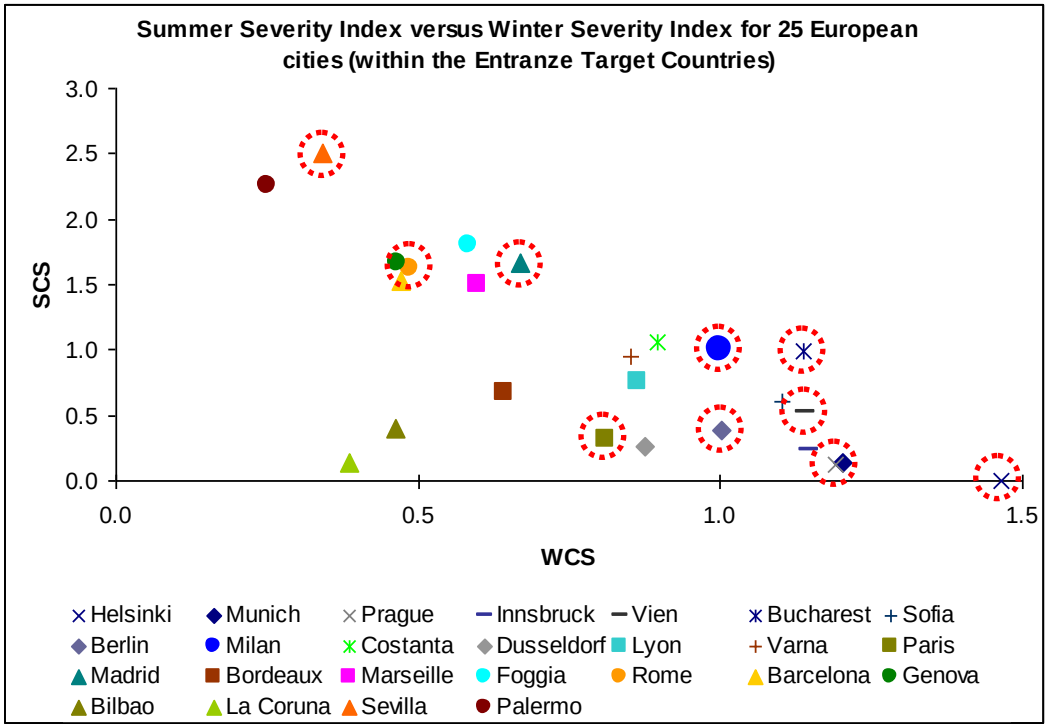

Figure 33: SCS versus WCS for 25 European cities.

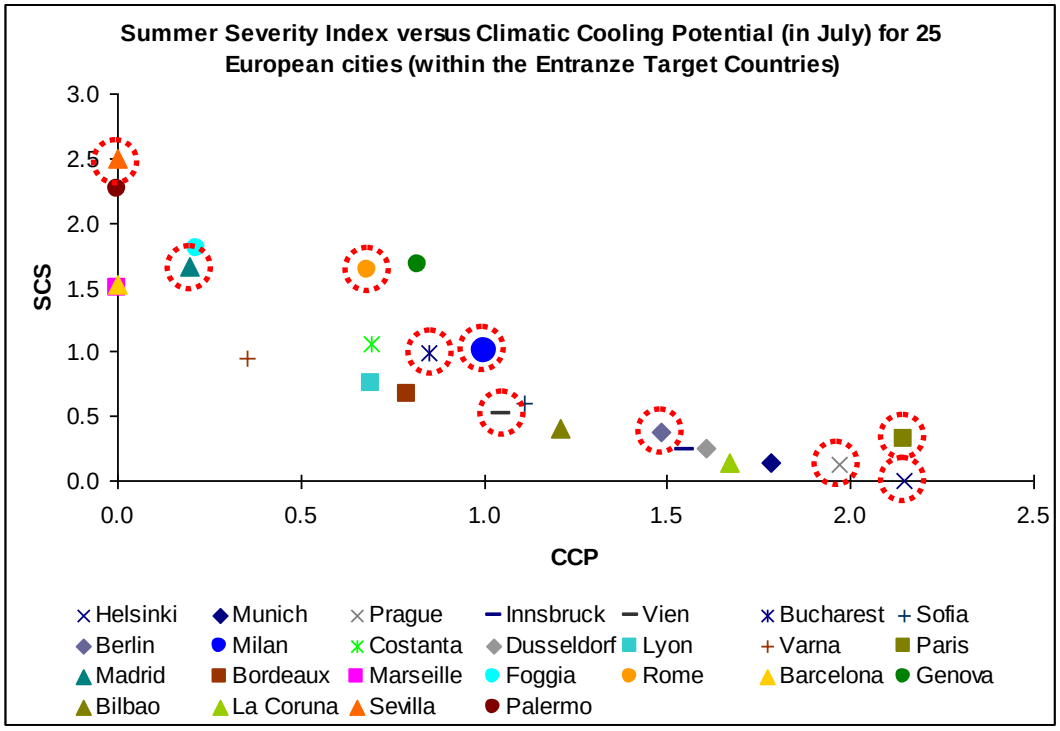

Figure 34: SCS versus CCP for 25 European cities

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Analysing the obtained data, we selected as key climatic conditions those of: Seville (ES), Madrid (ES), Rome (IT), Milan (IT), Bucharest (RO), Vienna (AT), Paris (FR), Prague (CZ), Berlin (DE), Helsinki (FI).

Table 5: Characterisation of the 10 selected climates.

Context	Climatic characterisation	Relevance
Seville (ES)	Mediterranean climate (hot summer subtype) with very low climatic cooling potential (extreme summer conditions)	Medium
Madrid (ES)	Semi-arid climate with low climatic cooling potential	High
Rome (IT)	Mediterranean climate (warm summer subtype) with medium climatic cooling potential	High
Milan (IT)	Humid subtropical climate with medium climatic cooling potential	High
Bucharest (RO)	Humid continental (hot summer subtype) / Subarctic climate with medium climatic cooling potential	High
Vienna (AT)	Humid continental climate (warm summer subtype) with high climatic cooling potential	High
Paris (FR)	Oceanic climate with very high climatic cooling potential	High
Prague (CZ)	Humid continental climate (warm summer subtype) with high climatic cooling potential	High
Berlin (DE)	Humid continental climate (warm summer subtype) with high climatic cooling potential	High
Helsinki (FI)	Humid continental / Subarctic climate (extreme winter conditions)	Medium

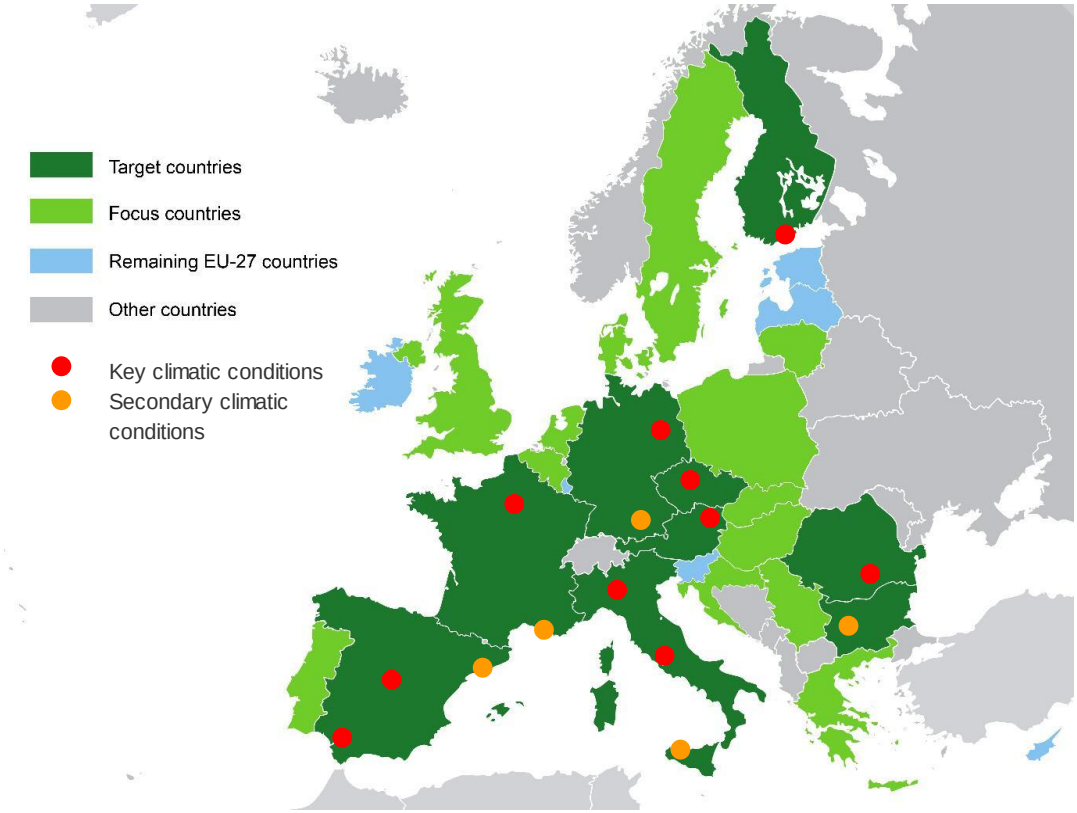

Figure 35: Key and secondary weather conditions selected for the Task2.2 and WP3 activities.

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3.4 Reference building types

3.4.1 Single family house

The building which has been selected as reference for single family house, (composed by an under ground level and two floors over ground level) has a conditioned surface of about 140 m^2 and a S/V ratio of 0.7. The main other characteristics involved on the simulation task are shown below.

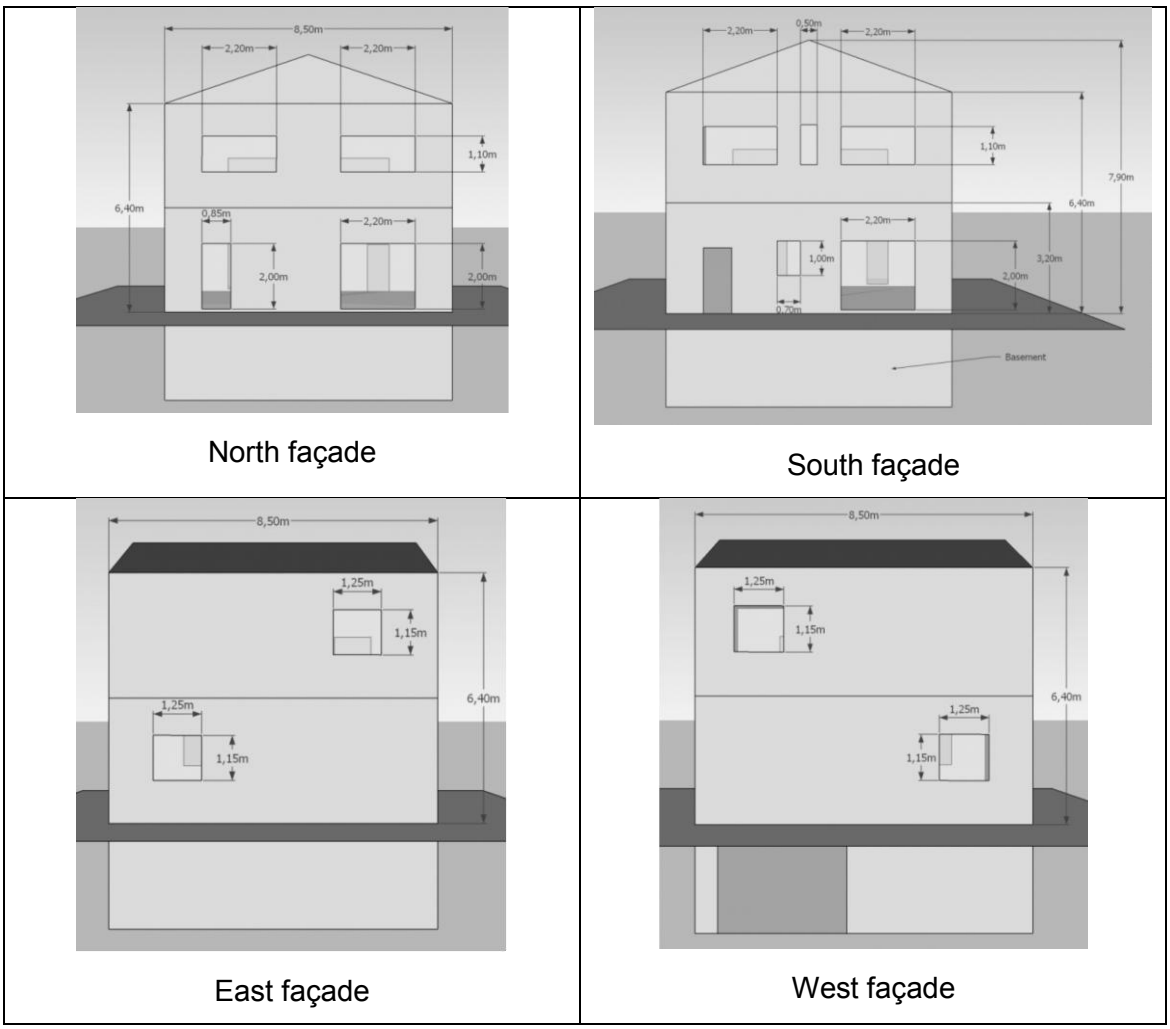

Figure 36: Prospects of the single house model.

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Table 6: Fixed characteristics of the single house model.

		All Countries
Building geometry	N° of heated floor =	2
	A/V ratio =	0.7 m^2/m^3
	Orientation:	S/N
	Net dimensions of heated volume =	8.5 x 8.5 x 6 m
	Net floor area of heated zones =	140 m^2
	Area of S façade =	51 m^2
	Area of E façade =	51 m^2
	Area of N façade =	51 m^2
	Area of W façade =	51 m^2
	Area of Roof =	72.25 m2
	Area of Basement =	72.25 m2
	Window area on S façade =	25%
	Window area on E façade =	7%
	Window area on N façade =	25%
	Window area on W façade =	7%
Internal gains	People design level =	50 m^2/people
	Lighting design level =	3.5 W/m2
	Appliances design level =	4 W/m^2

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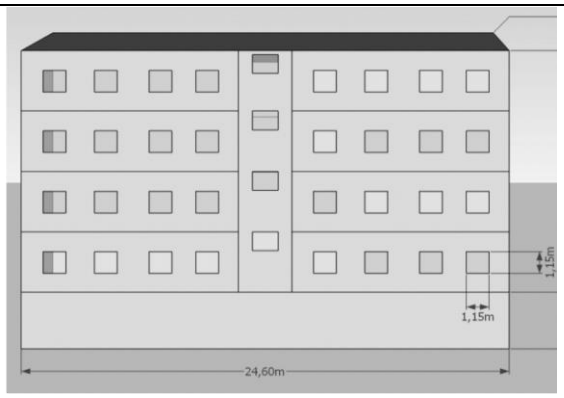
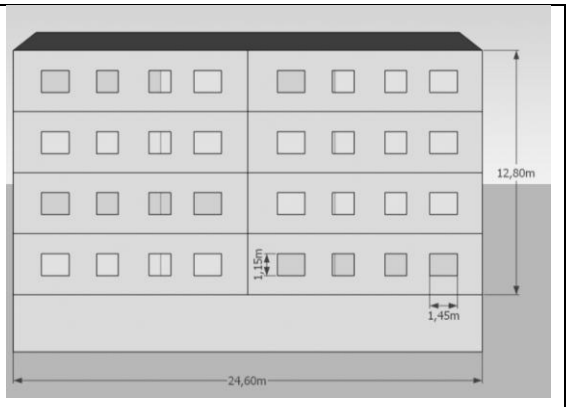
3.4.2 Apartment block

The building which has been selected as reference for apartment block (4 floors + cellar) is composed by 12 flats and its conditioned area is around 1000 m^2. The main other characteristics involved on the simulation task are shown below.



North façade



South façade

Fig. 1: Prospects of the apartment block model.

Tab. 1: Fixed characteristics of the apartment block model.

		ES, IT, FR	RO, AT, CZ, DE, FI
Building geometry	N° of heated floor =	4	
	A/V ratio =	0.33 m^2/m^3	
	Orientation:	S/N	
	Net dimensions of heated volume =	24.6 x 11.2 x 12.8 m	
	Net floor area of heated zones =	990 m^2	
	Area of S façade =	315 m^2	
	Area of E façade =	143 m^2	
	Area of N façade =	315 m^2	
	Area of W façade =	143 m^2	
	Area of Roof =	54 m^2	
	Area of Basement =	54 m2	
	Window area on S façade =	15%	30%
	Window area on E façade =	0%	0%
	Window area on N façade =	15%	30%
	Window area on W façade =	0%	0%
Internal gains	People design level =	25 m^2/people	
	Lighting design level =	3.5 W/m^2	
	Appliances design level =	4 W/m^2	

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3.4.3 Office

As reference of office building, a medium-size and highly-glazed office building has been selected, with 5 floors (of 3 m height each) an A/V ratio of 0,33 and a net heated area of 2400 m^2. The main other characteristics involved on the simulation task are shown in the following tables.

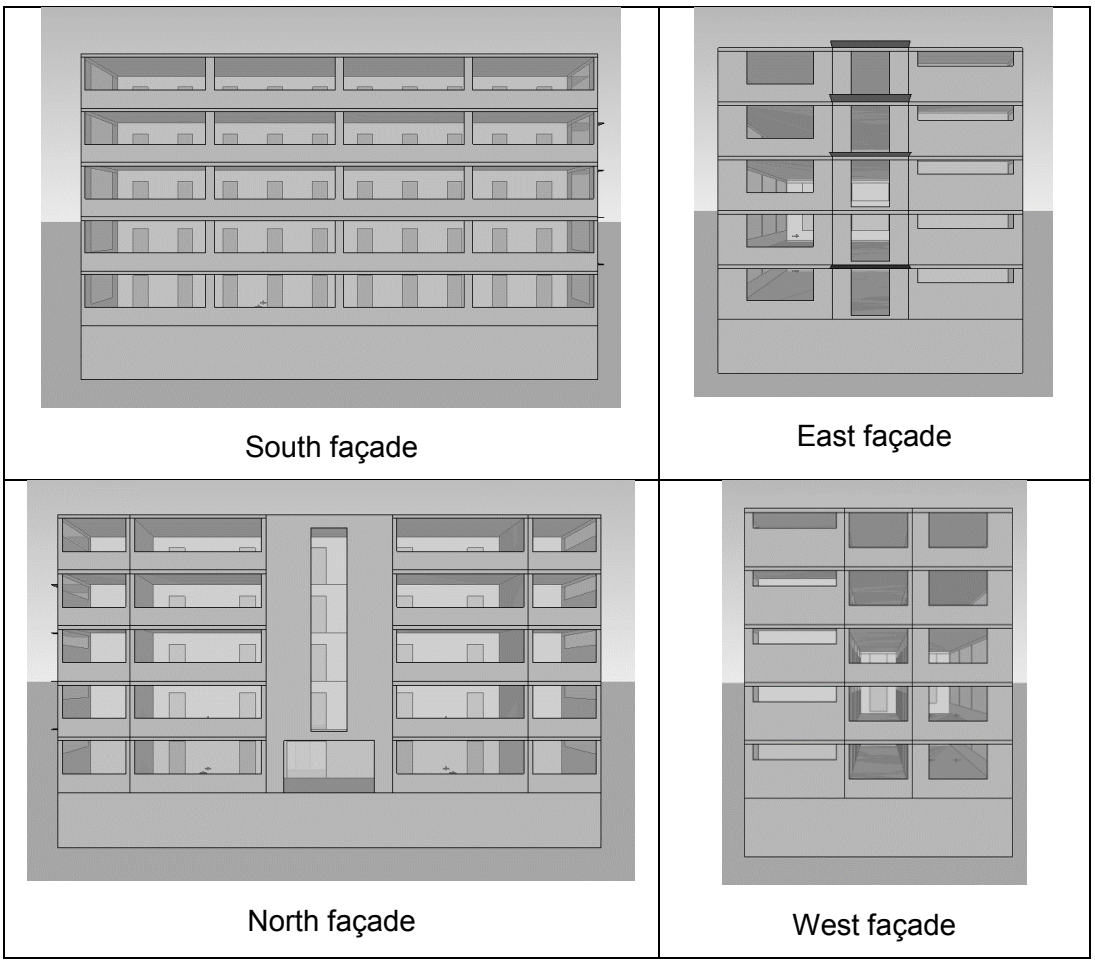

Figure 37: Prospects of the office building model.

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Table 7: Fixed characteristics of the office building model.

		All Countries
Building geometry	N° of heated floor =	5
	A/V ratio =	0.33 m^2/m^3
	Orientation:	S/N
	Net dimensions of heated volume =	30 x 16 x 15 m
	Net floor area of heated zones =	2400 m^2
	Area of S façade =	450 m^2
	Area of E façade =	240 m^2
	Area of N façade =	450 m^2
	Area of W façade =	240 m^2
	Area of Roof =	480 m2
	Area of Basement =	480 m2
	Window area on S façade =	56%
	Window area on E façade =	32%
	Window area on N façade =	50%
	Window area on W façade =	35%
Internal gains	People design level =	18 m^2/people
	Lighting design level =	14 W/m2
	Appliances design level =	9 W/m^2

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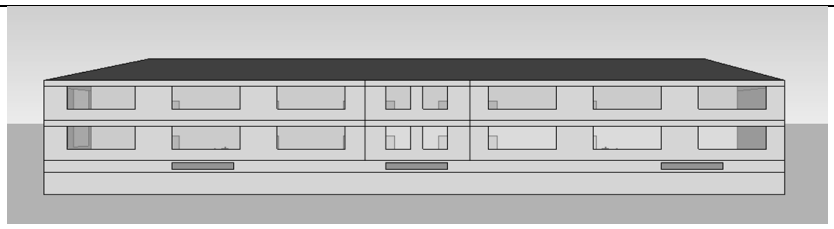
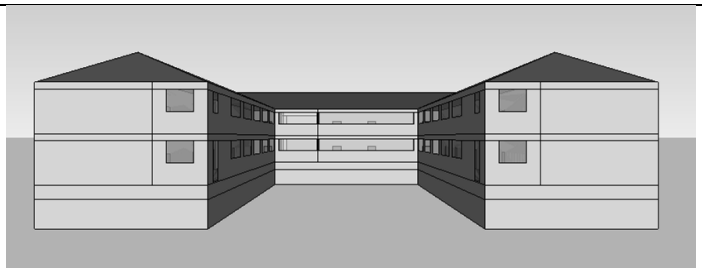
3.4.4 School

As reference model of school a two-floors building has been selected. It is “U” shaped with a heated surface of 3500 m^2 and its A/V ratio is 0.46. The main other characteristics involved on the simulation task are shown in the following tables.



South/North façade



East façade

West façade

Fig. 2: Prospects of the school model.

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Tab. 2: Fixed characteristics of the school model.

		All Countries
Building geometry	N° of heated floor =	2
	A/V ratio =	0.46 m2/m3
	Orientation:	S/N
	Net dimensions of heated volume =	45 x 60 x 7 m (U shape)
	Net floor area of heated zones =	3500 m^2
	Area of S façade =	752.5 m^2
	Area of E façade =	315 m^2
	Area of N façade =	752.5 m^2
	Area of W façade =	315 m^2
	Area of Roof =	1750 m2
	Area of Basement =	1750 m2
	Window area on S façade =	32%
	Window area on E façade =	22%
	Window area on N façade =	29%
	Window area on W façade =	40%
Internal gains	People design level =	5.6 m^2/people
	Lighting design level =	12 W/m2
	Appliances design level =	1.75 W/m^2

3.5 Identification of technical packages and building/system variants

In order to compile packages of measures to increase the energy performance compared to the reference cases, technologies and techniques from the following groups have been taken into account:

- Building envelope: measures that deal primarily with the reduction of heat transmission and improved air tightness of the building envelope with the intention of reducing transmission losses and losses from (uncontrolled) air-exchange.
- Space heating: an active system is usually necessary to meet the demand for heating. This demand can be met by efficient and/or renewable energy systems (e.g. condensing boilers, heat pumps, thermal solar panels, ...) in conjunction with suitable storage and distribution systems.
- Domestic hot water: DHW is often produced with the same system used for space heating, but it can also be supplied by combined systems (e.g. when integrating solar energy systems with a generator using fuel or electricity) or separate systems. High efficient storage and distribution systems are crucial for reducing heat losses along all the chain.
- Ventilation systems: mechanical ventilation systems allow having control on the air-change rates necessary for IAQ and can also limit losses from air-exchange if heat recovery systems are installed. Ventilation and heat recovery can have both a centralised or decentralised layout, with the latter sometimes easier to use in retrofit work.
- Cooling: passive cooling systems such as shading devices, night ventilation coupled with exposed mass, etc., can help reduce or avoid cooling needs to be met by active systems.
- Lighting: for office and school buildings, in combination with adopted cooling strategies, we adopted also energy efficiency actions on lighting, particularly: high efficiency lighting installations, and automatic control of high efficient lighting in function of indoor illuminance levels and glare reduction.

About the envelope measures, keeping the building geometries/orientations and the use schedules fixed, in this report we present an example where we chose to simulate the effect of five technological packages of increasing performance (low, medium-low, medium, medium-high, high) in the three technology areas:

- Opaque envelope **(e)**
- Windows (frame and glazing) **(w)**
- Solar protection and passive cooling **(c)**

Combining them in three steps of variation (see tables below) for each area. Please note that the three steps are different in different cities in order to take into account the climate.

In the following tables, we present

- the symbols with which this packages variants will be indicated in the results (-, o-, o, o+, +),
- the values corresponding to each level of performance,

respectively for single family house, apartment block, offices and school buildings in each climate.

Notes about following table:

* windows U-value indicated has been calculated for a window reference geometry

** variants linked to efficiency of lighting system:

- they haven't been adopted in single family houses and in apartment block
- for office building, the values indicated in the table, are refer respectively at the office, service and meeting rooms
- for school building, the values indicated in the table, are refer respectively at the classrooms, office and service rooms

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able 8: Considered envelope measures families for Single House - Part 1

SINGLE HOUSE				SEVILLE		MADRID		ROME		MILAN		BUCHAREST	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m^{2}K	e:-	1,43	e:-	1,43	e:-	1,22	e:-	1,22	e:-	1,43
	Roof	U	W/m^{2}K		1,90		1,90		1,67		1,67		1,60
	Basement	U	W/m^{2}K		1,32		1,32		1,69		1,69		1,28
	External Wall	U	W/m^{2}K	e:o-	0,51	e:o	0,31	e:o-	0,48	e:o	0,30	e:o	0,31
	Roof	U	W/m^{2}K		0,56		0,23		0,54		0,23		0,23
	Basement	U	W/m^{2}K		0,50		0,50		0,54		0,54		0,49
	External Wall	U	W/m^{2}K	e:o	0,31	e:o+	0,22	e:o	0,30	e:o+	0,22	e:o+	0,22
	Roof	U	W/m^{2}K		0,33		0,18		0,32		0,18		0,18
	Basement	U	W/m^{2}K		0,31		0,31		0,32		0,32		0,30
	External Wall	U	W/m^{2}K	e:o+	0,22	e:+	0,18	e:o+	0,22	e:+	0,17	e:+	0,18
	Roof	U	W/m^{2}K		0,23		0,12		0,23		0,12		0,12
	Basement	U	W/m^{2}K		0,22		0,22		0,23		0,23		0,22
WINDOWS	Window Air permeability	U *	W/m^{2}K	w:-	5,84	w:-	5,84	w:o	3,01	w:o	3,01	w:o	2,67
		Solar Trasm.	-		0,72		0,72		0,62		0,62		0,62
		Visible Trasm	-		0,72		0,72		0,65		0,65		0,65
		air infiltration	1/h		0,77		0,77		0,77		0,77		0,77
	Window Air permeability	U *	W/m^{2}K	w:o	2,60	w:o	2,60	w:o	2,60	w:o	2,60	w:o+	1,71
		Solar Trasm.	-		0,62		0,62		0,62		0,62		0,64
		Visible Trasm	-		0,65		0,65		0,65		0,65		0,65
		air infiltration	1/h		0,61		0,61		0,61		0,61		0,58
	Window Air permeability	U *	W/m^{2}K	w:o+	1,71	w:o+	1,71	w:o+	1,71	w:o+	1,71	w:+	1,03
		Solar Trasm.	-		0,64		0,64		0,64		0,64		0,55
		Visible Trasm	-		0,65		0,65		0,65		0,65		0,59
		air infiltration	1/h		0,58		0,58		0,58		0,58		0,58
COOLING STRATEGIES	Solar shading	-	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m^2		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										
	Solar shading	-	-	c:o+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-
	Night-Cooling	h^{-1}	1/h		4,0		4,0		4,0		4,0		4,0
	Lighting Load	power **	W/m^2		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										

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Table 9: Considered envelope measures families for Single House - Part 2

SINGLE HOUSE				VIENNA		PARIS		PRAGUE		BERLIN		HELSINKY	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m²K	e:-	1,25	e:-	1,54	e:-	1,34	e:-	0,93	e:-	0,48
	Roof	U	W/m²K		1,38		1,21		1,33		1,11		0,30
	Basement	U	W/m²K		1,80		1,98		1,24		1,02		0,48
	External Wall	U	W/m²K	e:o	0,30	e:o	0,32	e:o	0,31	e:o	0,28	e:o	0,22
	Roof	U	W/m²K		0,22		0,22		0,22		0,22		0,14
	Basement	U	W/m²K		0,55		0,57		0,49		0,45		0,48
	External Wall	U	W/m²K	e:o+	0,22	e:o+	0,23	e:o+	0,22	e:o+	0,21	e:o+	0,17
	Roof	U	W/m²K		0,17		0,17		0,17		0,17		0,12
	Basement	U	W/m²K		0,33		0,33		0,30		0,29		0,48
	External Wall	U	W/m²K	e:+	0,17	e:+	0,18	e:+	0,17	e:+	0,16	e:+	0,17
	Roof	U	W/m²K		0,12		0,12		0,12		0,12		0,09
	Basement	U	W/m²K		0,23		0,24		0,22		0,21		0,48
WINDOWS	Window Air permeability	U *	W/m²K	w:o	2,62	w:-	3,47	w:o	2,66	w:o	2,67	w:o	2,50
		Solar Trasm.	-		0,62		0,62		0,62		0,62		0,61
		Visible Trasm	-		0,65		0,65		0,65		0,65		0,65
		air infiltration	1/h		0,77		0,77		0,77		0,77		0,77
	Window Air permeability	U *	W/m²K	w:o+	1,71	w:o	2,60	w:o+	1,71	w:+	1,03	w:+	1,03
		Solar Trasm.	-		0,64		0,62		0,64		0,55		0,55
		Visible Trasm	-		0,65		0,65		0,65		0,59		0,59
		air infiltration	1/h		0,58		0,61		0,58		0,58		0,58
	Window Air permeability	U *	W/m²K	w:+	1,03	w:o+	1,71	w:+	1,03	w:+	0,70	w:+	0,70
		Solar Trasm.	-		0,55		0,64		0,55		0,50		0,50
		Visible Trasm	-		0,59		0,65		0,59		0,59		0,59
		air infiltration	1/h		0,58		0,58		0,58		0,58		0,58
COOLING STRATEGIES	Solar shading	-	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m²		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										
	Solar shading	-	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-
	Night-Cooling	h^{-1}	1/h		4,0		4,0		4,0		4,0		4,0
	Lighting Load	power **	W/m²		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										

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Table 10: Considered envelope measures families for Apartment Block - Part 1.

APARTMENT BLOCK				SEVILLE		MADRID		ROME		MILAN		BUCHAREST	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m²K	e:-	1,46	e:-	1,46	e:-	1,22	e:-	1,22	e:-	1,46
	Roof	U	W/m²K		1,90		1,90		1,67		1,67		1,25
	Basement	U	W/m²K		1,30		1,30		1,65		1,65		1,35
	External Wall	U	W/m²K	e:o-	0,52	e:o	0,31	e:o-	0,48	e:o	0,30	e:o	0,31
	Roof	U	W/m²K		0,56		0,23		0,54		0,23		0,22
	Basement	U	W/m²K		0,50		0,50		0,54		0,54		0,50
	External Wall	U	W/m²K	e:o	0,31	e:o+	0,23	e:o	0,30	e:o+	0,22	e:o+	0,23
	Roof	U	W/m²K		0,33		0,18		0,32		0,18		0,17
	Basement	U	W/m²K		0,31		0,31		0,32		0,32		0,31
	External Wall	U	W/m²K	e:o+	0,23	e:+	0,18	e:o+	0,22	e:+	0,17	e:+	0,18
	Roof	U	W/m²K		0,23		0,12		0,23		0,12		0,12
	Basement	U	W/m²K		0,22		0,22		0,23		0,23		0,22
WINDOWS	Window Air permeability	U *	W/m²K	w:-	5,83	w:-	5,83	w:o	2,99	w:o	2,99	w:o	2,67
		Solar Trasm.	-		0,69		0,69		0,59		0,59		0,62
		Visible Trasm	-		0,68		0,68		0,61		0,61		0,65
		air infiltration	1/h		0,77		0,77		0,77		0,77		0,77
	Window Air permeability	U *	W/m²K	w:o	2,58	w:o	2,58	w:o	2,58	w:o	2,58	w:o+	1,71
		Solar Trasm.	-		0,59		0,59		0,59		0,59		0,64
		Visible Trasm	-		0,61		0,61		0,61		0,61		0,65
		air infiltration	1/h		0,61		0,61		0,61		0,61		0,58
	Window Air permeability	U *	W/m²K	w:o+	1,69	w:o+	1,69	w:o+	1,69	w:o+	1,69	w:+	1,03
		Solar Trasm.	-		0,61		0,61		0,61		0,61		0,55
		Visible Trasm	-		0,62		0,62		0,62		0,62		0,59
		air infiltration	1/h		0,58		0,58		0,58		0,58		0,58
COOLING STRATEGIES	Solar shading	-	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m²		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										
	Solar shading	-	-	c:o+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-
	Night-Cooling	h^{-1}	1/h		4,0		4,0		4,0		4,0		4,0
	Lighting Load	power **	W/m²		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										

Table 11: Considered envelope measures families for Apartment Block - Part 2.

APARTMENT BLOCK				VIENNA		PARIS		PRAGUE		BERLIN		HELSINKY	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m^{2}K	e:-	1,25	e:-	2,87	e:-	0,63	e:-	1,43	e:-	0,60
	Roof	U	W/m^{2}K		1,38		2,56		0,65		1,18		0,39
	Basement	U	W/m^{2}K		1,80		1,98		1,24		1,65		0,48
	External Wall	U	W/m^{2}K	e:o	0,30	e:o	0,35	e:o	0,24	e:o	0,31	e:o	0,24
	Roof	U	W/m^{2}K		0,22		0,24		0,19		0,22		0,16
	Basement	U	W/m^{2}K		0,55		0,57		0,49		0,54		0,48
	External Wall	U	W/m^{2}K	e:o+	0,22	e:o+	0,24	e:o+	0,19	e:o+	0,22	e:o+	0,18
	Roof	U	W/m^{2}K		0,17		0,19		0,15		0,17		0,13
	Basement	U	W/m^{2}K		0,33		0,33		0,30		0,32		0,48
	External Wall	U	W/m^{2}K	e:+	0,17	e:+	0,19	e:+	0,15	e:+	0,18	e:+	0,15
	Roof	U	W/m^{2}K		0,12		0,13		0,11		0,12		0,10
	Basement	U	W/m^{2}K		0,23		0,24		0,22		0,23		0,48
WINDOWS	Window Air permeability	U *	W/m^{2}K	w:o	2,62	w:-	3,42	w:o	2,66	w:o	2,67	w:o	2,51
		Solar Trasm.	-		0,62		0,59		0,62		0,62		0,61
		Visible Trasm	-		0,65		0,61		0,65		0,65		0,65
		air infiltration	1/h		0,77		0,77		0,77		0,77		0,77
	Window Air permeability	U *	W/m^{2}K	w:o+	1,71	w:o	2,58	w:o+	1,71	w:+	1,03	w:+	1,03
		Solar Trasm.	-		0,64		0,59		0,64		0,55		0,55
		Visible Trasm	-		0,65		0,61		0,65		0,59		0,59
		air infiltration	1/h		0,58		0,61		0,58		0,58		0,58
	Window Air permeability	U *	W/m^{2}K	w:+	1,03	w:o+	1,69	w:+	1,03	w:+	0,70	w:+	0,70
		Solar Trasm.	-		0,55		0,61		0,55		0,50		0,50
		Visible Trasm	-		0,59		0,62		0,59		0,59		0,59
		air infiltration	1/h		0,58		0,58		0,58		0,58		0,58
COOLING STRATEGIES	Solar shading	-	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-	c:o L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m^2		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										
	Solar shading	-	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-	c:+ L: o	-
	Night-Cooling	h^{-1}	1/h		4,0		4,0		4,0		4,0		4,0
	Lighting Load	power **	W/m^2		3,50		3,50		3,50		3,50		3,50
	Lighting Control	-	-										

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Table 12: Considered envelope measures families for Office - Part 1.

OFFICE				SEVILLE		MADRID		ROME		MILAN		BUCHAREST	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m²K	e:-	1,37	e:-	1,37	e:-	1,17	e:-	1,17	e:-	1,34
	Roof	U	W/m²K		1,29		1,29		1,28		1,28		1,01
	Basement	U	W/m²K		1,54		1,54		1,74		1,74		1,10
	External Wall	U	W/m²K	e:o-	0,46	e:o-	0,46	e:o-	0,44	e:o-	0,44	e:o-	0,46
	Roof	U	W/m²K		0,45		0,45		0,45		0,45		0,26
	Basement	U	W/m²K		0,48		0,48		0,50		0,50		0,43
	External Wall	U	W/m²K	e:o	0,28	e:o	0,28	e:o	0,27	e:o	0,27	e:o	0,27
	Roof	U	W/m²K		0,20		0,20		0,20		0,20		0,15
	Basement	U	W/m²K		0,29		0,29		0,29		0,29		0,27
	External Wall	U	W/m²K	e:o+	0,16	e:o+	0,16	e:o+	0,15	e:o+	0,13	e:o+	0,12
	Roof	U	W/m²K		0,13		0,13		0,13		0,13		0,10
	Basement	U	W/m²K		0,20		0,20		0,21		0,21		0,19
WINDOWS	Window Air permeability	U *	W/m²K	w:-	5,86	w:-	5,86	w:-	5,78	w:o	3,47	w:o	2,72
		Solar Trasm.	-		0,85		0,85		0,85		0,73		0,73
		Visible Trasm	-		0,90		0,90		0,90		0,81		0,81
		air infiltration	1/h		1,15		1,15		1,15		1,15		0,75
	Window Air permeability	U *	W/m²K	w:o	2,72	w:o	2,72	w:o	2,72	w:o+	2,11	w:o+	2,11
		Solar Trasm.	-		0,73		0,73		0,73		0,52		0,52
		Visible Trasm	-		0,81		0,81		0,81		0,76		0,76
		air infiltration	1/h		0,61		0,61		0,61		0,23		0,23
	Window Air permeability	U *	W/m²K	w:o+	2,11	w:o+	2,11	w:o+	2,11	w:+	0,77	w:+	0,77
		Solar Trasm.	-		0,52		0,52		0,52		0,33		0,33
		Visible Trasm	-		0,76		0,76		0,76		0,65		0,65
		air infiltration	1/h		0,23		0,23		0,23		0,08		0,08
COOLING STRATEGIES	Solar shading	-	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m²		18-8-18		18-8-18		18-8-18		18-8-18		18-8-18
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:o+ L: o+	-	c:o+ L: o+	-	c:o+ L: o+	-	c:o+ L: o+	-	c:o+ L: o+	-
	Night-Cooling	h^{-1}	1/h		2,5		2,5		2,5		2,5		2,5
	Lighting Load	power **	W/m²		12-5-12		12-5-12		12-5-12		12-5-12		12-5-12
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:+ L:+	-	c:+ L:+	-	c:+ L:+	-	c:+ L:+	-	c:+ L:+	-
	Night-Cooling	h^{-1}	1/h		5,0		5,0		5,0		5,0		5,0
	Lighting Load	power **	W/m²		6-2-6		6-2-6		6-2-6		6-2-6		6-2-6
	Lighting Control	-	-		-		-		-		-		-

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Table 13: Considered envelope measures families for Office - Part 2.

OFFICE				VIENNA		PARIS		PRAGUE		BERLIN		HELSINKY	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m²K	e:-	1,19	e:-	1,06	e:-	1,07	e:-	1,42	e:-	0,46
	Roof	U	W/m²K		1,11		1,65		0,50		0,68		0,39
	Basement	U	W/m²K		1,24		3,47		3,97		1,15		0,53
	External Wall	U	W/m²K	e:o-	0,27	e:o-	0,42	e:o	0,26	e:o	0,28	e:o	0,20
	Roof	U	W/m²K		0,27		0,29		0,16		0,23		0,18
	Basement	U	W/m²K		0,45		0,58		0,32		0,43		0,30
	External Wall	U	W/m²K	e:o+	0,15	e:o	0,26	e:o+	0,19	e:o+	0,16	e:o+	0,13
	Roof	U	W/m²K		0,15		0,16		0,13		0,14		0,12
	Basement	U	W/m²K		0,27		0,32		0,27		0,27		0,21
	External Wall	U	W/m²K	e:+	0,11	e:+	0,12	e:+	0,15	e:+	0,11	e:+	0,09
	Roof	U	W/m²K		0,11		0,11		0,09		0,10		0,09
	Basement	U	W/m²K		0,20		0,22		0,22		0,19		0,16
WINDOWS	Window Air permeability	U *	W/m²K	w:o	2,72	w:-	5,78	w:o	3,50	w:o	2,72	w:o	2,95
		Solar Trasm.	-		0,73		0,85		0,73		0,73		0,73
		Visible Trasm	-		0,81		0,90		0,81		0,81		0,81
		air infiltration	1/h		1,30		1,15		1,15		1,15		1,15
	Window Air permeability	U *	W/m²K	w:o+	1,53	w:o+	2,11	w:o+	1,77	w:o+	1,53	w:o+	1,53
		Solar Trasm.	-		0,52		0,52		0,52		0,52		0,52
		Visible Trasm	-		0,76		0,76		0,76		0,76		0,76
		air infiltration	1/h		0,23		0,23		0,23		0,23		0,23
	Window Air permeability	U *	W/m²K	w:+	0,77	w:+	0,77	w:+	0,78	w:+	0,77	w:+	0,78
		Solar Trasm.	-		0,33		0,33		0,33		0,33		0,33
		Visible Trasm	-		0,65		0,65		0,65		0,65		0,65
		air infiltration	1/h		0,08		0,08		0,08		0,08		0,08
COOLING STRATEGIES	Solar shading	-	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m²		18-8-18		18-8-18		18-8-18		18-8-18		18-8-18
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:o L: o+	-	c:o+ L: o+	-	c:o L: o+	-	c:o L: o+	-	c:o L: o+	-
	Night-Cooling	h^{-1}	1/h		0,0		2,5		0,0		0,0		0,0
	Lighting Load	power **	W/m²		12-5-12		12-5-12		12-5-12		12-5-12		12-5-12
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:o+ L:+	-	c:+ L:+	-	c:o+ L:+	-	c:o+ L:+	-	c:o+ L:+	-
	Night-Cooling	h^{-1}	1/h		2,5		5,0		2,5		2,5		2,5
	Lighting Load	power **	W/m²		6-2-6		6-2-6		6-2-6		6-2-6		6-2-6
	Lighting Control	-	-		-		-		-		-		-

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Table 14: Considered envelope measures families for School- Part 1.

SCHOOL				SEVILLE		MADRID		ROME		MILAN		BUCHAREST	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m²K	e:-	1,37	e:-	1,37	e:-	1,17	e:-	1,17	e:-	1,34
	Roof	U	W/m²K		2,19		2,19		1,57		1,57		4,14
	Basement	U	W/m²K		2,57		2,57		1,74		1,74		1,10
	External Wall	U	W/m²K	e:o-	0,46	e:o-	0,46	e:o-	0,44	e:o-	0,44	e:o-	0,46
	Roof	U	W/m²K		0,53		0,53		0,48		0,48		0,24
	Basement	U	W/m²K		0,55		0,55		0,50		0,50		0,43
	External Wall	U	W/m²K	e:o	0,28	e:o	0,28	e:o	0,27	e:o	0,27	e:o	0,27
	Roof	U	W/m²K		0,21		0,21		0,20		0,20		0,14
	Basement	U	W/m²K		0,31		0,31		0,29		0,29		0,27
	External Wall	U	W/m²K	e:o+	0,16	e:o+	0,16	e:o+	0,15	e:o+	0,13	e:o+	0,12
	Roof	U	W/m²K		0,13		0,13		0,13		0,13		0,10
	Basement	U	W/m²K		0,21		0,21		0,21		0,21		0,19
WINDOWS	Window Air permeability	U *	W/m²K	w:-	5,85	w:-	5,85	w:-	5,77	w:o	3,47	w:o	2,71
		Solar Trasm.	-		0,85		0,85		0,85		0,73		0,73
		Visible Trasm	-		0,90		0,90		0,90		0,81		0,81
		air infiltration	1/h		0,75		0,75		0,75		0,75		0,49
	Window Air permeability	U *	W/m²K	w:o	2,71	w:o	2,71	w:o	2,71	w:o+	2,10	w:o+	2,10
		Solar Trasm.	-		0,73		0,73		0,77		0,52		0,52
		Visible Trasm	-		0,81		0,81		0,81		0,76		0,76
		air infiltration	1/h		0,40		0,40		0,40		0,15		0,15
	Window Air permeability	U *	W/m²K	w:o+	2,10	w:o+	2,10	w:o+	2,10	w:+	0,77	w:+	0,77
		Solar Trasm.	-		0,52		0,52		0,52		0,33		0,33
		Visible Trasm	-		0,76		0,76		0,76		0,65		0,65
		air infiltration	1/h		0,15		0,15		0,15		0,05		0,05
COOLING STRATEGIES	Solar shading	-	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m²		18-15-8		18-15-8		18-15-8		18-15-8		18-15-8
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:o+ L: o+	-	c:o+ L: o+	-	c:o+ L: o+	-	c:o+ L: o+	-	c:o+ L: o+	-
	Night-Cooling	h^{-1}	1/h		2,5		2,5		2,5		2,5		2,5
	Lighting Load	power **	W/m²		12-10-5		12-10-5		12-10-5		12-10-5		12-10-5
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:+ L:+	-	c:+ L:+	-	c:+ L:+	-	c:+ L:+	-	c:+ L:+	-
	Night-Cooling	h^{-1}	1/h		5,0		5,0		5,0		5,0		5,0
	Lighting Load	power **	W/m²		6-5-2		6-5-2		6-5-2		6-5-2		6-5-2
	Lighting Control	-	-		-		-		-		-		-

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Table 15: Considered envelope measures families for School- Part 2.

SCHOOL				VIENNA		PARIS		PRAGUE		BERLIN		HELSINKY	
PACKAGES	BUILDING TECNOLOGY	PARAMETERS	UNIT	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE	VARIANT	VALUE
OPAQUE ENVELOPE	External Wall	U	W/m²K	e:-	2,59	e:-	1,17	e:-	1,41	e:-	1,42	e:-	0,62
	Roof	U	W/m²K		1,50		2,83		0,63		0,88		0,84
	Basement	U	W/m²K		1,24		3,47		3,97		1,15		0,70
	External Wall	U	W/m²K	e:o-	0,31	e:o-	0,44	e:o	0,28	e:o	0,28	e:o	0,22
	Roof	U	W/m²K		0,28		0,29		0,17		0,25		0,19
	Basement	U	W/m²K		0,45		0,50		0,32		0,43		0,35
	External Wall	U	W/m²K	e:o+	0,16	e:o	0,27	e:o+	0,20	e:o+	0,16	e:o+	0,14
	Roof	U	W/m²K		0,16		0,16		0,14		0,15		0,12
	Basement	U	W/m²K		0,27		0,29		0,27		0,27		0,23
	External Wall	U	W/m²K	e:+	0,11	e:+	0,13	e:+	0,16	e:+	0,11	e:+	0,10
	Roof	U	W/m²K		0,11		0,11		0,10		0,10		0,09
	Basement	U	W/m²K		0,20		0,21		0,22		0,19		0,17
WINDOWS	Window Air permeability	U *	W/m²K	w:o	2,72	w:-	5,78	w:o	3,50	w:o	2,72	w:o	2,95
		Solar Trasm.	-		0,73		0,85		0,73		0,73		0,73
		Visible Trasm	-		0,81		0,90		0,81		0,81		0,81
		air infiltration	1/h		0,85		0,75		0,75		0,75		0,75
	Window Air permeability	U *	W/m²K	w:o+	1,53	w:o+	2,11	w:o+	1,77	w:o+	1,53	w:o+	1,53
		Solar Trasm.	-		0,52		0,52		0,52		0,52		0,52
		Visible Trasm	-		0,76		0,76		0,76		0,76		0,76
		air infiltration	1/h		0,15		0,15		0,15		0,15		0,15
	Window Air permeability	U *	W/m²K	w:+	0,77	w:+	0,77	w:+	0,77	w:+	0,77	w:+	0,77
		Solar Trasm.	-		0,33		0,33		0,33		0,33		0,33
		Visible Trasm	-		0,65		0,65		0,65		0,65		0,65
		air infiltration	1/h		0,05		0,05		0,05		0,05		0,05
COOLING STRATEGIES	Solar shading	-	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-	c:o- L: o	-
	Night-Cooling	h^{-1}	1/h		0		0		0		0		0
	Lighting Load	power **	W/m²		18-15-8		18-15-8		18-15-8		18-15-8		18-15-8
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:o L: o+	-	c:o+ L: o+	-	c:o L: o+	-	c:o L: o+	-	c:o L: o+	-
	Night-Cooling	h^{-1}	1/h		0,0		2,5		0,0		0,0		0,0
	Lighting Load	power **	W/m²		12-10-5		12-10-5		12-10-5		12-10-5		12-10-5
	Lighting Control	-	-		-		-		-		-		-
	Solar shading	-	-	c:o+ L:+	-	c:+ L:+	-	c:o+ L:+	-	c:o+ L:+	-	c:o+ L:+	-
	Night-Cooling	h^{-1}	1/h		2,5		5,0		2,5		2,5		2,5
	Lighting Load	power **	W/m²		6-5-2		6-5-2		6-5-2		6-5-2		6-5-2
	Lighting Control	-	-		-		-		-		-		-

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In addition, for office and school buildings, in combination with adopted cooling strategies, we adopted also energy efficiency actions on lighting **(L)**, particularly

- high efficient lighting installations (for reduction of energy use for lighting and thermal loads due to lighiting);
- automatic control of high efficient lighting in function of indoor illuminance levels and glare reduction.

At the next step we have associated the envelope variants with a large number of coherent heating/cooling system plant architectures starting from the sub-plant variants shown in the following table.

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Table 16. Variants of systems considered in this analysis.

System plants considered in the generation of cost energy cloud
HEATING GENERATION:
remove the old heating generation system and install a new system of the same type
standard gas boiler
condensig gas boiler
reversible heat pump
ground source heat pump
connection to a district heating
biomass boiler
COOLING GENERATION:
no cooling system *
remove the old cooling generation system and install a new system of the same type
reversible heat pump
ground source heat pump
chiller with high SEER
HEATING EMISSION:
insulated radiant floor
radiator
fan coil / split
air diffuser
COOLING EMISSION:
no cooling emission system *
insulated radiant floor + local dehumifidier
fan coil / split
air diffuser
HEATING DISTRIBUTION:
no insulation
insulated pipe
COOLING DISTRIBUTION:
no cooling distribution system *
insulated pipe
HEATING CONTROL:
climatic control system
climatic + room indoor control system
COOLING CONTROL:
no cooling control system *
climatic control system
climatic + room indoor control system
MECHANICAL VENTILATION:
no mechanical ventilation (open the window with conscientious user behavior)
mechanical ventilation for IAQ (install a plants only for indoor air quality)
mechanical ventilation HVAC (indoor air quality+conditioning)
SOLAR PANELS - PHOTOVOLTAIC:
photovoltaic absent
photovoltaic present
SOLAR PANELS - THERMAL:
solar thermal panels absent
solar thermal panels present only for DHW
HEAT RECOVERY:
heat recovery absent
heat recovery present with hiat efficiency (thermal exchange)

* when the building and the cooling strategies ensure comfort condition of the indoor environment.

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For the considered systems, common values of efficiency coefficients are assumed according to regulations and standards for systems design and energy performance certification of buildings.

Table 17. Ranges of efficiency coefficient considered for systems components.

System type:	Efficiency coefficient in heating	Efficiency coefficient in cooling
Generation systems		
gas boiler	80%	-
condensing gas boiler	95% -104%	-
air to water reversible heat pump (high SCOP - SEER)	different for each building model of use and climate (see below)	
ground source reversible heat pump (high SCOP - SEER)	different for each building model of use and climate (see below)	
district heating connection	100%	-
biomass boiler	90%	-
Emission systems		
insulated radiant floor	97%-99%	97%
radiator	92%-95%	-
fan coil / split	94% - 96%	98%
air diffuser	90% - 94%	97%
Distribution systems		
not insulated pipes	92% - 95	92% - 95
insulated pipes	99%	99%
Control systems		
climatic control system	86% - 80%	90%
climatic + room indoor control system	98%-95%	98%

For some emission systems, in heating, the efficiency change with the power of emission.

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For control systems and for condensing gas boiler, in heating, the efficiency change with the emission system.

Particularly for heat pumps systems, seasonal coefficient of performance for heating (SCOP) and seasonal energy efficiency ratio for cooling (SEER) were calculated for each building variant and climate condition according to standard EN 14825 (2012) (Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - Testing and rating at part load conditions and calculation of seasonal performance.)

About renewable contributions from heat pumps; heat pump systems were considered as “on-site generation from on-site renewables” with limits and method according to EU Commission Decision 2013//114/UE (1/3/2013).

For what concerns the characteristics of solar systems, we considered photovoltaic panels of monocrystalline silicon with peak power factor of 0,15 kW/m2 and "vacuum tubes" with high efficiency, (72%) as thermal solar panels.

About energy contributions from solar photovoltaic and solar thermal systems, we consider these assumptions

Solar thermal systems

- Priority to solar thermal collectors to cover about 50% of energy need for domestic hot water, at starting year
- Loss in solar thermal panels efficiency of 1% / year

Photovoltaic systems

- Maximum the 50% of remaining surface of the roof is covered by photovoltaic panels (PV), north exposition exclude (to consider the actual available roof surface taking into account chimneys and other components on the roof)
- PV designed to cover not more than the primary energy demand of building
- 50% of produced electrical energy from PV is consider as directly used in the building
- 50% of produced electrical energy from PV is exported to the grid (in order to consider a form of load matching using the grid. The electrical energy exported to the grid is considered in global cost calculation with a proper cost, approximately a third of the delivered electricity price.)
- Loss in PV efficiency of 1% / year

Heat recovery system for ventilation was considered directly in energy simulations, using EnergyPlus, with a heat exchange efficiency of 80%. In the calculation of total

primary energy demand, in case of presence of heat recovery system, the additional energy consumption of fans due to heat exchanger is taken into account.

For the base refurbishment level, the old generator is replace with component of the same technology and with efficiency of current state of the market.

In order to ensure same comfort conditions, in the base refurbishment level we always assume to install an active cooling system, also in case where building to be renovated has not it. Cooling system installation is avoided in case where energy simulations outcomes show that comfort conditions are reachable without active cooling systems.

In calculations about Finland, gas generation systems were not considered due to the very low diffusion of gas carrier in finnish building sector, as shown in deliverable D2.1 of Entranze project. While all other systems (in Table 16) were considered in calculations to determine cost-energy curves and frequencies analysis about Finland context, in order to show possible potential of all available technologies, even if they are not commonly used today. In buildings selection part (Target buildings selection), solutions adopting solar thermal systems or radiant floors were not selected because in finnish main urban area these kind of technologies have barriers in local market and policy context (for example solar thermal systems diffusion is limited by the wide diffusion of district heating municipal network), as indicated by the Partners from Finland and their stakeholders.

In calculation about Spain, district heating was not considered, due to its very low diffusion also in main urban areas.

3.6 Calculation tools

3.6.1 EnergyPlus

EnergyPlus is one of the most used and reliable programs for energy analysis and thermal load simulation. It is based on a user's description of a building from the perspective of the building's physical make-up, associated mechanical systems, etc. EnergyPlus is able to calculate dynamically the heating and cooling loads necessary to maintain thermal control setpoints, conditions throughout an secondary HVAC system and coil loads, and the energy consumption of primary plant equipment as well as many other simulation details that are necessary to verify that the simulation is performing as the actual building would. Many of the simulation characteristics have been inherited from the legacy programs of BLAST and DOE–2.

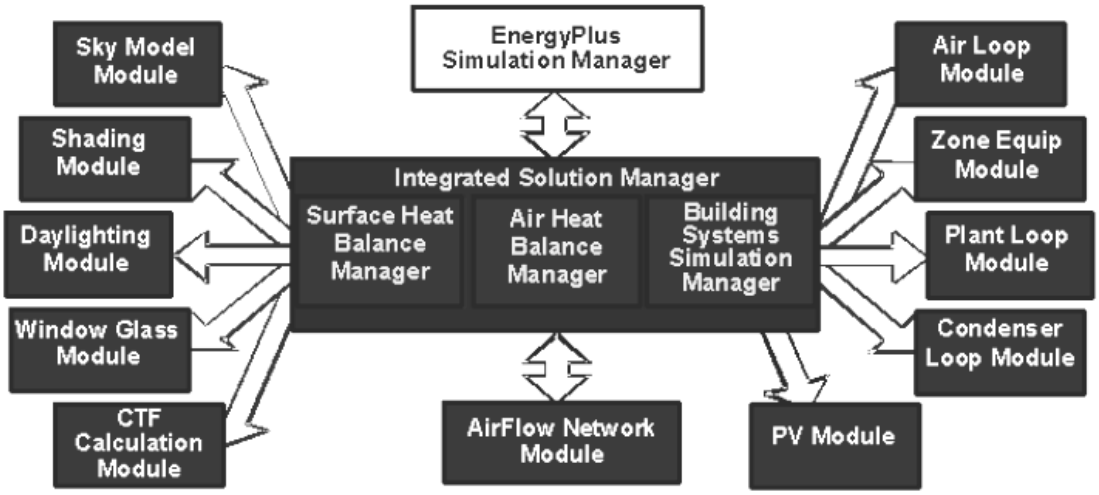

Fig. 3: EnergyPlus Program Schematic.

The principal program modules involved in the calculation of the energy needs for heating and cooling are the Surface Heat Balance and Air Heat Balance managers (with their sub-modules).

For more information see "EnergyPlus Engineering Reference"[5].

[5] http://apps1.eere.energy.gov/buildings/energyplus/pdfs/engineeringreference.pdf

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3.6.2 Cost / energy curves calculation tool

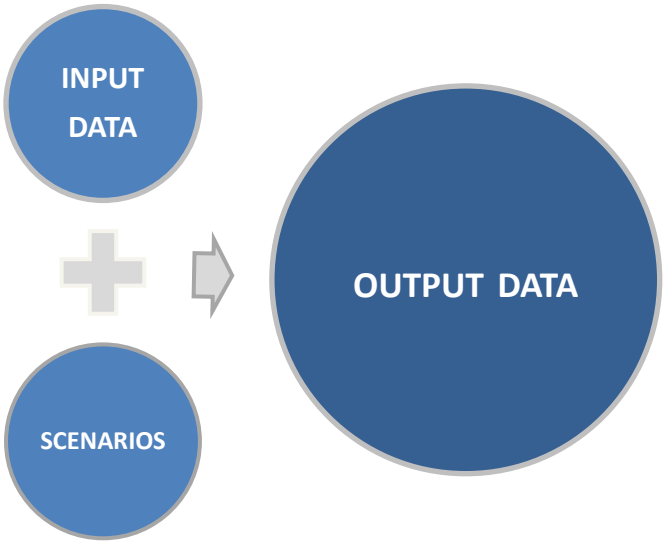
The cost / energy curves calculation tool (deliverable D3.4 of Entranze project [Entranze 2013 D34]) is composed of two different parts:

INPUT DATA

- Variant Code
- Building Data
- Energy Needs for domestic hot water
- Energy Needs (energy need for heating, cooling and energy use for lighting)
- Auxiliaries
- Envelope
- Plant system
- Renewable Sources (RES)

OUTPUT DATA

- Determination of Final Primary Energy (FPE)
- Global Cost Determination (Costs)
- Identification of the scenarios
- Generation of the graph (Graph)



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city:	city code
MILAN (IT)	4

Building type:	tipe code
office	2

Boundary floor surface:	
SMALL / LARGE BUILDING	
500	m²

Building Geometry		Units	Note
gross length	30,0	m	
gross width	16,0	m	
gross height	15,0	m	
n. level	5,0	n.	
floor surface (single level)	480,0	m²	
total (net) floor surface	2340,0	m²	*floor surface of conditioned space (external and internal partition wall excluded)*
total floor surface (gross)	2400,0	m²	auto calculated. You can enter a more precise value, if available
volume (gross)	7200,0	m³	auto calculated. You can enter a more precise value, if available
volume (air net)	7020,0	m³	volume without space occupied by walls, roofs and slabs
number of occupants	125,0	n.	
number of dwellings	34,0	n.	for office buildings input: approximates total floor surface (gross)/70m²
number of room	31,0		
gross envelopes surfaces (North)	450,0	m²	wall + windows surfaces
gross envelopes surfaces (East)	240,0	m²	wall + windows surfaces
gross envelopes surfaces (South)	450,0	m²	wall + windows surfaces
gross envelopes surfaces (West)	240,0	m²	wall + windows surfaces
wall surfaces (total)	1380,0	m²	
roof surfaces	480,0	m²	toward unconditioned space or outside
basament surfaces	480,0	m²	toward unconditioned space or ground
% windows [% env. surface(North)]	55,9%	-	
% windows [% env. surface(East)]	37,7%		
% windows [% env. surface(South)]	79,8%		
% windows [% env. surface(West)]	40,2%		
% windows [% env. surface(total)]	57,8%		
windows surfaces	797,5	m²	auto calculated. You can enter a more precise value, if available
net wall surfaces	582,5	m²	auto calculated. You can enter a more precise value, if available
total surface	2340,0	m²	auto calculated. You can enter a more precise value, if available
S/V	0,33	-	auto calculated. You can enter a more precise value, if available

Solar Surface Roof - Available		Units	Note
Slope roof South exposition	0,0	m²	*The Building roof is TOTALLY slope or TOTALLY orizzontal. NO MIX*
Slope roof Est exposition	0,0	m²	*Rules:*
Slope roof West exposition	0,0	m²	*-if Slope Roof >0 input , Orizzontal Roof must be =0*
Horizzontal roof-optimal exposition	450,0	m²	*-if Orizzontal Roof>0, Slop roof must be =0*
	CHECK OK		

Solar Surface Wall - Available			
South exposition	0,0	m²	
Est exposition	0,0	m²	
West exposition	0,0	m²	

Figure 38: Example of input building data.

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Energy needs: Domestic Hot Water [DHW]		Units	Note
T set point Domestic Hot Water	40,0	°C	
Using flow reducers?	NO		choose YES or NO
n. days of DHW demand Jan	15		
n. days of DHW demand Feb	20		
n. days of DHW demand Mar	20		
n. days of DHW demand Apr	20		
n. days of DHW demand Maj	20		
n. days of DHW demand Jun	20		
n. days of DHW demand Jul	20		
n. days of DHW demand Aug	10		
n. days of DHW demand Sept	20		
n. days of DHW demand Oct	20		
n. days of DHW demand Nov	20		
n. days of DHW demand Dec	15		
n. days of DHW demand Annual	220	n.	number of days in a year
l/(pers x day) without flow reducers	50	l	
l/(pers x day) with flow reducers	30	l	
	1375000,0	l/year	
density water	1	kg/l	
	1375000,0	kg/year	
thermal capacity water	4,182	kJ/kg °C	
cold water supply temperature [ºC]	11,0	°C	
energy needs	19,80	kWh/m²y	

Domestic Hot Water [DHW] - Efficiency		Units	Note
Type of DHW generation	centralized		
id. code	1		
⁇ generation	-		depends of the type centralized system
⁇ distribution	85%		
⁇ supply	95%		

Figure 39. Example of input on domestic hot water data.

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Heating	Cooling	Air chance for IAQ				Generation Power		Operation Time				Other Energy Demand		air to water heat pump EN 14825		water to water gound heat pump EN 14825	
q_he	q_co	infiltration		MAX Flow rate IAQ	Max Flow Rate HVAC	Qh [kW]	Qc [kW]	OT_he	OT_co	OT_IAQ	OT_Hvac	Lighting (*electric demand*)	Appliances (*electric demand*)	SCOP	SEER	SCOP	SEER
kWh/(m²y)	kWh/(m²y)	(m³/s)	ach	m³/s	m³/s	[kW]	[kW]	h	h	h	h	kWh/(m²y)	kWh/(m²y)	adim	adim	adim	adim
167.79	46.45	2.47	1.54	4.81	5.25	199.51	163.04	1453.00	492.00	461.00	2555.00	28.52		2.56	2.29	3.80	4.25
177.25	32.87	2.47	1.54	4.42	5.26	199.66	149.00	1534.00	381.00	272.00	2447.00	18.49		2.59	2.24	3.81	4.20
66.17	53.02	0.49	0.31	5.13	4.99	153.21	155.71	746.00	588.00	978.00	1910.00	28.97		2.33	2.34	3.47	4.26
73.00	32.89	0.49	0.31	4.76	4.69	154.08	138.75	819.00	410.00	718.00	1712.00	18.79		2.37	2.28	3.51	4.22
135.92	47.97	2.47	1.54	5.19	5.09	193.79	164.39	1212.00	504.00	459.00	2318.00	28.52		2.49	2.31	3.73	4.27
145.30	32.91	2.47	1.54	4.93	5.09	194.00	148.63	1294.00	383.00	252.00	2175.00	18.49		2.51	2.25	3.74	4.23
44.67	33.58	0.49	0.31	5.12	4.96	136.86	135.61	564.00	428.00	690.00	1362.00	18.79		2.26	2.31	3.39	4.27
50.99	17.41	0.49	0.31	4.76	4.77	137.65	111.10	640.00	271.00	563.00	1138.00	7.00		2.30	2.17	3.43	4.08
17.76	29.43	0.17	0.10	4.91	4.93	96.65	122.71	318.00	414.00	812.00	1130.00	19.85		2.00	2.32	3.19	4.29
22.44	14.57	0.17	0.10	4.80	4.74	98.14	109.15	395.00	231.00	662.00	904.00	7.36		2.09	2.14	3.30	3.99
37.00	34.26	0.49	0.31	5.15	4.98	131.58	137.04	486.00	432.00	699.00	1303.00	18.79		2.22	2.31	3.35	4.27
42.96	17.35	0.49	0.31	4.88	4.82	132.46	112.89	560.00	266.00	551.00	1051.00	7.00		2.27	2.16	3.39	4.06
11.64	30.15	0.17	0.10	5.08	4.98	87.89	122.58	229.00	425.00	802.00	1096.00	19.86		1.94	2.33	3.07	4.29
15.59	14.46	0.17	0.10	4.86	4.76	90.84	109.54	297.00	228.00	659.00	849.00	7.36		2.04	2.13	3.22	3.98
33.12	34.70	0.49	0.31	5.20	5.07	129.39	138.27	442.00	434.00	703.00	1258.00	18.79		2.19	2.31	3.32	4.27
38.86	17.39	0.49	0.31	4.92	4.85	130.35	113.22	515.00	265.00	550.00	1007.00	7.00		2.25	2.15	3.37	4.05
8.80	30.66	0.17	0.10	5.12	5.02	63.34	123.78	240.00	428.00	810.00	1086.00	19.86		2.03	2.33	3.22	4.29
12.23	14.49	0.17	0.10	4.86	4.76	68.88	109.35	307.00	229.00	663.00	829.00	7.36		2.13	2.13	3.36	3.98
167.36	46.43	2.47	1.54	4.81	5.25	199.49	163.04	1450.00	492.00	461.00	2555.00	28.52		2.56	2.29	3.80	4.25
176.81	32.85	2.47	1.54	4.42	5.26	199.64	149.00	1530.00	381.00	272.00	2446.00	18.49		2.58	2.24	3.81	4.20
60.59	52.70	0.49	0.31	5.13	4.99	150.71	155.68	695.00	585.00	978.00	1909.00	28.97		2.27	2.34	3.41	4.25

Energy Need Input data | Data about mechanical ventilation | Data about functioning of Plant System | Lighiting and Appliances | Data about Heat Pump Efficiency

Figure 40: Example of input of data on energy needs, ventilation systems and auxiliaries.

Required data on building envelope measures:

- Quantity
- Cost
- Lifespan
- Annual rate of increase of the cost
- Annual maintenance cost (percentage of initial cost)

Required data on systems measures:

- Quantities
- Costs
- Components lifespan
- Costs annual rate of increase
- Annual maintenance cost (percentage of initial cost – according to EN15459 - *Energy performance of buildings – Economic evaluation procedure for energy systems in buildings*)

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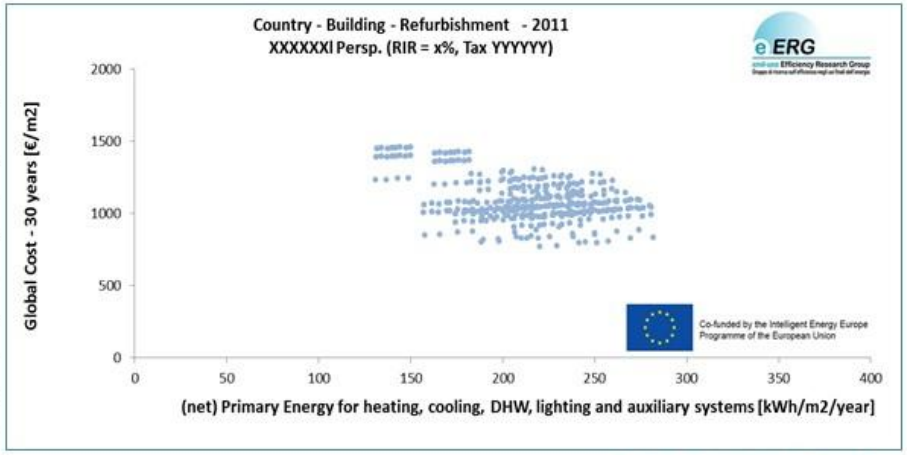
reference year of value in the input table below		2011
INPUT:		rb
PERSPECTIVE:		**1-Standard Private - reference scenarios**
reference year ("year 0") >=cell D2		**2011**
Y axis		**GLOBAL COST**
City		MILAN (IT)
INTEREST RATE	R	4,61%
INFLATION RATE	R_i	2,20%
REAL INTEREST RATE	R_r	2,36%
DISCOUNT FACTOR	R_d	0,50
BASE LEVEL OF ESCALATION RATE COSTS BUILDING TECNOLOGIES	R_p	0,00%
escalation rate of electric energy price (delivered)	$R_{p,el,d}$	-0,07%
escalation rate of electric energy price (exported)	$R_{p,el,ex}$	0,50%
escalation rate of gas energy price (delivered)	$R_{p,gas,d}$	0,98%
escalation rate of biomass energy price (delivered)	$R_{p,bio,d}$	0,15%
escalation rate of district heating energy price (delivered)	$R_{p,dh,d}$	1,43%
escalation rate of other cooling energy price (delivered)	$R_{p,dc,d}$	0,00%
TAX INCLUDED? (YES/NO)		YES
REFERENCE PERIOD	τ	30

SELECT:
Scenario
Starting Year



Example of Graph

Figure 41. Example of cost / energy cloud generation in the calculation tool.

4. Simulating energy needs for heating and cooling

4.1 Overview

The simulation/calculation campaign has been carried out within the EnergyPlus dynamic simulation environment (version 7.0-7.2) and applying the Standard EN 15316-3-1 (*Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-1: Domestic hot water systems, characterisation of needs*) and standard UNI 9182 for estimating the DHW demand.

For obtaining building envelopes fully comparable in terms of comfort performance (indoor comfort), the energy needs for all the building variants are calculated assuming the same indoor conditions for each typology:

- the same operative temperature and relative humidity setpoints:
    - residential buildings: 20°C in winter and 26°C in summer (latent control not applied);
    - tertiary buildings: 20°C and 25% in winter; 26°C and 60% in summer.
- the same values of minimum air change (at maximum occupation rate), coherent with the assumed occupation levels and the ventilation rates proposed by EN15251 for very low-polluted buildings:
    - 0.5 h^{-1} in the residential buildings;
    - 0.8 h^{-1} in the office building;
    - 1.6 h^{-1} in the school.

The thermal comfort levels have been chosen in this study, e.g. 20°C operative temperature in winter, while in summer 26°C, and 25 % minimum relative humidity in winter. Other choices, are also possible [Pagliano and Zangheri 2010] and may be one of the ways to reduce energy needs for heating and cooling below the ones calculated in this study, while offering comfortable living and working conditions to occupants, according to ISO 7730 and EN 15251 [Carlucci 2013].

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4.2 Results

4.2.1 Single family house

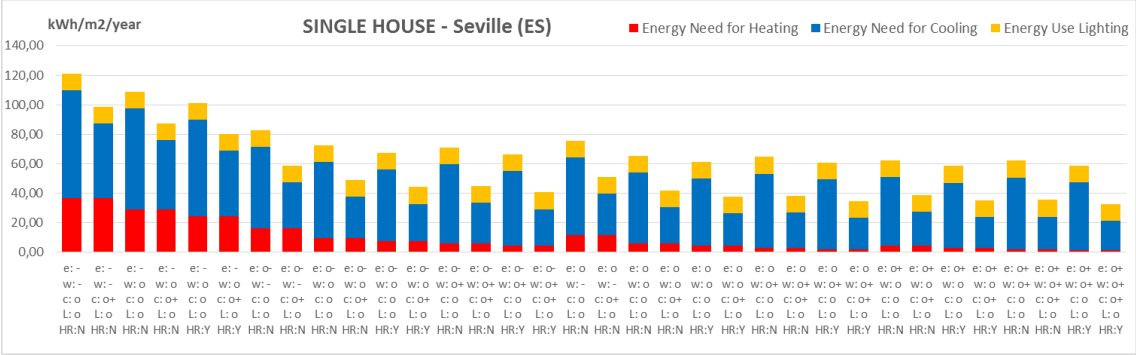

Figure 42: Energy needs for heating, cooling and energy use for lighting. Single House Seville

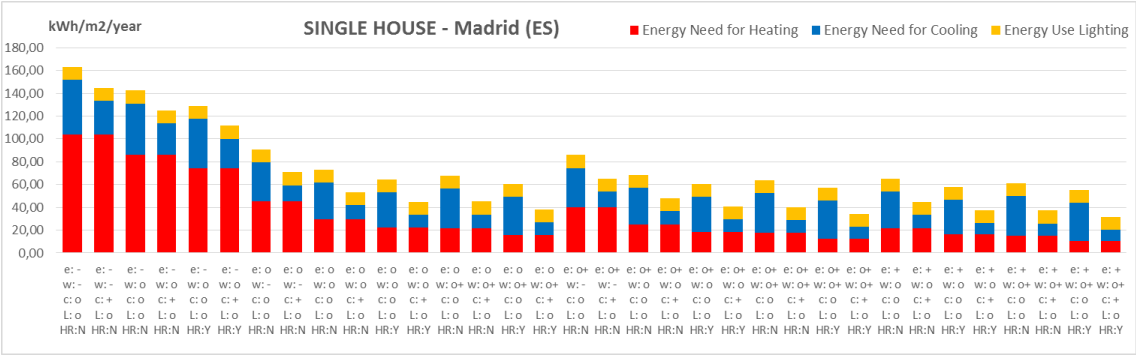

Figure 43: Energy needs for heating, cooling and energy use for lighting. Single House Madrid

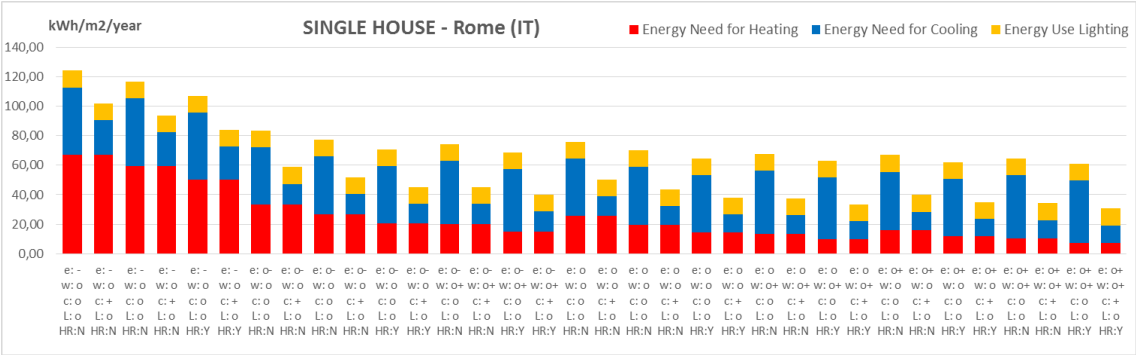

Figure 44: Energy needs for heating, cooling and energy use for lighting. Single House Rome

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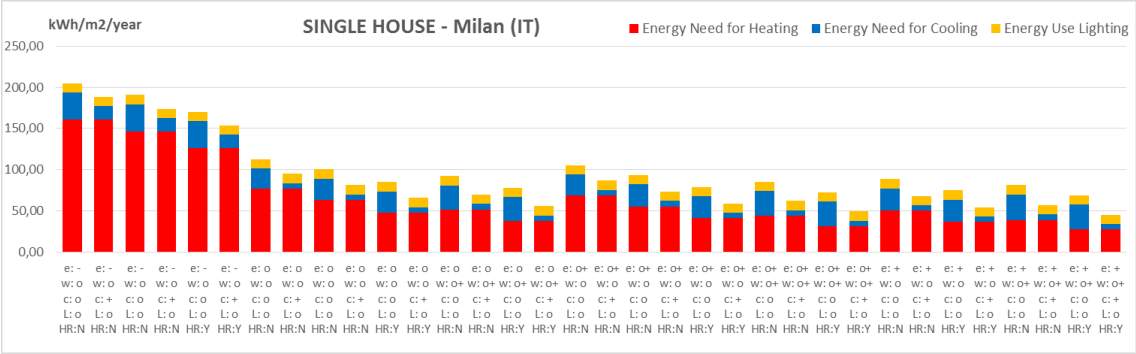

Figure 45: Energy needs for heating, cooling and energy use for lighting. Single House Milan

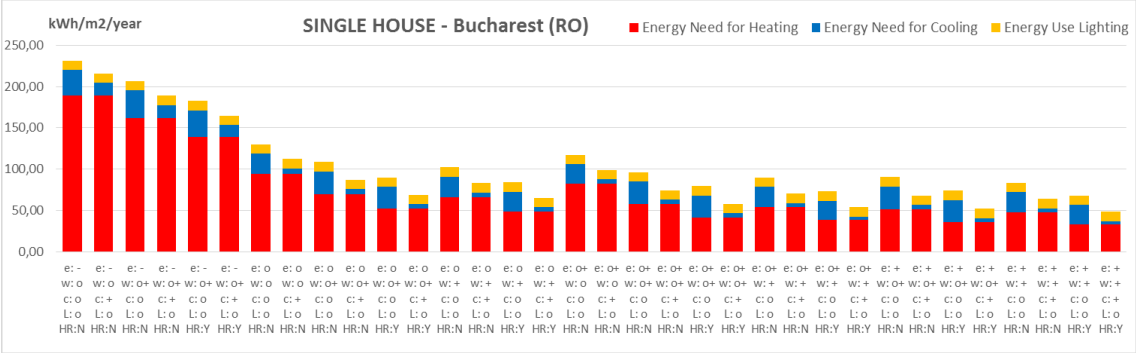

Figure 46: Energy needs for heating, cooling and energy use for lighting. Single House Bucharest

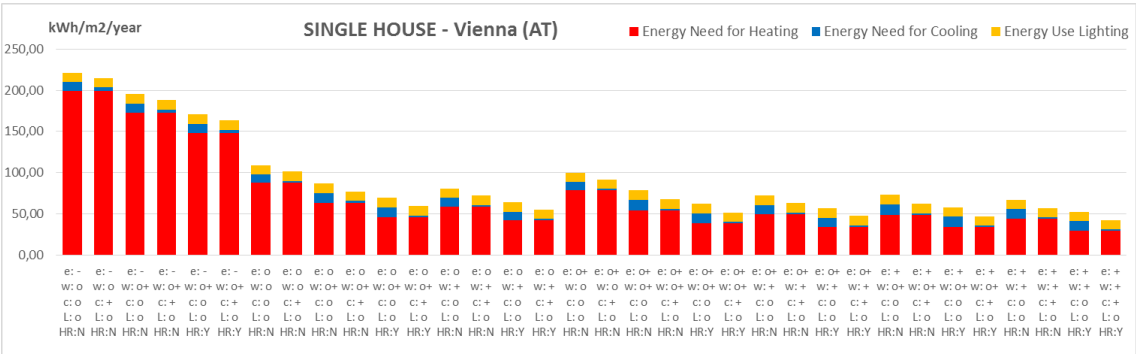

Figure 47: Energy needs for heating, cooling and energy use for lighting. Single House Vienna

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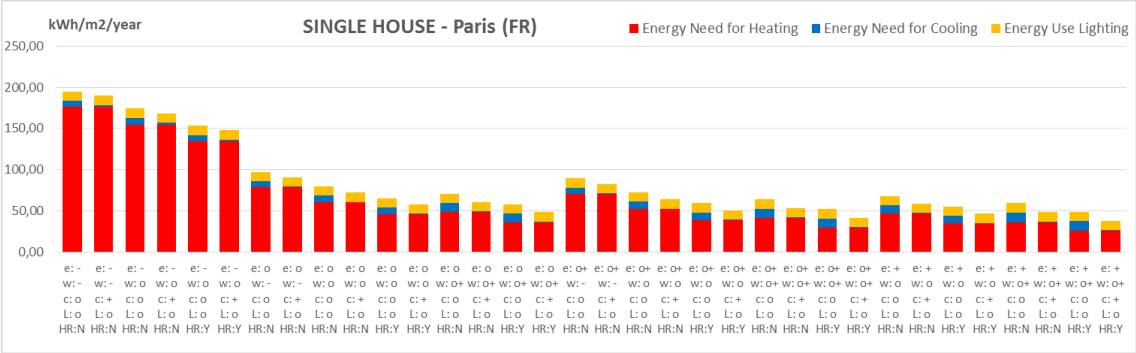

Figure 48: Energy needs for heating, cooling and energy use for lighting. Single House Paris

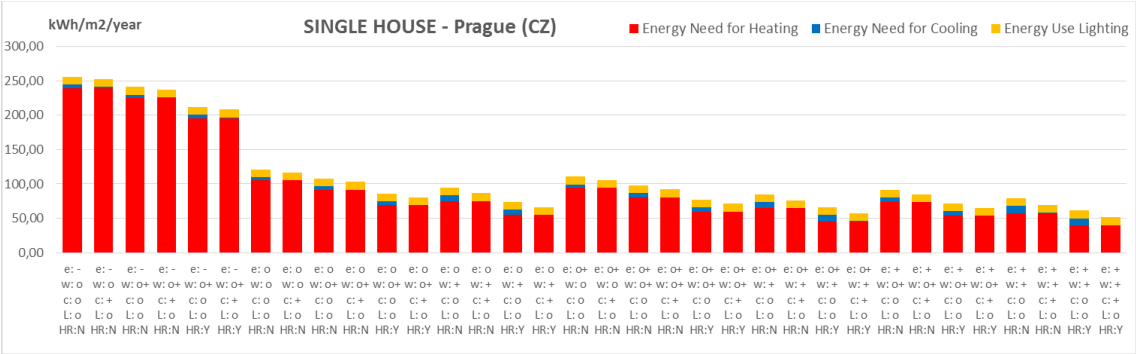

Figure 49: Energy needs for heating, cooling and energy use for lighting. Single House Prague

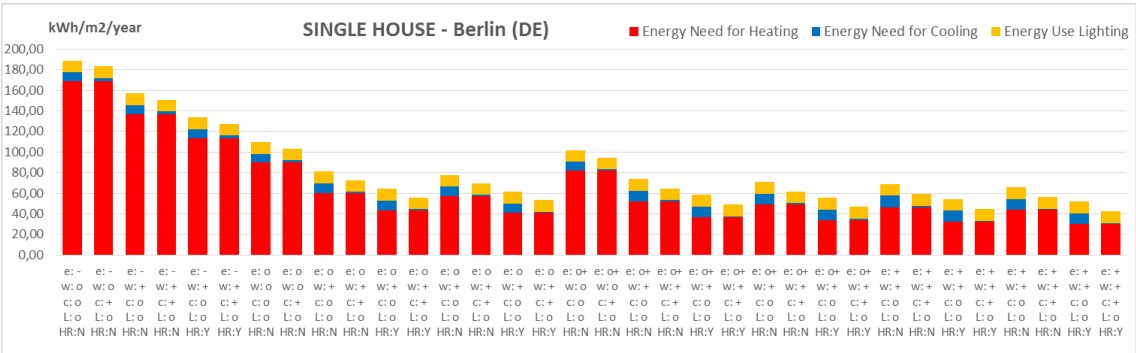

Figure 50: Energy needs for heating, cooling and energy use for lighting. Single House Berlin

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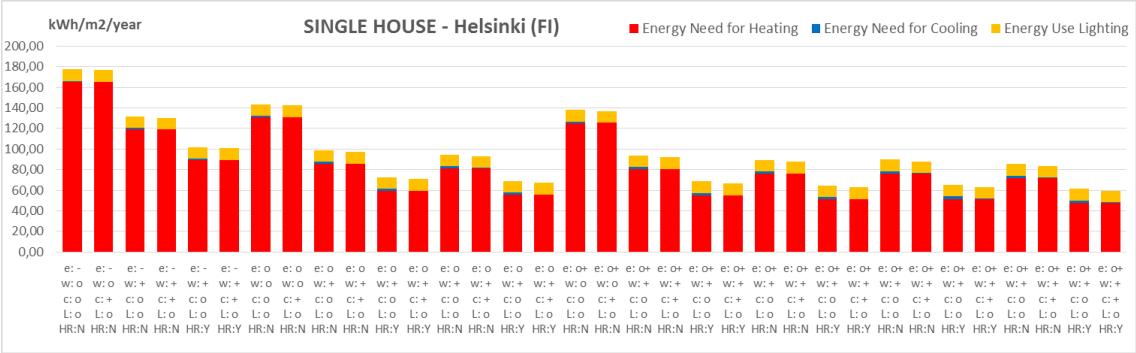

Figure 51: Energy needs for heating, cooling and energy use for lighting. Single House Seville

4.2.2 Apartment Block

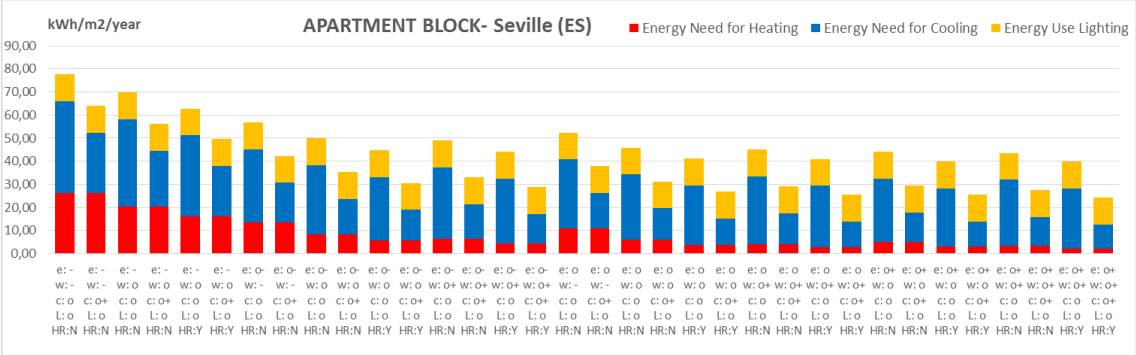

Figure 52: Energy needs for heating, cooling and energy use for lighting. Apartment Block Seville

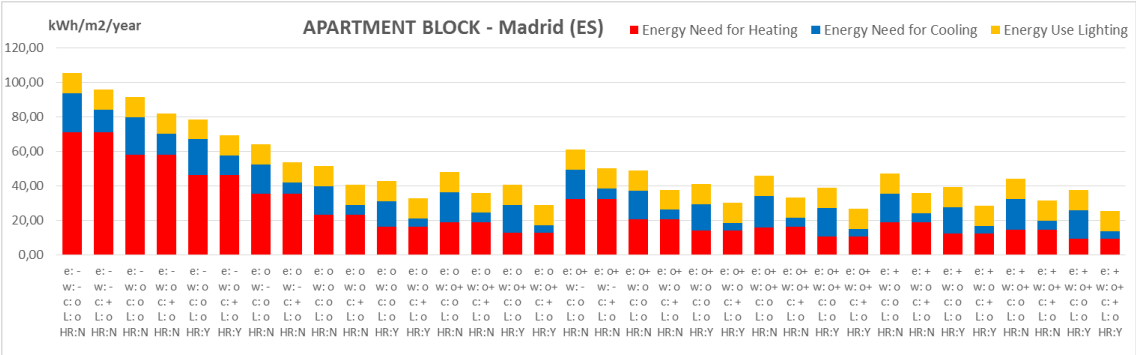

Figure 53: Energy needs for heating, cooling and energy use for lighting. Apartment Block Madrid

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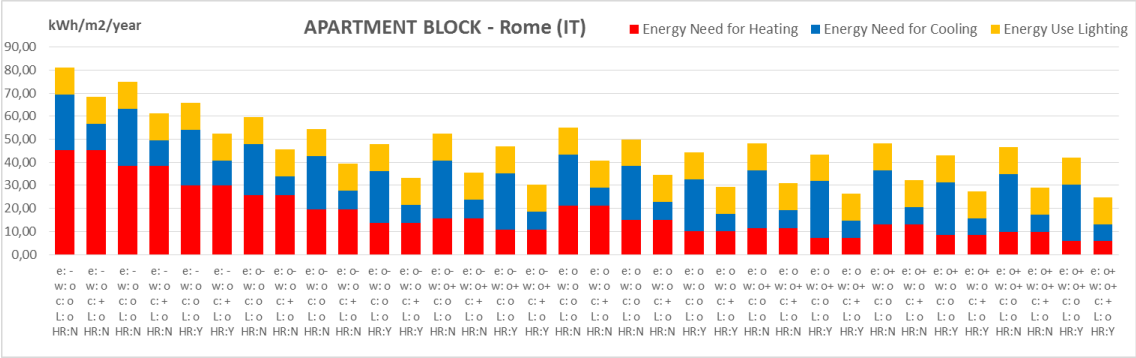

Figure 54: Energy needs for heating, cooling and energy use for lighting. Apartment Block Rome

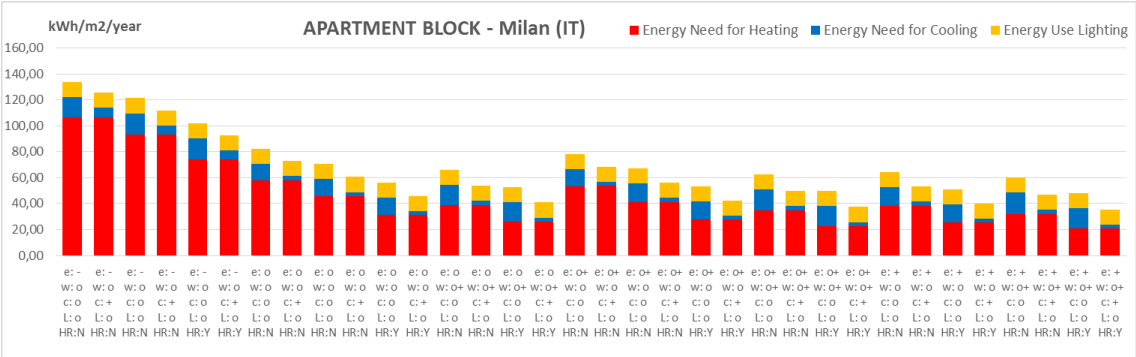

Figure 55: Energy needs for heating, cooling and energy use for lighting. Apartment Block Milan

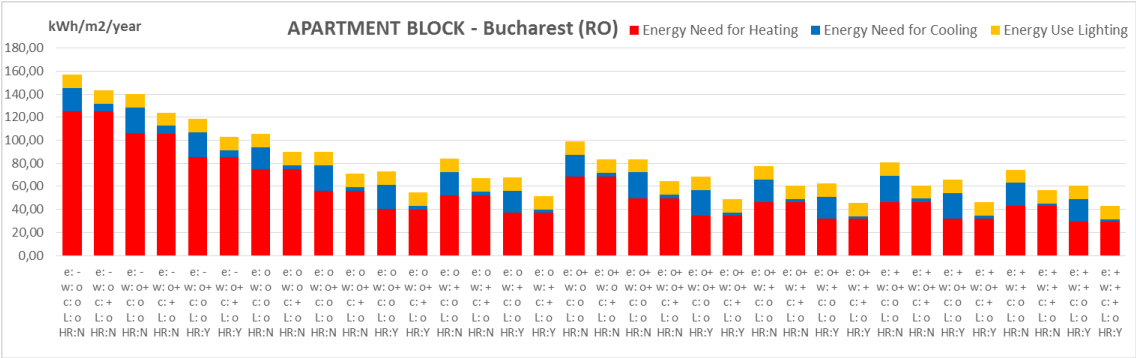

Figure 56: Energy needs for heating, cooling and energy use for lighting. Apartment Block Bucharest

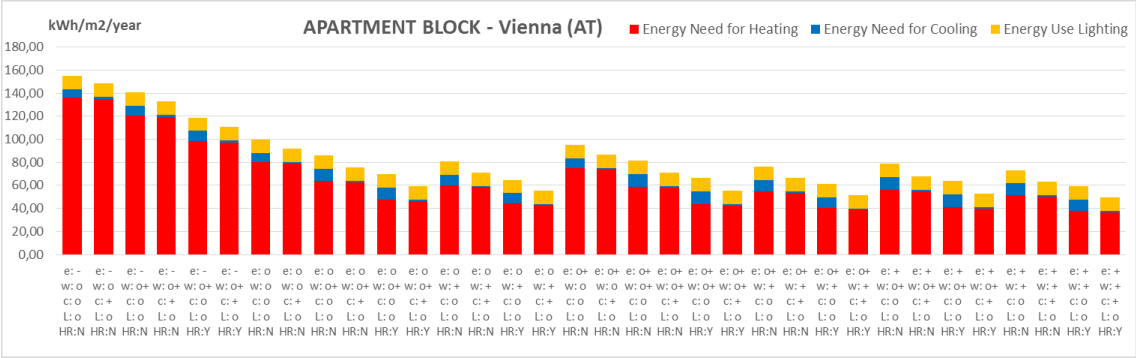

Figure 57: Energy needs for heating, cooling and energy use for lighting. Apartment Block Vienna

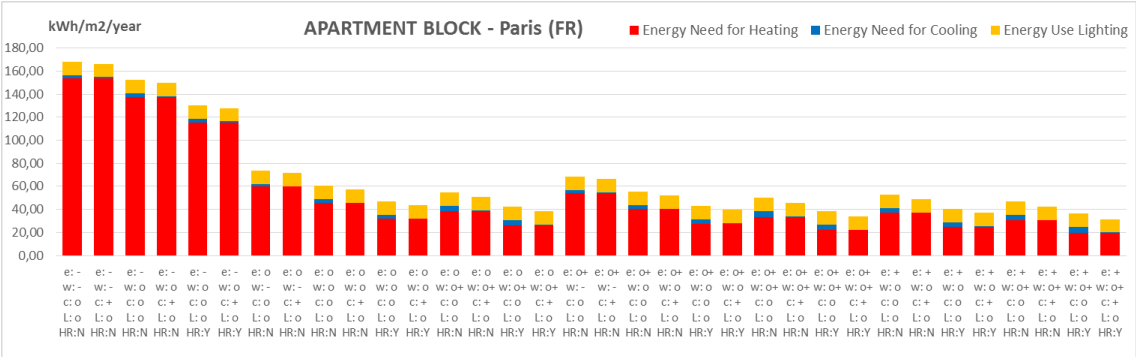

Figure 58: Energy needs for heating, cooling and energy use for lighting. Apartment Block Paris

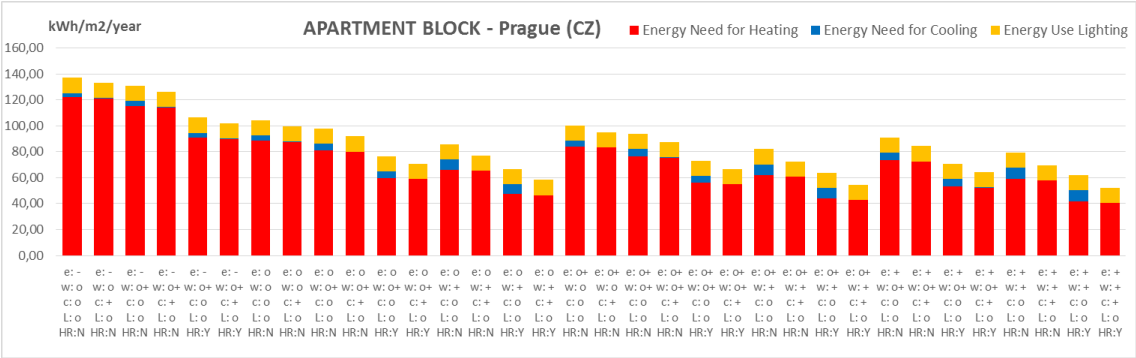

Figure 59: : Energy needs for heating, cooling and energy use for lighting. Apartment Block Prague

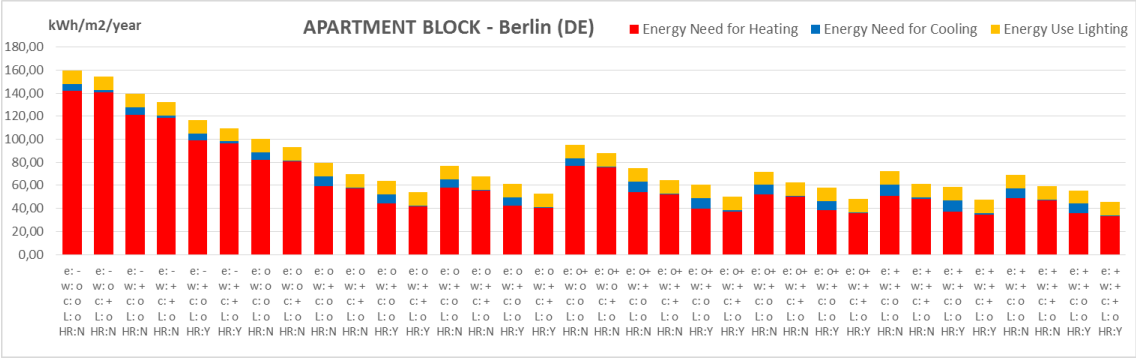

Figure 60: Energy needs for heating, cooling and energy use for lighting. Apartment Block Berlin

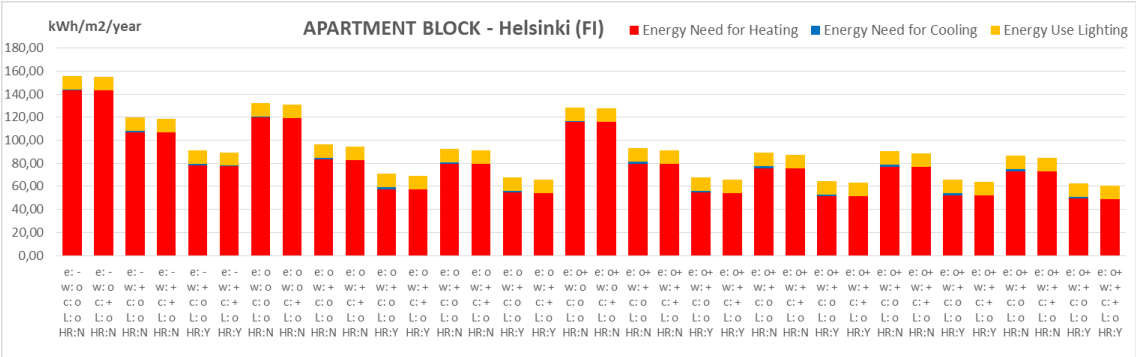

Figure 61: Energy needs for heating, cooling and energy use for lighting. Apartment Block Helsinki

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4.2.3 Office

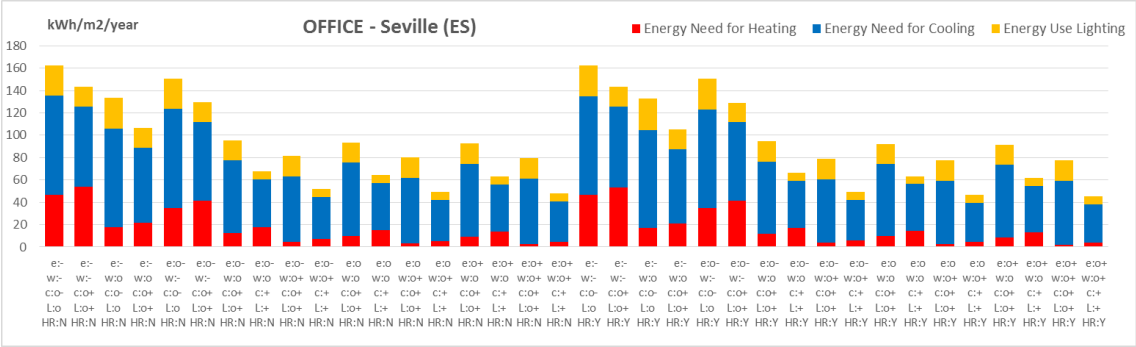

Figure 62: Energy needs for heating, cooling and energy use for lighting. Office Seville

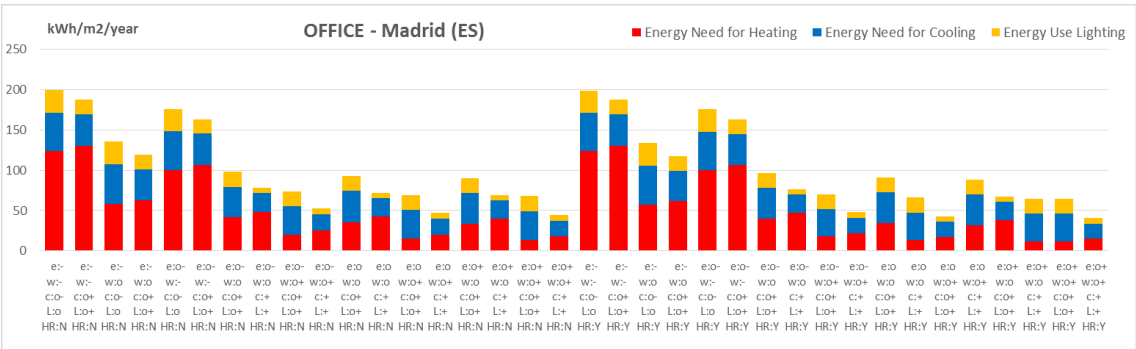

Figure 63: Energy needs for heating, cooling and energy use for lighting. Office Madrid

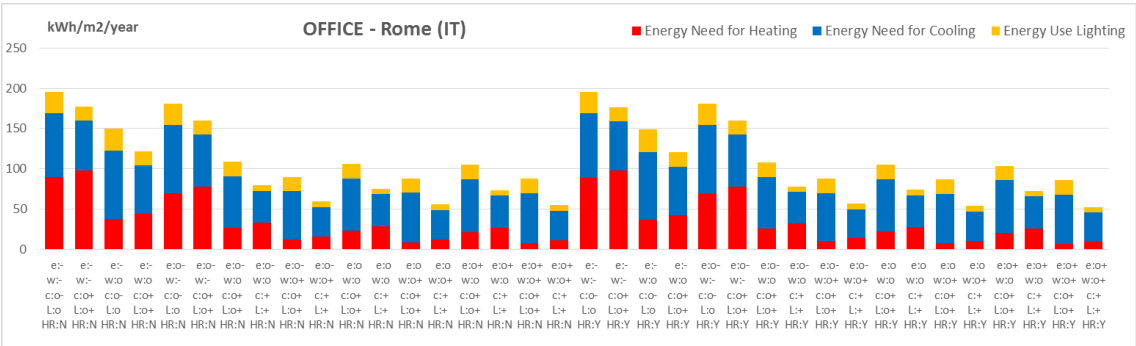

Figure 64: Energy needs for heating, cooling and energy use for lighting. Office Rome

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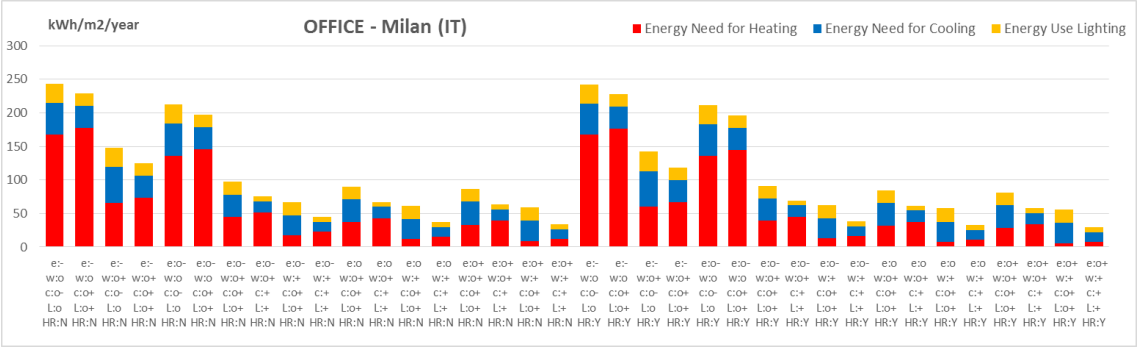

Figure 65: Energy needs for heating, cooling and energy use for lighting. Office Milan

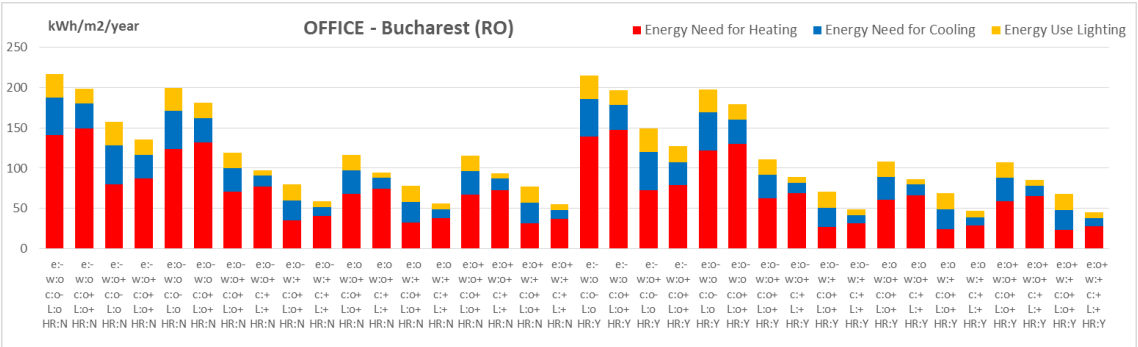

Figure 66: Energy needs for heating, cooling and energy use for lighting. Office Bucharest

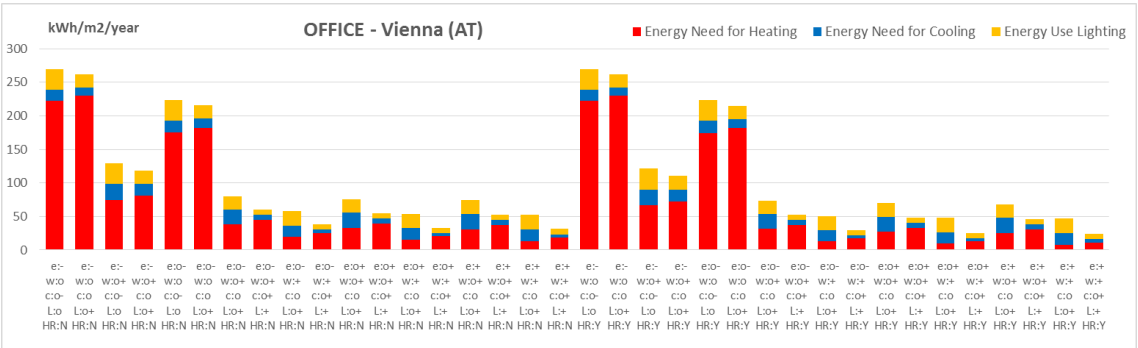

Figure 67: Energy needs for heating, cooling and energy use for lighting. Office Vienna

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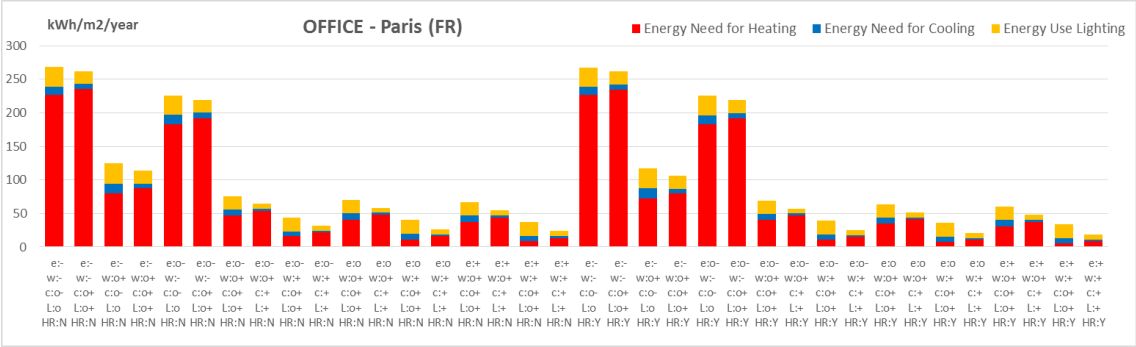

Figure 68: Energy needs for heating, cooling and energy use for lighting. Office Paris

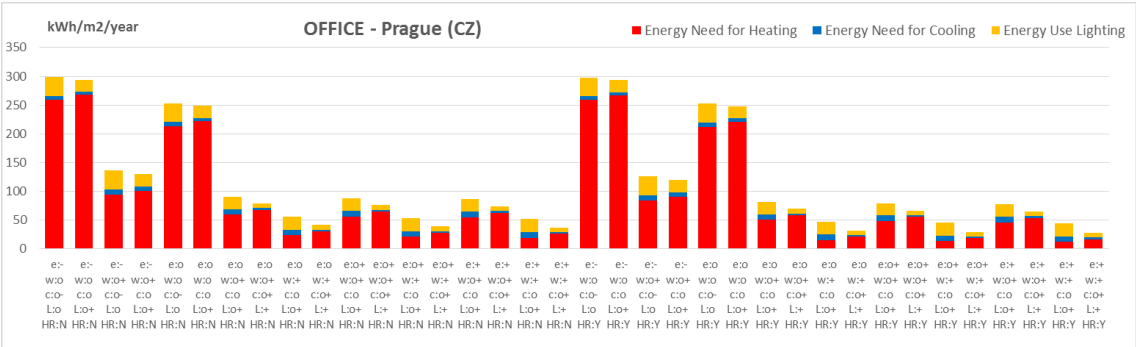

Figure 69: Energy needs for heating, cooling and energy use for lighting. Office Prague

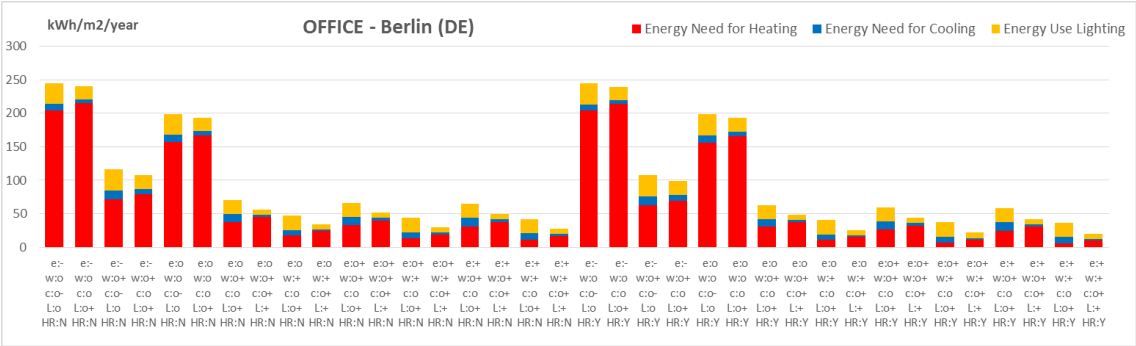

Figure 70: Energy needs for heating, cooling and energy use for lighting. Office Berlin

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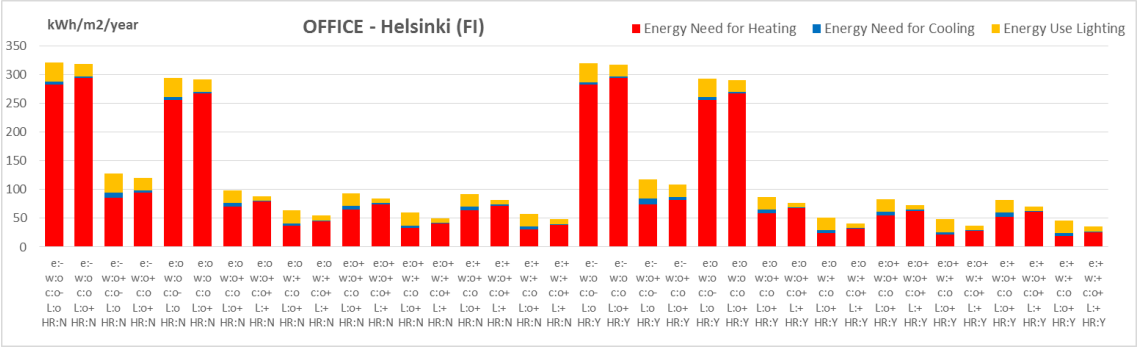

Figure 71: Energy needs for heating, cooling and energy use for lighting. Office Helsinki

4.2.4 School

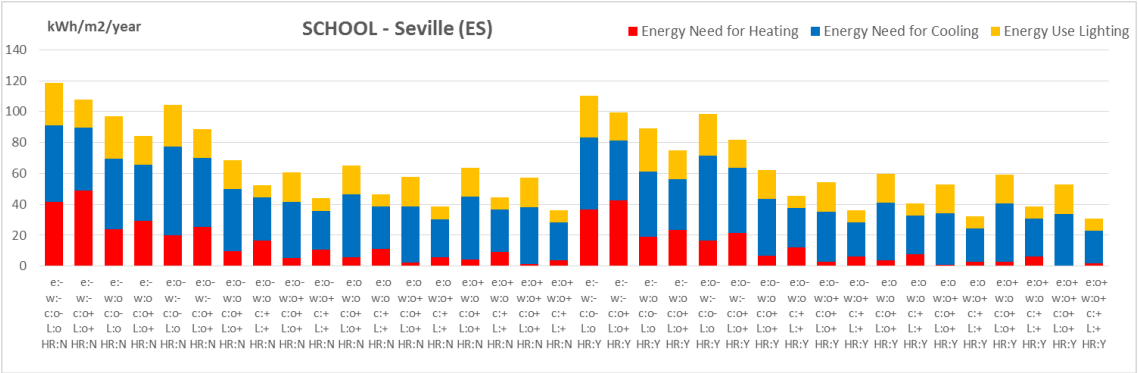

Figure 72: Energy needs for heating, cooling and energy use for lighting. School Seville

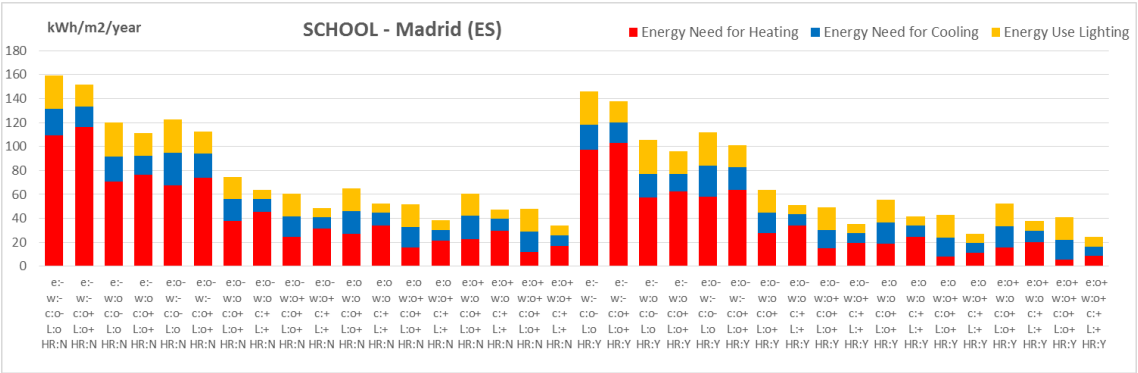

Figure 73: Energy needs for heating, cooling and energy use for lighting. School Madrid

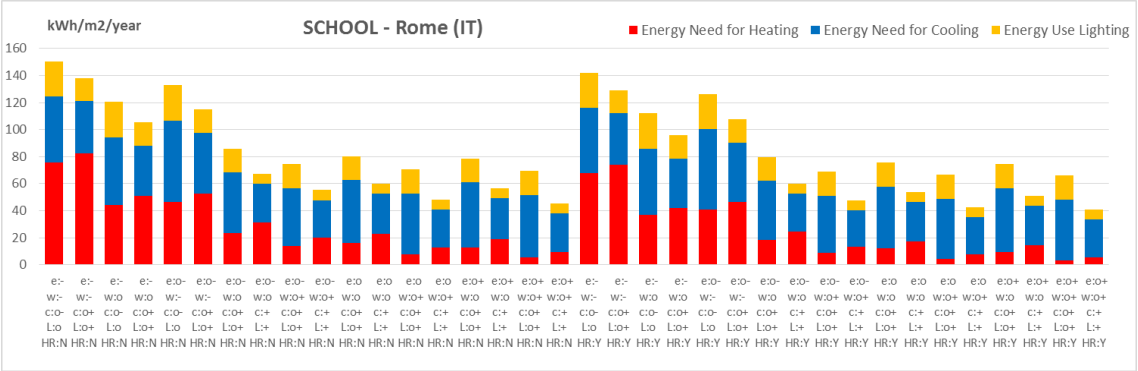

Figure 74: Energy needs for heating, cooling and energy use for lighting. School Rome

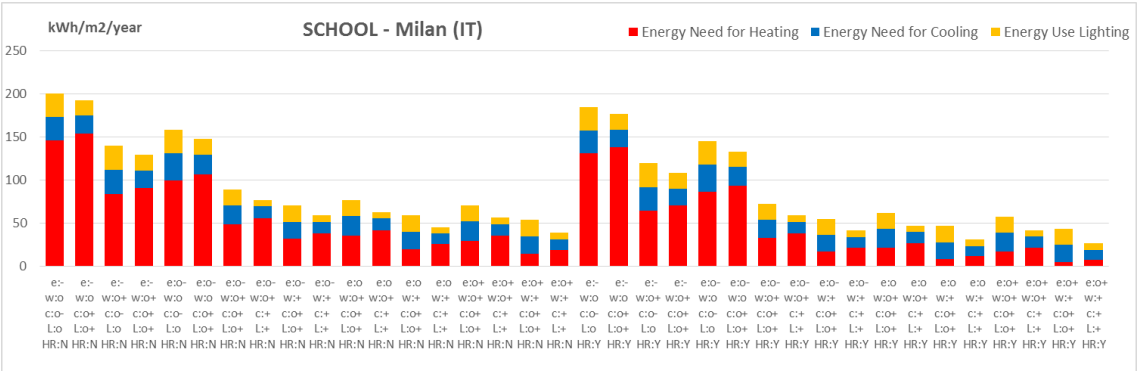

Figure 75: Energy needs for heating, cooling and energy use for lighting. School Milan

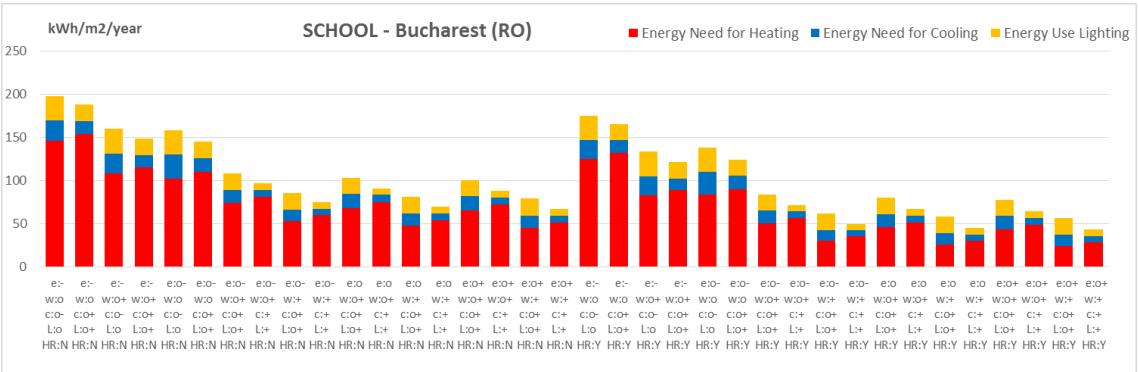

Figure 76: Energy needs for heating, cooling and energy use for lighting. School Bucharest

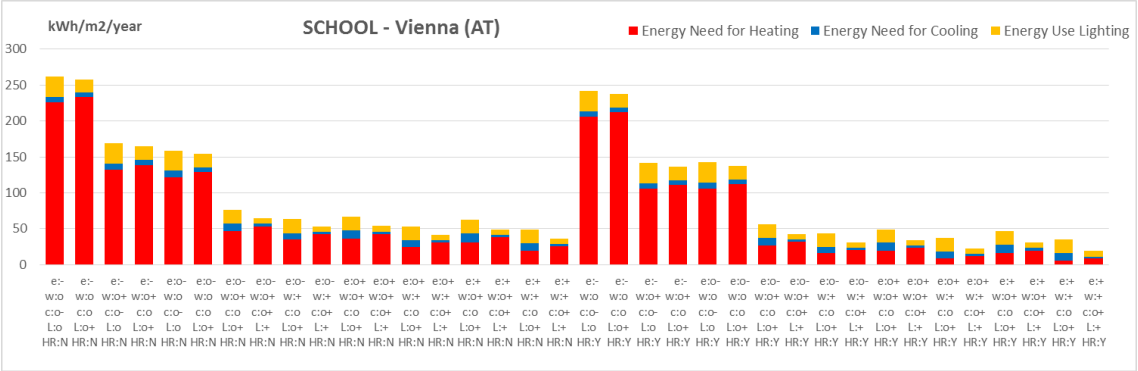

Figure 77: Energy needs for heating, cooling and energy use for lighting. School Vienna

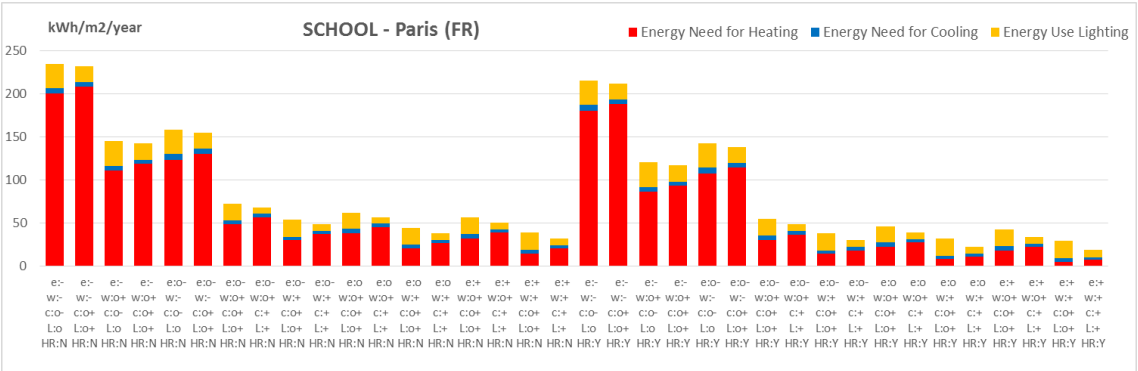

Figure 78: Energy needs for heating, cooling and energy use for lighting. School Paris

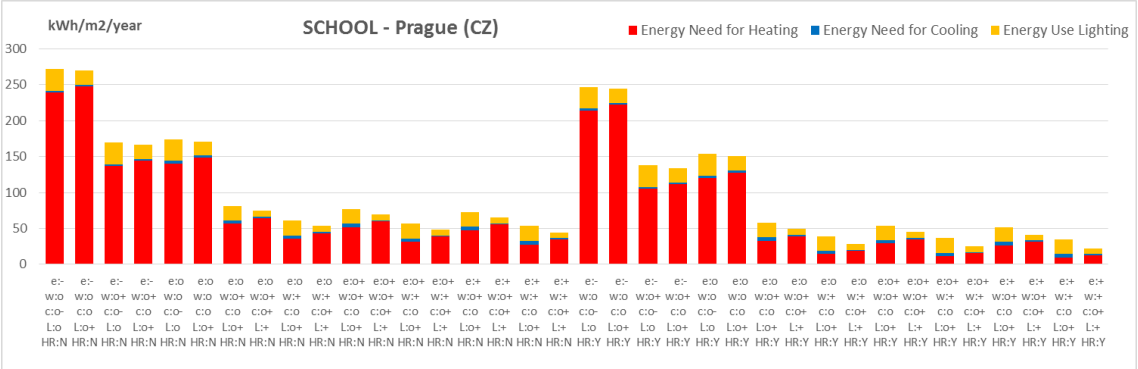

Figure 79: Energy needs for heating, cooling and energy use for lighting. School Prague

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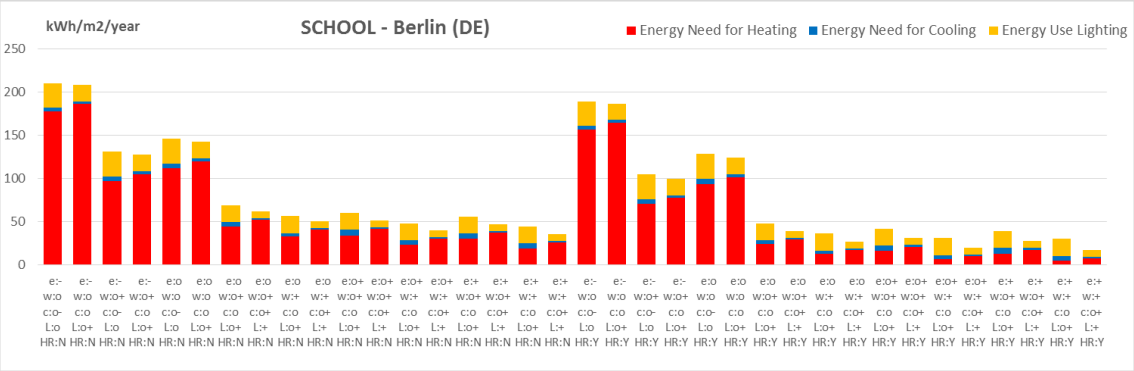

Figure 80: Energy needs for heating, cooling and energy use for lighting. School Berlin

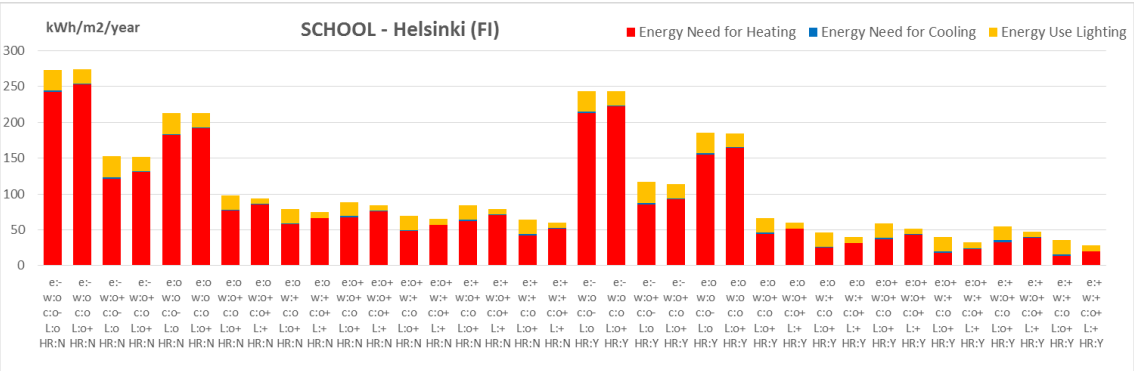

Figure 81: Energy needs for heating, cooling and energy use for lighting. School Helsinki

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5. Generating Cost-Energy Curves

5.1 Overview

In the annex of the present document we show the detailed results obtained for each building type (single family house - SFH, and Office buildings) in each climatic-economic context. In particular, the following analyses are shown:

- A**) Global costs versus (net) primary energy** demand calculated for renovated buildings in financial - standard private perspective, considering the cost data **2011** (calculation starting year)
- B**) Global costs versus (net) primary energy** demand calculated for renovated buildings in financial - standard private perspective, considering the cost data **2020** (calculation starting year)

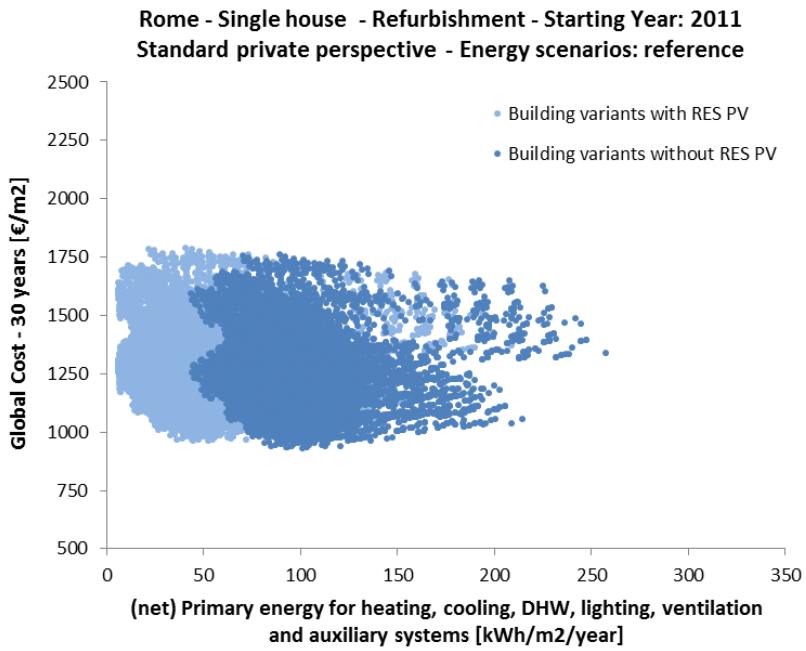

Figure 82: example of graph on Global costs versus (net) primary energy demand (analysis type A and B).

The analysis A and B may prove useful in discussing how it is possible to reduce net primary energy, with or without the possibility to make use of on-site solar energy from photovoltaic systems (RES PV) on the rooftop and building envelope, in each climate and for each building typology, under the specified set of hypotheses. It may also be used to identify a minimum global cost area, we could indicate also as "**cost-optimal**

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zone", and a minimum net primary energy area, we could indicate also as "**nearly zero-energy zone**", in each climate and for each building typology.

We recall here the definitions:

- Global costs include initial investments costs, costs of energy, maintenance costs, replacement costs, disposal costs, residual value at end of life, all discounted to year zero [6] with a given discount rate. For all items only market prices are considered and external costs related to environmental or health damages different from CO_2 are not included. Positive benefits other than energy savings are also neglected, even though they might be relevant, e.g in variants with high performance building envelope better distribution of temperatures, avoidance of draft, higher availability of daylighting, in a word higher thermal and visual comfort, might increase the usability of costly m^2 and productivity of workers according to various surveys.
- Net primary energy is the primary energy that would be consumed in one year by the building if renewable generation (in our assumptions on-site) were absent, minus the primary energy equivalent of renewable energy generated (in our assumptions on-site).

In most cases analysed this approach (net primary energy over a time frame of one year) results in a large mismatch between time when solar renewable energy is generated (mostly in summer) and when conventional energy (electricity from the grid and natural gas) is consumed (prevalently in winter, especially for residences). In this approach energy generated in summer in excess gives credit to the building to offset consumption in periods when generation is insufficient to cover demand.

This implies that even if the building reaches a yearly zero net energy performance, conventional energy is still drawn from the grid at certain times which further implies consumption of conventional fuels (gas, oil, coal, nuclear) and corresponding environmental impacts, and/or the need for energy storage in the energy infrastructure to deal with the mismatch of generation and demand. The corresponding external costs of environmental and health damage and of additional energy infrastructure are not considered in this study[7] (and in many other studies) as this is beyond its scope. They are nevertheless true economic costs that should be carefully considered in another study in order to achieve a complete economic and environmental picture.

[6] In our case year zero is alternatively assumed to be respectively 2011 or 2020

[7] Only CO_2 emission costs are considered in certain scenarios and only for the net primary energy consumption, not for the emission due to the time mismatch; also, other environmental, health and grid costs are disregarded

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Starting from graphs types A) and B), further analyses is C) as follows.

- C) graph showing the same structure and dots of graph types A) and B), where in addition the building variant corresponding to the **base refurbishment level** is pointed out as grey bold dot. The graph shows also the following indications from EPBD and the cost optimal regulation
    - *in cases where the outcome of the cost-optimal calculations gives the same global costs for different levels of energy performance, Member States are encouraged to use the requirements resulting in lower use of primary energy as the basis for comparison with the existing minimum energy performance requirements* [European Commission 2012b]: considering this, the blue horizontal segment indicates the range of net primary energy demand corresponding to the minimum global costs area, where the **minimum net primary energy dot** is pointed out (cross dot on the left)
    - respect the minimum net primary energy dot in cost optimal level, the dashed vertical lines show the range of ± 15%, for which the EPBD [European Parliament And Council 2010] says "*significant discrepancies, i.e. exceeding 15 %, exist between the calculated cost-optimal levels of minimum energy performance requirements and the minimum energy performance requirements in force, Member States should justify the difference or plan appropriate steps to reduce the discrepancy*".

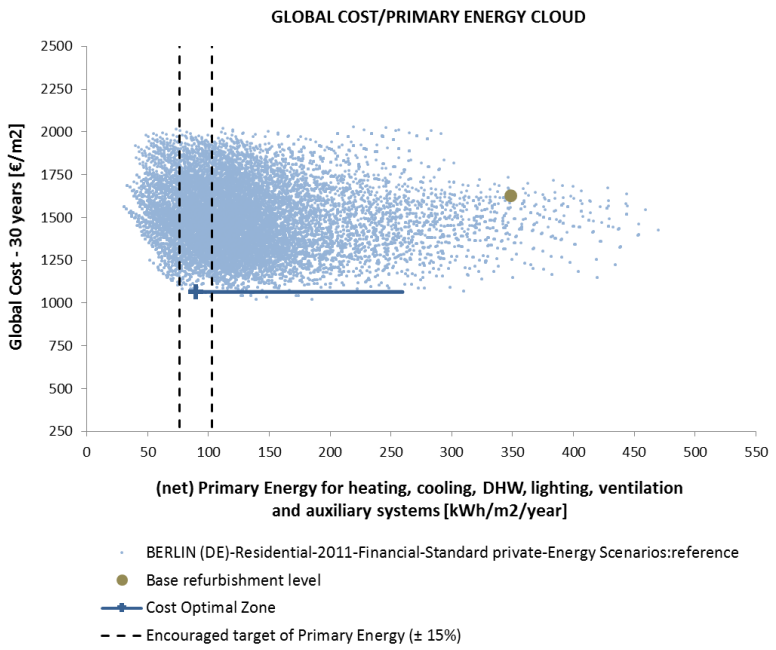

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Figure 83: example of graph on Global costs versus (net) primary energy demand (analysis type C).

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Further analyses:

- D) **Sensitivity analysis** on changes of the lower frontier ("Pareto Frontier") of the energy/cost domain as a function
  - several key economic perspectives
    - financial - standard private perspectives
    - macroeconomic perspectives
  - different scenarios of energy costs
    - reference
    - ambitious
  - respectively with calculation starting year
    - 2011
    - 2020

The Analysis D) is aimed at giving a visual, **QUALITATIVE overview of the influence of the various perspectives on the position of the lower frontier**, which would not be possible by superposing or comparing side by side the various corresponding complete clouds. In order to produce curves representing the lower frontier a polynomial interpolation (to second, third or higher order) of the points on the frontiers has been performed. This allows a quick perception of the trends but necessarily introduces imprecision. Given the approximation introduced this analysis is **NOT aimed at supporting a discussion about the position of the cost-optimal zone.**

The interested area of the cloud (cost/energy dot plot) is the area which include minimum global cost and the min. (net) primary energy (red circle in figure below).

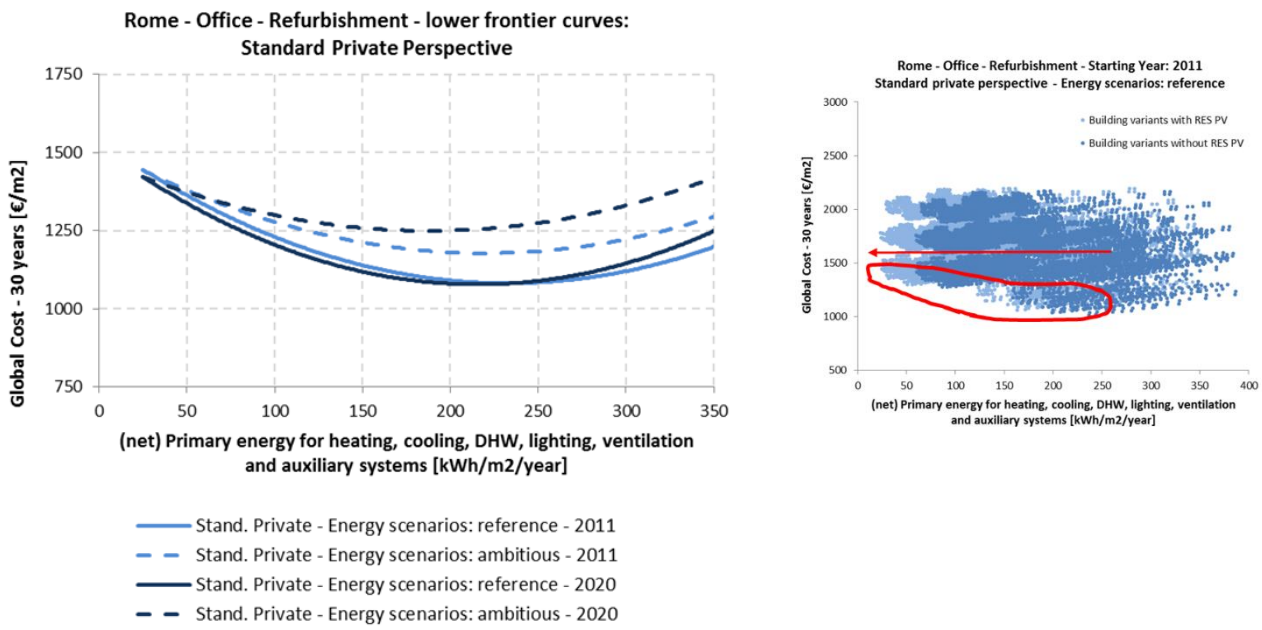

Figure 84: focus on interested area of cost/energy dot plot.

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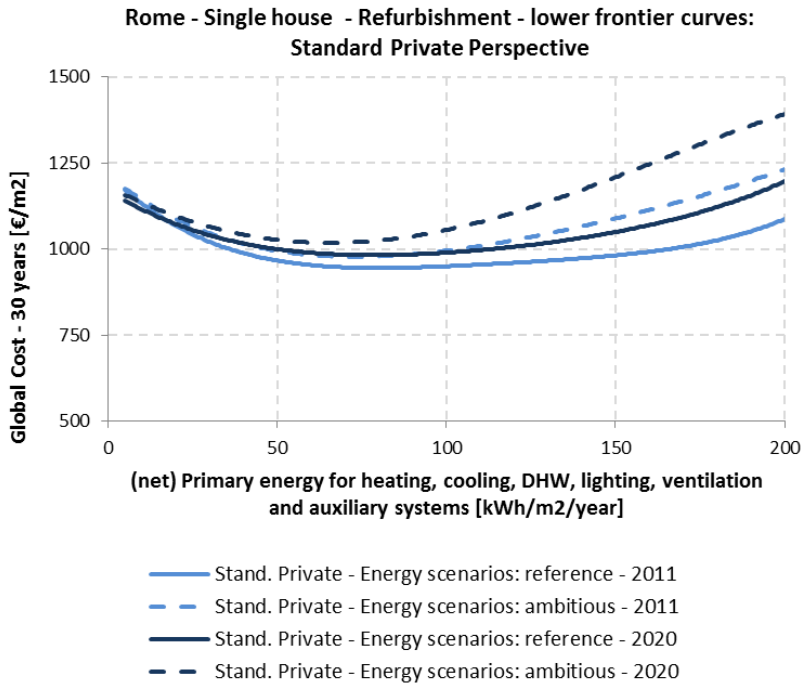

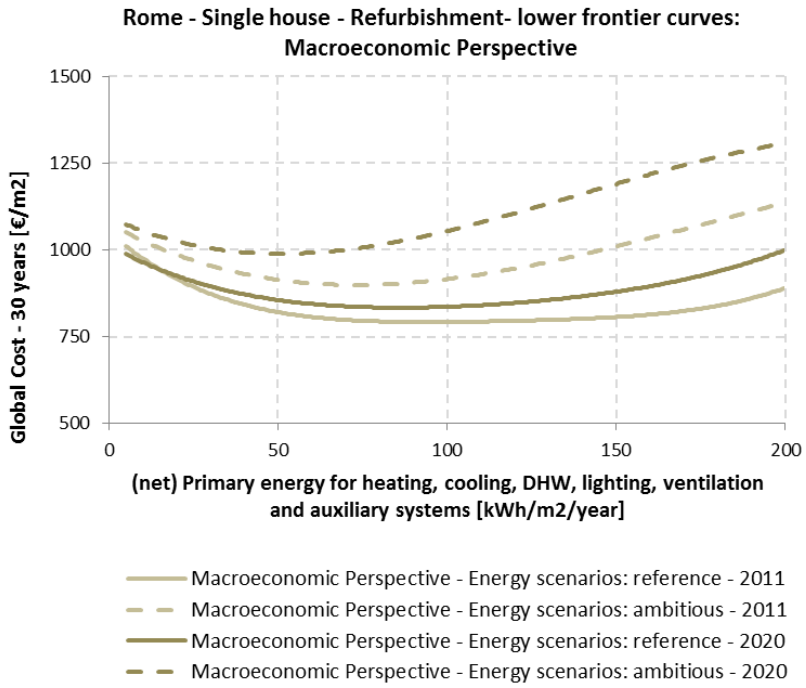

Figure 85: example of sensitivity analysis on changes of the lower profile (Pareto Frontier) (analysis type D)

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Further analysis:

- E) **Disaggregation of building costs** for several building variants **positioned on** the lower frontier of the energy/cost domain, considering a financial - standard private perspective and the calculation starting year **2011**.

Analysis E gives an impression of the relative weight of capital costs of energy related technologies (labelled “initial investment”), present value (i.e. discounted to year zero) of costs incurred for energy over the 30year time-horizon (labelled “energy- without PV credits”), present value (discounted to year zero) of income incurred selling electric energy from PV to the grid over the 30year time-horizon (labelled “PV credits”). Costs of construction not directly related to energy (structure, finishing materials, etc.) are not considering in this analysis We have assumed no subsidies hence PV energy is supposed to be sold to the grid at a price comparable to that of conventional generation sources on the wholesale market. Costs of land, property taxes etc. are not included. Maintenance and replacement costs are also represented.

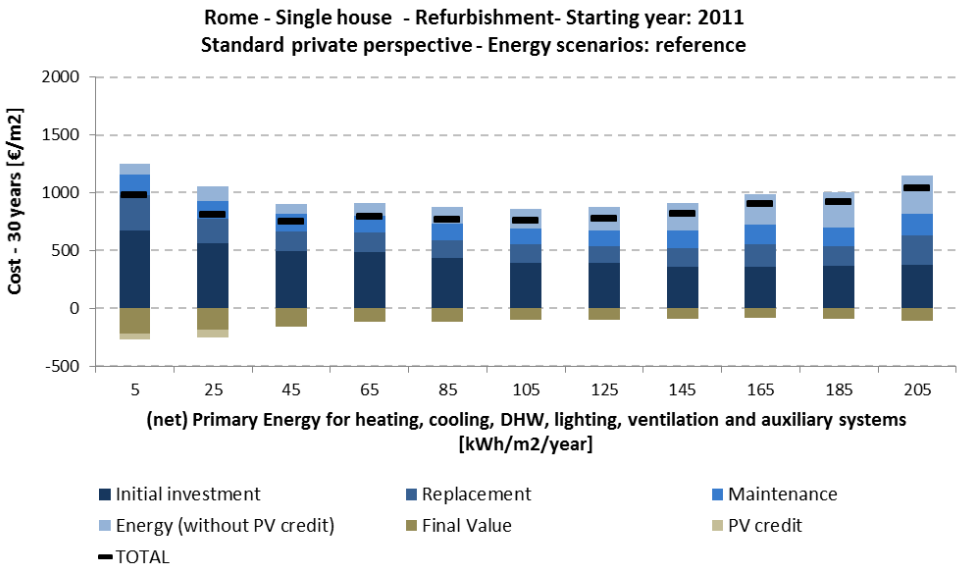

Figure 86: example of disaggregation of building costs for several building variants positioned on the lower profile of the energy/cost domain (analysis type E)

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Further analysis:

- F) **Percentages within** the entire dominium of variation (**the entire cloud**) **of** building variants by **different classes of energy needs** for heating and cooling with indication of minimum/mean/maximum global cost.

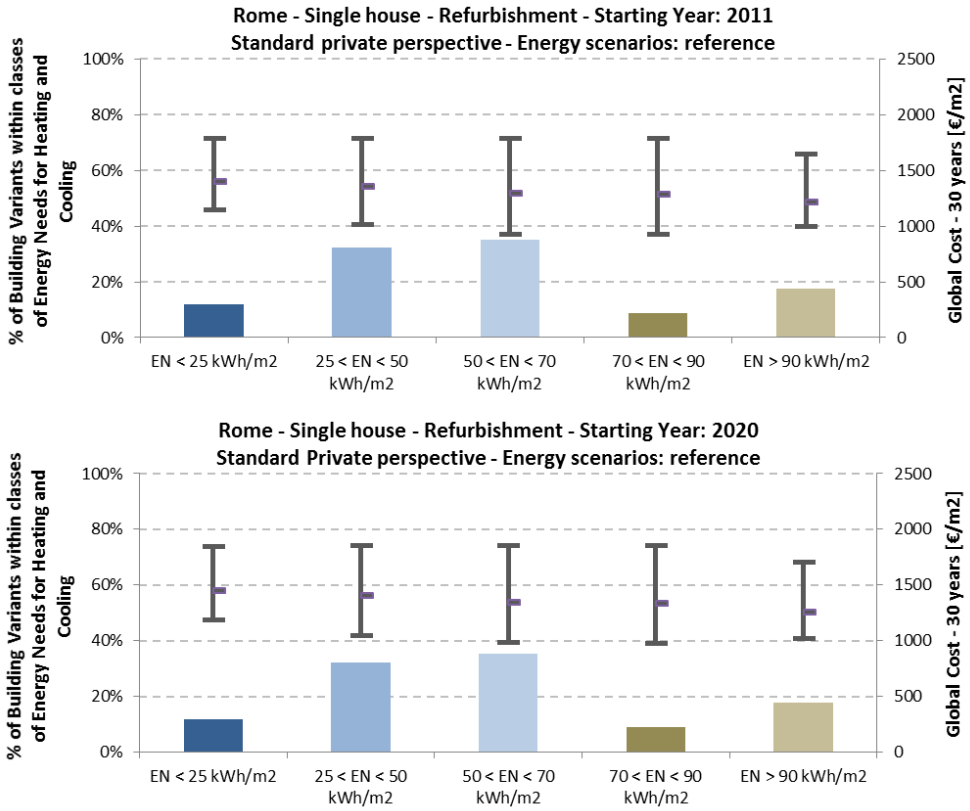

Figure 87: example of percentages of building variants by different classes of energy needs for heating and cooling with indication of minimum/mean/maximum global cost (analysis type F)

- G) **Ways to reach the nearly zero-energy building target**: statistical analysis of the “new building” variants characterized by lower net primary energy con-

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sumption values and lower global costs over 30 years (considering financial - standard private perspective, with calculation starting year 2011 and 2020). The exact ranges of global costs and net primary energy analysed are indicated in the table at the bottom, and identify what we call the “benchmark area”, e.g.

“benchmark area”	Min	Max
Range of NET primary energy [kWh/m^{2}y]:	0	15
Range of Global Costs over 30 years [€/m2]:	2397	2756
Number of Building Variants:	189	

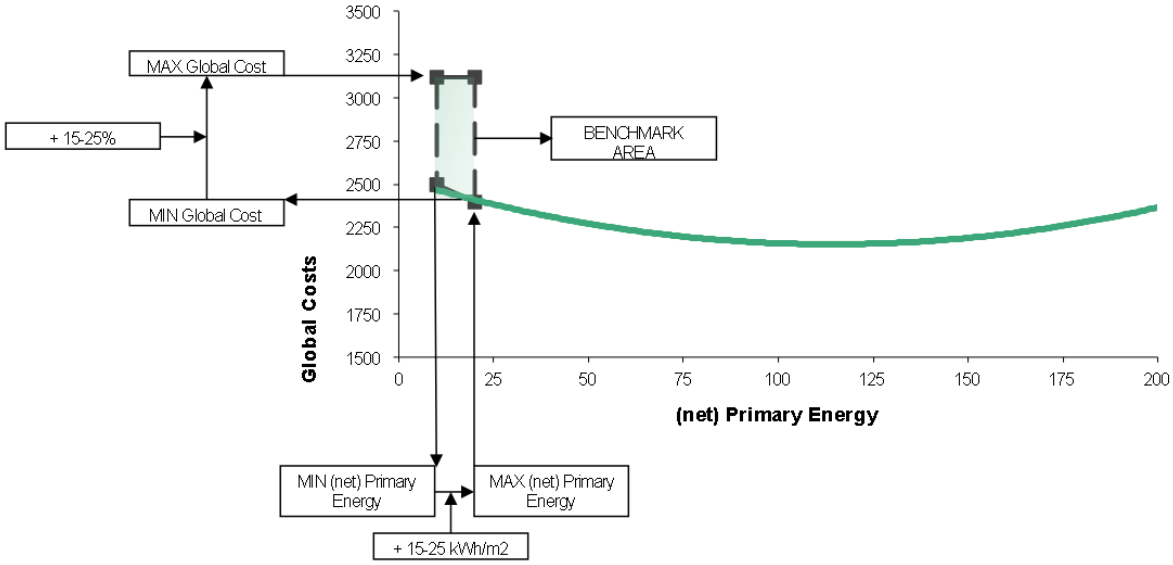

Figure 88. Steps to define the benchmark area

The “benchmark area” is determined in the following way:

- Determine the variant with minimum net primary energy,
- Consider an increase of 15 to 25 kWh/m2y,
- At this new level of net primary determine the variant with minimum global cost,
- Increase global cost by 10-25%.

The size of the area is adjusted in order to contain in the order of 150÷200 variants; these 200 best variants are then analysed and the frequency with which certain measures and packages appear is reported in graph G.

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Analysis G) gives an indication of the types of technologies that, for each building typology and climate and under the given assumptions for economic perspective, , etc. are available for reaching the “nearly zero-energy zone”, identified by the ranges described in the table “benchmark area”.

Depending on the specific constraints that the building might experience some of the technology packages might not be available, but other packages are available in the same energy and cost range. For example in dense urban centres ground source heat pumps (GSHP) and /or PV might not be available for some buildings. In that case the remaining available packages will comprise technologies with even higher performance in the envelope (lower energy needs) and plants (lower delivered energy) to compensate the non-availability of PV and GSHP. Other technologies not considered in this analysis and/or that will become technologically and market mature later might also be available.

The same approach has used to identify the combination of building variants and plant technologies that characterize the cost-optimal zone (labelled as “minimum global cost zone).

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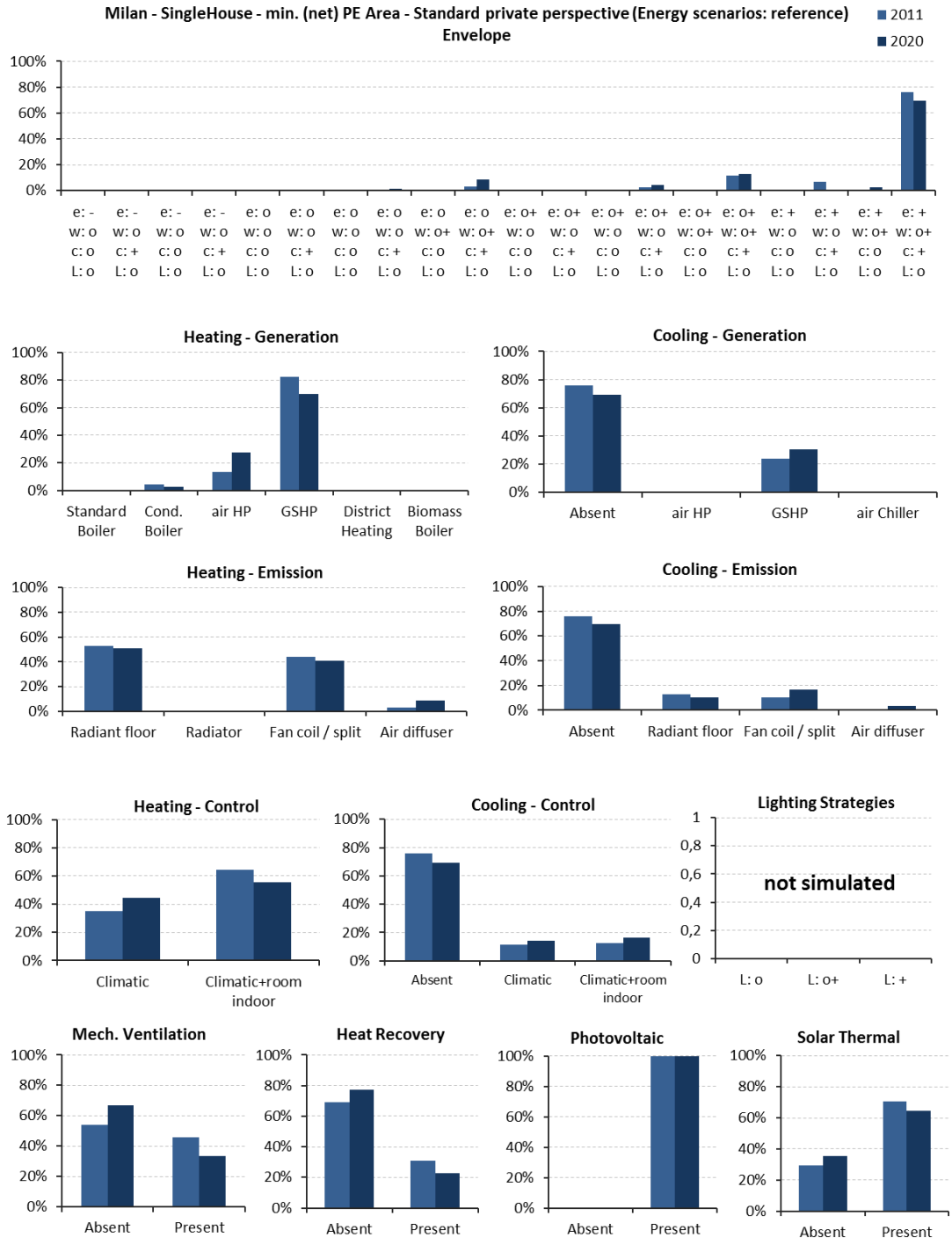

Figure 89: example of benchmark analysis in minimum net primary energy area of the cost/energy cloud (analysis type G)

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Further analyses:

- H) Indication of the energy **needs** for heating **and cooling** (both sensible and latent components) for the building variants within the benchmark area minimum net primary energy zone and minimum global cost zone, defined at the previous step.

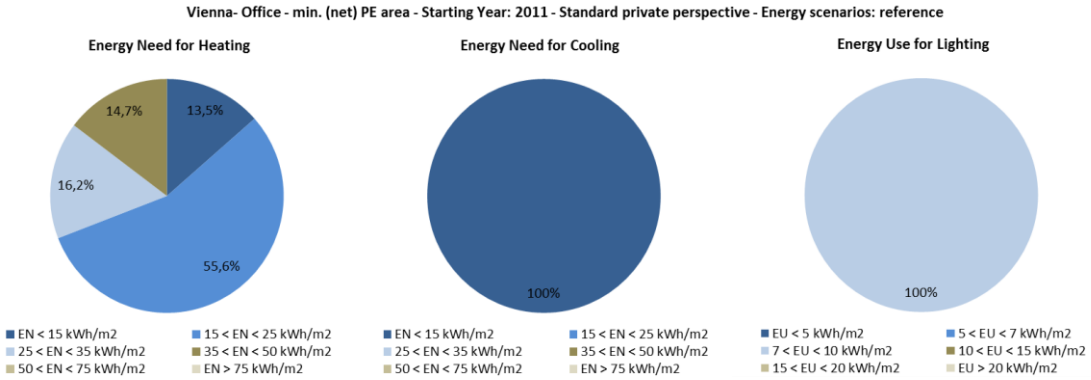

Figure 90: example of indication of the energy needs for heating and cooling for the building variants within the benchmark areas (analysis types H)

- I) Indication of the share of the considered solar renewable sources (photovoltaic, solar thermal and, reversible heat pump when it can be consider as renewable source) for the building variants within the benchmark area “nearly zero-energy zone”. On the horizontal axis of this graph it is reported the primary energy that the building would consume in a year in case there were no RES production is considered (e.g. no solar plant on the roof and hence solar energy for self-consumption or export to the grid would not be available). On the vertical axis there is the total energy credit for solar generation on the roof due to both self-consumption and export to the grid in a year and other on-site RES contributions; both generated (self-consumption plus export) and delivered energy are transformed into primary energy by using the same (symmetric) conversion factor assumed to be the official national conversion factor (ratio primary to delivered) of the energy vectors (electricity, gas) in 2011 and 2020. In the nearly zero-energy building definition used in this chapter the primary energy credits accrued via electricity generation in summer are used to offset electricity consumption for a period of one year (some of it concentrated in winter, e.g. lighting) and possibly fuel consumption in winter. We are not evaluating the mismatch index in this analysis. Large mismatches might imply large consumption of fossil fuel resources in some parts of the year. A way to reduce the absolute value of the mismatch is to reduce the energy needs and in the group of variants included in the nearly zero-energy building benchmark MS might decide to privilege the ones with very low energy needs also in view of reducing the mismatch. In order to take this into account, in primary energy balance for buildings we consider that 50% of the produced energy form photovoltaic systems is exported to the grid,

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considering the economic incomes due to this for the global costs calculations, while the amount of energy exported to the grid is not considered in the primary energy balance of buildings.

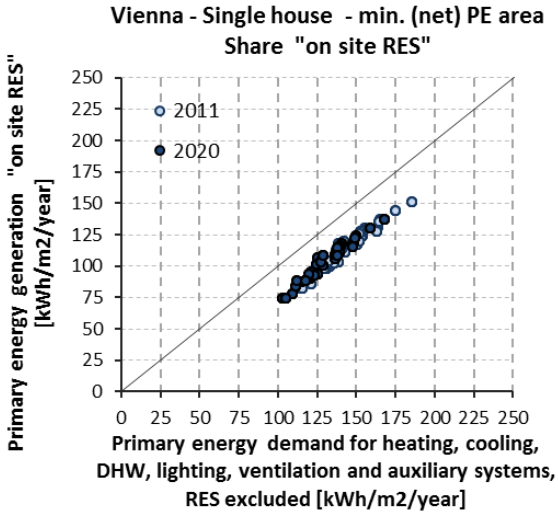

Figure 91: example of graph of primary energy demand

34 ÷ 36

variants of ENVELOPE packages for every building

≈ 800

combinations of SYSTEM for each ENVELOPE package

≈ 28.800

combinations of ENVELOPE packages + SYSTEM for each building

4

buildings for each country

≈ 115.200 points

For 10

target countries

≈ 1.152.000 points generated

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Figure 92: Calculation workflow in numbers.

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6. Target buildings selection

6.1 Selection method

Considering the cost-energy clouds calculated in this study (see Generating Cost-Energy Curves), we selected possible models for minimum global cost and minimum net primary energy targets adopting the following criteria.

For the selection, we based on cost-energy clouds calculated according to financial standard private perspective and reference energy scenario, with calculation starting year 2011 (considered as main starting year for Entranze analysis).

We fixed energy and costs targets with two different criteria as described below, respectively considering "absolute" minimum values of net primary energy and global cost, or considering fixed percentages of saving in net primary energy relatively to base refurbishment levels (with maximum thresholds). Particularly we considered these energy and costs targets

A. net primary energy at minimum global cost ("cost optimal" solution),

B. minimum net primary energy (nZEB solution),

and

C. 50% of saving in net primary energy respect base refurbishment level

(and net primary energy < 100 kWh/m^2/y),

D. 70% of saving in net primary energy respect base refurbishment level

(and net primary energy < 50 kWh/m^2/y).

These targets could reflect two approaches to fix energy performances for cost-optimal and nZEB levels. As we can see in the following results in some cases different targets can be very close reaching to the same building selection. It could be a robust indication on the possible way to be followed.

The considered percentages of saving (in point C. and D. above) are chosen as indicative. It's interesting to compare them with "absolute" targets (point A. and B.).

A detailed comparison with the obtain percentages of saving reached in net primary energy for cost-optimal (A.) and nZEB (B.) is presented in following paragraphs in Figure 93, Figure 94 and Table 18. Saving potential in net primary energy respect to base refurbishment level.

For each target, in order to select specific building and system variants as possible model, we select small ranges around the targets, adopting the following steps.

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5. Around each net primary energy target (see below A.,B.,C. and D.) we consider a range of ± 5 kWh/m^2/y.
6. In this net primary energy range, we consider all building/system variants whose global cost increments is lower the 10% of the minimum global cost for that target (In this way we consider interesting ranges with various type of solutions and low global cost, closed to the lower frontier of cost-energy cloud).
7. The selected variants are further filtered, considering only the cases with heating plus cooling energy needs with a maximum increment of 10 kWh/m^2/y respect the minimum values of the selected variants (in order to consider in details solutions with low energy need adopting efficiency measured first).
8. At this point, we select the best case with best value of net primary energy, energy needs for heating and cooling, energy use for lighting, and global cost.

Adopting this method we obtain the buildings selections presented in the following pages for each climate and building type. Possible solutions to reach the considered targets are presented in detailed tables reporting

- envelope features,
- selected cooling strategies descriptions,
- systems features,
- energy performances,
- global cost values.

We can see in some contexts we don't go below the 50 kWh/m^2/y threshold in net primary energy for apartment blocks. We have to consider in the present study we assumed that efficiency strategies in lighting were not implemented in residential building types, and the corresponding energy demand is not reduce respect the base refurbishment level.

In addition for Helsinki (Finland) context, we decided to not improve the thermal trasmittance of basement, according local stakeholders indications.

For apartment blocks we have also more geometric constraints, as a lower roof surface available for renewable solar systems respect to the net overall floor area, respect to single family houses.

In previous paragraph (Generating Cost-Energy Curves) and in the Annex detailed analysis were perform in larger areas of cost-energy clouds and curves. This gave results on general potential of all different measures. While in the present Target build-

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ings selection we select specific building solutions basing on chosen energy and cost targets.

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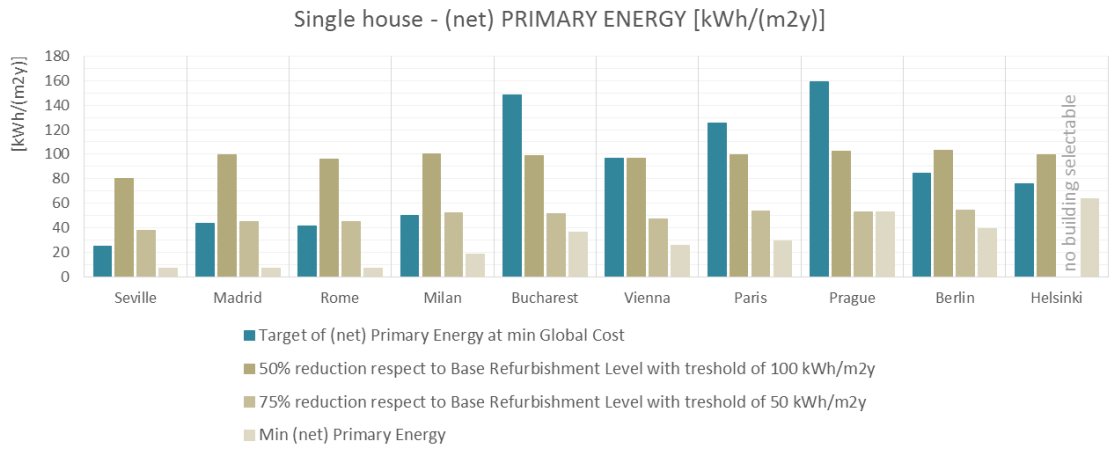
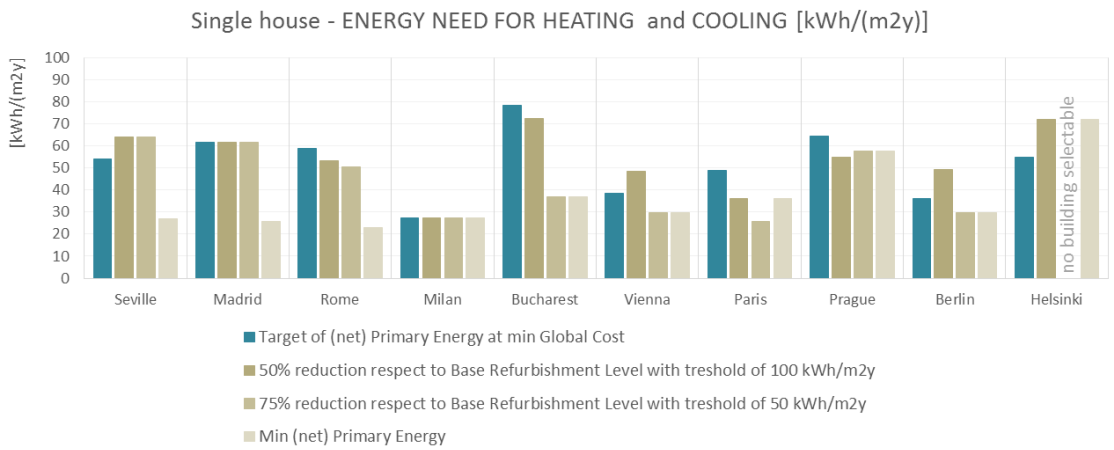
6.2 Selection and cross analysis for each climate

6.2.1 Single house





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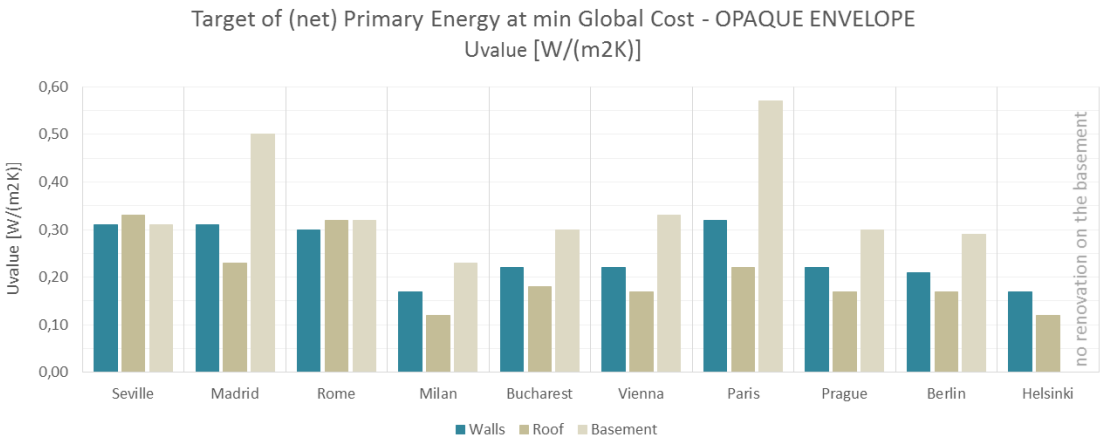

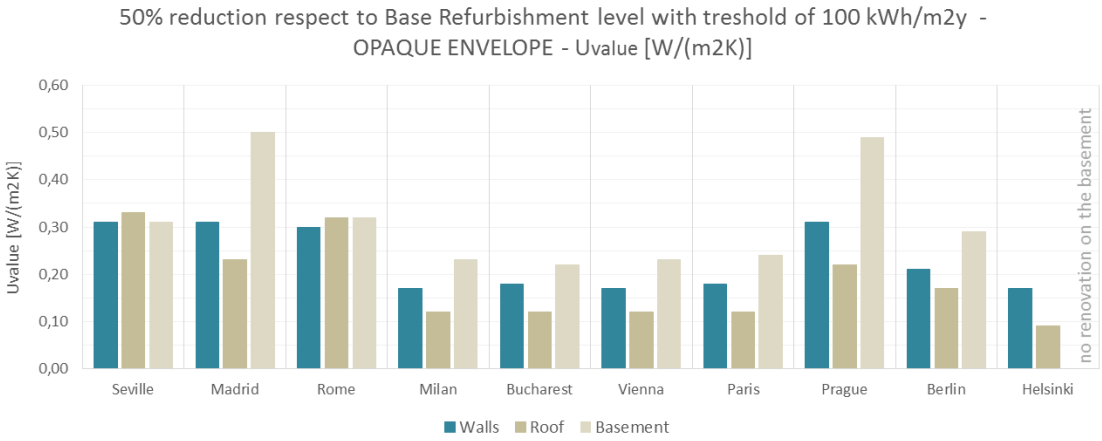

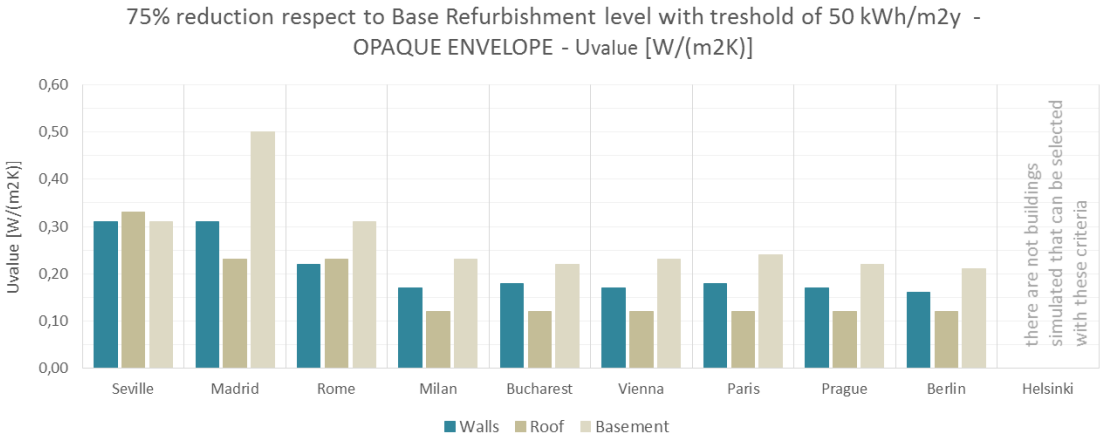

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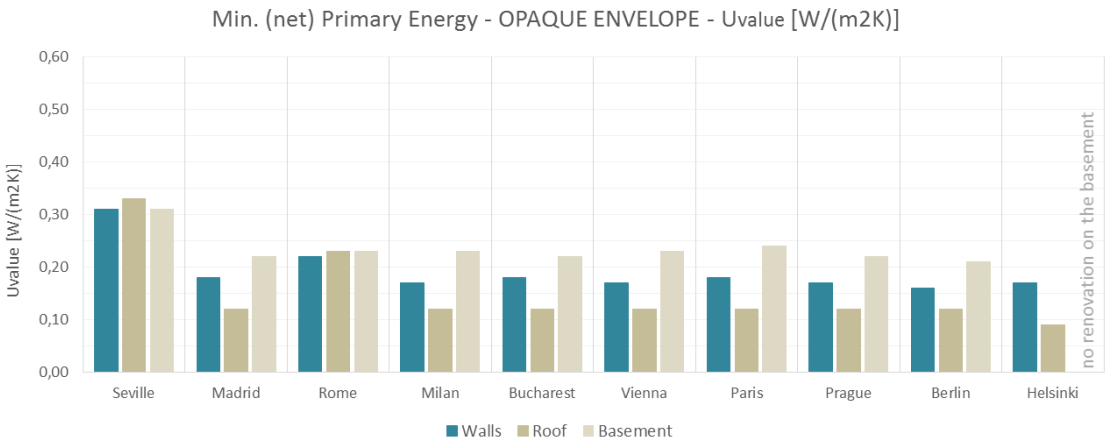

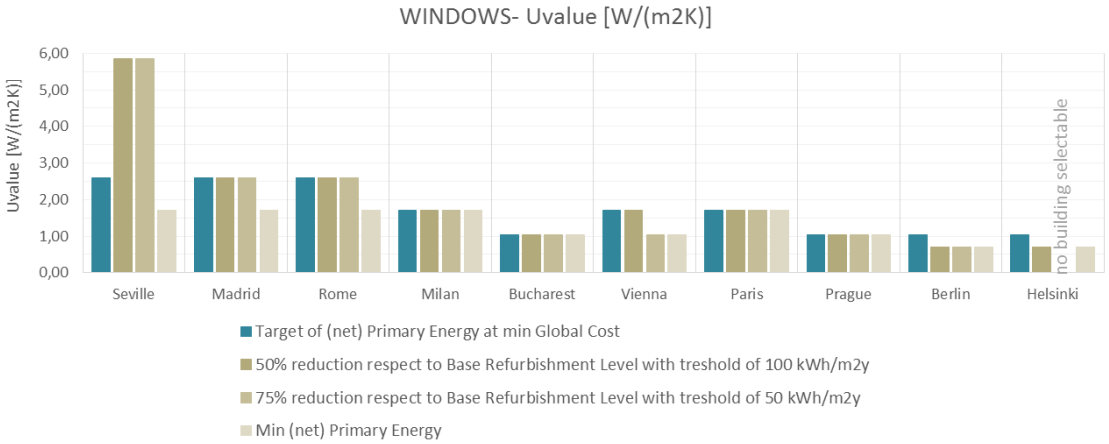

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Seville SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	19		17		17		24	
OPAQUE ENVELOPE-Package:	++		++		++		++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	10cm insulation -External insulation (EIFS System)	0,31	10cm insulation -External insulation (EIFS System)	0,31	10cm insulation -External insulation (EIFS System)	0,31	10cm insulation -External insulation (EIFS System)	0,31
Roof thermal insulation	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,33	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,33	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,33	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,33
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31
WINDOW PACKAGE:	+		n		n		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,6	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	5,84	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	5,84	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71
	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,72	Solar Trasmittance (-)	0,72	Solar Trasmittance (-)	0,64
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,72	Visible Trasmittance (-)	0,72	Visible Trasmittance (-)	0,65
	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,77	(airtightness) (1/h)	0,77	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		n		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
Night Ventilation for Cooling	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
Lighting Loads	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
	No change	3,5	No change	3,5	No change	3,5	No change	3,5
Lighting Control	description:		description:		description:		description:	
	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	44	reversible heat pump	62	reversible heat pump	62	reversible heat pump	32
Cooling Generation	reversible heat pump	80	reversible heat pump	75	reversible heat pump	75	reversible heat pump	99
Heating Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	fan coil / split	-
Cooling Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	present	-	present	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	6,0		11,7		11,7		3,1	
Energy Need for Cooling [kWh/m²y]	48,2		52,3		52,3		23,7	
Energy Need for DHW [kWh/m²y]	11,1		11,1		11,1		11,1	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		11,4		11,4	
(net) Primary Energy demand [kWh/m²y]	25,1		80,5		37,5		7,0	
RES contribution [kWh/m²y]	83,0		41,1		82,5		57,2	
Global Cost [€/m²]	792,7		721,8		730,0		934,5	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	36,7							
Energy Need for Cooling [kWh/m²y]	72,9							
Energy Need for DHW [kWh/m²y]	11,1							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	155,6							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	926,6							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Madrid SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	9		9		9		32	
OPAQUE ENVELOPE-Package:	+		+		+		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	10cm insulation -External insulation (EIFS System)	0,31	10cm insulation -External insulation (EIFS System)	0,31	10cm insulation -External insulation (EIFS System)	0,31	20cm insulation -External insulation (EIFS System)	0,18
Roof thermal insulation	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	5cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,5	5cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,5	5cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,5	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22
WINDOW PACKAGE:	+		+		+		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,6	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,6	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,6	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71
	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,64
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65
	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		n		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
Night Ventilation for Cooling	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
Lighting Loads	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
	No change	3,5	No change	3,5	No change	3,5	No change	3,5
Lighting Control	description:		description:		description:		description:	
	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	59	condensig gas boiler	59	reversible heat pump	59	reversible heat pump	26
Cooling Generation	reversible heat pump	74	chiller whit high performance	74	reversible heat pump	74	reversible heat pump	108
Heating Emission	insulated radiant floor	-	fan coil / split	-	insulated radiant floor	-	fan coil / split	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	fan coil / split	-	insulated radiant floor + local dehumifidier	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	29,7		29,7		29,7		14,8	
Energy Need for Cooling [kWh/m²y]	32,2		32,2		32,2		11,0	
Energy Need for DHW [kWh/m²y]	12,1		12,1		12,1		12,1	
Energy Use for Lighting [kWh/m²y]	12,1		12,1		12,1		12,1	
(net) Primary Energy demand [kWh/m²y]	43,2		99,9		45,3		6,7	
RES contribution [kWh/m²y]	107,5		0,0		107,5		90,7	
Global Cost [€/m²]	841,2		844,7		845,8		1025,8	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	103,9							
Energy Need for Cooling [kWh/m²y]	47,7							
Energy Need for DHW [kWh/m²y]	12,1							
Energy Use for Lighting [kWh/m²y]	12,1							
(net) Primary Energy demand [kWh/m²y]	235,9							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1031,0							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Rome SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	19		21		29		32	
OPAQUE ENVELOPE-Package:	++		++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	10cm insulation -External insulation (EIFS System)	0,3	10cm insulation -External insulation (EIFS System)	0,3	15cm insulation -External insulation (EIFS System)	0,22	15cm insulation -External insulation (EIFS System)	0,22
Roof thermal insulation	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,32	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,32	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,32	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,32	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	+		+		+		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,6	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,6	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,6	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71
	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,64
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65
	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		n		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in summer)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
Night Ventilation for Cooling	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
Lighting Loads	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
	No change	3,5	No change	3,5	No change	3,5	No change	3,5
Lighting Control	description:		description:		description:		description:	
	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	68	reversible heat pump	61	reversible heat pump	56	reversible heat pump	52
Cooling Generation	reversible heat pump	56	reversible heat pump	54	reversible heat pump	53	reversible heat pump	60
Heating Emission	fan coil / split	-	air diffuser	-	air diffuser	-	fan coil / split	-
Cooling Emission	fan coil / split	-	air diffuser	-	air diffuser	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	0,47	mechanical ventilation HVAC (IAQ+ conditioning)	0,54	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	present	0,05	present	0,05	absent	-
Thermal Solar Panels	absent	-	present	-	present	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	19,5		14,6		11,9		10,5	
Energy Need for Cooling [kWh/m²y]	39,4		38,7		38,7		12,3	
Energy Need for DHW [kWh/m²y]	12,1		12,1		12,1		12,1	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		11,4		11,4	
(net) Primary Energy demand [kWh/m²y]	41,1		96,0		44,7		6,7	
RES contribution [kWh/m²y]	97,6		51,6		95,5		88,6	
Global Cost [€/m²]	1014,5		1005,4		1051,7		1186,2	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	67,1							
Energy Need for Cooling [kWh/m²y]	45,8							
Energy Need for DHW [kWh/m²y]	12,1							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	193,4							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1141,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Milan SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	34		34		34		34	
OPAQUE ENVELOPE-Package:	+++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71
	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	61	connection to a district heating	61	connection to a district heating	61	reversible ground source heat pump	61
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05
Heat Recovery	present	0,05	present	0,05	present	0,05	present	0,05
Thermal Solar Panels	absent	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	27,3		27,3		27,3		27,3	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	13,2		13,2		13,2		13,2	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		11,4		11,4	
(net) Primary Energy demand [kWh/m²y]	50,2		100,0		52,3		18,6	
RES contribution [kWh/m²y]	42,7		0,0		42,7		116,3	
Global Cost [€/m²]	1037,6		984,7		1040,9		1438,5	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	160,9							
Energy Need for Cooling [kWh/m²y]	32,4							
Energy Need for DHW [kWh/m²y]	13,2							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	346,2							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1407,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Bucharest SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	23		31		34		34	
OPAQUE ENVELOPE-Package:	++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	15cm insulation -External insulation (Ventilated facade)	0,22	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,18	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,3	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	85	connection to a district heating	80	condensig gas boiler	74	reversible ground source heat pump	74
Cooling Generation	chiller whit high performance	49	chiller whit high performance	48	chiller whit high performance	26	reversible ground source heat pump	26
Heating Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	fan coil / split	-
Cooling Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05
Heat Recovery	absent	-	absent	-	present	0,05	present	0,05
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	54,1		47,8		32,8		32,8	
Energy Need for Cooling [kWh/m²y]	24,4		24,4		4,1		4,1	
Energy Need for DHW [kWh/m²y]	13,6		13,6		13,6		13,6	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		11,4		11,4	
(net) Primary Energy demand [kWh/m²y]	148,7		98,6		51,3		36,2	
RES contribution [kWh/m²y]	0,0		51,0		63,1		154,3	
Global Cost [€/m²]	626,2		669,3		846,1		1028,4	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	189,1							
Energy Need for Cooling [kWh/m²y]	31,0							
Energy Need for DHW [kWh/m²y]	13,6							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	392,5							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	772,8							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Vienna SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	21		27		33		33	
OPAQUE ENVELOPE-Package:	++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	15cm insulation -External insulation (EIFS System)	0,22	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,17	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,33	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	+		+		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		n		n	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-
Night Ventilation for Cooling	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0
LIGHTING STRATEGIES :	n		n		n		n	
Lighting Loads	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
	No change	3,5	No change	3,5	No change	3,5	No change	3,5
Lighting Control	description:		description:		description:		description:	
	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	68	connection to a district heating	72	connection to a district heating	58	reversible ground source heat pump	58
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation oly for IAQ	0,05	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05
Heat Recovery	present	0,05	absent	-	present	0,05	present	0,05
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	38,4		48,5		29,6		29,6	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	13,6		13,6		13,6		13,6	
Energy Use for Lighting [kWh/m²y]	13,6		13,6		13,6		13,6	
(net) Primary Energy demand [kWh/m²y]	96,8		97,0		46,8		25,7	
RES contribution [kWh/m²y]	0,0		0,0		40,2		98,1	
Global Cost [€/m²]	791,9		747,3		893,0		1150,7	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	199,5							
Energy Need for Cooling [kWh/m²y]	10,5							
Energy Need for DHW [kWh/m²y]	13,6							
Energy Use for Lighting [kWh/m²y]	13,6							
(net) Primary Energy demand [kWh/m²y]	450,8							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1604,9							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Paris SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	14		32		34		32	
OPAQUE ENVELOPE-Package:	+		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	10cm insulation -External insulation (Ventilated facade)	0,32	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18
Roof thermal insulation	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,22	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	5cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,57	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,24	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,24	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,24
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71
	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	74	connection to a district heating	65	connection to a district heating	57	reversible ground source heat pump	65
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,05	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	present	0,05	absent	-
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	48,9		36,2		25,6		36,2	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	13,6		13,6		13,6		13,6	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		11,4		11,4	
(net) Primary Energy demand [kWh/m²y]	125,6		99,5		53,4		29,2	
RES contribution [kWh/m²y]	0,0		0,0		59,7		177,3	
Global Cost [€/m²]	873,0		906,6		1010,3		1060,5	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	176,0							
Energy Need for Cooling [kWh/m²y]	7,4							
Energy Need for DHW [kWh/m²y]	13,6							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	363,4							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1229,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Prague SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	24		16		32		32	
OPAQUE ENVELOPE-Package:	++		+		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	15cm insulation -External insulation (EIFS System)	0,22	10cm insulation -External insulation (EIFS System)	0,31	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,17	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,22	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,3	5cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,49	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	78	condensig gas boiler	75	reversible ground source heat pump	73	reversible ground source heat pump	73
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	insulated radiant floor	-	radiator	-	insulated radiant floor	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,05	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	present	0,05	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	64,5		54,8		57,7		57,7	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	13,6		13,6		13,6		13,6	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		11,4		11,4	
(net) Primary Energy demand [kWh/m²y]	159,3		102,3		52,9		52,9	
RES contribution [kWh/m²y]	0,0		48,7		58,5		58,5	
Global Cost [€/m²]	748,5		812,1		1042,7		1042,7	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	239,4							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	13,6							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	518,7							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	782,1							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

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Berlin SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	22		24		34		34	
OPAQUE ENVELOPE-Package:	++		++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	15cm insulation -External insulation (EIFS System)	0,21	15cm insulation -External insulation (EIFS System)	0,21	20cm insulation -External insulation (EIFS System)	0,16	20cm insulation -External insulation (EIFS System)	0,16
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,17	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,17	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,29	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,29	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,21	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,21
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (18mm); low-e glassUg= 0,65 W/m²K; Uf=0,95 W/m2K; air permeability: 4th class EN 12207.	0,7	Triple glass with argon cavity (18mm); low-e glassUg= 0,65 W/m²K; Uf=0,95 W/m2K; air permeability: 4th class EN 12207.	0,7	Triple glass with argon cavity (18mm); low-e glassUg= 0,65 W/m²K; Uf=0,95 W/m2K; air permeability: 4th class EN 12207.	0,7
	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,5	Solar Trasmittance (-)	0,5	Solar Trasmittance (-)	0,5
	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	59	condensig gas boiler	63	condensig gas boiler	51	reversible ground source heat pump	51
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation oly for IAQ	0,05	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05
Heat Recovery	present	0,05	absent	-	present	0,05	present	0,05
Thermal Solar Panels	absent	-	present	-	present	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	36,3		49,1		29,8		29,8	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	13,6		13,6		13,6		13,6	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		11,4		11,4	
(net) Primary Energy demand [kWh/m²y]	84,7		103,5		54,1		39,3	
RES contribution [kWh/m²y]	37,2		10,2		47,4		129,8	
Global Cost [€/m²]	1139,5		1132,3		1331,5		1623,7	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	168,7							
Energy Need for Cooling [kWh/m²y]	8,9							
Energy Need for DHW [kWh/m²y]	13,6							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	348,2							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1630,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

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Helsinki SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	21		31		#N/D		31	
OPAQUE ENVELOPE-Package:	++		+++		#N/D		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	15cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (Ventilated facade)	0,17	#N/D	#N/D	20cm insulation -External insulation (Ventilated facade)	0,17
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,09	#N/D	#N/D	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,09
Basement thermal insulation	No renovation	0,48	No renovation	0,48	#N/D	#N/D	No renovation	0,48
WINDOW PACKAGE:	+		++		#N/D		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (18mm); low-e glassUg= 0,65 W/m²K; Uf=0,95 W/m2K; air permeability: 4th class EN 12207.	0,7	#N/D	#N/D	Triple glass with argon cavity (18mm); low-e glassUg= 0,65 W/m²K; Uf=0,95 W/m2K; air permeability: 4th class EN 12207.	0,7
	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,5	Solar Trasmittance (-)	#N/D	Solar Trasmittance (-)	0,5
	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	#N/D	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	#N/D	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		#N/D		n	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	#N/D	#N/D	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	#N/D	#N/D	Night ventilation absent	0
LIGHTING STRATEGIES :	n		n		#N/D		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	#N/D	#N/D	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	#N/D	#N/D	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	72	connection to a district heating	75	#N/D	#N/D	connection to a district heating	75
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	#N/D	-	radiator	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation oly for IAQ	0,05	no mechanical ventilation (open window by user)	-	#N/D	-	no mechanical ventilation (open window by user)	-
Heat Recovery	present	0,05	absent	-	#N/D	-	absent	-
Thermal Solar Panels	absent	-	absent	-	#N/D	-	absent	-
Photovoltaic Solar Panel	present	-	absent	-	#N/D	-	present	-
Energy Need for Heating [kWh/m²y]	54,9		71,9		#N/D		71,9	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		#N/D		0,0	
Energy Need for DHW [kWh/m²y]	15,0		15,0		#N/D		15,0	
Energy Use for Lighting [kWh/m²y]	11,4		11,4		#N/D		11,4	
(net) Primary Energy demand [kWh/m²y]	76,2		99,8		#N/D		63,3	
RES contribution [kWh/m²y]	42,0		5,6		#N/D		42,0	
Global Cost [€/m²]	989,8		968,4		#N/D		1002,5	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	165,2							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	15,0							
Energy Use for Lighting [kWh/m²y]	11,4							
(net) Primary Energy demand [kWh/m²y]	202,6							
RES contribution [kWh/m²y]	5,6							
Global Cost [€/m²]	1048,8							

there are not buildings simulated that can be selected with these criteria

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom- office room -service)

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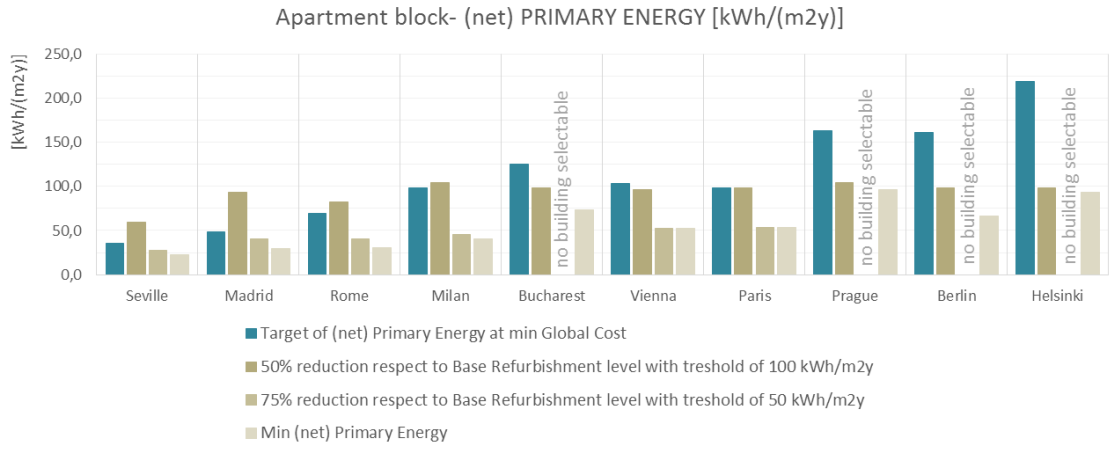
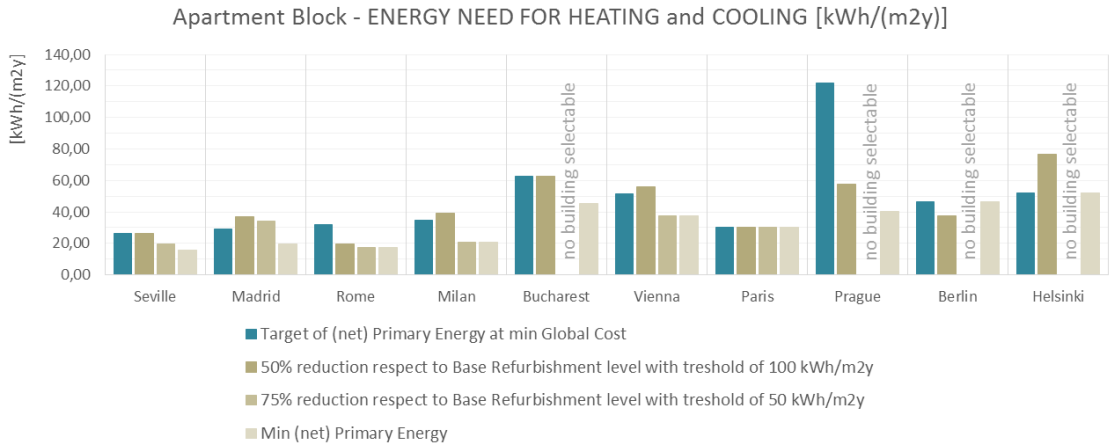
6.2.2 Apartment Block





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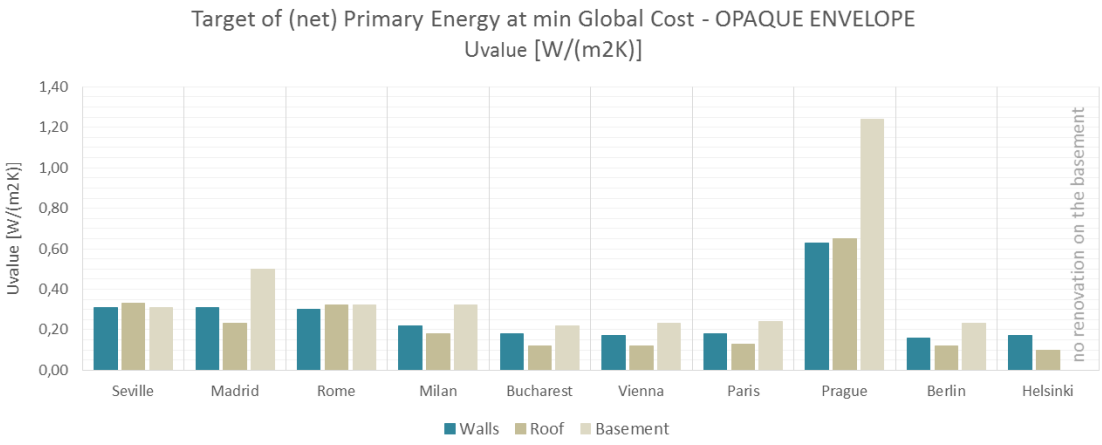

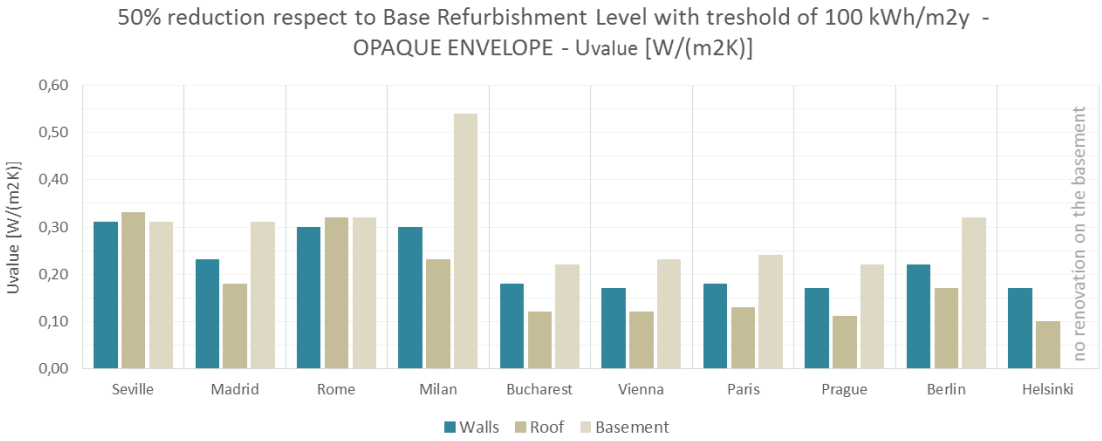

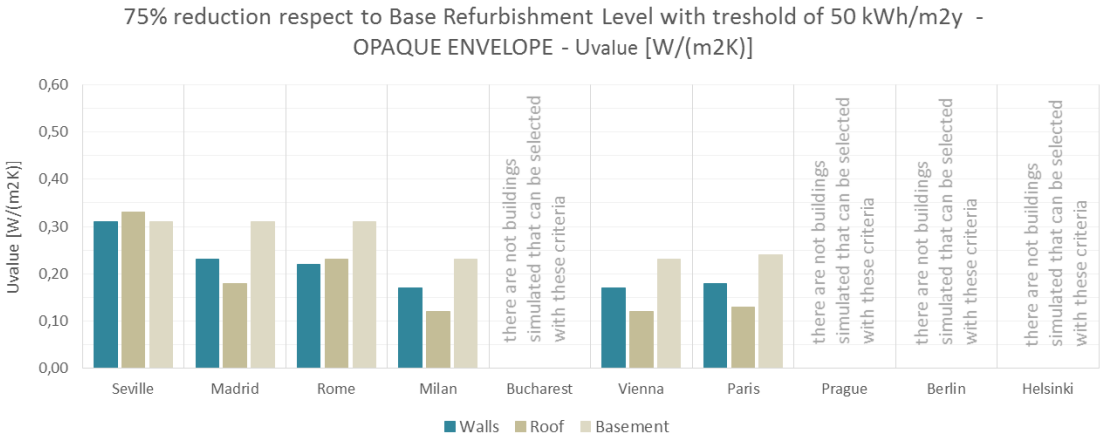

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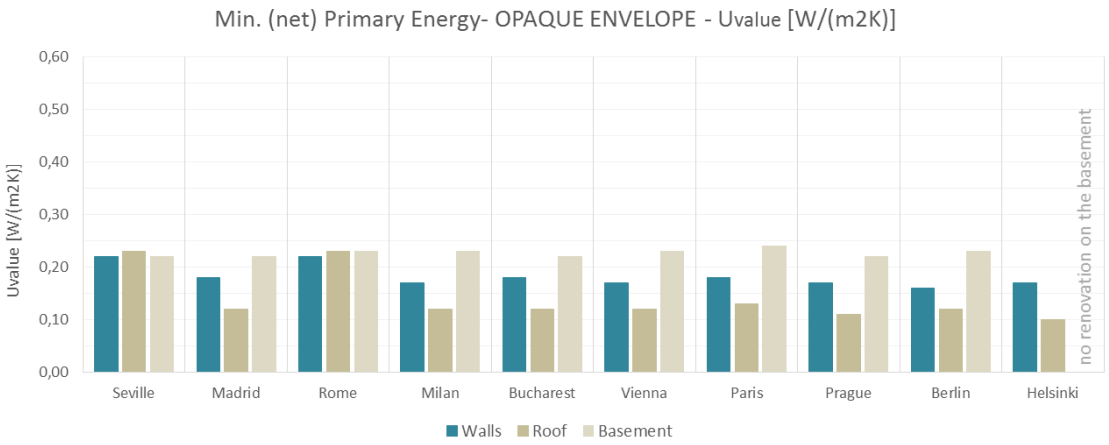

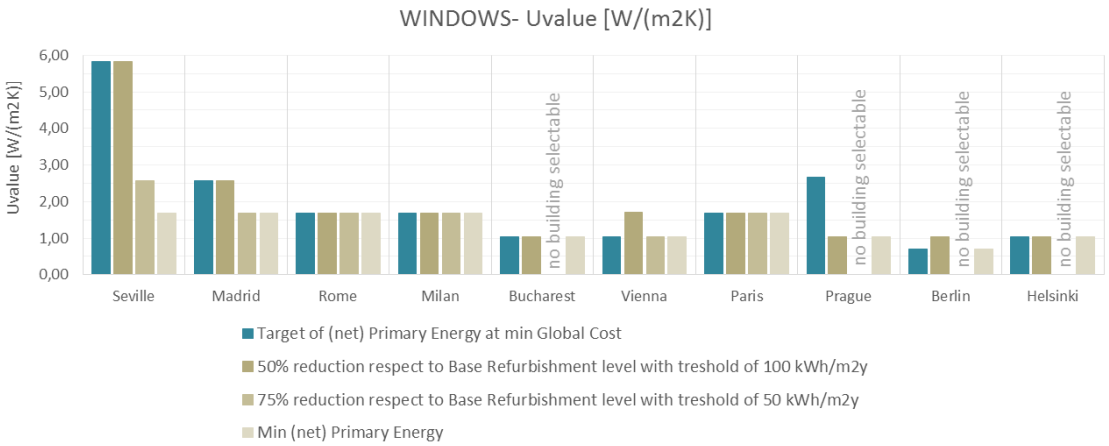

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Seville APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	18		18		20		32	
OPAQUE ENVELOPE-Package:	++		++		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	10cm insulation -External insulation (EIFS System)	0,31	10cm insulation -External insulation (EIFS System)	0,31	10cm insulation -External insulation (EIFS System)	0,31	15cm insulation -External insulation (EIFS System)	0,22
Roof thermal insulation	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,33	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,33	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,33	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22
WINDOW PACKAGE:	n		n		+		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	5,83	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	5,83	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,58	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69
	Solar Trasmittance (-)	0,69	Solar Trasmittance (-)	0,69	Solar Trasmittance (-)	0,59	Solar Trasmittance (-)	0,61
	Visible Trasmittance (-)	0,68	Visible Trasmittance (-)	0,68	Visible Trasmittance (-)	0,61	Visible Trasmittance (-)	0,62
	(airtightness) (1/h)	0,77	(airtightness) (1/h)	0,77	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	55	reversible heat pump	55	reversible heat pump	42	reversible heat pump	32
Cooling Generation	reversible heat pump	42	reversible heat pump	42	reversible heat pump	37	reversible heat pump	34
Heating Emission	insulated radiant floor	-	fan coil / split	-	fan coil / split	-	fan coil / split	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	fan coil / split	-	fan coil / split	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	10,8		10,8		6,0		3,4	
Energy Need for Cooling [kWh/m²y]	15,4		15,4		13,6		12,5	
Energy Need for DHW [kWh/m²y]	20,7		20,7		20,7		20,7	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		11,7		11,7	
(net) Primary Energy demand [kWh/m²y]	35,1		59,6		27,4		22,2	
RES contribution [kWh/m²y]	79,3		51,8		71,5		67,9	
Global Cost [€/m²]	531,6		529,8		552,4		570,7	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	26,2							
Energy Need for Cooling [kWh/m²y]	39,7							
Energy Need for DHW [kWh/m²y]	20,7							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	126,8							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	737,4							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Madrid APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	10		19		23		32	
OPAQUE ENVELOPE-Package:	+		++		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	10cm insulation -External insulation (EIFS System)	0,31	15cm insulation -External insulation (EIFS System)	0,23	15cm insulation -External insulation (EIFS System)	0,23	20cm insulation -External insulation (EIFS System)	0,18
Roof thermal insulation	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,18	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,18	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	5cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,5	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,31	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22
WINDOW PACKAGE:	+		+		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,58	Double glass with air cavity (16mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,58	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69
	Solar Trasmittance (-)	0,59	Solar Trasmittance (-)	0,59	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61
	Visible Trasmittance (-)	0,61	Visible Trasmittance (-)	0,61	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62
	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		n		n		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	56	condensig gas boiler	54	reversible heat pump	50	reversible heat pump	48
Cooling Generation	chiller whit high performance	26	chiller whit high performance	33	reversible heat pump	34	reversible heat pump	24
Heating Emission	insulated radiant floor	-	insulated radiant floor	-	fan coil / split	-	fan coil / split	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	insulated radiant floor + local dehumifidier	-	fan coil / split	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	present	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	23,4		20,5		16,1		14,5	
Energy Need for Cooling [kWh/m²y]	5,8		16,6		17,8		5,3	
Energy Need for DHW [kWh/m²y]	22,6		22,6		22,6		22,6	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		11,7		11,7	
(net) Primary Energy demand [kWh/m²y]	48,6		93,0		40,9		29,7	
RES contribution [kWh/m²y]	37,4		0,0		88,2		85,7	
Global Cost [€/m²]	578,4		548,5		553,9		609,6	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	71,0							
Energy Need for Cooling [kWh/m²y]	22,8							
Energy Need for DHW [kWh/m²y]	22,6							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	182,1							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	806,3							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Rome APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	25		24		32		32	
OPAQUE ENVELOPE-Package:	++		++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	10cm insulation -External insulation (EIFS System)	0,3	10cm insulation -External insulation (EIFS System)	0,3	15cm insulation -External insulation (EIFS System)	0,22	15cm insulation -External insulation (EIFS System)	0,22
Roof thermal insulation	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,32	10cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,32	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,32	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,32	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1):	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69
	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61
	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	49	connection to a district heating	57	reversible heat pump	55	reversible heat pump	55
Cooling Generation	chiller whit high performance	49	chiller whit high performance	32	reversible heat pump	31	reversible heat pump	31
Heating Emission	air diffuser	-	air diffuser	-	fan coil / split	-	fan coil / split	-
Cooling Emission	air diffuser	-	air diffuser	-	fan coil / split	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation HVAC (IAQ+ conditioning)	2,50	mechanical ventilation HVAC (IAQ+ conditioning)	3,08	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	present	0,39	absent	0,39	absent	-	absent	-
Thermal Solar Panels	present	-	present	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	7,3		11,5		9,6		9,6	
Energy Need for Cooling [kWh/m²y]	24,5		7,8		7,7		7,7	
Energy Need for DHW [kWh/m²y]	22,6		22,6		22,6		22,6	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		11,7		11,7	
(net) Primary Energy demand [kWh/m²y]	69,5		82,0		41,0		30,9	
RES contribution [kWh/m²y]	39,8		14,0		25,8		36,2	
Global Cost [€/m²]	650,0		682,0		756,4		747,8	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	45,1							
Energy Need for Cooling [kWh/m²y]	24,2							
Energy Need for DHW [kWh/m²y]	22,6							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	157,4							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	823,1							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Milan APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	24		14		34		34	
OPAQUE ENVELOPE-Package:	++		+		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	15cm insulation -External insulation (EIFS System)	0,22	10cm insulation -External insulation (EIFS System)	0,3	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,18	15cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,23	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,32	5cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,54	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1):	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69
	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61
	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	63	connection to a district heating	67	reversible ground source heat pump	54	reversible ground source heat pump	54
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	air diffuser	-	air diffuser	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	2,64	mechanical ventilation HVAC (IAQ+ conditioning)	2,64
Heat Recovery	absent	-	absent	-	present	0,39	present	0,39
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	34,8		39,1		20,7		20,7	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	24,6		24,6		24,6		24,6	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		11,7		11,7	
(net) Primary Energy demand [kWh/m²y]	98,2		104,7		45,3		40,2	
RES contribution [kWh/m²y]	15,5		15,5		113,9		109,1	
Global Cost [€/m²]	468,0		463,7		842,5		866,3	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	106,8							
Energy Need for Cooling [kWh/m²y]	15,6							
Energy Need for DHW [kWh/m²y]	24,6							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	259,9							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	992,1							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Bucharest APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	31		31		#N/D		32	
OPAQUE ENVELOPE-Package:	+++		+++		#N/D		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18	#N/D	#N/D	20cm insulation -External insulation (Ventilated facade)	0,18
Roof thermal insulation	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	#N/D	#N/D	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22	#N/D	#N/D	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22
WINDOW PACKAGE:	++		++		#N/D		++	
WINDOW Variant (1):	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	#N/D	#N/D	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	#N/D	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	#N/D	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	#N/D	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		#N/D		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	#N/D	#N/D	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	#N/D	#N/D	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		#N/D		n	
	description:	power [W/m2](2)	description:	power [W/m2](2)	description:	power [W/m2](2)	description:	power [W/m2](2)
Lighting Loads	No change	3,5	No change	3,5	#N/D	#N/D	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	#N/D	#N/D	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	59	condensig gas boiler	59	#N/D	#N/D	condensig gas boiler	59
Cooling Generation	chiller whit high performance	41	chiller whit high performance	41	no cooling generation system	-	chiller whit high performance	23
Heating Emission	fan coil / split	-	fan coil / split	-	#N/D	-	fan coil / split	-
Cooling Emission	fan coil / split	-	fan coil / split	-	no cooling emission system	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	#N/D	—	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	#N/D	—	absent	-
Thermal Solar Panels	present	-	present	-	#N/D	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	#N/D	-	present	-
Energy Need for Heating [kWh/m²y]	42,7		42,7		#N/D		42,7	
Energy Need for Cooling [kWh/m²y]	20,2		20,2		#N/D		2,6	
Energy Need for DHW [kWh/m²y]	25,4		25,4		#N/D		25,4	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		#N/D		11,7	
(net) Primary Energy demand [kWh/m²y]	125,3		98,6		#N/D		73,1	
RES contribution [kWh/m²y]	12,0		38,7		#N/D		38,7	
Global Cost [€/m²]	474,9		494,9		#N/D		596,1	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	125,2							
Energy Need for Cooling [kWh/m²y]	19,8							
Energy Need for DHW [kWh/m²y]	25,4							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	306,7							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	653,4							

there are not buildings simulated that can be selected with these criteria

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Vienna APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	31		27		33		33	
OPAQUE ENVELOPE-Package:	+++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	++		+		++		++	
WINDOW Variant (1):	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (adim)	0,55	Solar Trasmittance (adim)	0,64	Solar Trasmittance (adim)	0,55	Solar Trasmittance (adim)	0,55
	Visible Trasmittance (adim.)	0,59	Visible Trasmittance (adim.)	0,65	Visible Trasmittance (adim.)	0,59	Visible Trasmittance (adim.)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		n		n	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-
Night Ventilation for Cooling	description: Night ventilation absent	h^{-1} 0	description: Night ventilation absent	h^{-1} 0	description: Night ventilation absent	h^{-1} 0	description: Night ventilation absent	h^{-1} 0
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2](2)	description:	power [W/m2](2)	description:	power [W/m2](2)	description:	power [W/m2](2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	55	connection to a district heating	59	reversible ground source heat pump	46	reversible ground source heat pump	46
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	insulated radiant floor	-	insulated radiant floor	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,36	mechanical ventilation oly for IAQ	0,36
Heat Recovery	absent	-	absent	-	present	0,36	present	0,36
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	51,5		55,9		37,7		37,7	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	25,4		25,4		25,4		25,4	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		11,7		11,7	
(net) Primary Energy demand [kWh/m²y]	103,4		96,4		52,3		52,3	
RES contribution [kWh/m²y]	12,8		27,6		112,7		112,7	
Global Cost [€/m²]	527,8		574,1		831,4		831,4	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	135,9							
Energy Need for Cooling [kWh/m²y]	7,3							
Energy Need for DHW [kWh/m²y]	25,4							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	343,7							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1226,6							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Paris APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	32		32		32		32	
OPAQUE ENVELOPE-Package:	+++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18	20cm insulation -External insulation (Ventilated facade)	0,18
Roof thermal insulation	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,13	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,13	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,13	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,13
Basement thermal insulation	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,24	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,24	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,24	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,24
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,69
	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61	Solar Trasmittance (-)	0,61
	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62	Visible Trasmittance (-)	0,62
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		+		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	54	connection to a district heating	54	reversible ground source heat pump	54	reversible ground source heat pump	54
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	insulated radiant floor	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	30,4		30,4		30,4		30,4	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	25,4		25,4		25,4		25,4	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		11,7		11,7	
(net) Primary Energy demand [kWh/m²y]	98,8		98,8		53,5		53,5	
RES contribution [kWh/m²y]	17,5		17,5		172,8		172,8	
Global Cost [€/m²]	467,4		467,4		555,5		555,5	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	153,8							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	25,4							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	336,5							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	636,9							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Prague APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	1		32		#N/D		34	
OPAQUE ENVELOPE-Package:	n		+++		#N/D		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	0,63	20cm insulation -External insulation (EIFS System)	0,17	#N/D	#N/D	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	No renovation	0,65	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,11	#N/D	#N/D	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,11
Basement thermal insulation	No renovation	1,24	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22	#N/D	#N/D	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,22
WINDOW PACKAGE:	n		++		#N/D		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	2,66	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	#N/D	#N/D	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,62	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	#N/D	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	#N/D	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,77	(airtightness) (1/h)	0,58	(airtightness) (1/h)	#N/D	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		+		#N/D		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	#N/D	#N/D	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	#N/D	#N/D	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		#N/D		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	#N/D	#N/D	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	#N/D	#N/D	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	90	condensig gas boiler	60	#N/D	#N/D	condensig gas boiler	51
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	insulated radiant floor	-	insulated radiant floor	-	#N/D	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	#N/D	---	mechanical ventilation oly for IAQ	0,37
Heat Recovery	absent	-	absent	-	#N/D	---	present	0,37
Thermal Solar Panels	present	-	present	-	#N/D	-	present	-
Photovoltaic Solar Panel	present	-	present	-	#N/D	-	present	-
Energy Need for Heating [kWh/m²y]	121,9		57,8		#N/D		40,4	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		#N/D		0,0	
Energy Need for DHW [kWh/m²y]	25,4		25,4		#N/D		25,4	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		#N/D		11,7	
(net) Primary Energy demand [kWh/m²y]	163,7		104,0		#N/D		96,9	
RES contribution [kWh/m²y]	37,7		37,7		#N/D		37,7	
Global Cost [€/m²]	428,8		585,5		#N/D		653,2	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	121,9							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	25,4							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	302,8							
RES contribution [kWh/m²y]	175,9							
Global Cost [€/m²]	608,7							

there are not buildings simulated that can be selected with these criteria

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building

(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

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Berlin APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	32		22		#N/D		32	
OPAQUE ENVELOPE-Package:	+++		++		#N/D		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	20cm insulation -External insulation (EIFS System)	0,16	15cm insulation -External insulation (EIFS System)	0,22	#N/D	#N/D	20cm insulation -External insulation (EIFS System)	0,16
Roof thermal insulation	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,17	#N/D	#N/D	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,32	#N/D	#N/D	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	++		+		#N/D		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (18mm); low-e glassUg= 0,65 W/m²K; Uf=0,95 W/m2K; air permeability: 4th class EN 12207.	0,7	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	#N/D	#N/D	Triple glass with argon cavity (18mm); low-e glassUg= 0,65 W/m²K; Uf=0,95 W/m2K; air permeability: 4th class EN 12207.	0,7
	Solar Trasmittance (-)	0,5	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	#N/D	Solar Trasmittance (-)	0,5
	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	#N/D	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	#N/D	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	+		+		#N/D		+	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-	#N/D	#N/D	External window blinds - fixed slat angle - automatic control (setpoint 100W/m2)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4	#N/D	#N/D	Natural extra ventilation in SUMMER (automatic control to open windows) - automatic control through differential temperature	4
LIGHTING STRATEGIES :	n		n		#N/D		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	#N/D	#N/D	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	#N/D	#N/D	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	biomass boiler	46	condensig gas boiler	42	#N/D	#N/D	reversible ground source heat pump	46
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	insulated radiant floor	-	radiator	-	#N/D	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,36	#N/D	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	present	0,36	#N/D	-	absent	-
Thermal Solar Panels	present	-	present	-	#N/D	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	#N/D	-	present	-
Energy Need for Heating [kWh/m²y]	46,6		37,4		#N/D		46,6	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		#N/D		0,0	
Energy Need for DHW [kWh/m²y]	25,4		25,4		#N/D		25,4	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		#N/D		11,7	
(net) Primary Energy demand [kWh/m²y]	161,0		98,8		#N/D		66,2	
RES contribution [kWh/m²y]	72,6		31,6		#N/D		188,6	
Global Cost [€/m²]	897,3		955,0		#N/D		1019,8	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	141,9							
Energy Need for Cooling [kWh/m²y]	6,2							
Energy Need for DHW [kWh/m²y]	25,4							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	318,7							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1439,5							

there are not buildings simulated that can be selected with these criteria

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

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Helsinki APARTMENT BLOCK	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	29		27		#N/D		29	
OPAQUE ENVELOPE-Package:	+++		+++		#N/D		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	20cm insulation -External insulation (Ventilated facade)	0,17	20cm insulation -External insulation (Ventilated facade)	0,17	#N/D	#N/D	20cm insulation -External insulation (Ventilated facade)	0,17
Roof thermal insulation	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,1	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,1	#N/D	#N/D	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,1
Basement thermal insulation	No renovation	0,48	No renovation	0,48	#N/D	#N/D	No renovation	0,48
WINDOW PACKAGE:	+		+		#N/D		+	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	#N/D	#N/D	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	#N/D	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	#N/D	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	#N/D	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		#N/D		n	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	#N/D	#N/D	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	#N/D	#N/D	Night ventilation absent	0
LIGHTING STRATEGIES :	n		n		#N/D		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	#N/D	#N/D	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	#N/D	#N/D	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	biomass boiler	56	connection to a district heating	66	#N/D	#N/D	connection to a district heating	56
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	#N/D	-	radiator	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation oly for IAQ	0,36	no mechanical ventilation (open window by user)	-	#N/D	-	mechanical ventilation oly for IAQ	0,36
Heat Recovery	present	0,36	absent	-	#N/D	-	present	0,36
Thermal Solar Panels	absent	-	absent	-	#N/D	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	#N/D	-	present	-
Energy Need for Heating [kWh/m²y]	52,2		76,8		#N/D		52,2	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		#N/D		0,0	
Energy Need for DHW [kWh/m²y]	28,0		28,0		#N/D		28,0	
Energy Use for Lighting [kWh/m²y]	11,7		11,7		#N/D		11,7	
(net) Primary Energy demand [kWh/m²y]	219,4		98,2		#N/D		93,9	
RES contribution [kWh/m²y]	55,8		18,0		#N/D		28,5	
Global Cost [€/m²]	657,4		717,5		#N/D		709,9	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	143,4							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	28,0							
Energy Use for Lighting [kWh/m²y]	11,7							
(net) Primary Energy demand [kWh/m²y]	194,6							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	814,5							

there are not buildings simulated that can be selected with these criteria

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom -office room -service)

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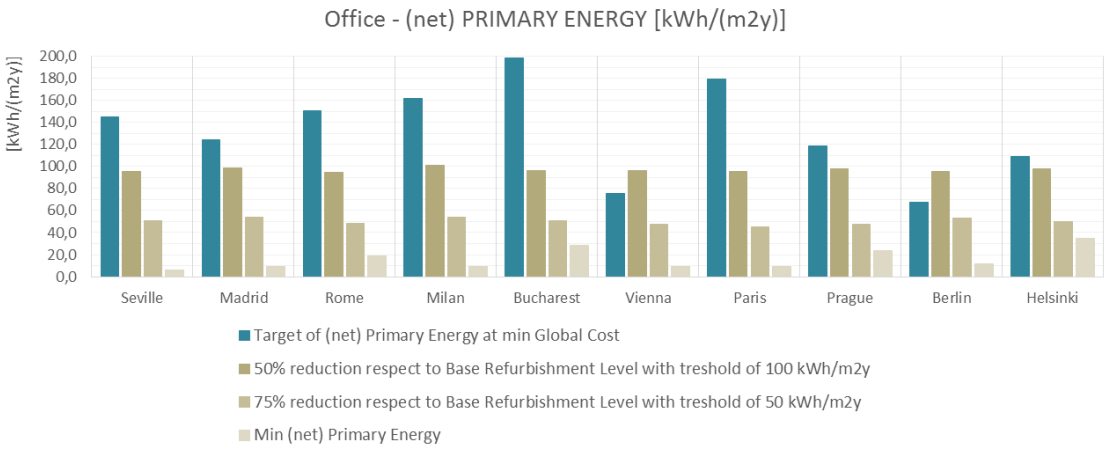
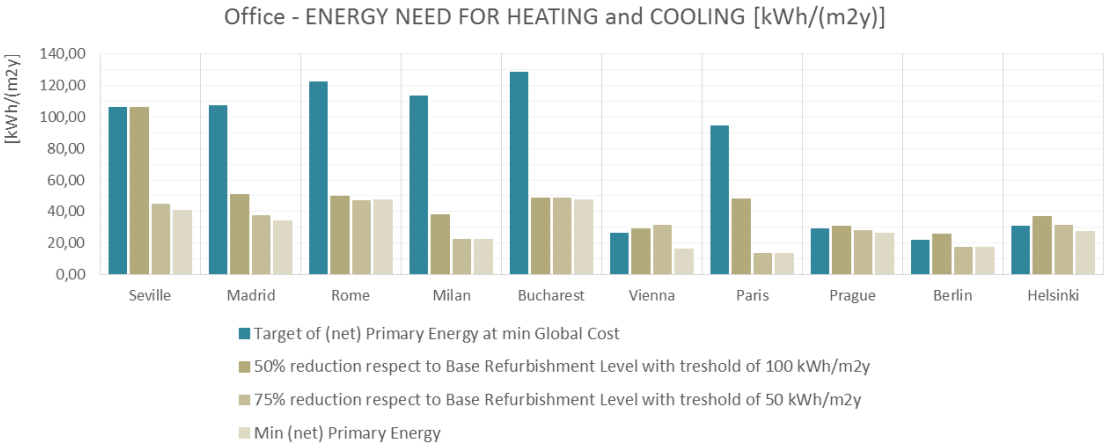
6.2.3 Office





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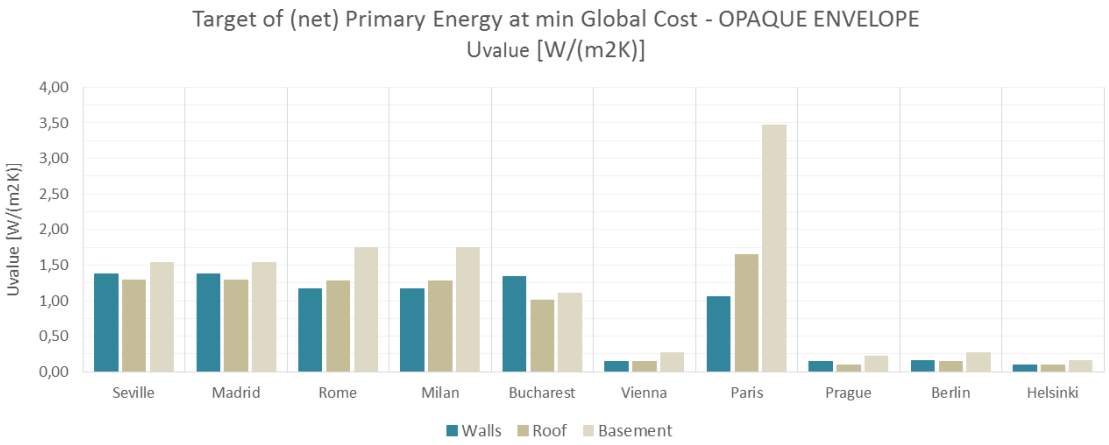

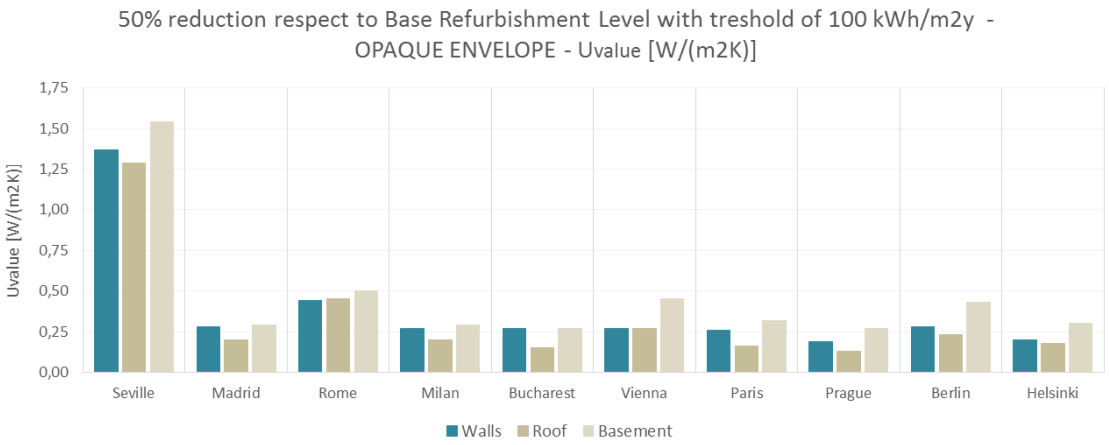

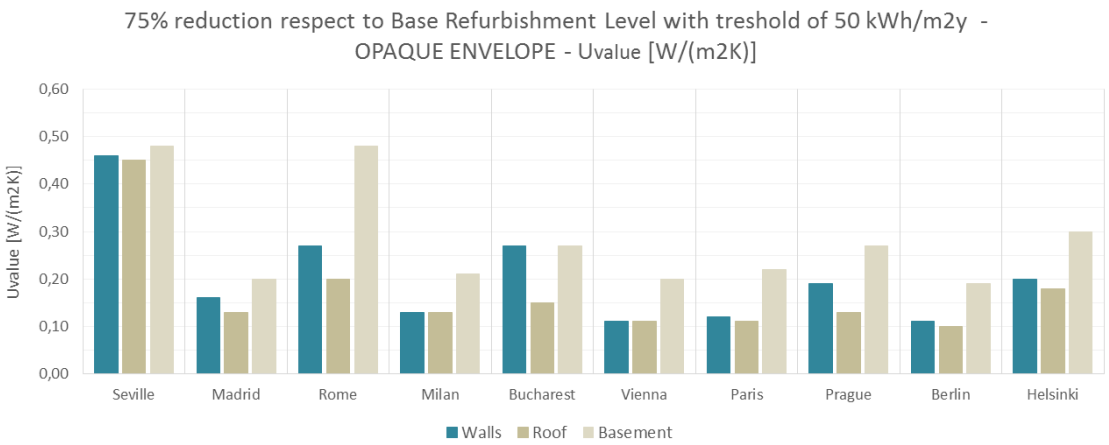

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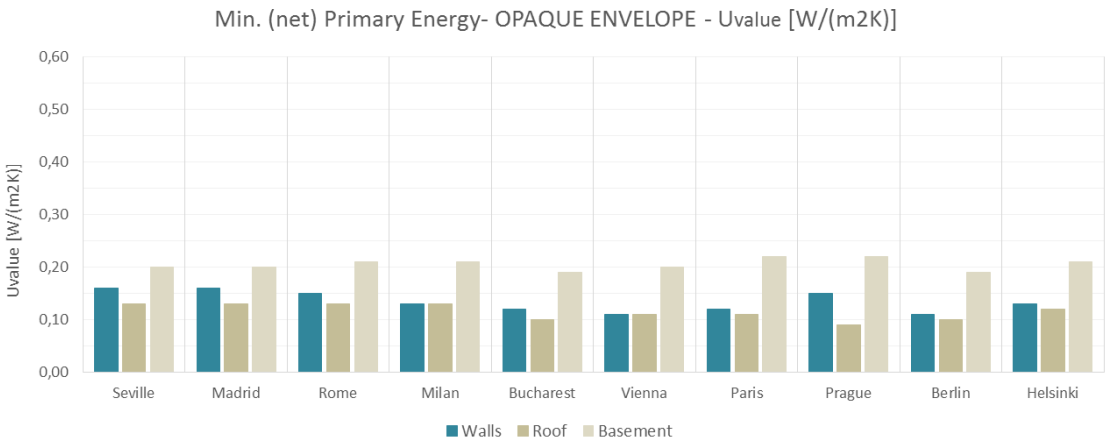

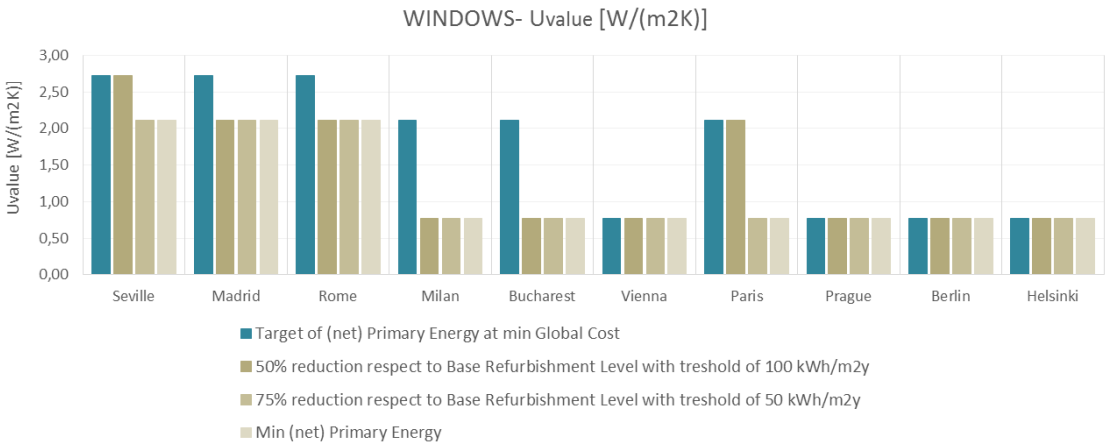

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Seville OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		3		10		18	
OPAQUE ENVELOPE-Package:	n		n		+		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	1,37	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	1,37	External insulation (EIFS System): 5 cm	0,46	External insulation (EIFS System): 20 cm	0,16
Roof thermal insulation	Renovation of the exterior layer of the roof (tile or tar or ...) for aesthetic/functional/security reasons	1,29	Renovation of the exterior layer of the roof (tile or tar or ...) for aesthetic/functional/security reasons	1,29	Remove roof and refit adding a new layer of insulation: 5 cm of insulation layer	0,45	Remove roof and refit adding a new layer of insulation: 25 cm of insulation layer	0,13
Basement thermal insulation	No renovation	1,54	No renovation	1,54	Install 5 cm insulation in the outer of the floor slabs or frameworks	0,48	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,2
WINDOW PACKAGE:	+		+		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,72	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,72	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11
	Solar Trasmittance (-)	0,727	Solar Trasmittance (-)	0,727	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,52
	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,76
	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,23
COOLING STRATEGIES PACKAGE:	n		n		++		++	
	description:		description:		description:		description:	
Solar shading	External-internal window blinds - fixed slat angle - manual control	-	External-internal window blinds - fixed slat angle - manual control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		n		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-8-18	Luminaire with fluorescent lamp medium efficiency	18-8-18	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	44	reversible ground source heat pump	44	reversible ground source heat pump	29	reversible ground source heat pump	20
Cooling Generation	reversible heat pump	63	reversible ground source heat pump	63	reversible ground source heat pump	51	reversible ground source heat pump	52
Heating Emission	insulated radiant floor	-	insulated radiant floor	-	insulated radiant floor	-	fan coil / split	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	insulated radiant floor + local dehumifidier	-	insulated radiant floor + local dehumifidier	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	present	-	absent	-	present	-
Energy Need for Heating [kWh/m²y]	17,7		17,7		7,3		4,4	
Energy Need for Cooling [kWh/m²y]	88,3		88,3		37,4		36,6	
Energy Need for DHW [kWh/m²y]	6,7		6,7		6,7		6,7	
Energy Use for Lighting [kWh/m²y]	27,7		27,7		7,2		7,2	
(net) Primary Energy demand [kWh/m²y]	144,7		95,3		50,9		5,8	
RES contribution [kWh/m²y]	74,4		79,1		23,1		58,1	
Global Cost [€/m²]	942,1		973,6		1135,6		1146,2	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	46,5							
Energy Need for Cooling [kWh/m²y]	88,8							
Energy Need for DHW [kWh/m²y]	6,7							
Energy Use for Lighting [kWh/m²y]	27,1							
(net) Primary Energy demand [kWh/m²y]	225,4							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	989,3							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

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Madrid OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		13		18		36	
OPAQUE ENVELOPE-Package:	n		++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	1,37	External insulation (EIFS System): 10 cm	0,28	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 20 cm	0,16
Roof thermal insulation	Renovation of the exterior layer of the roof (tile or tar or ...) for aesthetic/functional/security reasons	1,29	Remove roof and refit adding a new layer of insulation: 15 cm of insulation layer	0,2	Remove roof and refit adding a new layer of insulation: 25 cm of insulation layer	0,13	Remove roof and refit adding a new layer of insulation: 25 cm of insulation layer	0,13
Basement thermal insulation	No renovation	1,54	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,2	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,2
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,72	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11
	Solar Trasmittance (-)	0,727	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,52
	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,76
	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,23
COOLING STRATEGIES PACKAGE:	n		+		++		++	
	description:		description:		description:		description:	
Solar shading	External-internal window blinds - fixed slat angle - manual control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		+		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-8-18	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	61	reversible heat pump	41	reversible heat pump	39	reversible ground source heat pump	38
Cooling Generation	reversible heat pump	64	reversible heat pump	61	reversible heat pump	38	reversible ground source heat pump	36
Heating Emission	insulated radiant floor	-	insulated radiant floor	-	fan coil / split	-	air diffuser	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	insulated radiant floor + local dehumifidier	-	fan coil / split	-	air diffuser	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	5,01
Heat Recovery	absent	-	absent	-	absent	-	present	5,14
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	absent	-	present	-
Energy Need for Heating [kWh/m²y]	58,5		15,6		17,6		14,8	
Energy Need for Cooling [kWh/m²y]	48,6		35,1		20,0		19,1	
Energy Need for DHW [kWh/m²y]	7,3		7,3		7,3		7,3	
Energy Use for Lighting [kWh/m²y]	28,3		18,8		7,0		7,0	
(net) Primary Energy demand [kWh/m²y]	124,2		98,5		54,0		9,0	
RES contribution [kWh/m²y]	121,7		3,5		35,9		71,7	
Global Cost [€/m²]	931,4		1116,9		1103,3		1296,4	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	124,0							
Energy Need for Cooling [kWh/m²y]	47,7							
Energy Need for DHW [kWh/m²y]	7,3							
Energy Use for Lighting [kWh/m²y]	27,7							
(net) Primary Energy demand [kWh/m²y]	298,3							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1077,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Rome OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		28		32		18	
OPAQUE ENVELOPE-Package:	n		+		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	1,17	External insulation (EIFS System): 5 cm	0,44	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 20 cm	0,15
Roof thermal insulation	Renovation of the exterior layer of the roof (tile or tar or ...) for aesthetic/functional/security reasons	1,28	Remove roof and refit adding a new layer of insulation: 5 cm of insulation layer	0,45	Remove roof and refit adding a new layer of insulation: 15 cm of insulation layer	0,2	Remove roof and refit adding a new layer of insulation: 25 cm of insulation layer	0,13
Basement thermal insulation	No renovation	1,74	Install 5 cm insulation in the outer of the floor slabs or frameworks	0,5	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,72	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11
	Solar Trasmittance (-)	0,727	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,52
	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,76
	(airtightness) (1/h)	0,61	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,23
COOLING STRATEGIES PACKAGE:	n		++		++		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		++		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-8-18	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	72	connection to a district heating	47	connection to a district heating	43	reversible ground source heat pump	41
Cooling Generation	reversible heat pump	76	chiller whit high performance	57	chiller whit high performance	58	reversible ground source heat pump	60
Heating Emission	fan coil / split	-	air diffuser	-	air diffuser	-	fan coil / split	-
Cooling Emission	fan coil / split	-	air diffuser	-	air diffuser	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	4,89	mechanical ventilation HVAC (IAQ+ conditioning)	4,87	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	present	4,82	present	4,96	absent	-
Thermal Solar Panels	present	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	37,8		13,9		10,4		10,7	
Energy Need for Cooling [kWh/m²y]	84,6		35,8		36,2		37,0	
Energy Need for DHW [kWh/m²y]	7,3		7,3		7,3		7,3	
Energy Use for Lighting [kWh/m²y]	27,4		7,0		7,0		7,0	
(net) Primary Energy demand [kWh/m²y]	150,7		95,1		48,5		19,1	
RES contribution [kWh/m²y]	107,9		0,0		36,5		69,5	
Global Cost [€/m²]	1108,0		1226,6		1264,6		1368,3	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	89,3							
Energy Need for Cooling [kWh/m²y]	79,7							
Energy Need for DHW [kWh/m²y]	7,3							
Energy Use for Lighting [kWh/m²y]	27,0							
(net) Primary Energy demand [kWh/m²y]	295,9							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1206,6							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Milan OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	21		31		36		36	
OPAQUE ENVELOPE-Package:	n		++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	1,17	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 25 cm	0,13	External insulation (EIFS System): 25 cm	0,13
Roof thermal insulation	Renovation of the exterior layer of the roof (tile or tar or ...) for aesthetic/functional/security reasons	1,28	Remove roof and refit adding a new layer of insulation: 15 cm of insulation layer	0,2	Remove roof and refit adding a new layer of insulation: 25 cm of insulation layer	0,13	Remove roof and refit adding a new layer of insulation: 25 cm of insulation layer	0,13
Basement thermal insulation	No renovation	1,74	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08
COOLING STRATEGIES PACKAGE:	n		+		++		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		+		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-8-18	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	64	connection to a district heating	36	condensig gas boiler	28	reversible ground source heat pump	28
Cooling Generation	reversible heat pump	67	chiller whit high performance	52	chiller whit high performance	47	reversible ground source heat pump	47
Heating Emission	air diffuser	-	air diffuser	-	air diffuser	-	air diffuser	-
Cooling Emission	air diffuser	-	air diffuser	-	air diffuser	-	air diffuser	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation HVAC (IAQ+ conditioning)	4,99	mechanical ventilation HVAC (IAQ+ conditioning)	4,98	mechanical ventilation HVAC (IAQ+ conditioning)	4,76	mechanical ventilation HVAC (IAQ+ conditioning)	4,76
Heat Recovery	present	5,13	present	5,08	present	4,86	present	4,86
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	absent	-	present	-
Energy Need for Heating [kWh/m²y]	60,6		8,1		8,1		8,1	
Energy Need for Cooling [kWh/m²y]	52,7		29,6		14,1		14,1	
Energy Need for DHW [kWh/m²y]	7,9		7,9		7,9		7,9	
Energy Use for Lighting [kWh/m²y]	29,0		19,9		7,4		7,4	
(net) Primary Energy demand [kWh/m²y]	161,9		101,4		53,6		8,9	
RES contribution [kWh/m²y]	36,1		5,3		4,2		60,8	
Global Cost [€/m²]	1099,4		1271,4		1240,3		1274,4	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	167,8							
Energy Need for Cooling [kWh/m²y]	46,5							
Energy Need for DHW [kWh/m²y]	7,9							
Energy Use for Lighting [kWh/m²y]	28,5							
(net) Primary Energy demand [kWh/m²y]	400,1							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1368,9							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Bucharest OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		14		14		18	
OPAQUE ENVELOPE-Package:	n		++		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	1,34	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 25 cm	0,12
Roof thermal insulation	Renovation of the exterior layer of the roof (tile or tar or ...) for aesthetic/functional/security reasons	1,01	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,15	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,15	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,1
Basement thermal insulation	No renovation	1,1	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,19
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08
COOLING STRATEGIES PACKAGE:	n		++		++		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		++		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-8-18	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	76	connection to a district heating	57	condensig gas boiler	57	reversible ground source heat pump	57
Cooling Generation	chiller whit high performance	63	chiller whit high performance	33	chiller whit high performance	33	reversible ground source heat pump	34
Heating Emission	fan coil / split	-	fan coil / split	-	radiator	-	fan coil / split	-
Cooling Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	80,0		38,1		38,1		36,9	
Energy Need for Cooling [kWh/m²y]	48,4		10,7		10,7		10,7	
Energy Need for DHW [kWh/m²y]	8,2		8,2		8,2		8,2	
Energy Use for Lighting [kWh/m²y]	29,4		7,4		7,4		7,4	
(net) Primary Energy demand [kWh/m²y]	198,3		95,9		51,0		28,7	
RES contribution [kWh/m²y]	38,0		0,0		42,0		131,3	
Global Cost [€/m²]	655,3		714,7		787,8		820,8	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	141,1							
Energy Need for Cooling [kWh/m²y]	46,6							
Energy Need for DHW [kWh/m²y]	8,2							
Energy Use for Lighting [kWh/m²y]	28,9							
(net) Primary Energy demand [kWh/m²y]	379,1							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	896,2							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

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Vienna OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	31		27		17		36	
OPAQUE ENVELOPE-Package:	++		+		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 20 cm	0,15	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 30 cm	0,11	External insulation (EIFS System): 30 cm	0,11
Roof thermal insulation	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,15	Remove roof and refit adding a new layer of insulation: 10 cm of insulation layer	0,27	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,11	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,11
Basement thermal insulation	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 5 cm insulation in the outer of the floor slabs or frameworks	0,45	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,2	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,2
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08
COOLING STRATEGIES PACKAGE:	+		+		+		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		+		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	38	gas boiler	39	reversible heat pump	38	reversible ground source heat pump	37
Cooling Generation	chiller whit high performance	46	chiller whit high performance	46	reversible heat pump	47	reversible ground source heat pump	28
Heating Emission	air diffuser	-	air diffuser	-	fan coil / split	-	air diffuser	-
Cooling Emission	air diffuser	-	air diffuser	-	fan coil / split	-	air diffuser	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation HVAC (IAQ+ conditioning)	5,04	mechanical ventilation HVAC (IAQ+ conditioning)	5,04	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	4,16
Heat Recovery	present	5,16	present	5,16	absent	-	present	4,24
Thermal Solar Panels	present	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	9,3		12,9		13,2		11,4	
Energy Need for Cooling [kWh/m²y]	17,2		16,4		17,9		4,9	
Energy Need for DHW [kWh/m²y]	8,2		8,2		8,2		8,2	
Energy Use for Lighting [kWh/m²y]	21,3		21,3		21,3		7,9	
(net) Primary Energy demand [kWh/m²y]	75,1		96,0		47,8		9,3	
RES contribution [kWh/m²y]	4,5		0,0		46,7		49,3	
Global Cost [€/m²]	903,6		932,5		928,2		1305,4	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	222,7							
Energy Need for Cooling [kWh/m²y]	16,3							
Energy Need for DHW [kWh/m²y]	8,2							
Energy Use for Lighting [kWh/m²y]	30,5							
(net) Primary Energy demand [kWh/m²y]	525,0							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1586,4							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

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Paris OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		12		18		18	
OPAQUE ENVELOPE-Package:	n		++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls (plaster or tile or ...) for aesthetic/functional/security reasons	1,06	External insulation (EIFS System): 10 cm	0,26	External insulation (EIFS System): 25 cm	0,12	External insulation (EIFS System): 25 cm	0,12
Roof thermal insulation	Renovation of the exterior layer of the roof (tile or tar or ...) for aesthetic/functional/security reasons	1,65	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,16	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,11	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,11
Basement thermal insulation	No renovation	3,47	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,32	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22
WINDOW PACKAGE:	+		+		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,23	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08
COOLING STRATEGIES PACKAGE:	n		++		++		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		++		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-8-18	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible ground source heat pump	60	connection to a district heating	49	condensig gas boiler	28	condensig gas boiler	28
Cooling Generation	reversible ground source heat pump	54	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	insulated radiant floor	-	radiator	-	radiator	-	insulated radiant floor	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	absent	-	present	-
Energy Need for Heating [kWh/m²y]	79,8		47,8		13,6		13,6	
Energy Need for Cooling [kWh/m²y]	14,6		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	8,2		8,2		8,2		8,2	
Energy Use for Lighting [kWh/m²y]	30,5		7,1		7,5		7,5	
(net) Primary Energy demand [kWh/m²y]	179,7		95,5		45,1		9,0	
RES contribution [kWh/m²y]	188,5		0,0		4,2		38,5	
Global Cost [€/m²]	800,7		903,1		932,2		985,6	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	226,9							
Energy Need for Cooling [kWh/m²y]	11,9							
Energy Need for DHW [kWh/m²y]	8,2							
Energy Use for Lighting [kWh/m²y]	29,3							
(net) Primary Energy demand [kWh/m²y]	492,9							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1522,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

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Prague OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	17		13		14		18	
OPAQUE ENVELOPE-Package:	+++		++		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 20 cm	0,15	External insulation (EIFS System): 15 cm	0,19	External insulation (EIFS System): 15 cm	0,19	External insulation (EIFS System): 20 cm	0,15
Roof thermal insulation	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,09	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,13	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,13	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,09
Basement thermal insulation	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22	Install 12 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 12 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08
COOLING STRATEGIES PACKAGE:	+		+		++		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	43	connection to a district heating	44	connection to a district heating	44	condensig gas boiler	43
Cooling Generation	chiller whit high performance	45	chiller whit high performance	45	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	insulated radiant floor	-	insulated radiant floor	-	insulated radiant floor	-	insulated radiant floor	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	insulated radiant floor + local dehumifidier	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	present	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	19,4		21,2		28,0		26,0	
Energy Need for Cooling [kWh/m²y]	9,8		9,5		0,0		0,0	
Energy Need for DHW [kWh/m²y]	8,2		8,2		8,2		8,2	
Energy Use for Lighting [kWh/m²y]	22,6		22,6		8,3		8,3	
(net) Primary Energy demand [kWh/m²y]	118,3		98,1		47,4		23,9	
RES contribution [kWh/m²y]	3,9		36,2		36,2		40,1	
Global Cost [€/m²]	655,9		687,8		758,9		751,7	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	259,2							
Energy Need for Cooling [kWh/m²y]	6,9							
Energy Need for DHW [kWh/m²y]	8,2							
Energy Use for Lighting [kWh/m²y]	32,5							
(net) Primary Energy demand [kWh/m²y]	615,0							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1139,9							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

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Berlin OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	13		9		18		18	
OPAQUE ENVELOPE-Package:	++		+		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 10 cm	0,28	External insulation (EIFS System): 30 cm	0,11	External insulation (EIFS System): 30 cm	0,11
Roof thermal insulation	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,14	Remove roof and refit adding a new layer of insulation: 10 cm of insulation layer	0,23	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,1	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,1
Basement thermal insulation	Install 10 cm insulation in the inner of the floor slabs or frameworks	0,27	Install 5 cm insulation in the inner of the floor slabs or frameworks	0,43	Install 15 cm insulation in the inner of the floor slabs or frameworks	0,19	Install 15 cm insulation in the inner of the floor slabs or frameworks	0,19
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08
COOLING STRATEGIES PACKAGE:	+		+		++		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	27	condensig gas boiler	25	condensig gas boiler	28	reversible ground source heat pump	28
Cooling Generation	chiller whit high performance	35	chiller whit high performance	35	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	insulated radiant floor	-	insulated radiant floor	-	radiator	-	insulated radiant floor	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	insulated radiant floor + local dehumifidier	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	absent	-	present	-
Energy Need for Heating [kWh/m²y]	13,0		17,6		17,2		17,2	
Energy Need for Cooling [kWh/m²y]	9,0		8,2		0,0		0,0	
Energy Need for DHW [kWh/m²y]	8,2		8,2		8,2		8,2	
Energy Use for Lighting [kWh/m²y]	21,7		21,7		8,0		8,0	
(net) Primary Energy demand [kWh/m²y]	67,9		95,1		52,8		11,9	
RES contribution [kWh/m²y]	27,9		0,0		0,0		86,6	
Global Cost [€/m²]	1000,2		977,7		1091,1		1179,8	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	204,5							
Energy Need for Cooling [kWh/m²y]	9,0							
Energy Need for DHW [kWh/m²y]	8,2							
Energy Use for Lighting [kWh/m²y]	31,1							
(net) Primary Energy demand [kWh/m²y]	441,7							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1671,9							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

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Helsinki OFFICE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	17		9		28		32	
OPAQUE ENVELOPE-Package:	+++		+		+		++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 30 cm	0,09	External insulation (EIFS System): 10 cm	0,2	External insulation (EIFS System): 10 cm	0,2	External insulation (EIFS System): 20 cm	0,13
Roof thermal insulation	Remove roof and refit adding a new layer of insulation: 30 cm of insulation layer	0,09	Remove roof and refit adding a new layer of insulation: 10 cm of insulation layer	0,18	Remove roof and refit adding a new layer of insulation: 10 cm of insulation layer	0,18	Remove roof and refit adding a new layer of insulation: 20 cm of insulation layer	0,12
Basement thermal insulation	Install 15 cm insulation in the inner of the floor slabs or frameworks	0,16	Install 5 cm insulation in the inner of the floor slabs or frameworks	0,3	Install 5 cm insulation in the inner of the floor slabs or frameworks	0,3	Install 10 cm insulation in the inner of the floor slabs or frameworks	0,21
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,78
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08	(airtightness) (1/h)	0,08
COOLING STRATEGIES PACKAGE:	+		+		++		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with fluorescent lamp high efficiency	12-5-12	Luminaire with LED lamp high efficiency	6-2-6	Luminaire with LED lamp high efficiency	6-2-6
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	biomass boiler	45	connection to a district heating	48	reversible ground source heat pump	46	connection to a district heating	45
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	insulated radiant floor	-	air diffuser	-	air diffuser	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	3,13	mechanical ventilation HVAC (IAQ+ conditioning)	3,14
Heat Recovery	absent	-	absent	-	present	3,12	present	3,16
Thermal Solar Panels	absent	-	absent	-	absent	-	absent	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	30,7		37,0		31,4		27,5	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	9,0		9,0		9,0		9,0	
Energy Use for Lighting [kWh/m²y]	22,7		22,7		8,3		8,3	
(net) Primary Energy demand [kWh/m²y]	109,2		98,1		49,9		34,6	
RES contribution [kWh/m²y]	52,5		3,3		122,9		30,8	
Global Cost [€/m²]	729,1		727,3		1165,1		1101,0	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	282,7							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	9,0							
Energy Use for Lighting [kWh/m²y]	32,8							
(net) Primary Energy demand [kWh/m²y]	370,8							
RES contribution [kWh/m²y]	3,3							
Global Cost [€/m²]	1662,2							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room - service)

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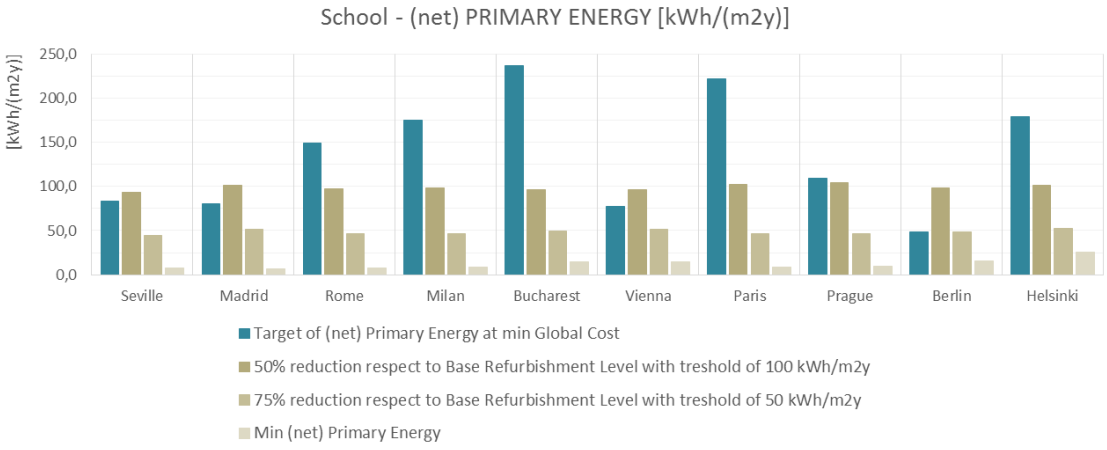
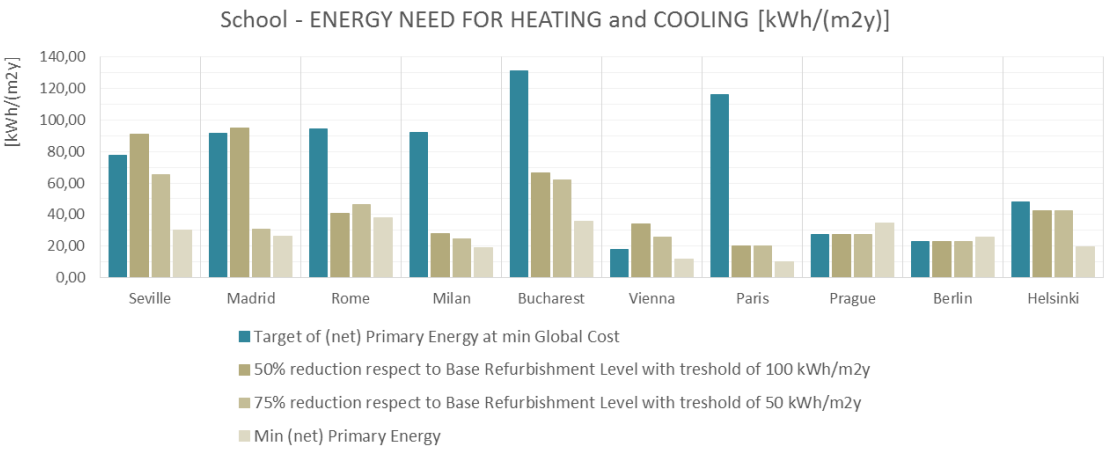
6.2.4 School





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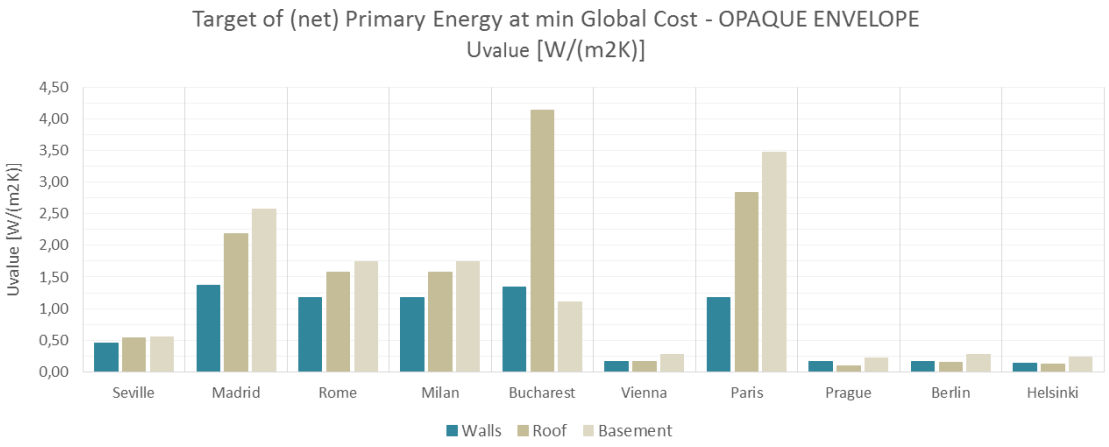

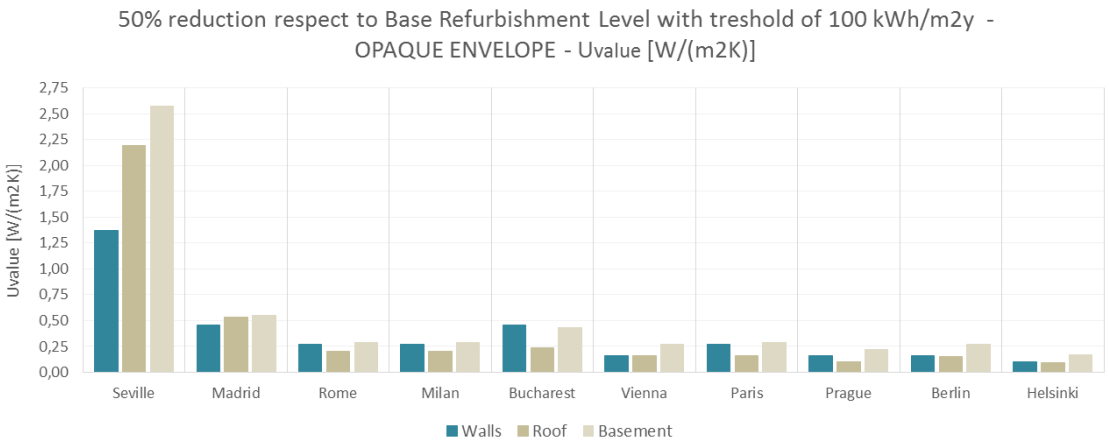

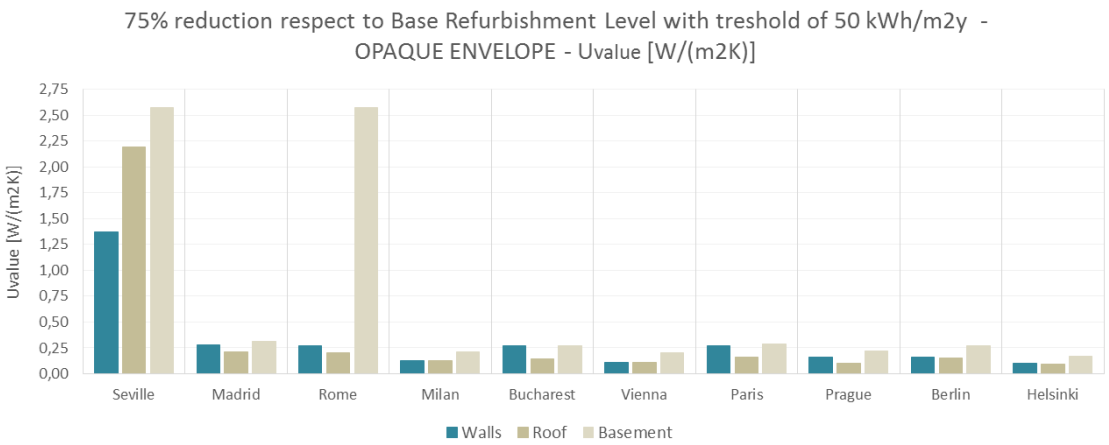

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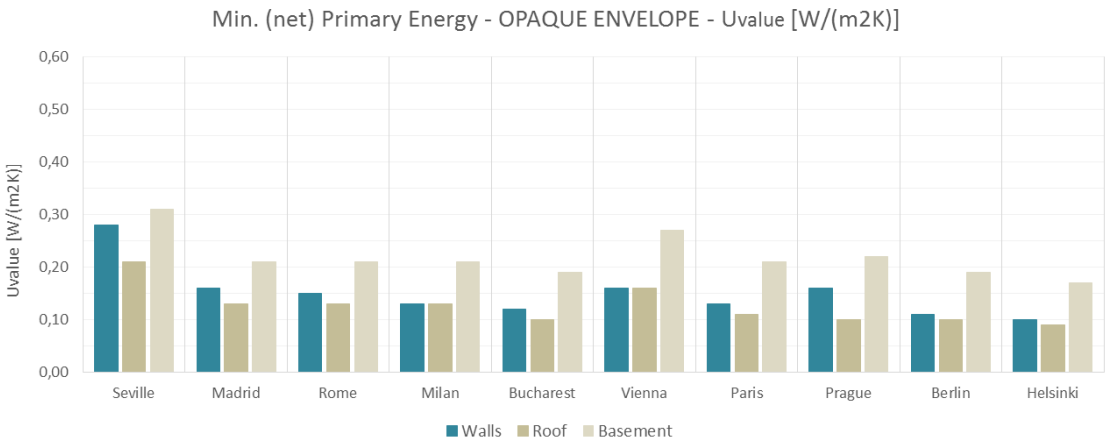

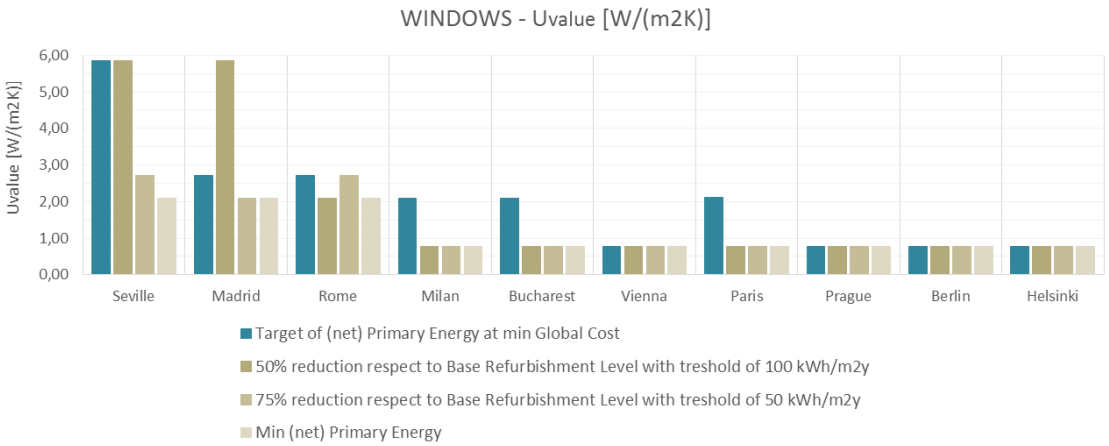

Co-funded by the Intelligent Energy Europe Programme of the European Union

Seville SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	5		1		4		14	
OPAQUE ENVELOPE-Package:	+		n		n		++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 5 cm	0,46	Renovation of the exterior layer of the walls for aesthetic/functional/security reasons	1,37	Renovation of the exterior layer of the walls for aesthetic/functional/security reasons	1,37	External insulation (EIFS System): 10 cm	0,28
Roof thermal insulation	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 5 cm of insulation layer	0,53	No renovation	2,19	No renovation	2,19	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 15 cm of insulation layer	0,21
Basement thermal insulation	Install 5 cm insulation in the outer of the floor slabs or frameworks	0,55	No renovation	2,57	No renovation	2,57	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,31
WINDOW PACKAGE:	n		n		+		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	5,85	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	5,85	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,71	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,10
	Solar Trasmittance (-)	0,85	Solar Trasmittance (-)	0,85	Solar Trasmittance (-)	0,727	Solar Trasmittance (-)	0,52
	Visible Trasmittance (-)	0,898	Visible Trasmittance (-)	0,898	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,76
	(airtightness) (1/h)	0,75	(airtightness) (1/h)	0,75	(airtightness) (1/h)	0,4	(airtightness) (1/h)	0,15
COOLING STRATEGIES PACKAGE:	n		n		+		++	
	description:		description:		description:		description:	
Solar shading	External-internal window blinds - fixed slat angle - manual control	-	External-internal window blinds - fixed slat angle - manual control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		n		+		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	62	reversible heat pump	76	reversible heat pump	60	reversible heat pump	35
Cooling Generation	reversible heat pump	109	reversible heat pump	108	reversible heat pump	101	reversible heat pump	96
Heating Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	insulated radiant floor	-
Cooling Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	insulated radiant floor + local dehumifidier	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	present	-	present	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	19,9		41,8		29,4		5,9	
Energy Need for Cooling [kWh/m²y]	57,5		49,4		36,1		24,5	
Energy Need for DHW [kWh/m²y]	11,9		11,9		11,9		11,9	
Energy Use for Lighting [kWh/m²y]	27,2		27,2		18,7		8,0	
(net) Primary Energy demand [kWh/m²y]	83,1		93,2		44,7		7,5	
RES contribution [kWh/m²y]	117,3		152,4		137,9		81,1	
Global Cost [€/m²]	821,9		776,0		923,4		959,2	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	41,8							
Energy Need for Cooling [kWh/m²y]	49,4							
Energy Need for DHW [kWh/m²y]	11,9							
Energy Use for Lighting [kWh/m²y]	27,2							
(net) Primary Energy demand [kWh/m²y]	189,4							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	889,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Madrid SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		5		14		18	
OPAQUE ENVELOPE-Package:	n		+		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls for aesthetic/functional/security reasons	1,37	External insulation (EIFS System): 5 cm	0,46	External insulation (EIFS System): 10 cm	0,28	External insulation (EIFS System): 20 cm	0,16
Roof thermal insulation	No renovation	2,19	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 5 cm of insulation layer	0,53	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 15 cm of insulation layer	0,21	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 25 cm of insulation layer	0,13
Basement thermal insulation	No renovation	2,57	Install 5 cm insulation in the outer of the floor slabs or frameworks	0,55	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,31	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21
WINDOW PACKAGE:	+		n		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,71	BASE LEVEL: Repair/restoration the old window components (glasses and frames) for aesthetic/functional/security reasons	5,85	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,10	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,10
	Solar Trasmittance (-)	0,727	Solar Trasmittance (-)	0,85	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,52
	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,898	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,76
	(airtightness) (1/h)	0,4	(airtightness) (1/h)	0,75	(airtightness) (1/h)	0,15	(airtightness) (1/h)	0,15
COOLING STRATEGIES PACKAGE:	n		n		++		++	
	description:		description:		description:		description:	
Solar shading	External-internal window blinds - fixed slat angle - manual control	-	External-internal window blinds - fixed slat angle - manual control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		n		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with LED lamp high efficiency	6-5-2	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible heat pump	95	condensig gas boiler	103	reversible heat pump	70	reversible heat pump	63
Cooling Generation	reversible heat pump	66	chiller whit high performance	73	reversible heat pump	55	reversible heat pump	54
Heating Emission	fan coil / split	-	fan coil / split	-	insulated radiant floor	-	fan coil / split	-
Cooling Emission	fan coil / split	-	fan coil / split	-	insulated radiant floor + local dehumifidier	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	present	-	present	-	absent	-	present	-
Energy Need for Heating [kWh/m²y]	70,8		67,8		21,2		16,8	
Energy Need for Cooling [kWh/m²y]	20,8		27,2		9,3		9,3	
Energy Need for DHW [kWh/m²y]	13,0		13,0		13,0		13,0	
Energy Use for Lighting [kWh/m²y]	28,1		27,5		7,8		7,8	
(net) Primary Energy demand [kWh/m²y]	79,9		101,4		51,8		6,6	
RES contribution [kWh/m²y]	179,1		71,9		49,1		90,4	
Global Cost [€/m²]	861,5		866,2		965,4		1014,8	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	109,4							
Energy Need for Cooling [kWh/m²y]	22,1							
Energy Need for DHW [kWh/m²y]	13,0							
Energy Use for Lighting [kWh/m²y]	27,5							
(net) Primary Energy demand [kWh/m²y]	261,5							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	955,1							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Rome SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		14		30		18	
OPAQUE ENVELOPE-Package:	n		++		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls for aesthetic/functional/security reasons	1,17	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 20 cm	0,15
Roof thermal insulation	No renovation	1,57	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 15 cm of insulation layer	0,2	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 15 cm of insulation layer	0,2	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 25 cm of insulation layer	0,13
Basement thermal insulation	No renovation	1,74	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21
WINDOW PACKAGE:	+		++		+		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,71	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,10	Double glass with air cavity (12mm); Ug= 2,7 W/m²K; Uf=2,2 W/m2K; air permeability: 2nd class EN 12207.	2,71	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,10
	Solar Trasmittance (-)	0,77	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,77	Solar Trasmittance (-)	0,52
	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,812	Visible Trasmittance (-)	0,76
	(airtightness) (1/h)	0,4	(airtightness) (1/h)	0,15	(airtightness) (1/h)	0,4	(airtightness) (1/h)	0,15
COOLING STRATEGIES PACKAGE:	n		++		++		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		++		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with LED lamp high efficiency	6-5-2	Luminaire with LED lamp high efficiency	6-5-2	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	83	condensig gas boiler	73	condensig gas boiler	91	reversible heat pump	55
Cooling Generation	chiller whit high performance	85	chiller whit high performance	76	chiller whit high performance	74	reversible heat pump	76
Heating Emission	fan coil / split	-	air diffuser	-	air diffuser	-	fan coil / split	-
Cooling Emission	fan coil / split	-	air diffuser	-	air diffuser	-	fan coil / split	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	8,59	mechanical ventilation HVAC (IAQ+ conditioning)	10,12	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	present	8,35	absent	-
Thermal Solar Panels	present	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	44,5		12,6		17,4		9,4	
Energy Need for Cooling [kWh/m²y]	50,0		28,1		28,9		28,5	
Energy Need for DHW [kWh/m²y]	13,0		13,0		13,0		13,0	
Energy Use for Lighting [kWh/m²y]	26,4		7,5		7,3		7,5	
(net) Primary Energy demand [kWh/m²y]	149,0		97,5		46,2		8,0	
RES contribution [kWh/m²y]	72,5		0,0		65,7		95,0	
Global Cost [€/m²]	1040,8		1096,3		1195,9		1188,8	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	75,5							
Energy Need for Cooling [kWh/m²y]	49,1							
Energy Need for DHW [kWh/m²y]	13,0							
Energy Use for Lighting [kWh/m²y]	26,0							
(net) Primary Energy demand [kWh/m²y]	356,9							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1085,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Milan SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	21		31		35		36	
OPAQUE ENVELOPE-Package:	n		++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls for aesthetic/functional/security reasons	1,17	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 25 cm	0,13	External insulation (EIFS System): 25 cm	0,13
Roof thermal insulation	No renovation	1,57	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 15 cm of insulation layer	0,2	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 25 cm of insulation layer	0,13	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 25 cm of insulation layer	0,13
Basement thermal insulation	No renovation	1,74	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,10	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,15	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05
COOLING STRATEGIES PACKAGE:	n		+		+		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		+		+		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	83	reversible heat pump	55	reversible heat pump	46	reversible heat pump	52
Cooling Generation	chiller whit high performance	75	reversible heat pump	78	reversible heat pump	79	reversible heat pump	68
Heating Emission	air diffuser	-	air diffuser	-	air diffuser	-	air diffuser	-
Cooling Emission	air diffuser	-	air diffuser	-	air diffuser	-	air diffuser	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation HVAC (IAQ+ conditioning)	9,24	mechanical ventilation HVAC (IAQ+ conditioning)	9,51	mechanical ventilation HVAC (IAQ+ conditioning)	9,67	mechanical ventilation HVAC (IAQ+ conditioning)	8,56
Heat Recovery	present	8,81	present	9,74	present	9,90	present	8,75
Thermal Solar Panels	absent	-	present	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	64,4		8,5		4,9		7,2	
Energy Need for Cooling [kWh/m²y]	27,6		19,4		19,7		11,7	
Energy Need for DHW [kWh/m²y]	14,1		14,1		14,1		14,1	
Energy Use for Lighting [kWh/m²y]	27,7		19,2		19,2		7,7	
(net) Primary Energy demand [kWh/m²y]	175,2		98,3		46,9		8,5	
RES contribution [kWh/m²y]	57,5		8,2		57,5		63,9	
Global Cost [€/m²]	1038,3		1131,9		1244,3		1200,0	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	145,8							
Energy Need for Cooling [kWh/m²y]	27,4							
Energy Need for DHW [kWh/m²y]	14,1							
Energy Use for Lighting [kWh/m²y]	27,3							
(net) Primary Energy demand [kWh/m²y]	356,9							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1247,5							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Bucharest SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		9		14		36	
OPAQUE ENVELOPE-Package:	n		+		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls for aesthetic/functional/security reasons	1,34	External insulation (EIFS System): 5 cm	0,46	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 25 cm	0,12
Roof thermal insulation	No renovation	4,14	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 10 cm of insulation layer	0,24	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,14	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,1
Basement thermal insulation	No renovation	1,1	Install 5 cm insulation in the outer of the floor slabs or frameworks	0,43	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,19
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,10	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,15	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05
COOLING STRATEGIES PACKAGE:	n		+		++		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		+		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	137	connection to a district heating	108	connection to a district heating	108	reversible ground source heat pump	76
Cooling Generation	chiller whit high performance	85	chiller whit high performance	69	chiller whit high performance	53	reversible ground source heat pump	49
Heating Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	air diffuser	-
Cooling Emission	fan coil / split	-	fan coil / split	-	fan coil / split	-	air diffuser	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	8,36
Heat Recovery	absent	-	absent	-	absent	-	present	6,82
Thermal Solar Panels	present	-	present	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	present	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	108,2		53,2		54,2		28,5	
Energy Need for Cooling [kWh/m²y]	23,3		13,3		7,6		7,2	
Energy Need for DHW [kWh/m²y]	14,6		14,6		14,6		14,6	
Energy Use for Lighting [kWh/m²y]	28,5		19,5		7,8		7,8	
(net) Primary Energy demand [kWh/m²y]	237,2		96,2		49,2		14,5	
RES contribution [kWh/m²y]	7,9		79,3		79,3		162,2	
Global Cost [€/m²]	629,0		737,2		750,3		950,2	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	146,6							
Energy Need for Cooling [kWh/m²y]	23,1							
Energy Need for DHW [kWh/m²y]	14,6							
Energy Use for Lighting [kWh/m²y]	28,1							
(net) Primary Energy demand [kWh/m²y]	380,8							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	957,8							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Vienna SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	31		13		18		32	
OPAQUE ENVELOPE-Package:	++		++		+++		++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 30 cm	0,11	External insulation (EIFS System): 20 cm	0,16
Roof thermal insulation	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,16	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,16	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,11	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,16
Basement thermal insulation	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,27	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,2	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,27
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05
COOLING STRATEGIES PACKAGE:	+		+		++		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		++		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	connection to a district heating	52	condensig gas boiler	76	connection to a district heating	75	connection to a district heating	68
Cooling Generation	chiller whit high performance	60	chiller whit high performance	60	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	air diffuser	-	fan coil / split	-	insulated radiant floor	-	air diffuser	-
Cooling Emission	air diffuser	-	fan coil / split	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation HVAC (IAQ+ conditioning)	9,60	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	6,85
Heat Recovery	present	9,77	absent	-	absent	-	present	6,52
Thermal Solar Panels	present	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	absent	-	present	-
Energy Need for Heating [kWh/m²y]	8,5		24,2		25,6		11,8	
Energy Need for Cooling [kWh/m²y]	9,5		9,8		0,0		0,0	
Energy Need for DHW [kWh/m²y]	14,6		14,6		14,6		14,6	
Energy Use for Lighting [kWh/m²y]	19,5		19,5		7,8		7,8	
(net) Primary Energy demand [kWh/m²y]	77,0		96,5		51,8		14,2	
RES contribution [kWh/m²y]	7,8		0,0		7,8		46,5	
Global Cost [€/m²]	907,6		873,4		953,7		1091,9	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	226,1							
Energy Need for Cooling [kWh/m²y]	7,2							
Energy Need for DHW [kWh/m²y]	14,6							
Energy Use for Lighting [kWh/m²y]	28,2							
(net) Primary Energy demand [kWh/m²y]	539,8							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1636,1							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Paris SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	3		13		13		36	
OPAQUE ENVELOPE-Package:	n		++		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	Renovation of the exterior layer of the walls for aesthetic/functional/security reasons	1,17	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 10 cm	0,27	External insulation (EIFS System): 25 cm	0,13
Roof thermal insulation	No renovation	2,83	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,16	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,16	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,11
Basement thermal insulation	No renovation	3,47	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 10 cm insulation in the outer of the floor slabs or frameworks	0,29	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,21
WINDOW PACKAGE:	+		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (8mm); low-e glass Ug= 2,0 W/m²K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	2,11	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,52	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,76	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,15	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05
COOLING STRATEGIES PACKAGE:	n		+		+		++	
	description:		description:		description:		description:	
Solar shading	Internal window blinds - fixed slat angle - manual control	-	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - medium flow rate	2,5	Natural ventilation (automatic control to open windows through differential temperature) - high flow rate	5
LIGHTING STRATEGIES :	n		+		+		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp medium efficiency	18-15-8	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	reversible ground source heat pump	90	connection to a district heating	56	gas boiler	56	reversible ground source heat pump	50
Cooling Generation	reversible ground source heat pump	54	no cooling generetion system	-	no cooling generetion system	-	reversible ground source heat pump	33
Heating Emission	insulated radiant floor	-	radiator	-	insulated radiant floor	-	air diffuser	-
Cooling Emission	insulated radiant floor + local dehumifidier	-	no cooling emission system	-	no cooling emission system	-	air diffuser	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	6,79
Heat Recovery	absent	-	absent	-	absent	-	present	5,87
Thermal Solar Panels	present	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	110,5		20,0		20,0		6,8	
Energy Need for Cooling [kWh/m²y]	5,6		0,0		0,0		3,4	
Energy Need for DHW [kWh/m²y]	14,6		14,6		14,6		14,6	
Energy Use for Lighting [kWh/m²y]	28,8		19,7		19,7		8,0	
(net) Primary Energy demand [kWh/m²y]	222,0		102,1		46,9		8,2	
RES contribution [kWh/m²y]	324,4		0,0		62,2		62,3	
Global Cost [€/m²]	754,6		861,3		987,5		1050,1	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	199,9							
Energy Need for Cooling [kWh/m²y]	6,4							
Energy Need for DHW [kWh/m²y]	14,6							
Energy Use for Lighting [kWh/m²y]	28,1							
(net) Primary Energy demand [kWh/m²y]	452,3							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1167,7							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Prague SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	17		17		17		18	
OPAQUE ENVELOPE-Package:	+++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 20 cm	0,16
Roof thermal insulation	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,1	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,1	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,1	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,1
Basement thermal insulation	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22	Install 15 cm insulation in the outer of the floor slabs or frameworks	0,22
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05
COOLING STRATEGIES PACKAGE:	+		+		+		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		+		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	96	condensig gas boiler	96	condensig gas boiler	96	condensig gas boiler	98
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	insulated radiant floor	-	insulated radiant floor	-	insulated radiant floor	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	present	-	present	-	absent	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	27,6		27,6		27,6		34,7	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	14,6		14,6		14,6		14,6	
Energy Use for Lighting [kWh/m²y]	20,6		20,6		20,6		8,4	
(net) Primary Energy demand [kWh/m²y]	109,7		104,2		46,0		9,8	
RES contribution [kWh/m²y]	7,8		7,8		65,9		71,8	
Global Cost [€/m²]	512,5		508,5		570,6		728,5	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	238,9							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	14,6							
Energy Use for Lighting [kWh/m²y]	29,9							
(net) Primary Energy demand [kWh/m²y]	579,4							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	824,2							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

Co-funded by the Intelligent Energy Europe Programme of the European Union

Berlin SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	13		13		13		18	
OPAQUE ENVELOPE-Package:	++		++		++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 20 cm	0,16	External insulation (EIFS System): 30 cm	0,11
Roof thermal insulation	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,15	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,15	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,15	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,1
Basement thermal insulation	Install 10 cm insulation in the inner of the floor slabs or frameworks	0,27	Install 10 cm insulation in the inner of the floor slabs or frameworks	0,27	Install 10 cm insulation in the inner of the floor slabs or frameworks	0,27	Install 15 cm insulation in the inner of the floor slabs or frameworks	0,19
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05
COOLING STRATEGIES PACKAGE:	+		+		+		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		+		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	condensig gas boiler	53	condensig gas boiler	53	condensig gas boiler	53	condensig gas boiler	54
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	radiator	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-
Heat Recovery	absent	-	absent	-	absent	-	absent	-
Thermal Solar Panels	absent	-	absent	-	absent	-	present	-
Photovoltaic Solar Panel	present	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	23,1		23,1		23,1		25,7	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	14,6		14,6		14,6		14,6	
Energy Use for Lighting [kWh/m²y]	20,0		20,0		20,0		8,1	
(net) Primary Energy demand [kWh/m²y]	48,7		98,9		48,7		15,5	
RES contribution [kWh/m²y]	50,2		0,0		50,2		57,8	
Global Cost [€/m²]	853,8		824,8		853,8		1068,5	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	177,4							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	14,6							
Energy Use for Lighting [kWh/m²y]	28,8							
(net) Primary Energy demand [kWh/m²y]	398,0							
RES contribution [kWh/m²y]	0,0							
Global Cost [€/m²]	1088,1							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

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Helsinki SCHOOL	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	13		17		17		36	
OPAQUE ENVELOPE-Package:	++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]	description:	U-value [W/m²K]
Wall thermal insulation	External insulation (EIFS System): 20 cm	0,14	External insulation (EIFS System): 30 cm	0,1	External insulation (EIFS System): 30 cm	0,1	External insulation (EIFS System): 30 cm	0,1
Roof thermal insulation	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 20 cm of insulation layer	0,12	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,09	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,09	Add on a thermal insulation layer over the last slab in contact with unconditioned space: 30 cm of insulation layer	0,09
Basement thermal insulation	Install 10 cm insulation in the inner of the floor slabs or frameworks	0,23	Install 15 cm insulation in the inner of the floor slabs or frameworks	0,17	Install 15 cm insulation in the inner of the floor slabs or frameworks	0,17	Install 15 cm insulation in the inner of the floor slabs or frameworks	0,17
WINDOW PACKAGE:	++		++		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m²K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	0,77
	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33	Solar Trasmittance (-)	0,33
	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646	Visible Trasmittance (-)	0,646
	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05	(airtightness) (1/h)	0,05
COOLING STRATEGIES PACKAGE:	+		+		+		++	
	description:		description:		description:		description:	
Solar shading	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External/internal window blinds - fixed slat angle - automation control	-	External window blinds - block beam solar - automation control	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Natural extra ventilation (automatic control to open windows) - automatic control through differential temperature (medium flow rate)	2,5
LIGHTING STRATEGIES :	+		+		+		++	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with fluorescent lamp high efficiency	12-10-5	Luminaire with LED lamp high efficiency	6-5-2
	description:		description:		description:		description:	
Lighting Control	Manual switch off	-	Manual switch off	-	Manual switch off	-	Automatic continuous daylight dimming in illuminated areas + occupancy sensors	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]		POWER [W/m2] Flow Rate [m³/s]
Heating Generation	biomass boiler	93	connection to a district heating	89	connection to a district heating	89	connection to a district heating	73
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	air diffuser	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	no mechanical ventilation (open window by user)	-	mechanical ventilation HVAC (IAQ+ conditioning)	7,35
Heat Recovery	absent	-	absent	-	absent	-	present	5,70
Thermal Solar Panels	absent	-	absent	-	absent	-	absent	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating [kWh/m²y]	48,3		42,4		42,4		19,7	
Energy Need for Cooling [kWh/m²y]	0,0		0,0		0,0		0,0	
Energy Need for DHW [kWh/m²y]	16,1		16,1		16,1		16,1	
Energy Use for Lighting [kWh/m²y]	20,1		20,1		20,1		7,9	
(net) Primary Energy demand [kWh/m²y]	178,7		101,3		52,6		26,0	
RES contribution [kWh/m²y]	41,3		6,0		54,7		54,7	
Global Cost [€/m²]	819,3		842,3		893,9		1168,4	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating [kWh/m²y]	242,6							
Energy Need for Cooling [kWh/m²y]	0,0							
Energy Need for DHW [kWh/m²y]	16,1							
Energy Use for Lighting [kWh/m²y]	29,1							
(net) Primary Energy demand [kWh/m²y]	339,3							
RES contribution [kWh/m²y]	6,0							
Global Cost [€/m²]	1554,8							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building
(2) For office buildings the lighting load is indicated for every use of rooms (office room - service - meeting room)
For school buildings the lighting load is indicated for every use of rooms (classroom - office room-service)

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7. Conclusions

7.1 Results analysis

The quantitative results obtained in this study are obviously depending on the hypothesis made on the typologies of buildings (e.g. window-to-wall ratio, surface-volume ratio, etc.) and can hence result different under different boundary conditions.

One should also consider that in a large scale study as the present one, which used quite conservative assumptions, certain assumptions cannot be as detailed as it would be possible in a national or regional study or in the design of a specific building.

What is extremely important for a proper use of the results is that in this and other similar studies the assumptions, boundary conditions and methodology should be explicitly and thoroughly presented so that results can be compared and lessons learned from them for the design of actual buildings, preparation of legislation, etc.

Keeping hence in mind the crucial importance of the actual boundary conditions that might differ in the considered context and analysis**.**

In general we can see the minimum (net) primary energy zone appears characterized by medium-high/high recurrences of efficient/RES technologies in all countries and for both the building destinations.

In the minimum global cost zone the cross comparison appears more heterogonous for the different climatic regions and for the different building destination.

In general the minimum global cost zone is characterized by medium level of efficiency for the envelope strategies, probably due to a more equilibrate balance between initial investment costs and energy savings. Single house in Milan is an exception if compared with the other target countries. This exception is due to a discrepancy related to the presence/absence of active cooling strategies: here, in summer, only the best envelope variant (with automatized night natural ventilation and high performance solar shading systems, but also with high insulation levels and very low infiltrations during the day) allows to guarantee the summer comfort conditions without an active cooling system. We don't observe the same for the office building located in Milan, where the higher internal loads don't allow to guarantee the indoor comfort conditions, without an active cooling system.

For the single family house it is quite evident that, also within the minimum global cost zone, the penetration of renewable energy technologies is more effective in Mediterranean climates (characterized by higher solar radiation) than the other target countries. Similar tendency is observed for office buildings, but with less differences between South and North Europe. This is due to a more relevant role played by photovoltaic systems in a building type characterized by higher electric consumptions for auxiliary systems and mechanical ventilation.

Further analysis have been carried out to compare the key energy levels obtained in the different climatic contexts and for the different building types and to evaluate the percentage reduction of net primary energy between the cost optimal target and the base refurbishment level. These results could be relevant also to determine eventual targets consisting in saving percentages in net primary energy respect base refurbishment level.

In the following Table 18 and Figure 93, we can see that net primary energy saving percentages for cost-optimal and nZEB targets are more close in residential buildings than in office and school buildings.

In residential sector, considered apartment building type shows lower energy saving potential (Figure 93), due to geometric limits (e.g. lower available roof surface for solar systems respect total floor area respect single family house).

In many cases global cost of selected nZEB solutions (minimum net primary energy) are lower and more advantageous than global cost of corresponding base refurbishment levels (see orange bar and cells in Figure 94. Target buildings energy and costs variations respect to base refurbishment level (graphs and tables) - in the following pages).

Particularly for school and office buildings, saving percentages in global cost are greater in colder climates, starting from Milano, but also in warmer ones they could be interesting.

Table 18. Saving potential in net primary energy respect to base refurbishment level

net primary energy demand

	Building type	Base refurbishment level	Minimum global cost Target (**)		Minimum net primary energy Target (**)	
Seville (ES)	single family house	156 kWh/(m²y)	-84%	25 kWh/(m²y)	-96%	7 kWh/(m²y)
	apartaments block	127 kWh/(m²y)	-72%	35 kWh/(m²y)	-83%	22 kWh/(m²y)
	office	225 kWh/(m²y)	-36%	145 kWh/(m²y)	-97%	6 kWh/(m²y)
	school	189 kWh/(m²y)	-56%	83 kWh/(m²y)	-96%	8 kWh/(m²y)
Madrid (ES)	single family house	236 kWh/(m2y)	-82%	43 kWh/(m2y)	-97%	7 kWh/(m2y)
	apartaments block	182 kWh/(m2y)	-73%	49 kWh/(m2y)	-84%	30 kWh/(m2y)
	office	298 kWh/(m2y)	-58%	124 kWh/(m2y)	-97%	9 kWh/(m2y)
	school	262 kWh/(m2y)	-69%	80 kWh/(m2y)	-97%	7 kWh/(m2y)
Rome (IT)	single family house	193 kWh/(m2y)	-79%	41 kWh/(m2y)	-97%	7 kWh/(m2y)
	apartaments block	157 kWh/(m2y)	-56%	69 kWh/(m2y)	-80%	31 kWh/(m2y)
	office	296 kWh/(m2y)	-49%	151 kWh/(m2y)	-94%	19 kWh/(m2y)
	school	357 kWh/(m2y)	-58%	149 kWh/(m2y)	-98%	8 kWh/(m2y)
Milan (IT)	single family house	346 kWh/(m2y)	-86%	50 kWh/(m2y)	-95%	19 kWh/(m2y)
	apartaments block	260 kWh/(m2y)	-62%	98 kWh/(m2y)	-85%	40 kWh/(m2y)
	office	400 kWh/(m2y)	-60%	162 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	357 kWh/(m2y)	-51%	175 kWh/(m2y)	-98%	9 kWh/(m2y)
Bucharest (RO)	single family house	392 kWh/(m2y)	-62%	149 kWh/(m2y)	-91%	36 kWh/(m2y)
	apartaments block	307 kWh/(m2y)	-59%	125 kWh/(m2y)	-76%	73 kWh/(m2y)
	office	379 kWh/(m2y)	-48%	198 kWh/(m2y)	-92%	29 kWh/(m2y)
	school	381 kWh/(m2y)	-38%	237 kWh/(m2y)	-96%	15 kWh/(m2y)
Vienna (AT)	single family house	451 kWh/(m2y)	-79%	97 kWh/(m2y)	-94%	26 kWh/(m2y)
	apartaments block	344 kWh/(m2y)	-70%	103 kWh/(m2y)	-85%	52 kWh/(m2y)
	office	525 kWh/(m2y)	-86%	75 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	540 kWh/(m2y)	-86%	77 kWh/(m2y)	-97%	14 kWh/(m2y)
Paris (FR)	single family house	363 kWh/(m2y)	-65%	126 kWh/(m2y)	-92%	29 kWh/(m2y)
	apartaments block	336 kWh/(m2y)	-71%	99 kWh/(m2y)	-84%	54 kWh/(m2y)
	office	493 kWh/(m2y)	-64%	180 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	452 kWh/(m2y)	-51%	222 kWh/(m2y)	-98%	8 kWh/(m2y)
Prague (CZ)	single family house	519 kWh/(m2y)	-69%	159 kWh/(m2y)	-90%	53 kWh/(m2y)
	apartaments block	303 kWh/(m2y)	-46%	164 kWh/(m2y)	-68%	97 kWh/(m2y)
	office	615 kWh/(m2y)	-81%	118 kWh/(m2y)	-96%	24 kWh/(m2y)
	school	579 kWh/(m2y)	-81%	110 kWh/(m2y)	-98%	10 kWh/(m2y)
Berlin (DE)	single family house	348 kWh/(m2y)	-76%	85 kWh/(m2y)	-89%	39 kWh/(m2y)
	apartaments block	319 kWh/(m2y)	-49%	161 kWh/(m2y)	-79%	66 kWh/(m2y)
	office	442 kWh/(m2y)	-85%	68 kWh/(m2y)	-97%	12 kWh/(m2y)
	school	398 kWh/(m2y)	-88%	49 kWh/(m2y)	-96%	16 kWh/(m2y)
Helsinki (FI)	single family house	203 kWh/(m2y)	-62%	76 kWh/(m2y)	-69%	63 kWh/(m2y)
	apartaments block	195 kWh/(m2y)	+13%	219 kWh/(m2y)	-52%	94 kWh/(m2y)
	office	371 kWh/(m2y)	-71%	109 kWh/(m2y)	-91%	35 kWh/(m2y)
	school	339 kWh/(m2y)	-47%	179 kWh/(m2y)	-92%	26 kWh/(m2y)

(**) Percentage variation respect Base refurbishment level

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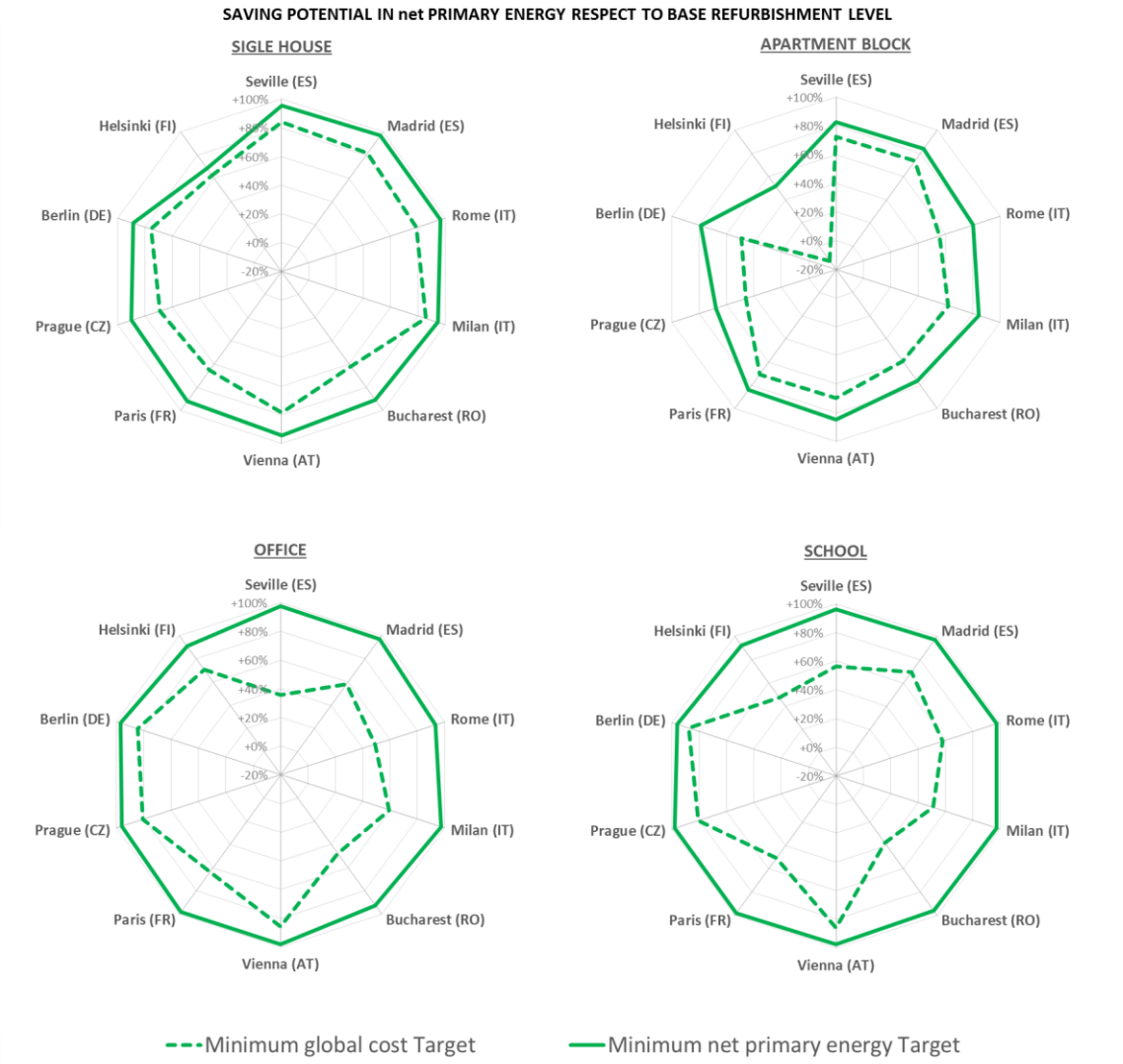

Figure 93. Saving potential in net primary energy: percentage of saving respect to base refurbishment level

Figure 94. Target buildings energy and costs variations respect to base refurbishment level (graphs and tables) - in the following pages

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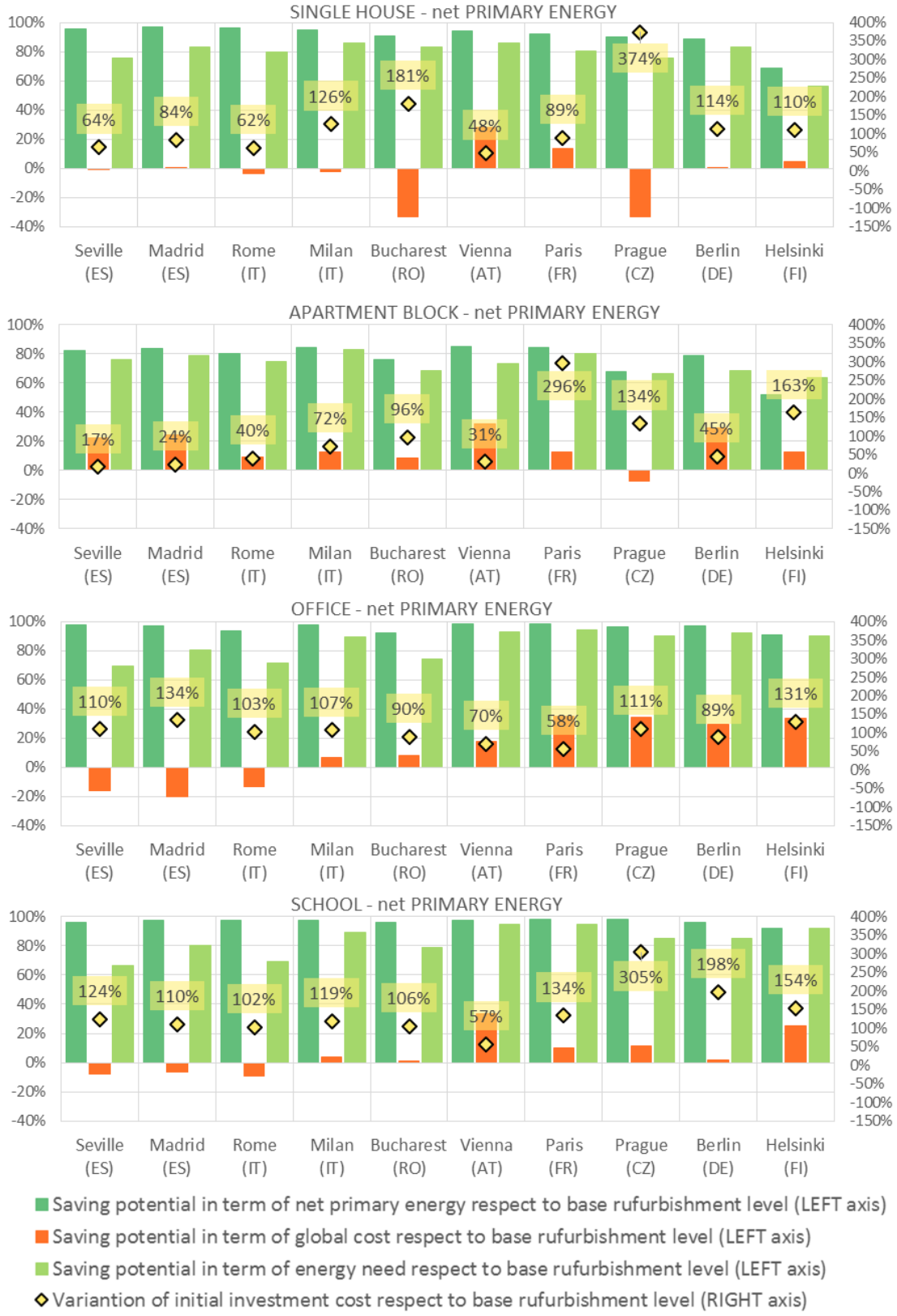
TARGET BUILDINGS ENERGY AND COSTS VARIATION RESPECT TO BASE REFURBISHMENT LEVEL

TARGET BUILDINGS ENERGY AND COSTS VARIATION RESPECT TO BASE REFURBISHMENT LEVEL



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Single Family House

		Base refurbishment level	Minimum global cost Target (**)		Minimum net primary energy Target (**)	
Seville (ES)	net primary energy demand	156 kWh/(m²y)	-84%	25 kWh/(m²y)	-96%	7 kWh/(m²y)
	global cost	927 €/m²	-14%	793 €/m²	+1%	934 €/m²
	initial investment cost	318 €/m²	+36%	431 €/m²	+64%	521 €/m²
	heating+cooling energy need	110 kWh/(m²y)	-51%	54 kWh/(m²y)	-76%	27 kWh/(m²y)
Madrid (ES)	net primary energy demand	236 kWh/(m²y)	-82%	43 kWh/(m²y)	-97%	7 kWh/(m²y)
	global cost	1 031 €/m²	-18%	841 €/m²	-1%	1 026 €/m²
	initial investment cost	315 €/m²	+66%	523 €/m²	+84%	579 €/m²
	heating+cooling energy need	152 kWh/(m²y)	-59%	62 kWh/(m²y)	-83%	26 kWh/(m²y)
Rome (IT)	net primary energy demand	193 kWh/(m²y)	-79%	41 kWh/(m²y)	-97%	7 kWh/(m²y)
	global cost	1 142 €/m²	-11%	1 014 €/m²	+4%	1 186 €/m²
	initial investment cost	385 €/m²	+30%	500 €/m²	+62%	623 €/m²
	heating+cooling energy need	113 kWh/(m²y)	-48%	59 kWh/(m²y)	-80%	23 kWh/(m²y)
Milan (IT)	net primary energy demand	346 kWh/(m²y)	-86%	50 kWh/(m²y)	-95%	19 kWh/(m²y)
	global cost	1 408 €/m²	-26%	1 038 €/m²	+2%	1 438 €/m²
	initial investment cost	390 €/m²	+51%	588 €/m²	+126%	883 €/m²
	heating+cooling energy need	193 kWh/(m²y)	-86%	27 kWh/(m²y)	-86%	27 kWh/(m²y)
Bucharest (RO)	net primary energy demand	392 kWh/(m²y)	-62%	149 kWh/(m²y)	-91%	36 kWh/(m²y)
	global cost	773 €/m²	-19%	626 €/m²	+33%	1 028 €/m²
	initial investment cost	152 €/m²	+40%	214 €/m²	+181%	428 €/m²
	heating+cooling energy need	220 kWh/(m²y)	-64%	79 kWh/(m²y)	-83%	37 kWh/(m²y)
Vienna (AT)	net primary energy demand	451 kWh/(m²y)	-79%	97 kWh/(m²y)	-94%	26 kWh/(m²y)
	global cost	1 605 €/m²	-51%	792 €/m²	-28%	1 151 €/m²
	initial investment cost	403 €/m²	-2%	394 €/m²	+48%	595 €/m²
	heating+cooling energy need	210 kWh/(m²y)	-82%	38 kWh/(m²y)	-86%	30 kWh/(m²y)
Paris (FR)	net primary energy demand	363 kWh/(m²y)	-65%	126 kWh/(m²y)	-92%	29 kWh/(m²y)
	global cost	1 230 €/m²	-29%	873 €/m²	-14%	1 061 €/m²
	initial investment cost	306 €/m²	+39%	427 €/m²	+89%	579 €/m²
	heating+cooling energy need	183 kWh/(m²y)	-73%	49 kWh/(m²y)	-80%	36 kWh/(m²y)
Prague (CZ)	net primary energy demand	519 kWh/(m²y)	-69%	159 kWh/(m²y)	-90%	53 kWh/(m²y)
	global cost	782 €/m²	-4%	748 €/m²	+33%	1 043 €/m²
	initial investment cost	106 €/m²	+201%	319 €/m²	+374%	502 €/m²
	heating+cooling energy need	239 kWh/(m²y)	-73%	65 kWh/(m²y)	-76%	58 kWh/(m²y)
Berlin (DE)	net primary energy demand	348 kWh/(m²y)	-76%	85 kWh/(m²y)	-89%	39 kWh/(m²y)
	global cost	1 631 €/m²	-30%	1 139 €/m²	-0%	1 624 €/m²
	initial investment cost	406 €/m²	+39%	565 €/m²	+114%	871 €/m²
	heating+cooling energy need	178 kWh/(m²y)	-80%	36 kWh/(m²y)	-83%	30 kWh/(m²y)
Helsinki (FI)	net primary energy demand	203 kWh/(m²y)	-62%	76 kWh/(m²y)	-69%	63 kWh/(m²y)
	global cost	1 049 €/m²	-6%	990 €/m²	-4%	1 002 €/m²
	initial investment cost	202 €/m²	+100%	403 €/m²	+110%	424 €/m²
	heating+cooling energy need	165 kWh/(m²y)	-67%	55 kWh/(m²y)	-56%	72 kWh/(m²y)

(**) Percentage variation respect Base refurbishment level

Apartaments Block

		Base refurbishment level	Minimum global cost Target (**)		Minimum net primary energy Target (**)	
Seville (ES)	net primary energy demand	127 kWh/(m²y)	-72%	35 kWh/(m²y)	-83%	22 kWh/(m²y)
	global cost	737 €/m²	-28%	532 €/m²	-23%	571 €/m²
	initial investment cost	233 €/m²	+32%	306 €/m²	+17%	271 €/m²
	heating+cooling energy need	66 kWh/(m²y)	-60%	26 kWh/(m²y)	-76%	16 kWh/(m²y)
Madrid (ES)	net primary energy demand	182 kWh/(m²y)	-73%	49 kWh/(m²y)	-84%	30 kWh/(m²y)
	global cost	806 €/m²	-28%	578 €/m²	-24%	610 €/m²
	initial investment cost	230 €/m²	+50%	344 €/m²	+24%	285 €/m²
	heating+cooling energy need	94 kWh/(m²y)	-69%	29 kWh/(m²y)	-79%	20 kWh/(m²y)
Rome (IT)	net primary energy demand	157 kWh/(m²y)	-56%	69 kWh/(m²y)	-80%	31 kWh/(m²y)
	global cost	823 €/m²	-21%	650 €/m²	-9%	748 €/m²
	initial investment cost	236 €/m²	+23%	289 €/m²	+40%	329 €/m²
	heating+cooling energy need	69 kWh/(m²y)	-54%	32 kWh/(m²y)	-75%	17 kWh/(m²y)
Milan (IT)	net primary energy demand	260 kWh/(m²y)	-62%	98 kWh/(m²y)	-85%	40 kWh/(m²y)
	global cost	992 €/m²	-53%	468 €/m²	-13%	866 €/m²
	initial investment cost	234 €/m²	-6%	220 €/m²	+72%	404 €/m²
	heating+cooling energy need	122 kWh/(m²y)	-72%	35 kWh/(m²y)	-83%	21 kWh/(m²y)
Bucharest (RO)	net primary energy demand	307 kWh/(m²y)	-59%	125 kWh/(m²y)	-76%	73 kWh/(m²y)
	global cost	653 €/m²	-27%	475 €/m²	-9%	596 €/m²
	initial investment cost	115 €/m²	+28%	148 €/m²	+96%	226 €/m²
	heating+cooling energy need	145 kWh/(m²y)	-57%	63 kWh/(m²y)	-69%	45 kWh/(m²y)
Vienna (AT)	net primary energy demand	344 kWh/(m²y)	-70%	103 kWh/(m²y)	-85%	52 kWh/(m²y)
	global cost	1 227 €/m²	-57%	528 €/m²	-32%	831 €/m²
	initial investment cost	302 €/m²	-18%	249 €/m²	+31%	395 €/m²
	heating+cooling energy need	143 kWh/(m²y)	-64%	52 kWh/(m²y)	-74%	38 kWh/(m²y)
Paris (FR)	net primary energy demand	336 kWh/(m²y)	-71%	99 kWh/(m²y)	-84%	54 kWh/(m²y)
	global cost	637 €/m²	-27%	467 €/m²	-13%	555 €/m²
	initial investment cost	71 €/m²	+196%	211 €/m²	+296%	282 €/m²
	heating+cooling energy need	154 kWh/(m²y)	-80%	30 kWh/(m²y)	-80%	30 kWh/(m²y)
Prague (CZ)	net primary energy demand	303 kWh/(m²y)	-46%	164 kWh/(m²y)	-68%	97 kWh/(m²y)
	global cost	609 €/m²	-30%	429 €/m²	+7%	653 €/m²
	initial investment cost	123 €/m²	+8%	133 €/m²	+134%	287 €/m²
	heating+cooling energy need	122 kWh/(m²y)	+0%	122 kWh/(m²y)	-67%	40 kWh/(m²y)
Berlin (DE)	net primary energy demand	319 kWh/(m²y)	-49%	161 kWh/(m²y)	-79%	66 kWh/(m²y)
	global cost	1 440 €/m²	-38%	897 €/m²	-29%	1 020 €/m²
	initial investment cost	347 €/m²	+31%	454 €/m²	+45%	504 €/m²
	heating+cooling energy need	148 kWh/(m²y)	-69%	47 kWh/(m²y)	-69%	47 kWh/(m²y)
Helsinki (FI)	net primary energy demand	195 kWh/(m²y)	+13%	219 kWh/(m²y)	-52%	94 kWh/(m²y)
	global cost	814 €/m²	-19%	657 €/m²	-13%	710 €/m²
	initial investment cost	93 €/m²	+162%	245 €/m²	+163%	246 €/m²
	heating+cooling energy need	143 kWh/(m²y)	-64%	52 kWh/(m²y)	-64%	52 kWh/(m²y)

(**) Percentage variation respect Base refurbishment level

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Office

		Base refurbishment level	Minimum global cost Target (**)		Minimum net primary energy Target (**)	
Seville (ES)	net primary energy demand	225 kWh/(m²y)	-36%	145 kWh/(m²y)	-97%	6 kWh/(m²y)
	global cost	989 €/m²	-5%	942 €/m²	+16%	1 146 €/m²
	initial investment cost	292 €/m²	+51%	440 €/m²	+110%	612 €/m²
	heating+cooling energy need	135 kWh/(m²y)	-22%	106 kWh/(m²y)	-70%	41 kWh/(m²y)
Madrid (ES)	net primary energy demand	298 kWh/(m²y)	-58%	124 kWh/(m²y)	-97%	9 kWh/(m²y)
	global cost	1 078 €/m²	-14%	931 €/m²	+20%	1 296 €/m²
	initial investment cost	292 €/m²	+56%	454 €/m²	+134%	683 €/m²
	heating+cooling energy need	172 kWh/(m²y)	-38%	107 kWh/(m²y)	-80%	34 kWh/(m²y)
Rome (IT)	net primary energy demand	296 kWh/(m²y)	-49%	151 kWh/(m²y)	-94%	19 kWh/(m²y)
	global cost	1 207 €/m²	-8%	1 108 €/m²	+13%	1 368 €/m²
	initial investment cost	321 €/m²	+27%	408 €/m²	+103%	654 €/m²
	heating+cooling energy need	169 kWh/(m²y)	-28%	122 kWh/(m²y)	-72%	48 kWh/(m²y)
Milan (IT)	net primary energy demand	400 kWh/(m²y)	-60%	162 kWh/(m²y)	-98%	9 kWh/(m²y)
	global cost	1 369 €/m²	-20%	1 099 €/m²	-7%	1 274 €/m²
	initial investment cost	320 €/m²	+34%	429 €/m²	+107%	663 €/m²
	heating+cooling energy need	214 kWh/(m²y)	-47%	113 kWh/(m²y)	-90%	22 kWh/(m²y)
Bucharest (RO)	net primary energy demand	379 kWh/(m²y)	-48%	198 kWh/(m²y)	-92%	29 kWh/(m²y)
	global cost	896 €/m²	-27%	655 €/m²	-8%	821 €/m²
	initial investment cost	201 €/m²	+1%	204 €/m²	+90%	383 €/m²
	heating+cooling energy need	188 kWh/(m²y)	-32%	128 kWh/(m²y)	-75%	48 kWh/(m²y)
Vienna (AT)	net primary energy demand	525 kWh/(m²y)	-86%	75 kWh/(m²y)	-98%	9 kWh/(m²y)
	global cost	1 586 €/m²	-43%	904 €/m²	-18%	1 305 €/m²
	initial investment cost	371 €/m²	+11%	412 €/m²	+70%	631 €/m²
	heating+cooling energy need	239 kWh/(m²y)	-89%	26 kWh/(m²y)	-93%	16 kWh/(m²y)
Paris (FR)	net primary energy demand	493 kWh/(m²y)	-64%	180 kWh/(m²y)	-98%	9 kWh/(m²y)
	global cost	1 523 €/m²	-47%	801 €/m²	-35%	986 €/m²
	initial investment cost	392 €/m²	+9%	428 €/m²	+58%	619 €/m²
	heating+cooling energy need	239 kWh/(m²y)	-60%	94 kWh/(m²y)	-94%	14 kWh/(m²y)
Prague (CZ)	net primary energy demand	615 kWh/(m²y)	-81%	118 kWh/(m²y)	-96%	24 kWh/(m²y)
	global cost	1 140 €/m²	-42%	656 €/m²	-34%	752 €/m²
	initial investment cost	199 €/m²	+79%	357 €/m²	+111%	421 €/m²
	heating+cooling energy need	266 kWh/(m²y)	-89%	29 kWh/(m²y)	-90%	26 kWh/(m²y)
Berlin (DE)	net primary energy demand	442 kWh/(m²y)	-85%	68 kWh/(m²y)	-97%	12 kWh/(m²y)
	global cost	1 672 €/m²	-40%	1 000 €/m²	-29%	1 180 €/m²
	initial investment cost	381 €/m²	+62%	616 €/m²	+89%	719 €/m²
	heating+cooling energy need	214 kWh/(m²y)	-90%	22 kWh/(m²y)	-92%	17 kWh/(m²y)
Helsinki (FI)	net primary energy demand	371 kWh/(m²y)	-71%	109 kWh/(m²y)	-91%	35 kWh/(m²y)
	global cost	1 662 €/m²	-56%	729 €/m²	-34%	1 101 €/m²
	initial investment cost	224 €/m²	+72%	385 €/m²	+131%	517 €/m²
	heating+cooling energy need	283 kWh/(m²y)	-89%	31 kWh/(m²y)	-90%	28 kWh/(m²y)

(**) Percentage variation respect Base refurbishment level

School

		Base refurbishment level	Minimum global cost Target (**)		Minimum net primary energy Target (**)	
Seville (ES)	net primary energy demand	189 kWh/(m²y)	-56%	83 kWh/(m²y)	-96%	8 kWh/(m²y)
	global cost	890 €/m²	-8%	822 €/m²	+8%	959 €/m²
	initial investment cost	269 €/m²	+20%	324 €/m²	+124%	602 €/m²
	heating+cooling energy need	91 kWh/(m²y)	-15%	77 kWh/(m²y)	-67%	30 kWh/(m²y)
Madrid (ES)	net primary energy demand	262 kWh/(m²y)	-69%	80 kWh/(m²y)	-97%	7 kWh/(m²y)
	global cost	955 €/m²	-10%	861 €/m²	+6%	1 015 €/m²
	initial investment cost	259 €/m²	+40%	361 €/m²	+110%	544 €/m²
	heating+cooling energy need	131 kWh/(m²y)	-30%	92 kWh/(m²y)	-80%	26 kWh/(m²y)
Rome (IT)	net primary energy demand	357 kWh/(m²y)	-58%	149 kWh/(m²y)	-98%	8 kWh/(m²y)
	global cost	1 086 €/m²	-4%	1 041 €/m²	+9%	1 189 €/m²
	initial investment cost	289 €/m²	+42%	410 €/m²	+102%	584 €/m²
	heating+cooling energy need	125 kWh/(m²y)	-24%	94 kWh/(m²y)	-70%	38 kWh/(m²y)
Milan (IT)	net primary energy demand	357 kWh/(m²y)	-51%	175 kWh/(m²y)	-98%	9 kWh/(m²y)
	global cost	1 248 €/m²	-17%	1 038 €/m²	-4%	1 200 €/m²
	initial investment cost	287 €/m²	+46%	418 €/m²	+119%	628 €/m²
	heating+cooling energy need	173 kWh/(m²y)	-47%	92 kWh/(m²y)	-89%	19 kWh/(m²y)
Bucharest (RO)	net primary energy demand	381 kWh/(m²y)	-38%	237 kWh/(m²y)	-96%	15 kWh/(m²y)
	global cost	958 €/m²	-34%	629 €/m²	-1%	950 €/m²
	initial investment cost	217 €/m²	-29%	154 €/m²	+106%	447 €/m²
	heating+cooling energy need	170 kWh/(m²y)	-23%	131 kWh/(m²y)	-79%	36 kWh/(m²y)
Vienna (AT)	net primary energy demand	540 kWh/(m²y)	-86%	77 kWh/(m²y)	-97%	14 kWh/(m²y)
	global cost	1 636 €/m²	-45%	908 €/m²	-33%	1 092 €/m²
	initial investment cost	356 €/m²	+10%	391 €/m²	+57%	559 €/m²
	heating+cooling energy need	233 kWh/(m²y)	-92%	18 kWh/(m²y)	-95%	12 kWh/(m²y)
Paris (FR)	net primary energy demand	452 kWh/(m²y)	-51%	222 kWh/(m²y)	-98%	8 kWh/(m²y)
	global cost	1 168 €/m²	-35%	755 €/m²	-10%	1 050 €/m²
	initial investment cost	258 €/m²	+34%	346 €/m²	+134%	605 €/m²
	heating+cooling energy need	206 kWh/(m²y)	-44%	116 kWh/(m²y)	-95%	10 kWh/(m²y)
Prague (CZ)	net primary energy demand	579 kWh/(m²y)	-81%	110 kWh/(m²y)	-98%	10 kWh/(m²y)
	global cost	824 €/m²	-38%	513 €/m²	-12%	728 €/m²
	initial investment cost	103 €/m²	+154%	261 €/m²	+305%	417 €/m²
	heating+cooling energy need	239 kWh/(m²y)	-88%	28 kWh/(m²y)	-85%	35 kWh/(m²y)
Berlin (DE)	net primary energy demand	398 kWh/(m²y)	-88%	49 kWh/(m²y)	-96%	16 kWh/(m²y)
	global cost	1 088 €/m²	-22%	854 €/m²	-2%	1 068 €/m²
	initial investment cost	218 €/m²	+128%	498 €/m²	+198%	651 €/m²
	heating+cooling energy need	177 kWh/(m²y)	-87%	23 kWh/(m²y)	-85%	26 kWh/(m²y)
Helsinki (FI)	net primary energy demand	339 kWh/(m²y)	-47%	179 kWh/(m²y)	-92%	26 kWh/(m²y)
	global cost	1 555 €/m²	-47%	819 €/m²	-25%	1 168 €/m²
	initial investment cost	219 €/m²	+70%	372 €/m²	+154%	554 €/m²
	heating+cooling energy need	243 kWh/(m²y)	-80%	48 kWh/(m²y)	-92%	20 kWh/(m²y)

(**) Percentage variation respect Base refurbishment level

The inversion of tendency in the percentage reduction of the net primary energy, that can be observed passing from single house to office, could be associate to the effect of internal loads: in the target countries where the heating phase is predominant is more simple to reach important reductions with high internal loads, while in Mediterranean contexts is simpler to do more for residential building types.

In addition the following features can be seen from minimum net primary energy and minimum global costs areas.

- For many climates, cost/energy curves low frontiers are quite flat.
- Higher energy prices scenarios increase the minimum global cost range and lead to a lower value of net primary energy for cost optimal levels.
- Higher prices for CO_2 emissions and eventual costs related to environmental damages and other externalities could increase the minimum global cost range and lead to a lower value of net primary energy for cost optimal levels.
- About solar RES, photovoltaic systems are very frequent in minimum net primary energy area, while it's less frequent in minimum global cost area. The solar thermal systems don't seem to show so clearly this difference.
- In some cases, we can recognize building variants with worse performance (higher net primary energy demand and/or higher global cost) respect the base refurbishment level. This could be due to bad combination of energy efficiency actions adopted in renovation. This stresses the importance of a good integrated energy design with proper energy calculations and global cost analysis.
- Medium/low temperature emission systems for heating are present both in many variants of minimum net primary energy area both in minimum global cost area.
- In office buildings, efficient lighting strategies appear always as good intervention to reach the minimum net primary energy area.
- In some climate contexts, biomass and district heating systems appear with low frequency in benchmark areas. This could be associated to difficulties to define actual primary energy factor, initial costs for installation (due to different installation conditions) and energy prices (due to private negotiation).
- In benchmark areas generally heat recovery for ventilation doesn't appear. It produces effective energy savings but with higher initial costs for ventilation systems installations (see examples below with sensitivity analysis about heat recovery systems in cost-energy clouds). While in the selection of target buildings, when we consider variants with low global cost but also low energy need for heating plus cooling also solutions with heat recovery system appears and are suitable to be selected.

- We have to consider also that in the present study we are considering a good users behaviour in natural ventilation and window opening: occupants open windows in good way when air changes need, avoiding excessive openings. So we assumed building users who are quite trained or at least aware on natural ventilation issue. This helps to reach natural ventilation solutions in cost optimal and sometimes also in minimum net primary energy area, more often respect mechanical ventilation.

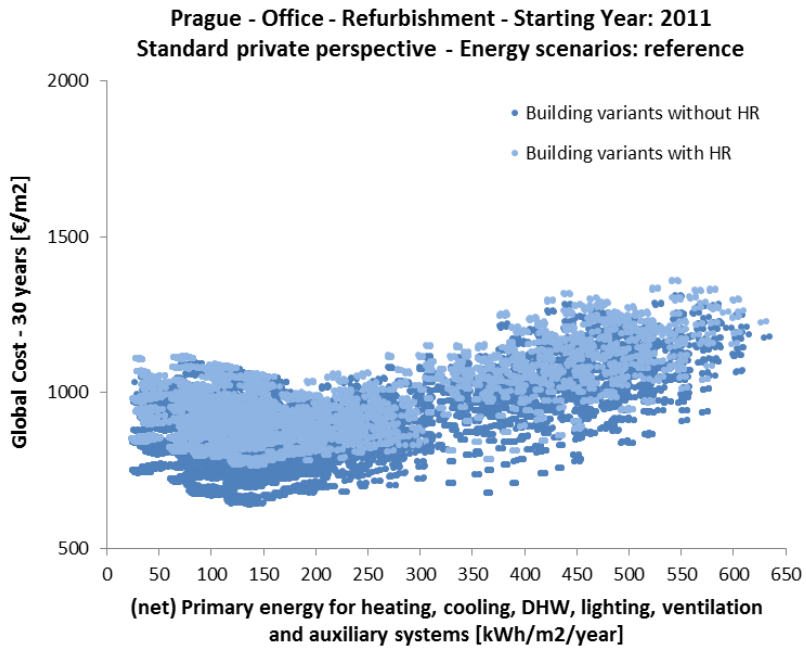

Figure 95. Sensitivity analysis on heat recovery in ventilation - office in Prague.

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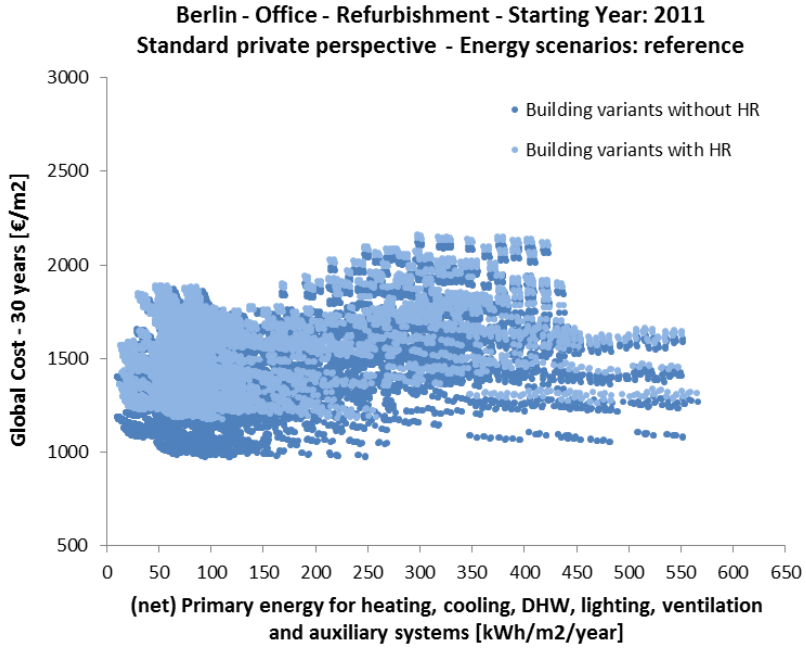

Figure 96. Sensitivity analysis on heat recovery in ventilation - office in Berlin.

7.2 Methodology comments

In this analysis, European common methodology for cost optimal calculation was carefully considered and adopted, according to European Commission regulations and framework. Applying it in a quite large amount of buildings and variants bring us to develop the following comments on the common methodology.

- Cost/energy curves and clouds show important information on net primary energy values and global costs, but can't show explicit information on **energy needs** for different energy end uses. For this further analysis, as some of presented ones, could be useful to study energy needs (for heating, cooling, domestic hot water, energy use for lighting, etc.) in detail.
- On the same graph, cost optimal zone selection (blue segment in the following kind of graph) can be very variable in terms of net primary energy range, depending on **chosen increment respect the minimum global cost** value:
    - in order to select the minimum global cost dot (or dots) in more consistent way, it could be better to choose not only one dot/building variant but a group of them. For this, it could be useful to fix a value (or a values range) for percentage of dots/building variants under the global cost level considered as minimum global cost: for example the global cost under which there are not more than the 1% of the analysed building variant (the global cost corresponding to 1 percentile of all dots/building variants in the graph).

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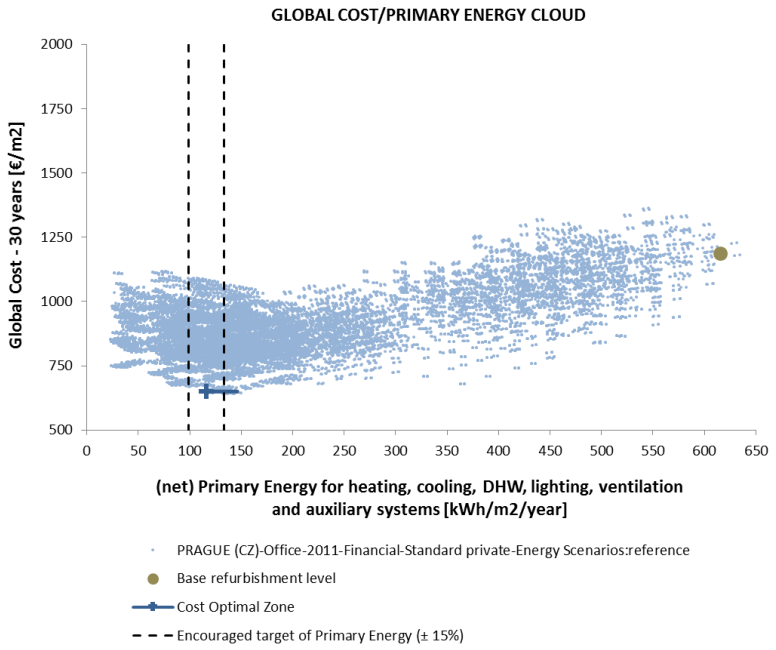
- Then in order to select a range of minimum global cost, also considering a kind of result confidence interval, we should define an increment value (e.g. 2%) respect the minimum global cost defined in previous point. This value variations could bring to high variations of net primary energy range corresponding to minimum global cost value, so it's important to give common guideline in this also to avoid too high or too low net primary energy values.



- The fixed **±15% encouraged target**, by EPBD, for net primary energy respect the minimum global cost dot (see graph above), could lead to very low values for low net primary energy value (e.g. for total net primary energy < 20 kWh/m^2/y). For this field of low values, maybe a fixed threshold of increment/decrement in [kWh/m^2/y] could be defined.
- Global cost over calculation period is an important economic indicator to show the long term behaviour of a building. However not specialist people are used to consider initial investment costs and they don't have sensibility respect global cost values. So it could be important to give references for the obtain results. The indication of **base refurbishment level** case (grey bold dot in the graph above) could be an useful reference for a direct results evaluation.
- Great care has to be taken to produce **accurate and consistent cost data base** for the considered buildings. Considering building sector and buildings variability, determined costs for a not specific and detailed building project could be difficult and a kind of confidence interval should be determined for the results.

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- Cost/energy clouds and curves are very useful to determine net primary energy values and cost optimal targets, also analysing the **sensitivity** respect the main calculation outputs (as energy prices scenarios, primary energy factors, eventual environmental damages cost, etc.).
- Further studies could be useful to consider with more detail also **costs related to environmental damages** and environmental externalities due to energy consumption and emissions. This could bring to very advantageous results for energy efficiency improvements and renewable energy systems development.
- Often, also in the methodology, the attention is focused on low frontier of cost energy curves. Of course this part of the graphs represents the most profitable solutions in terms of global cost. But in general also **higher dots in the graphs** could represent interesting solutions in terms of energy efficiency or environmental value, maybe consisting in technological actions to be advantageously supported with policy and financial solutions.

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[European Commission 2012a] European Commission - Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements - Official Journal of the European Union, 19.4.2012

[European Commission 2012b] European Commission - COMMISSION DELEGATED REGULATION (EU) No 244/2012 of 16 January 2012: supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements - Official Journal of the European Union, 21.3.2012

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[European Commission 2013] European Commission - EU Commission Decision 2013//114/UE of 1 March 2013 establishing the guidelines for Member States on calculating renewable energy from heat pumps from different heat pump technologies pursuant to Article 5 of Directive 2009/28/EC of the European Parliament and of the Council, March 2013

[European Parliament And Council 2010] European Parliament And Council - DIRECTIVE 2010/31/EU of 19 May 2010 on the energy performance of buildings (recast) - Official Journal of the European Union, 18.6.2010

[Marszal 2011] Marszal, Anna; Heiselberg, Per; Bourrelle', Julien; Musall, Eike; Voss, Karsten; Sartori, Igor; Napolitano, Assunta (2011): Zero Energy Building - A Review of definitions and calculation methodologies. In: Energy and Buildings 43 (4), page 971–979.

[Pagliano and Zangheri 2010] L. Pagliano, P. Zangheri. Comfort models and cooling of buildings in the Mediterranean zone, Advances In Building Energy Research 4b (2010) 167–200.

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8. Annex

8.1 Cost Energy Curves results and analysis

8.1.1 Single house

Results about single family houses are presented in the following chapters. About “Envelope Section” divided in these fields

- Opaque envelope Insulation **(e)**
- Windows (frame and glazing) **(w)**
- Cooling Strategies **(c)**
- Lighting efficiency (as internal gain) **(L)**

variants are expressed using this code with “-, o-, o, o+, +”, see table below

Tabella 3: variants codes for opaque envelope, windows, cooling strategies and lighting efficiency in SFH.

cod.	Opaque Envelope Insulation			Windows	Cooling strategies			
	Additional insulation compared to base case (in thickness of insulation "x" [cm])			number of glass + type of glass + "Air permeability Classification EN12207"	solar shading + control systems - natural night ventilation	lighting load + control system		
	Wall	Roof	Basement			cod	efficiency of ligthing	control
-	0	0	0	single glass standard glass Class 0	solar shading ABSENT natural night ventilation ABSENT	o	standard	manual
o-	5	5	5	***	solar shading PRESENT + MANUAL Control Automatised natural ventilation ABSENT	o	standard	manual
o	10	10 ÷ 15	5 ÷ 10	double glass standard glass Class 2	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation ABSENT	o	standard	manual
o+	15	15 ÷ 20	10 ÷ 15	double glass low-e glass Class 3	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT medium performance	o	standard	manual
+	20	30	15	triple glass low-e glass Class 4	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT high performance	o	standard	manual

*** There aren’t variant that can be assigned to this code

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Additional notes:

For Helsinki and Berlin calculations, the variant number 2 and 3 of windows strategies correspond respectively at a triple glass with high performance and one's with very high performance. Both are classified with the code "+". For more deep analysis of results in the bar plot graph "Envelope" the columns n. 3-4-7-8-13-14-17-18 correspond at the variant n. 2 of window substitution and the column 9-10-15-16-19-20 at the variant n. 3.

For Helsinki, for insulation of basement, it wasn't simulated any renovation package for every level of refurbishment.

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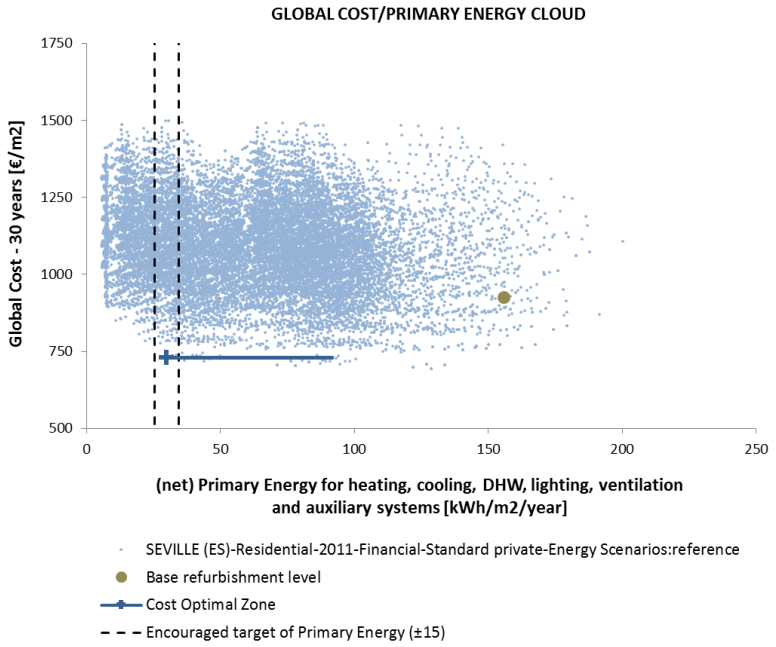
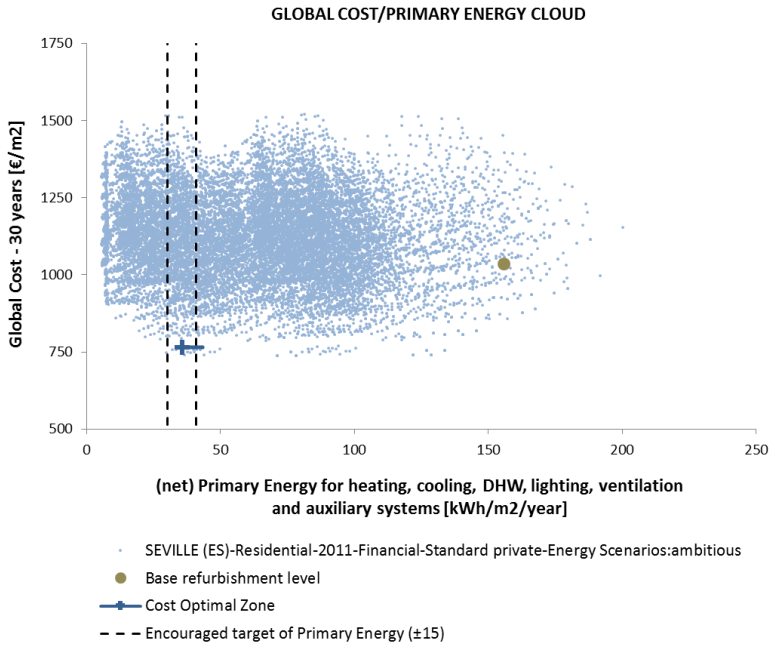
8.1.1.1 Seville





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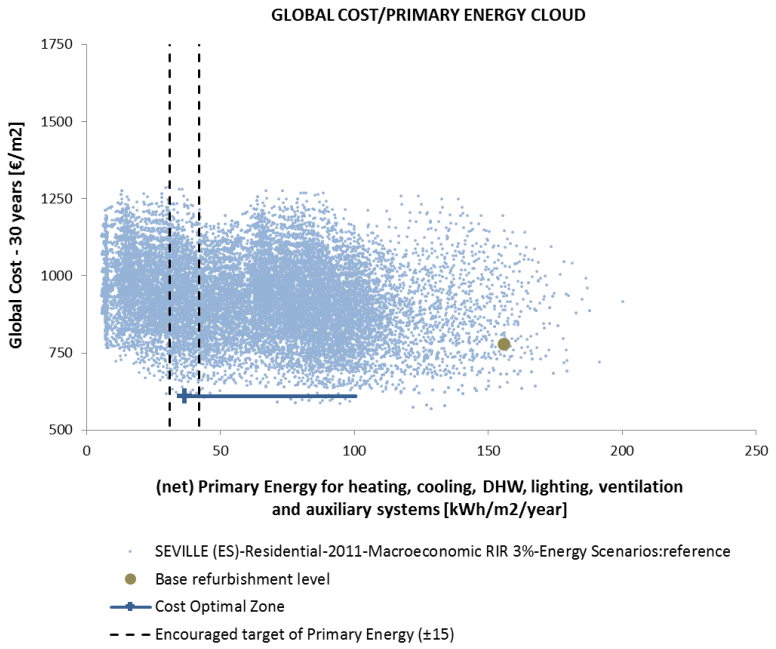

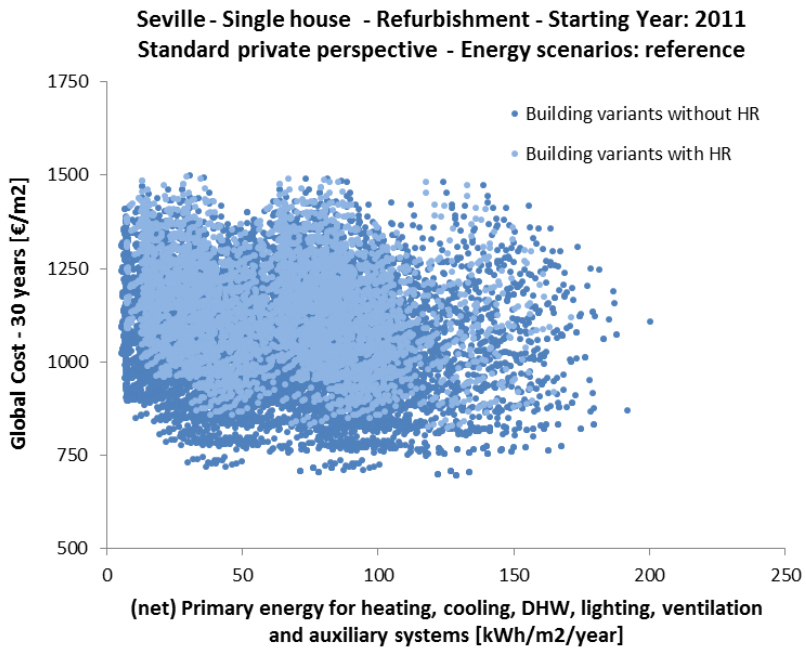

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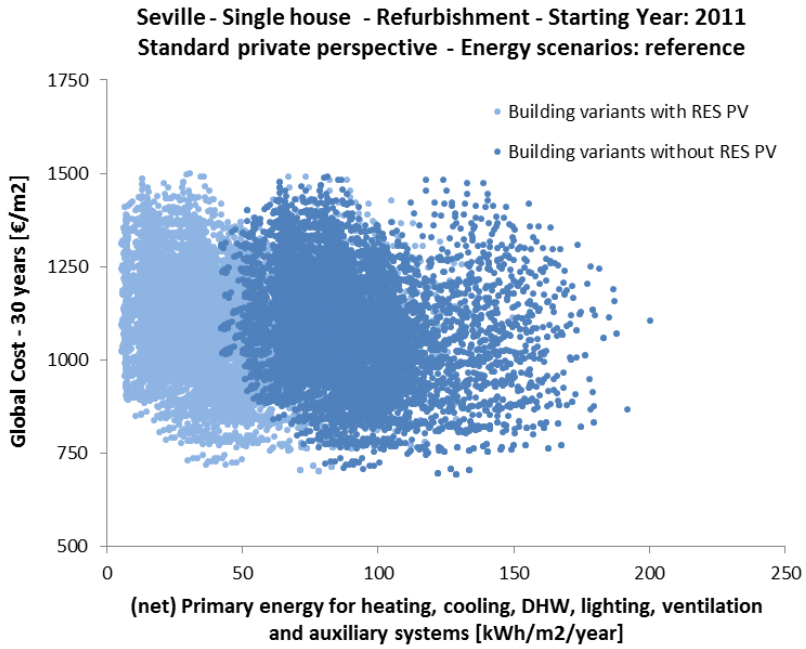

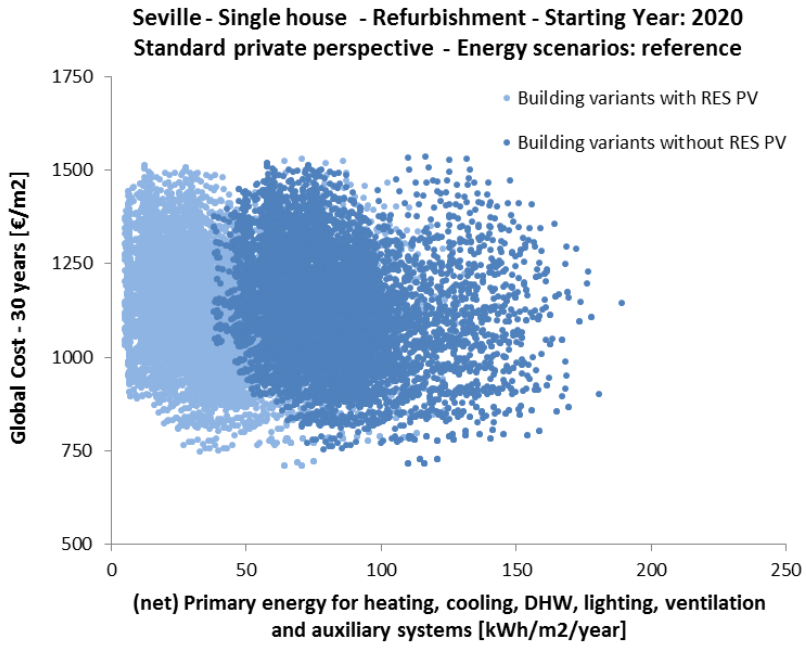

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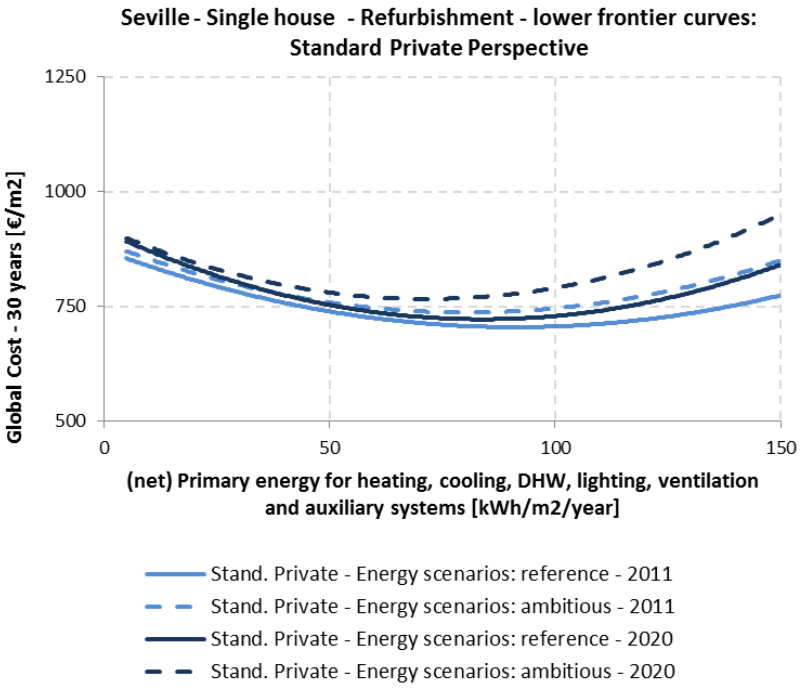

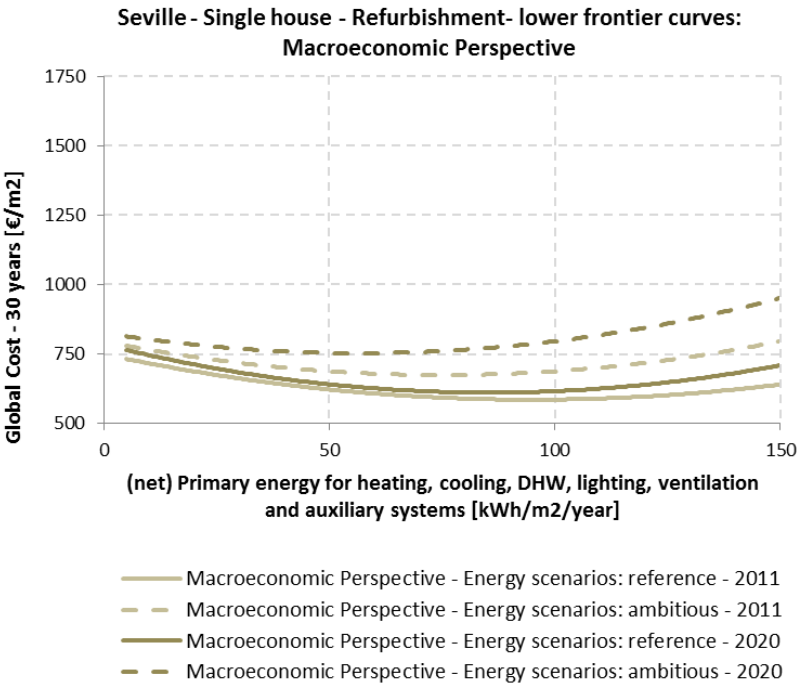

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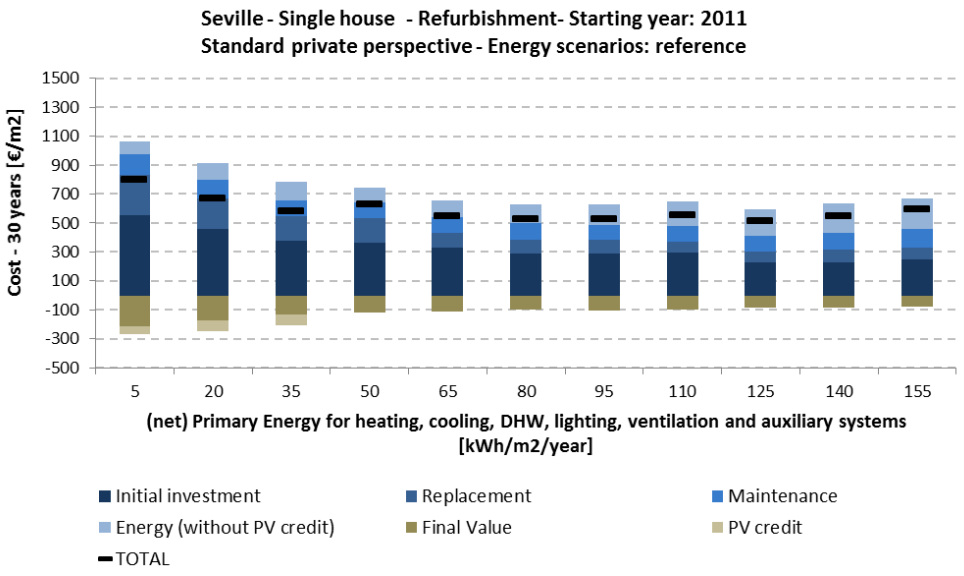

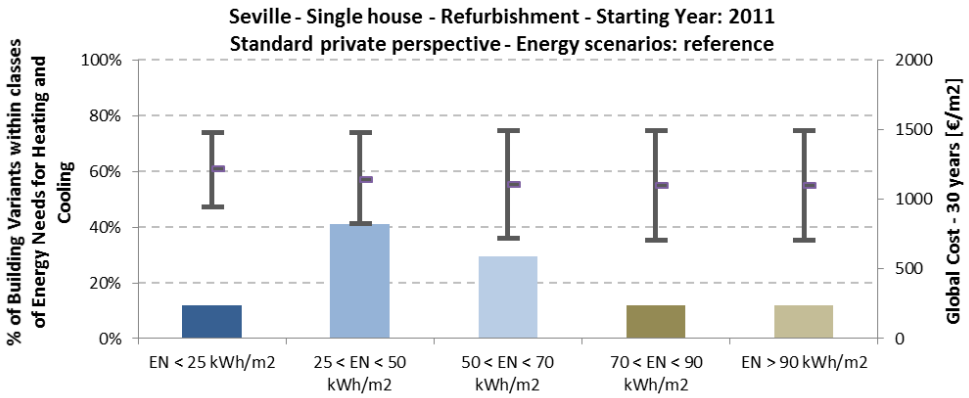

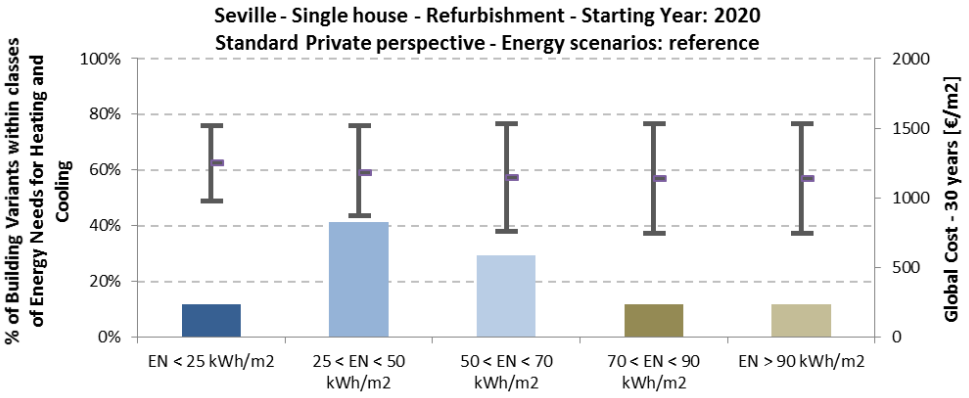

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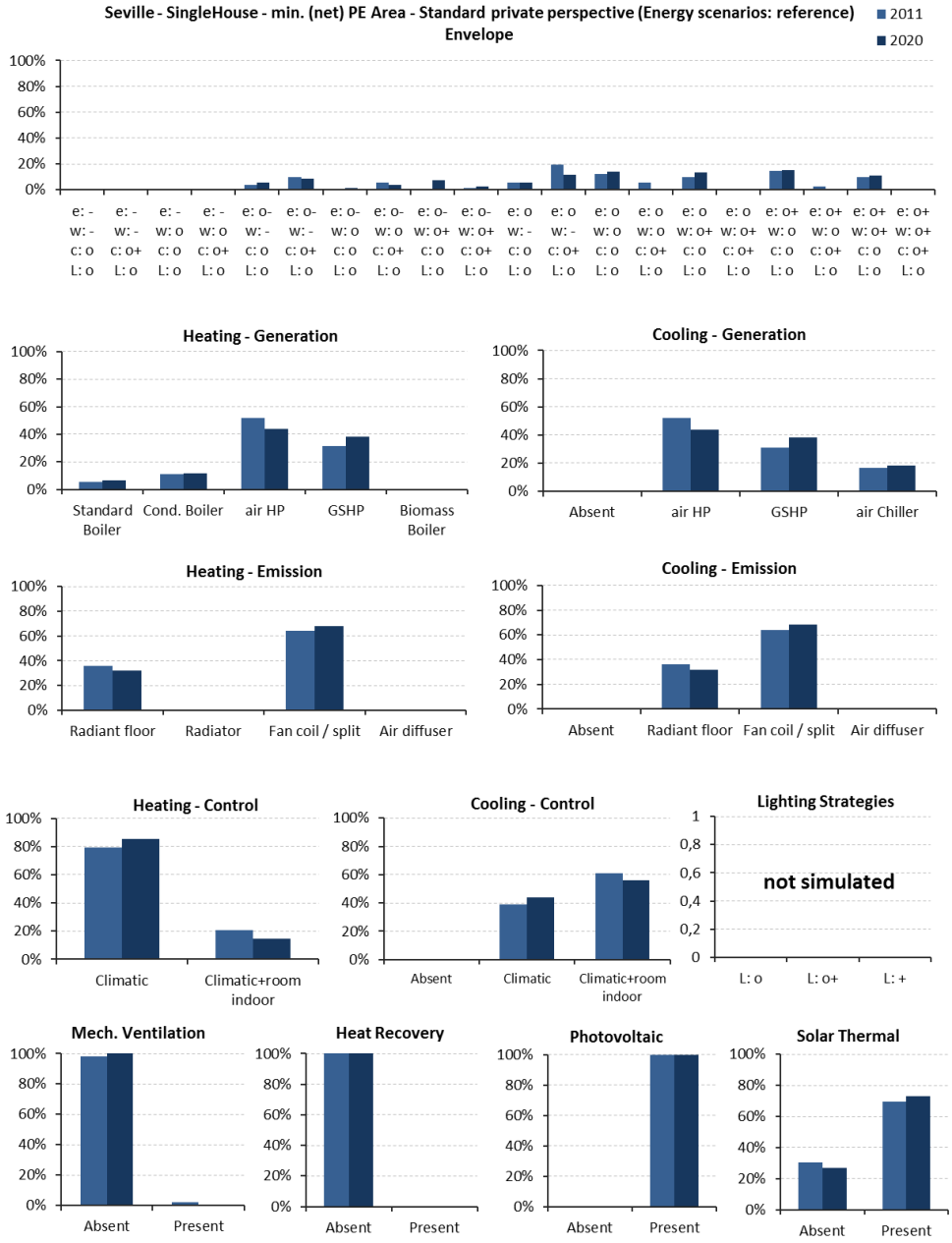
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	6	25	5	25
Range of Global Costs [€/m^2]:	777	932	765	944
Number of Building Variants:	144		144	



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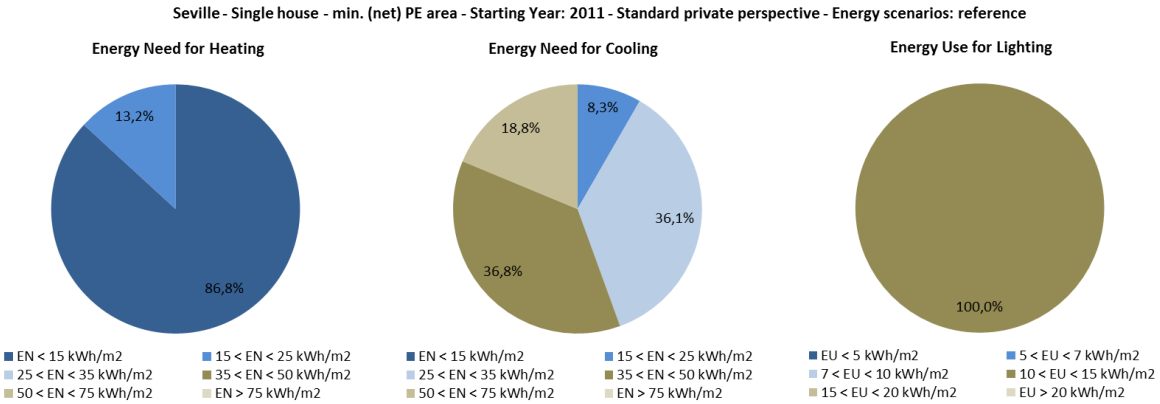

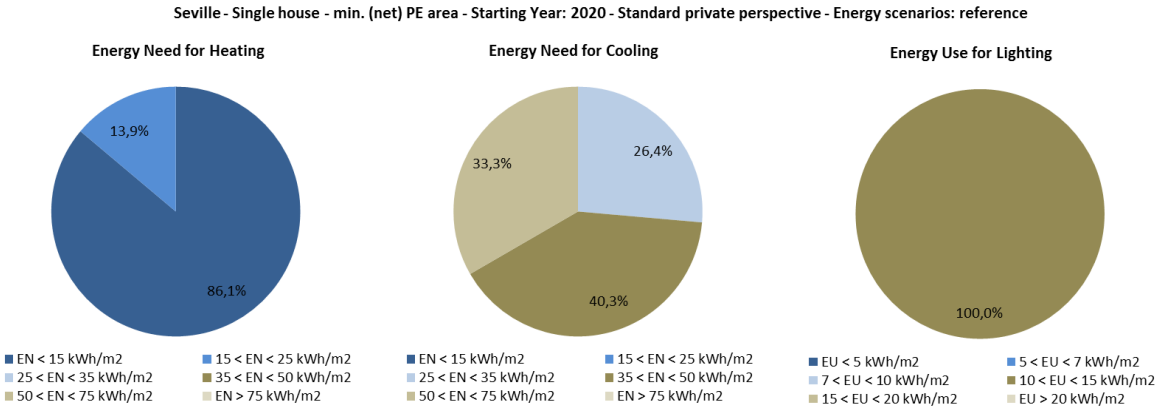

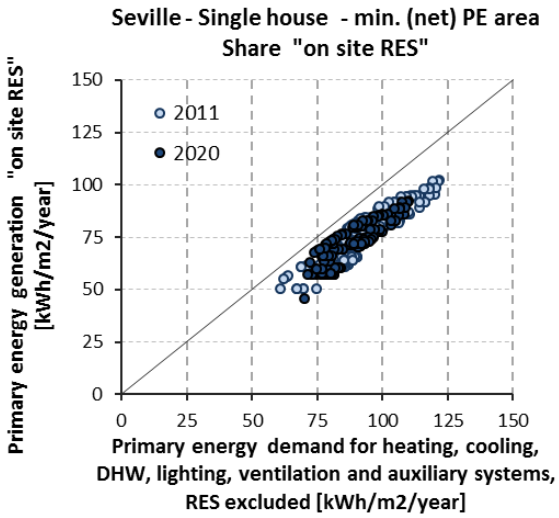

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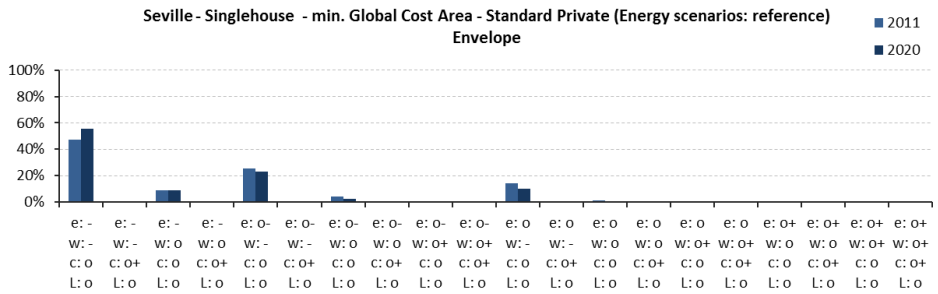
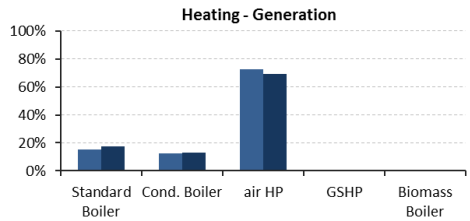
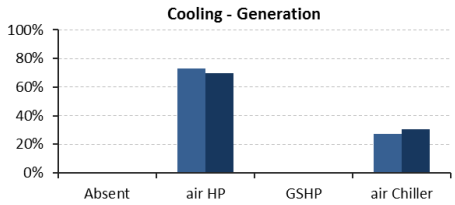
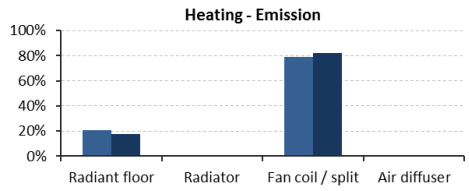
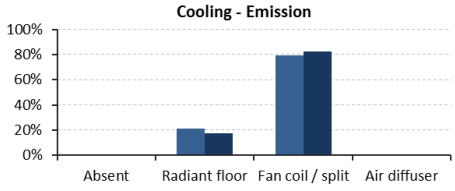
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	20	150	25	175
Range of Global Costs [€/m^2]:	695	778	709	817
Number of Building Variants:	187		187	

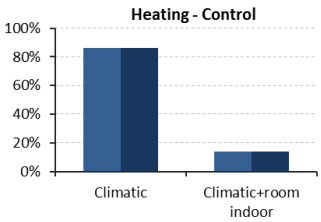


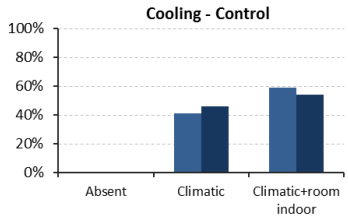


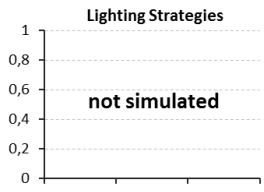


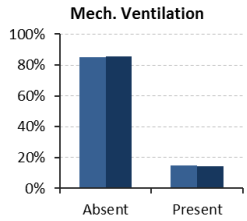


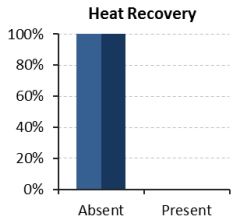


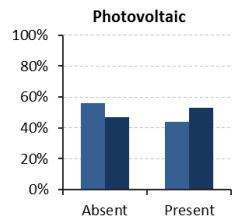


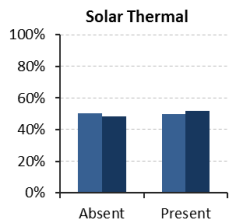












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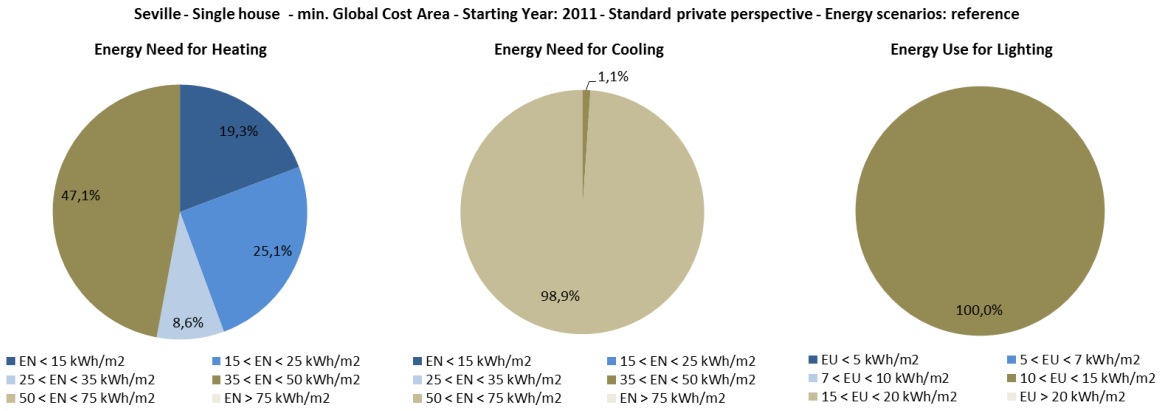
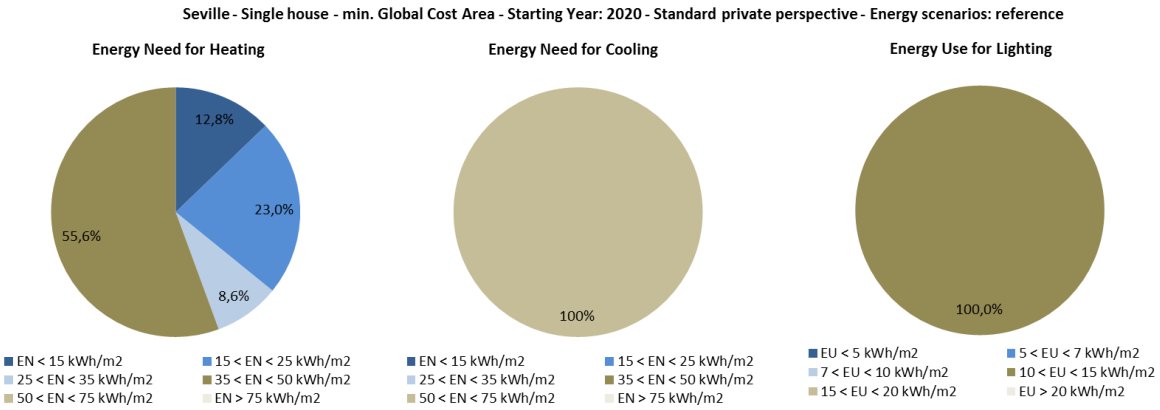
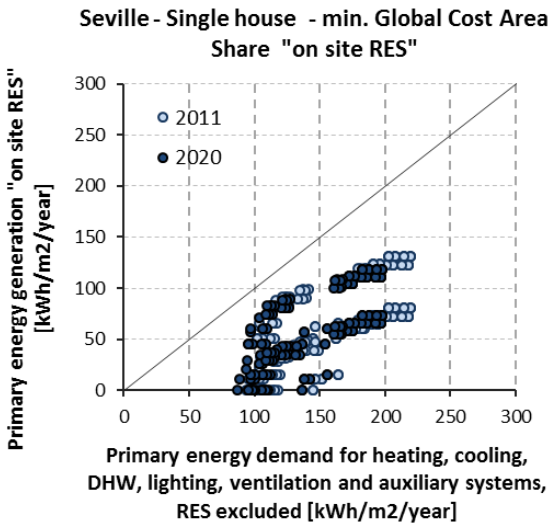
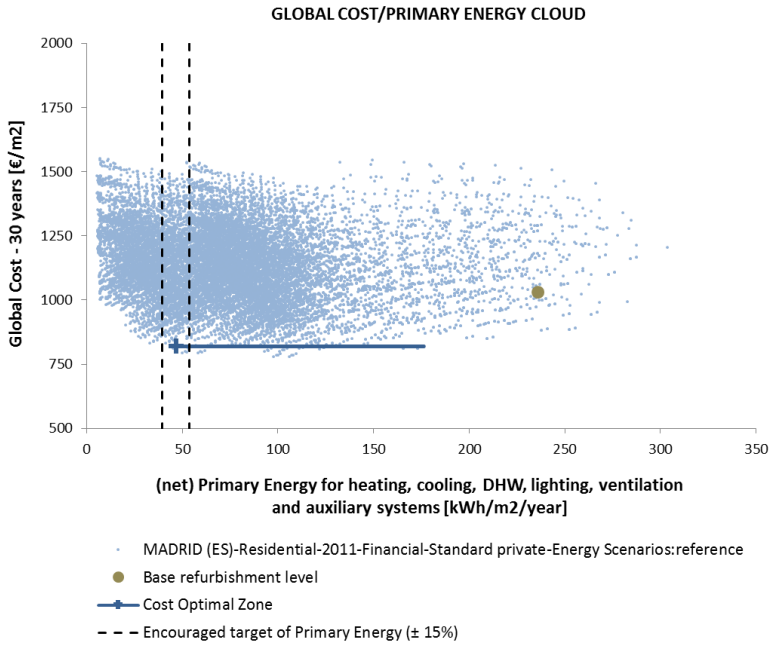
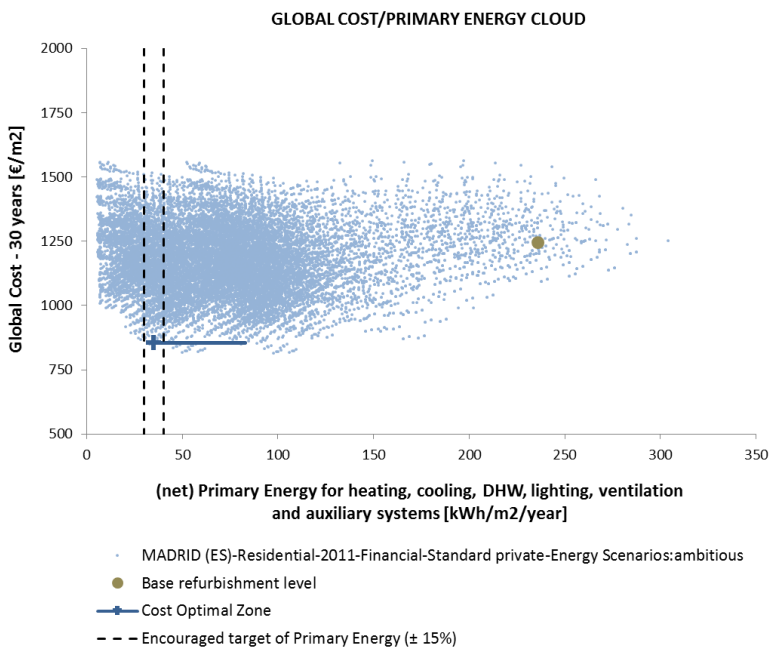

Seville - Single house - min. Global Cost Area - Starting Year: 2011 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
19,3%
25,1%
8,6%
47,1%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Need for Cooling
1,1%
98,9%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Use for Lighting
100,0%
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2


Seville - Single house - min. Global Cost Area - Starting Year: 2020 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
12,8%
23,0%
8,6%
55,6%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Need for Cooling
100%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Use for Lighting
100,0%
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2


Seville - Single house - min. Global Cost Area
Share "on site RES"
Primary energy generation "on site RES" [kWh/m2/year]
300
250
200
150
100
50
0
2011
2020
0
50
100
150
200
250
300
Primary energy demand for heating, cooling, DHW, lighting, ventilation and auxiliary systems, RES excluded [kWh/m2/year]

8.1.1.2 Madrid





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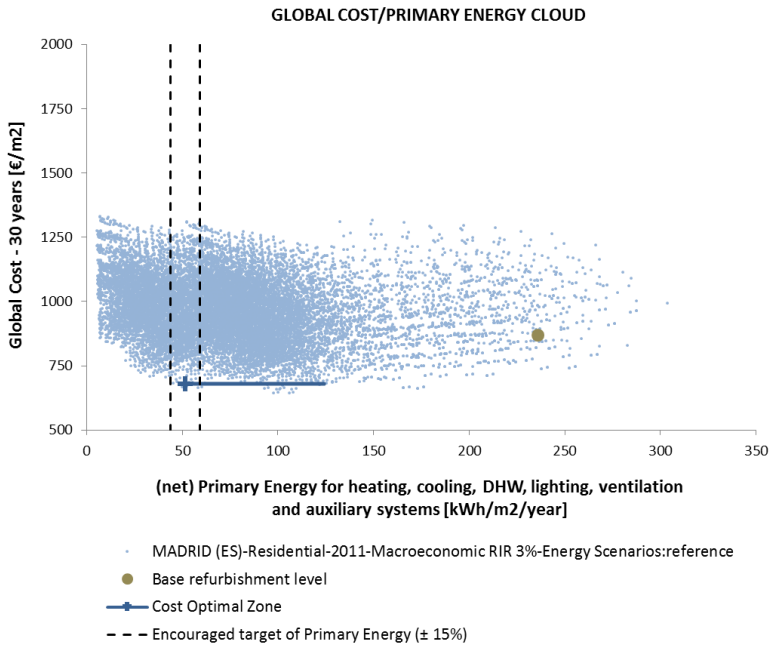

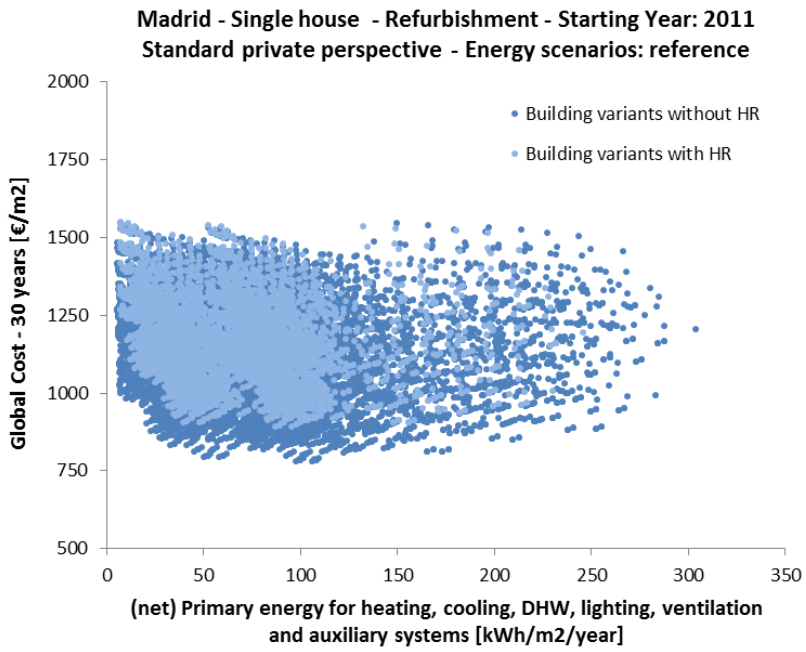

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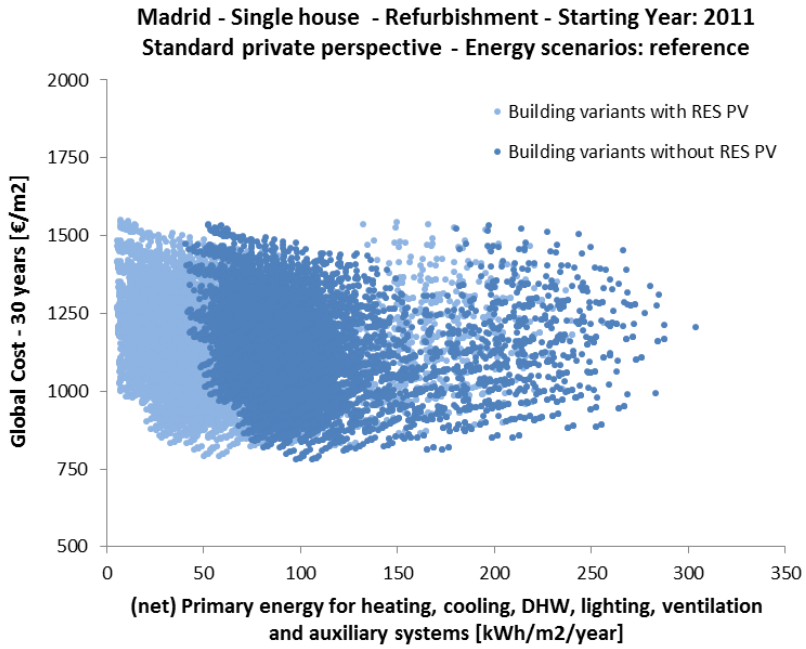

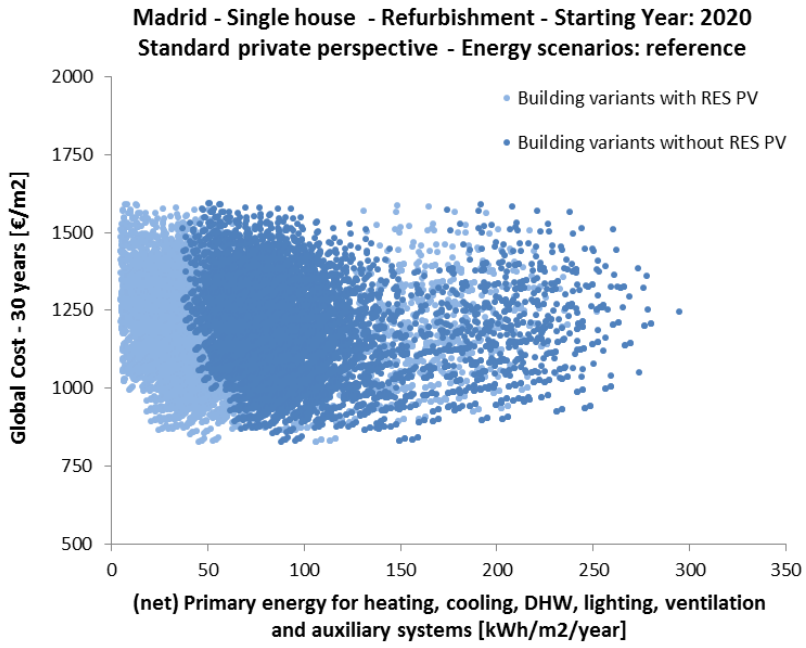

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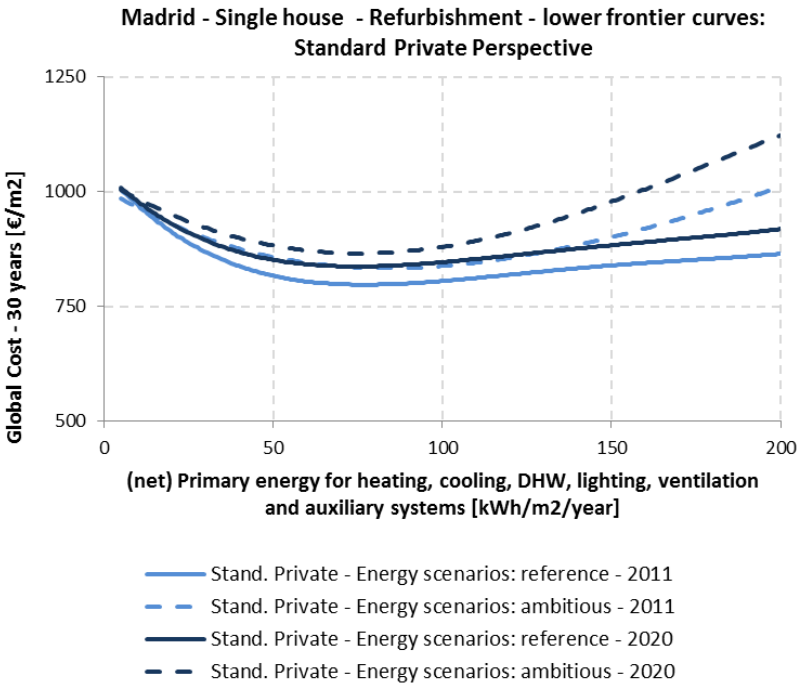

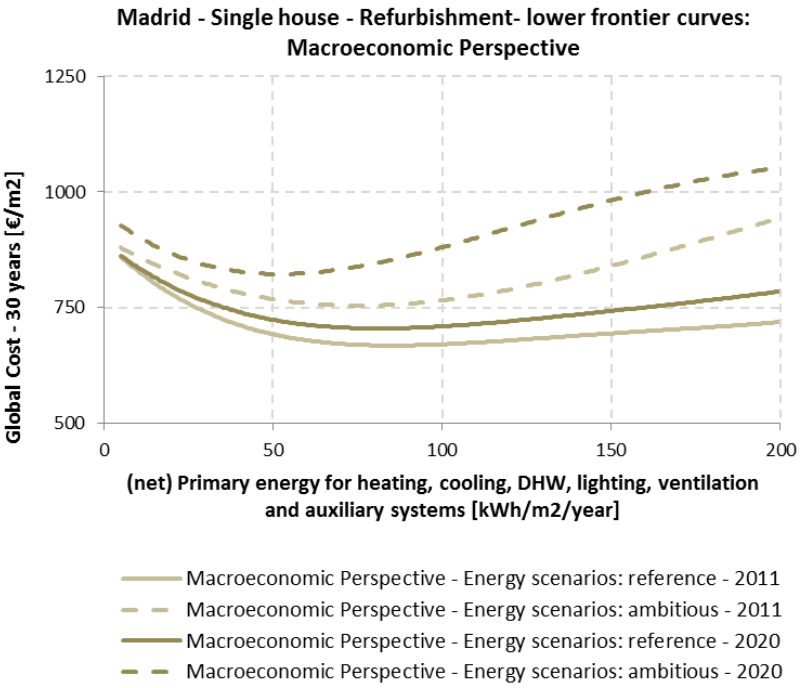

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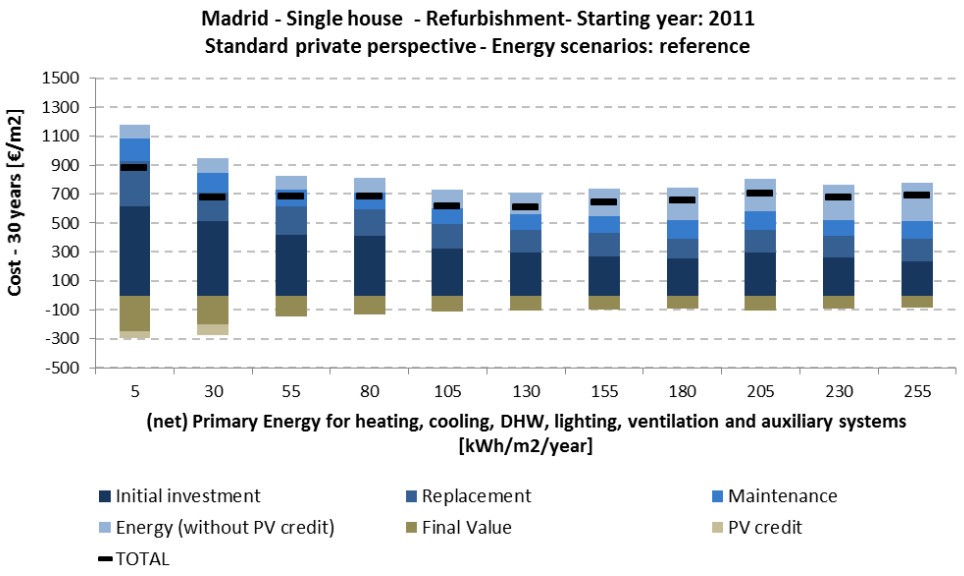

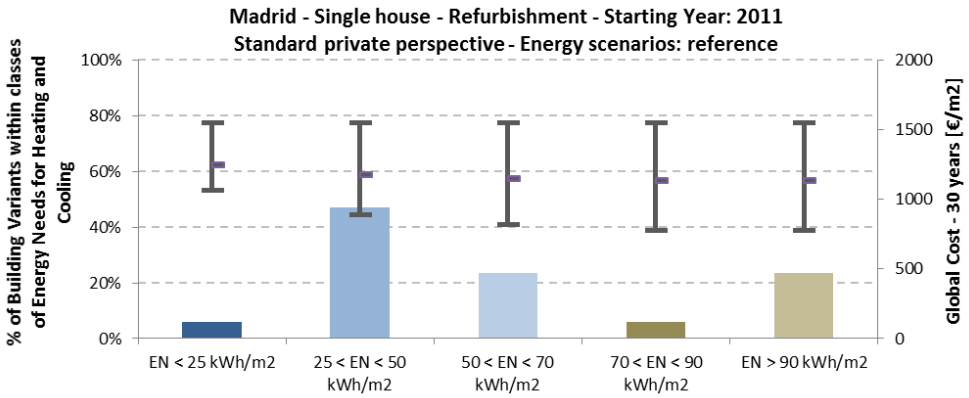

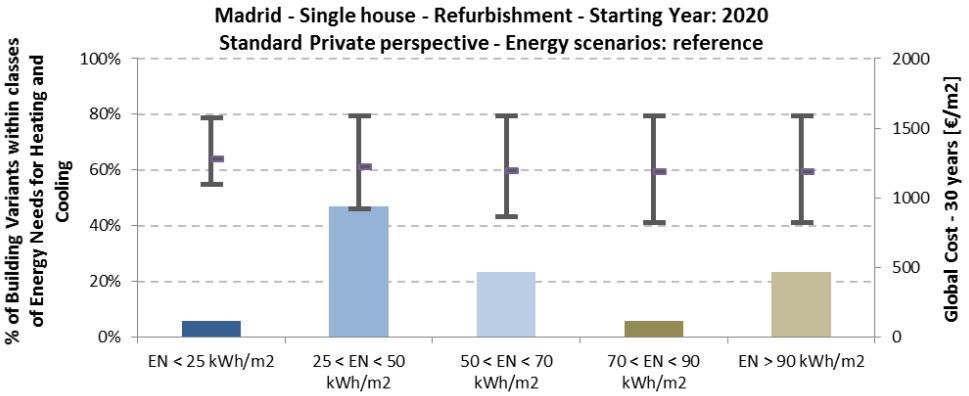

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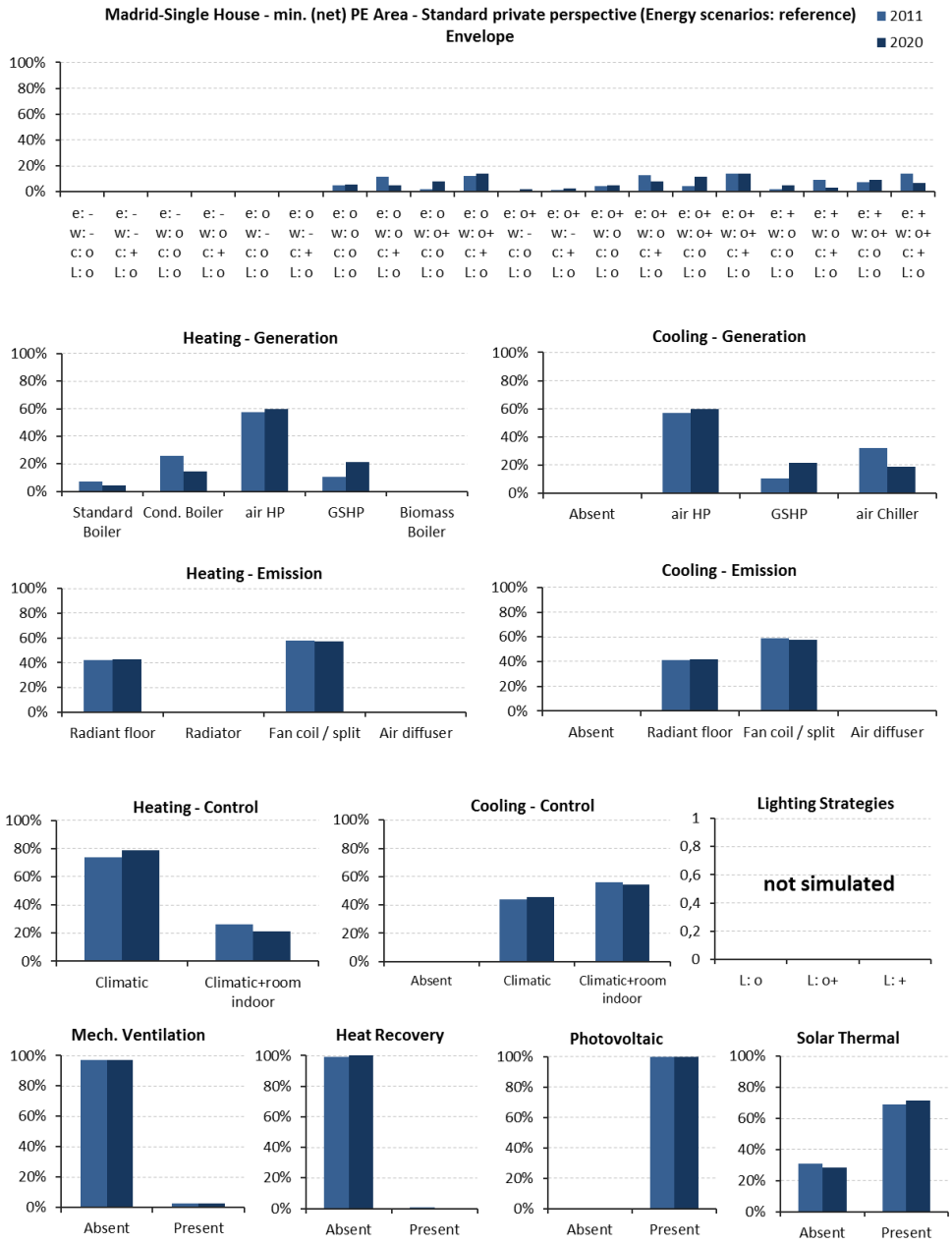
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	5	25	5	25
Range of Global Costs [€/m^2]:	859	1048	866	1069
Number of Building Variants:	145		145	



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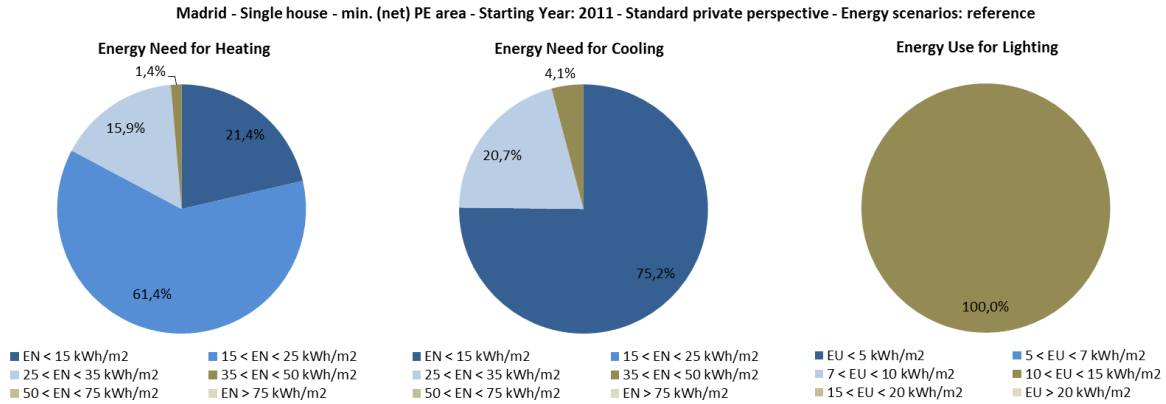

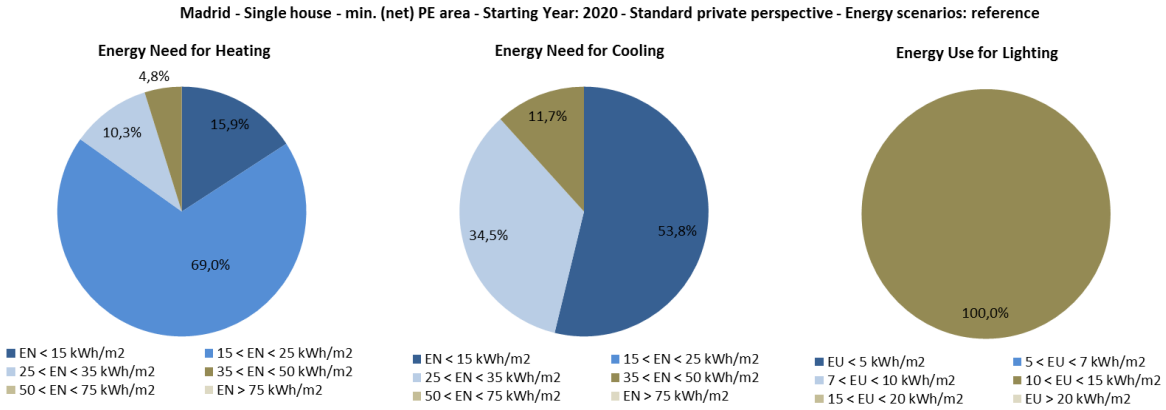

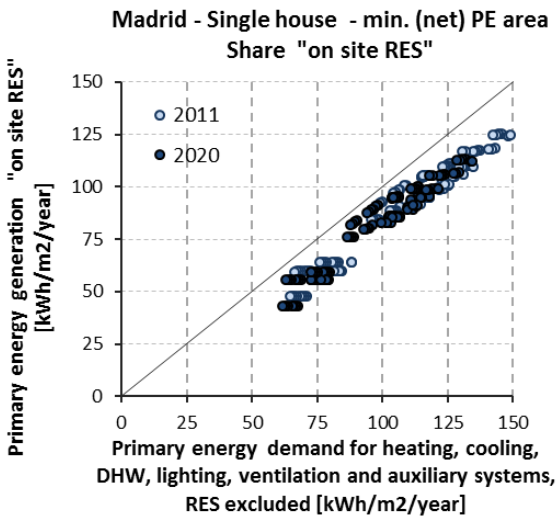

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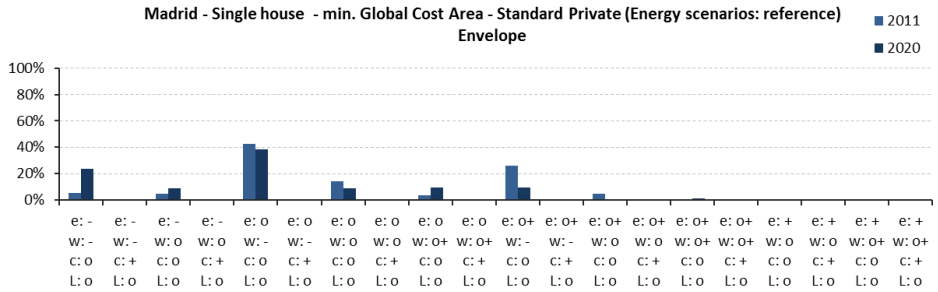
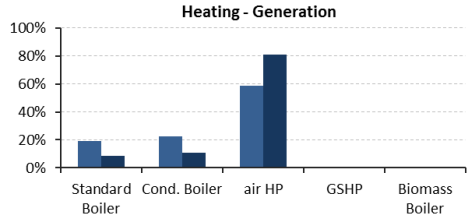
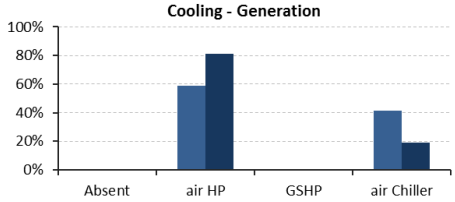
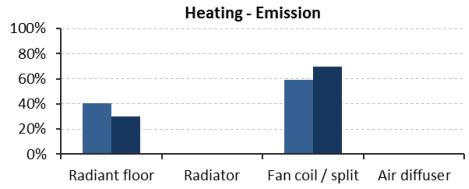
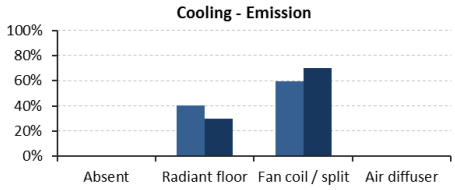
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	40	160	20	160
Range of Global Costs [€/m^2]:	780	858	827	898
Number of Building Variants:	180		180	

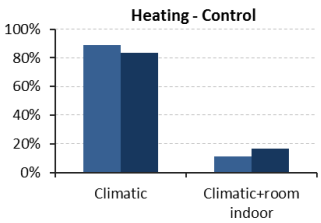


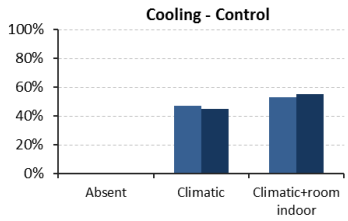


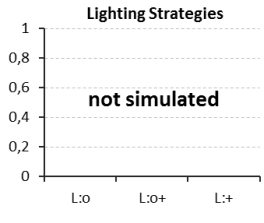


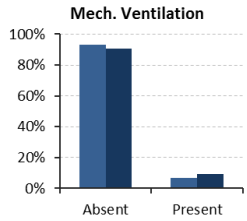


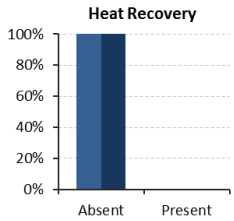


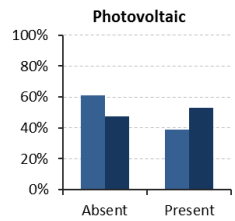


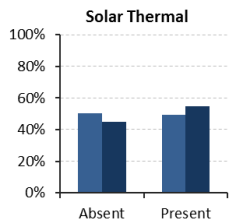












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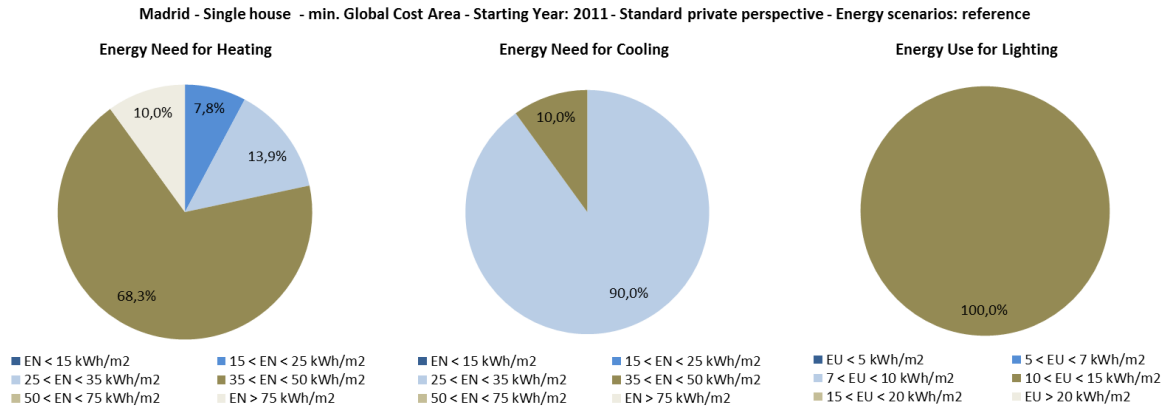

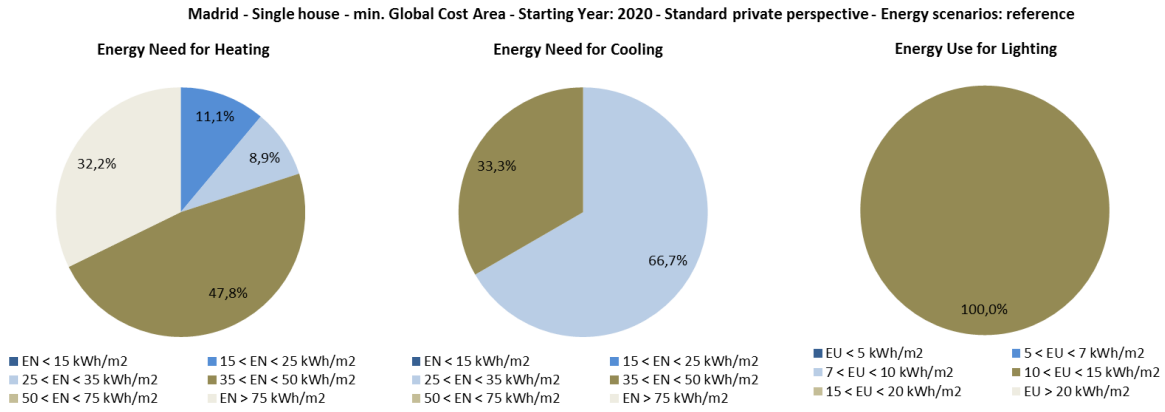

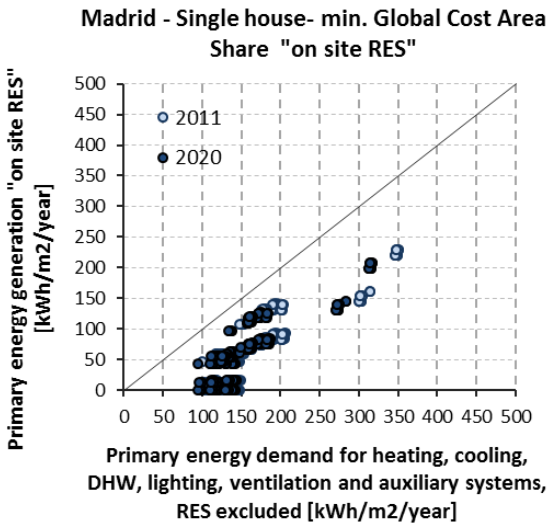

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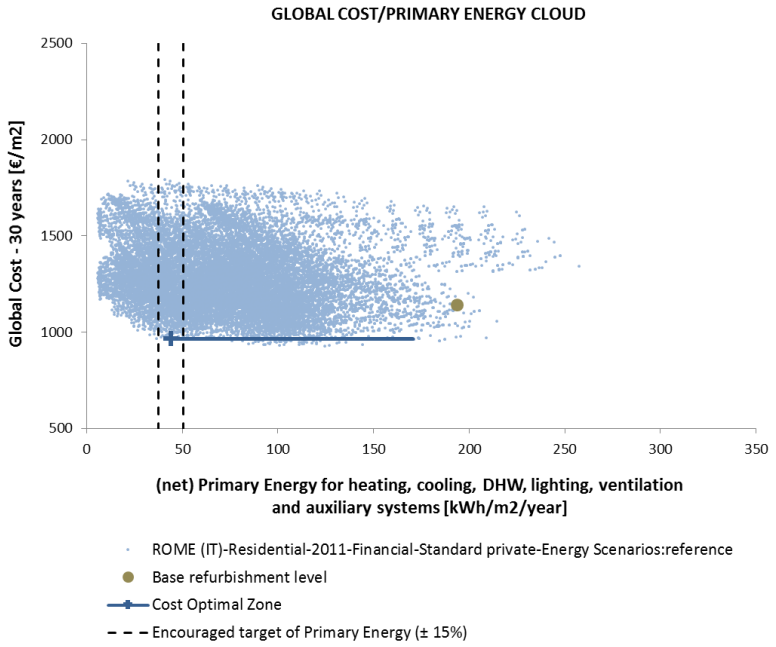
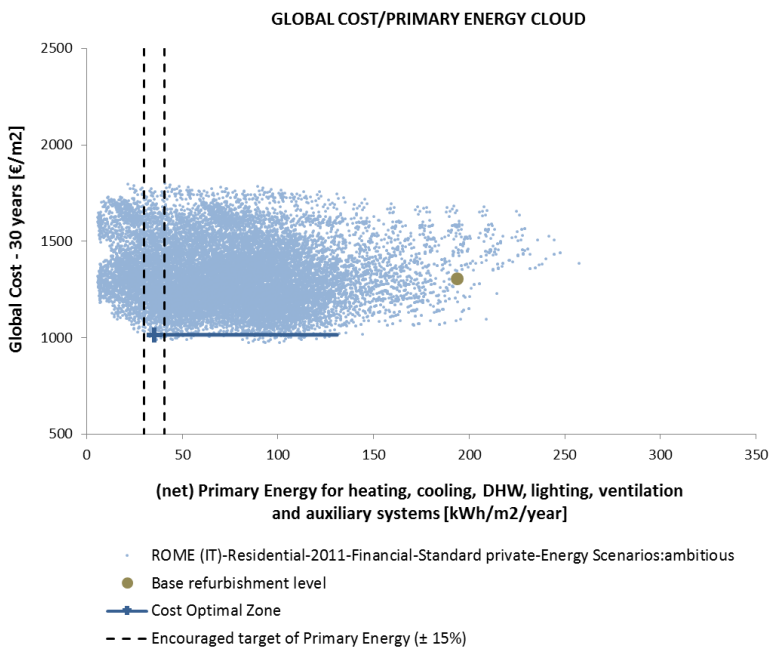
8.1.1.3 Rome





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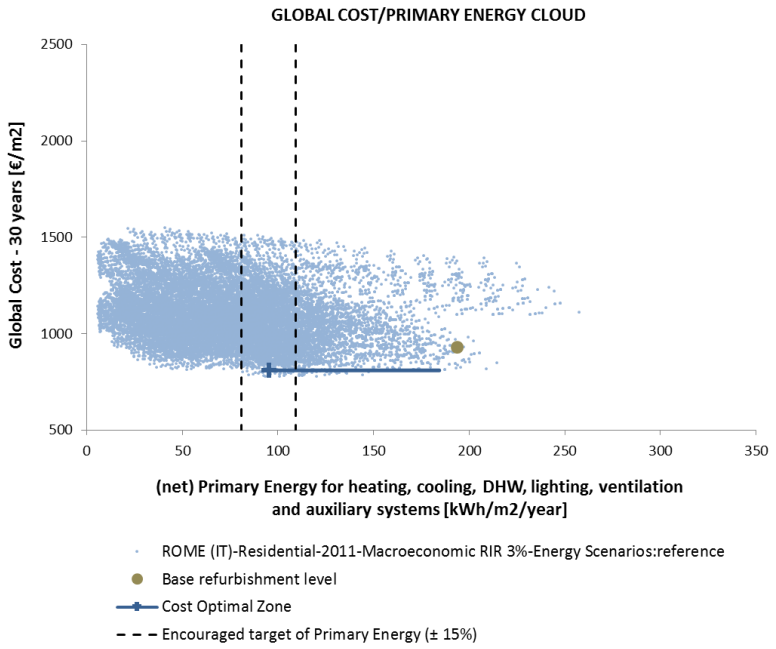

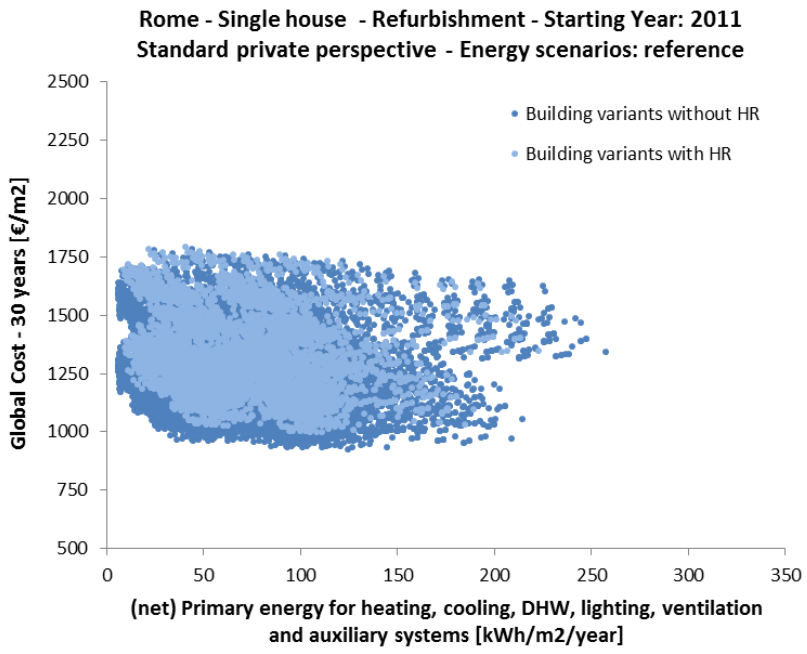

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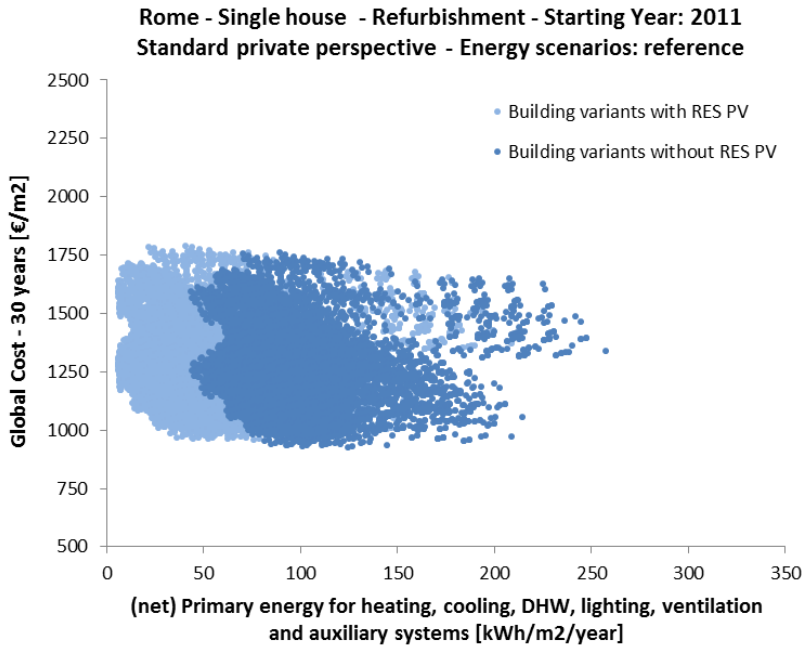

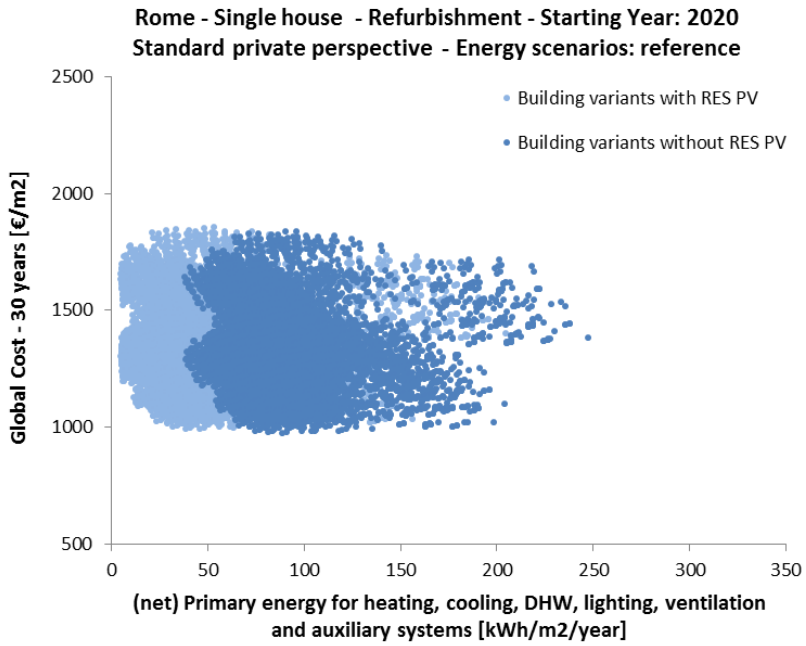

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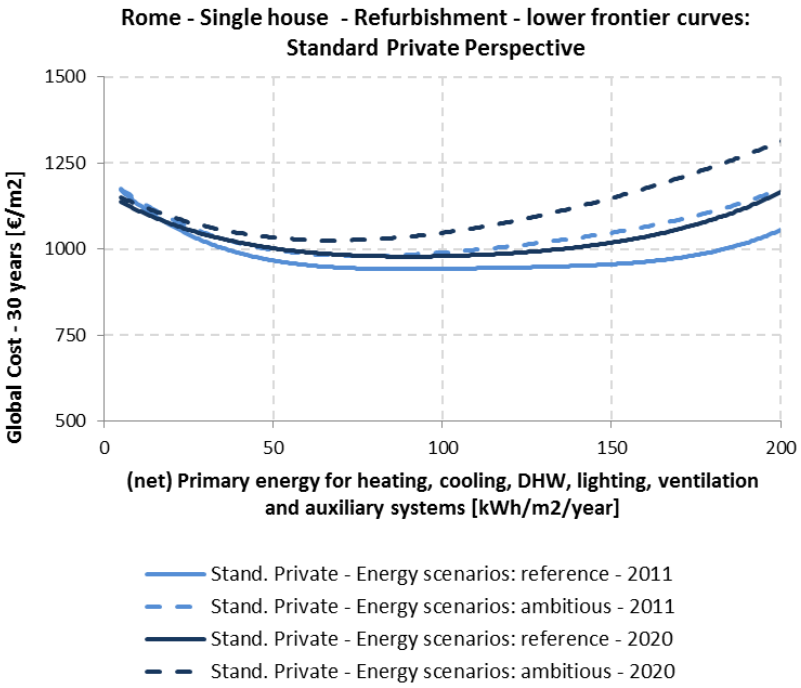

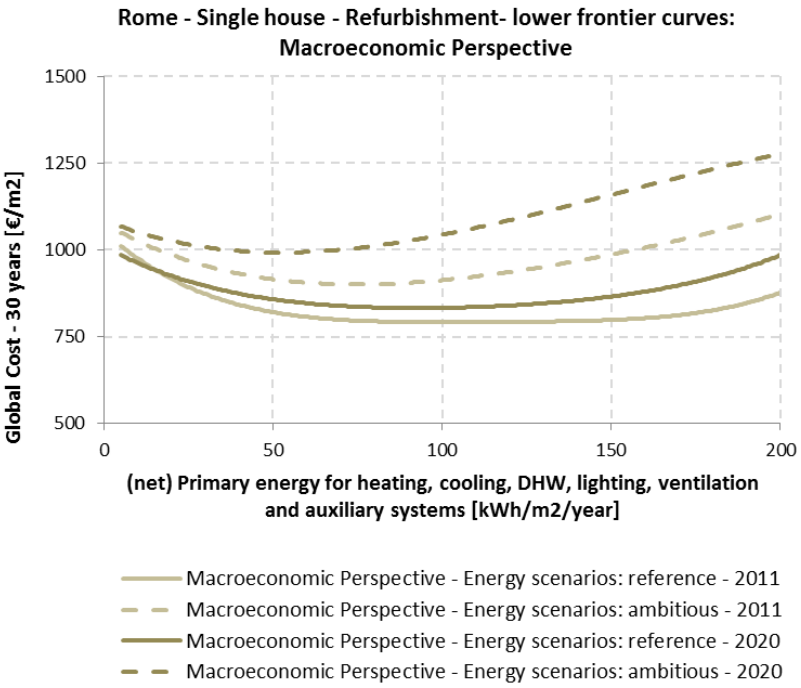

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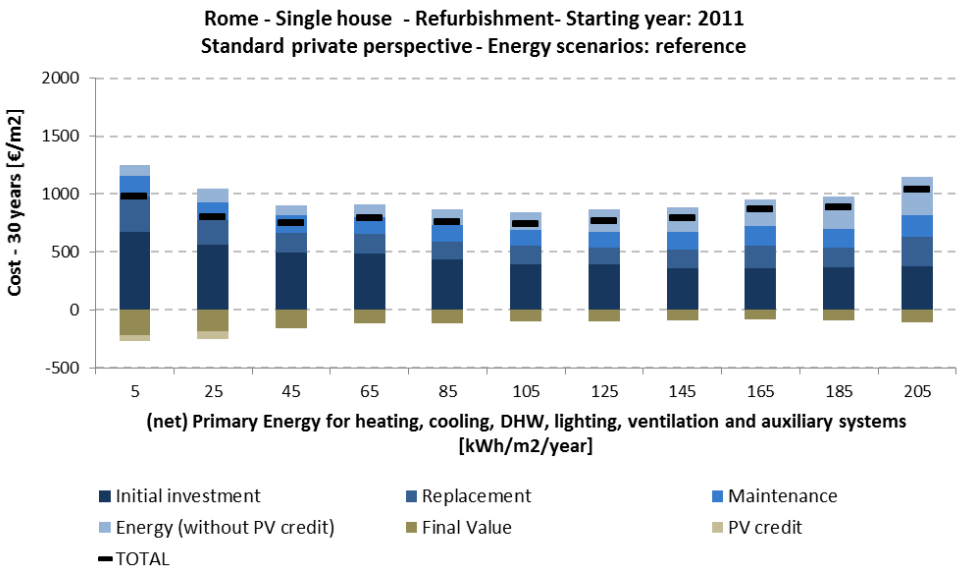

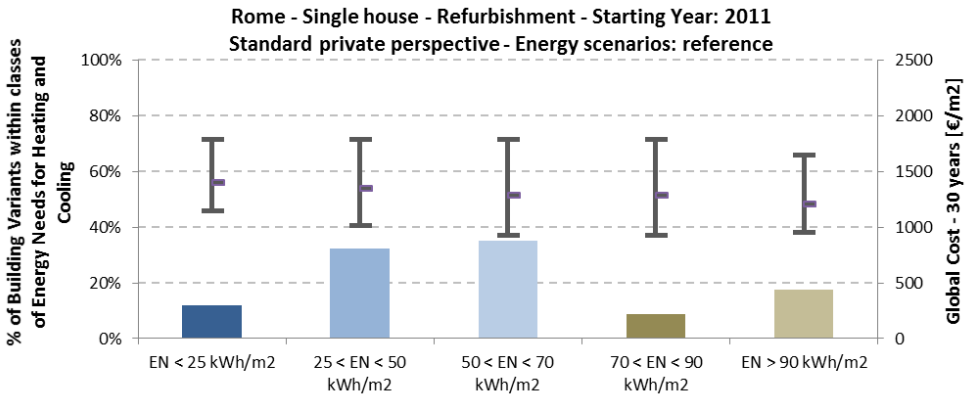

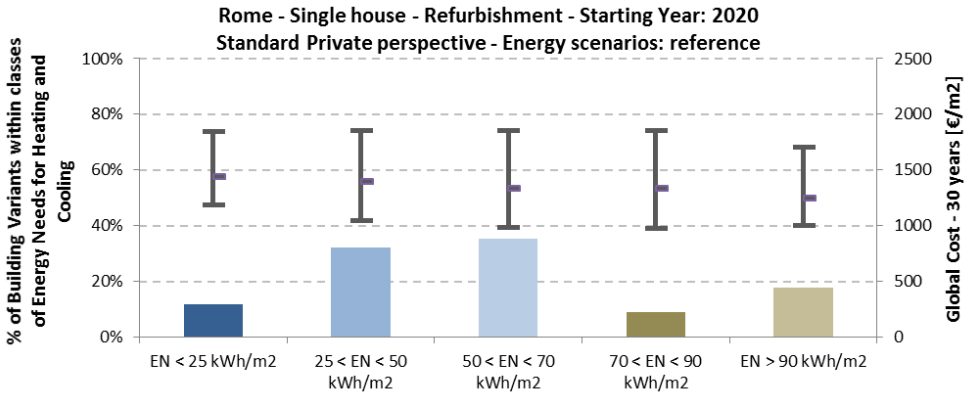

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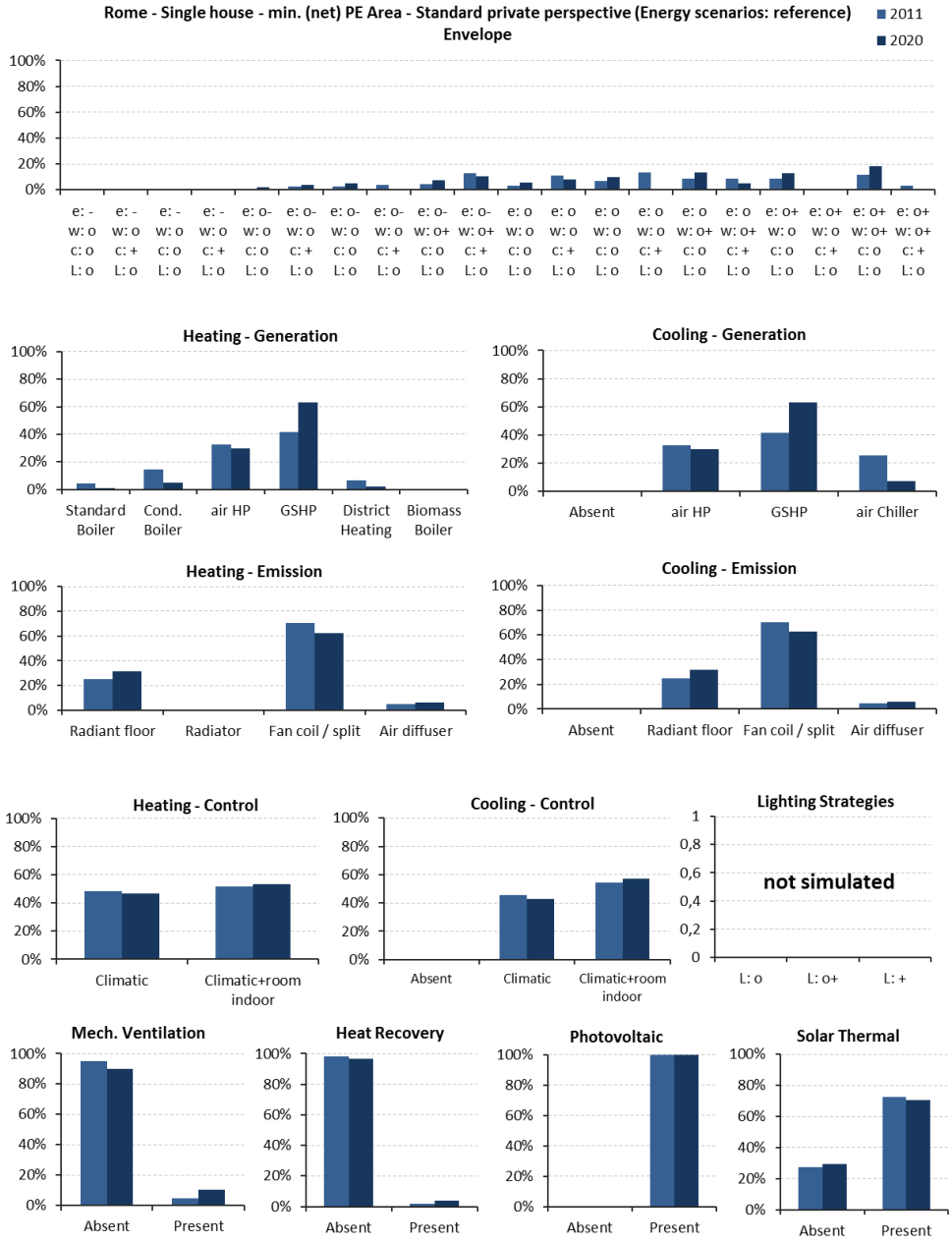
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	6	25	5	25
Range of Global Costs [€/m^2]:	1011	1193	1026	1212
Number of Building Variants:	165		165	



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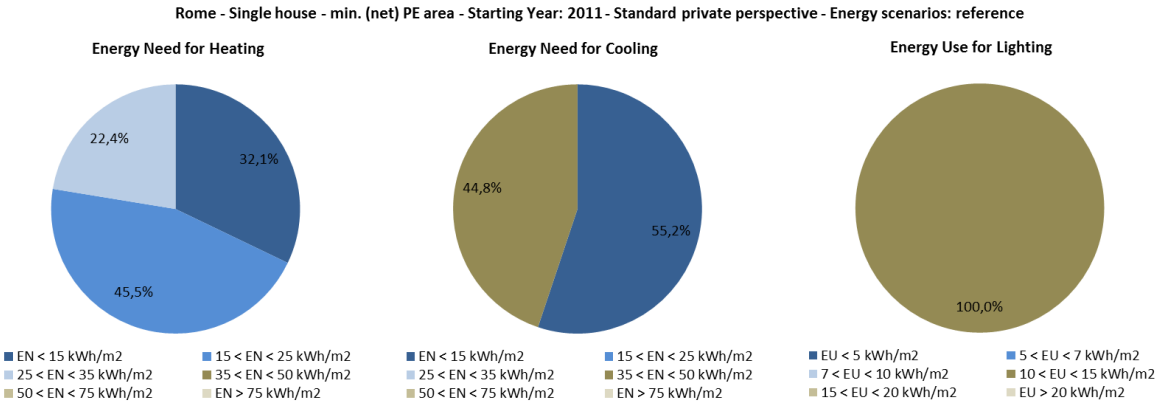

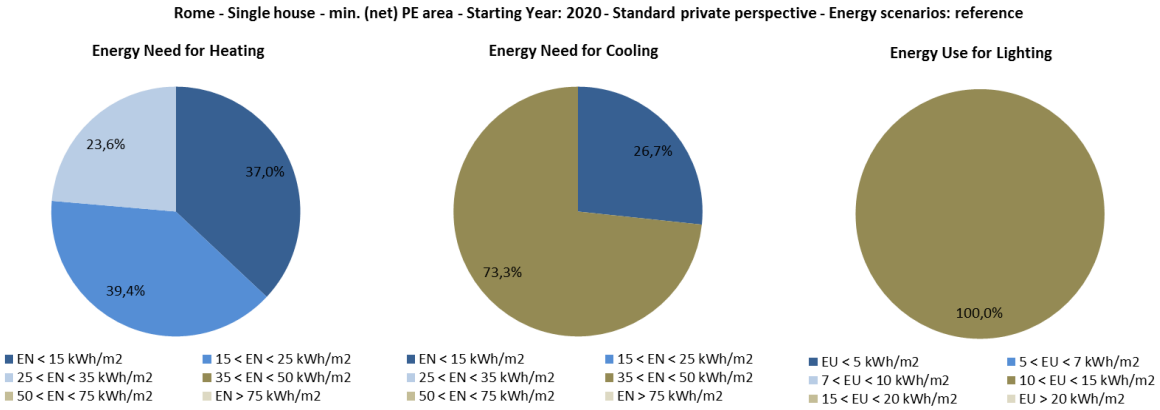

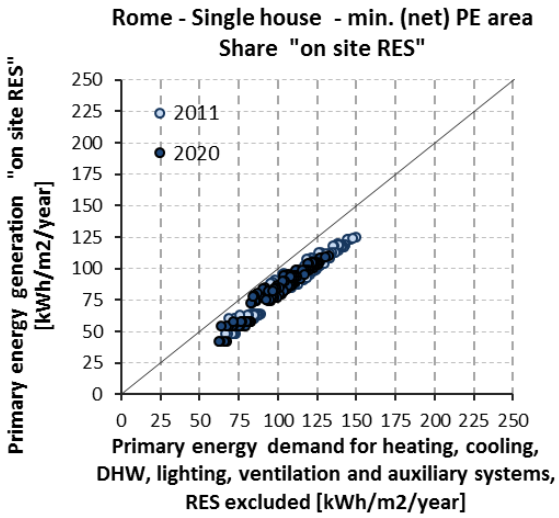

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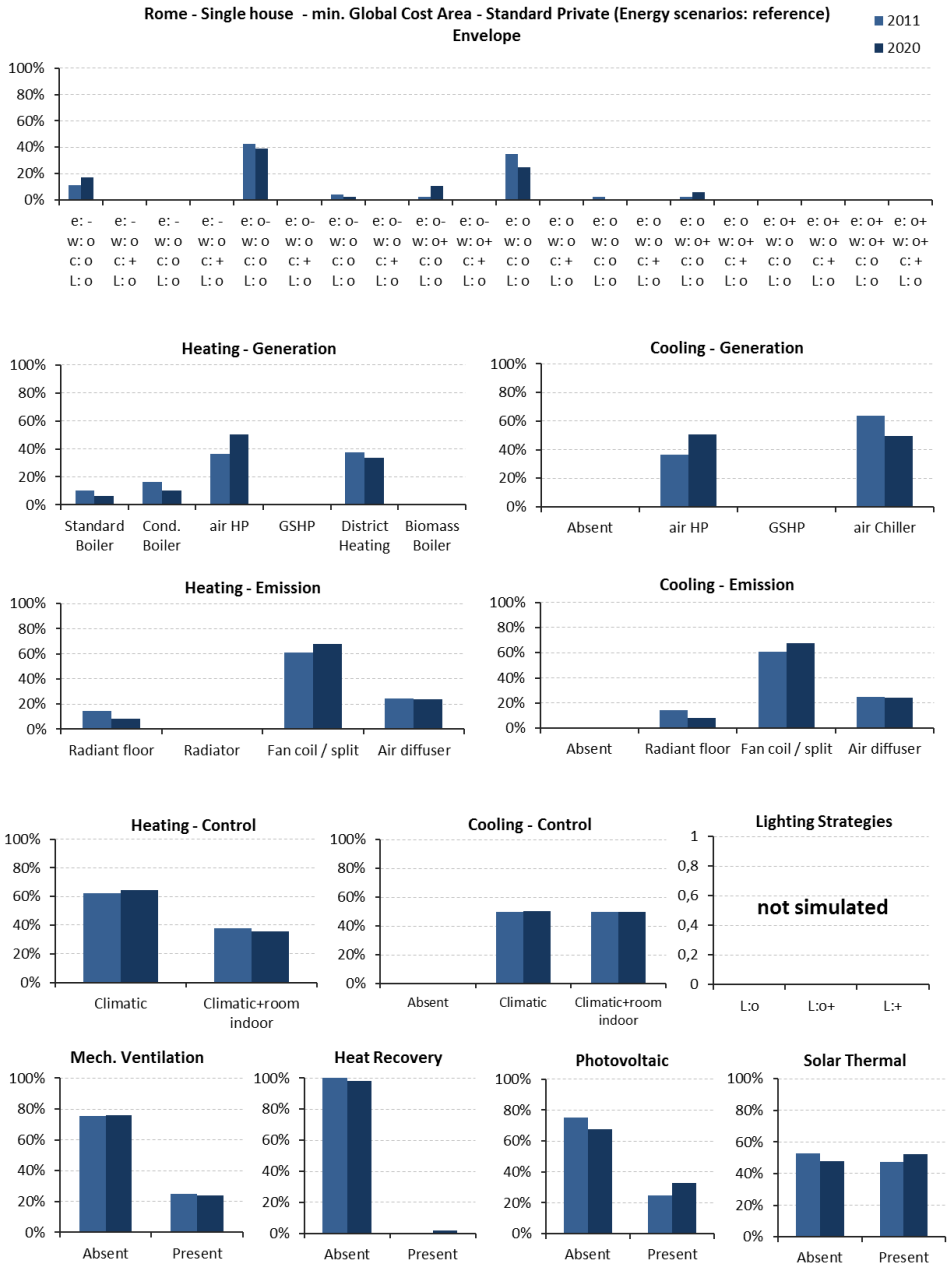
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	35	215	10	170
Range of Global Costs [€/m^2]:	927	992	977	1034
Number of Building Variants:	230		230	



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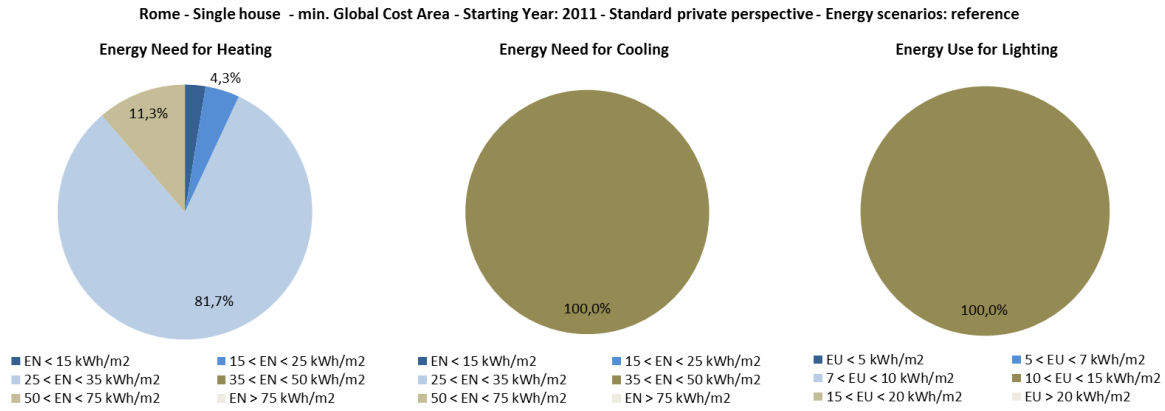

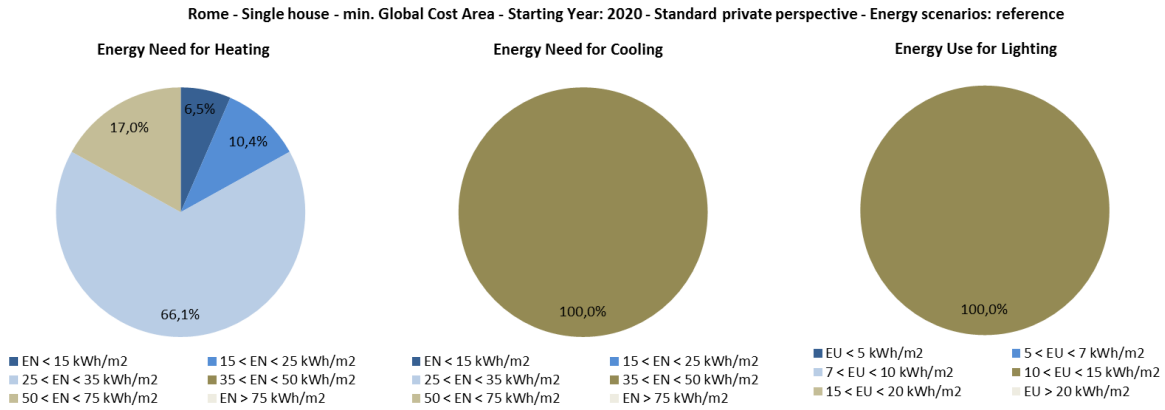

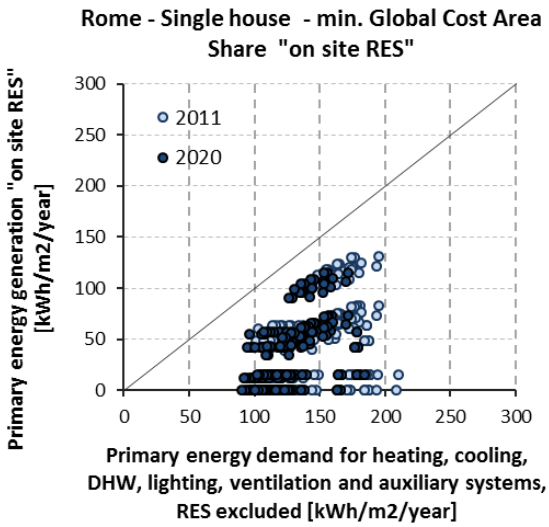

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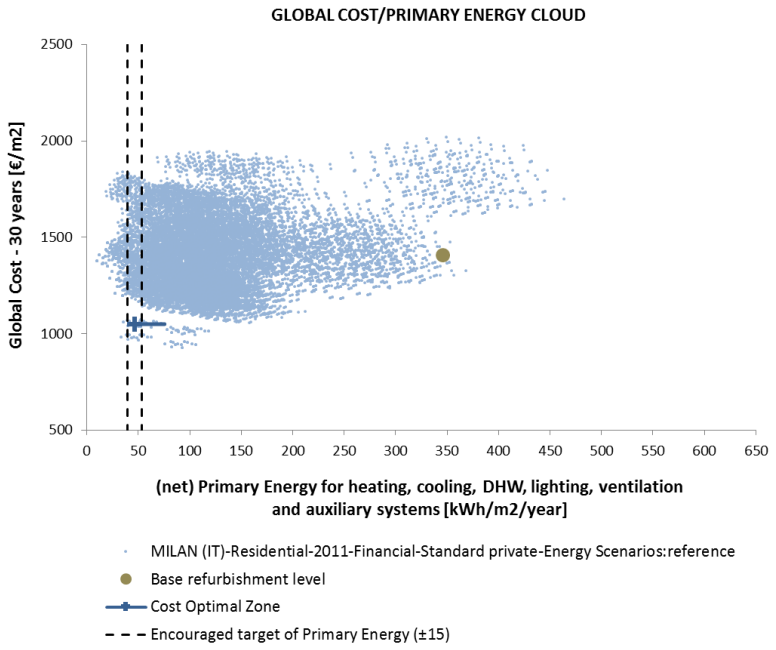
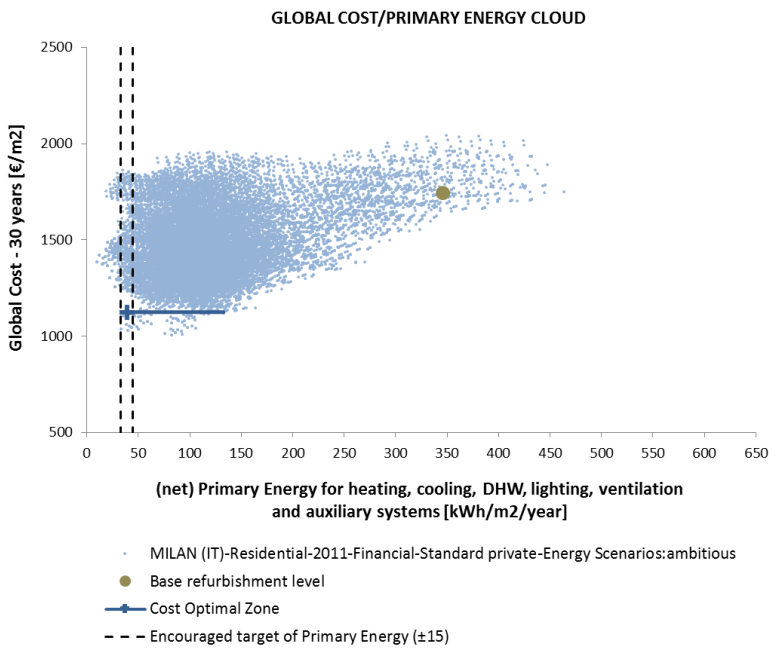
8.1.1.4 Milan





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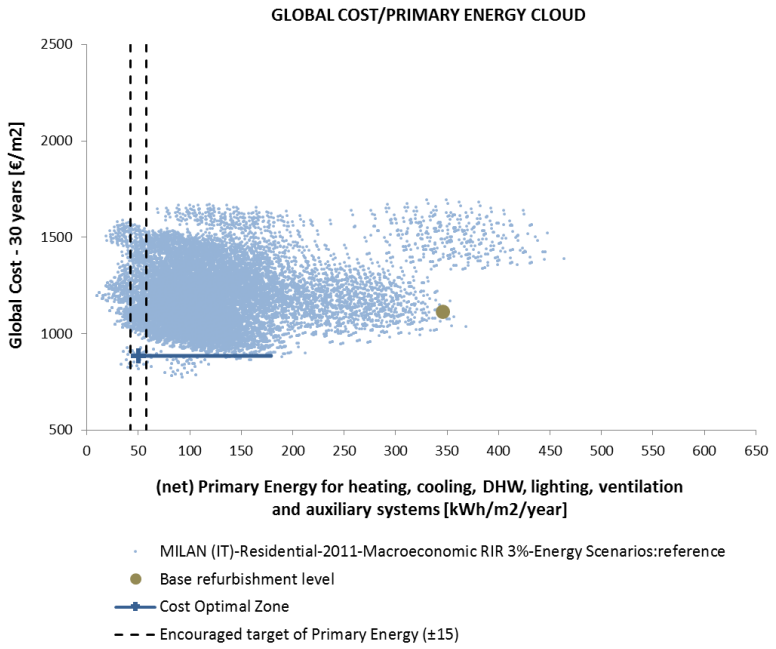

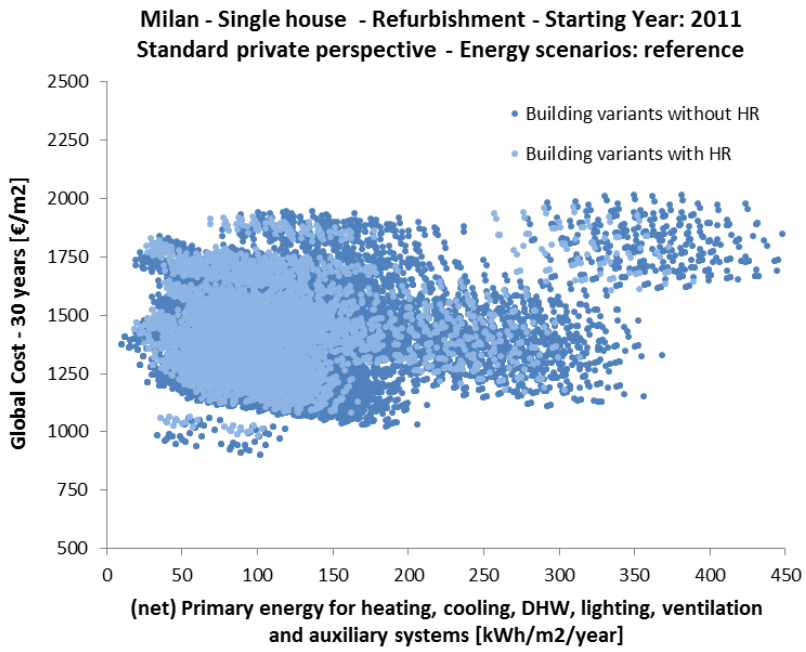

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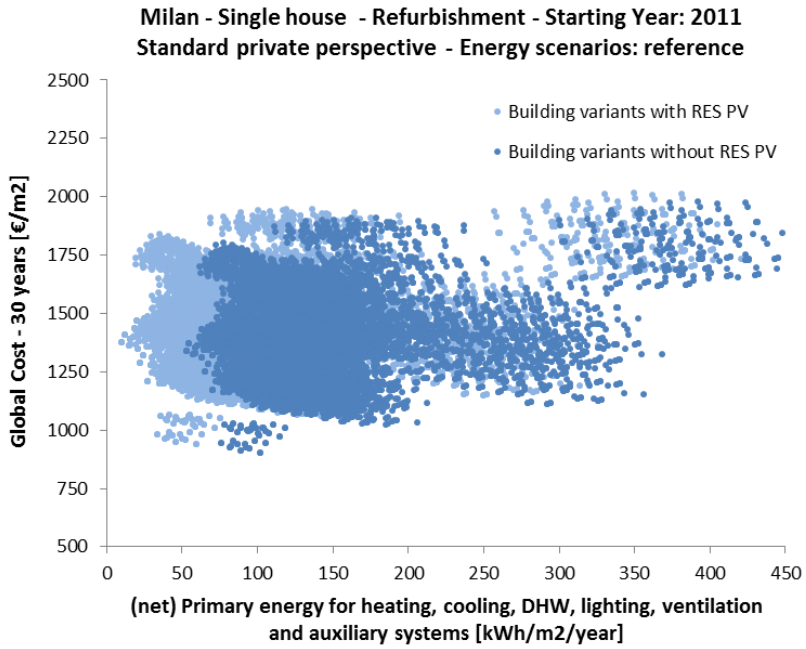

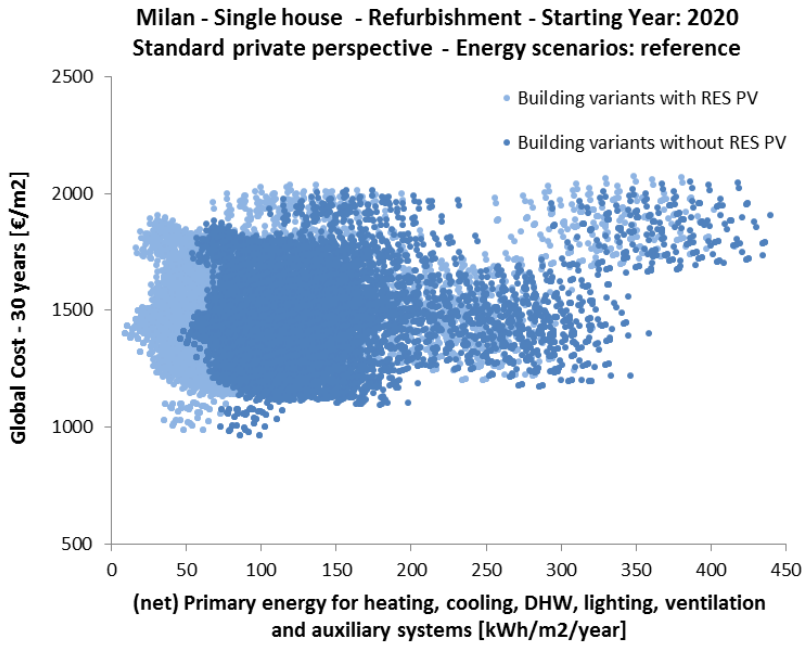

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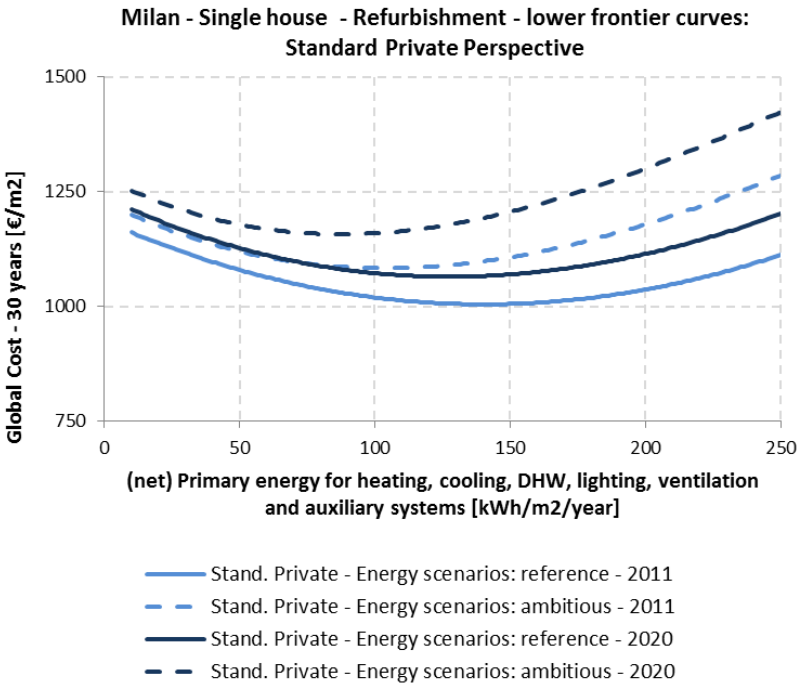

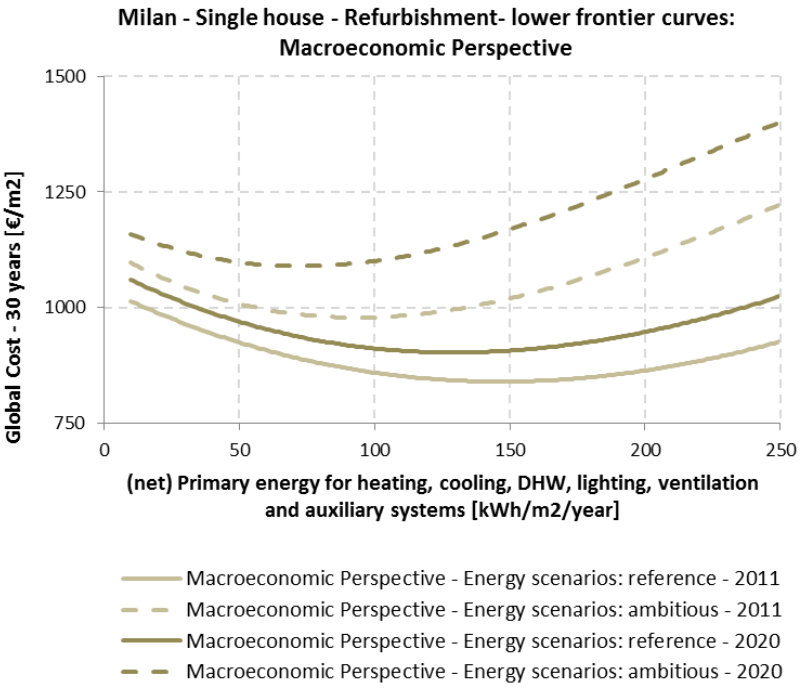

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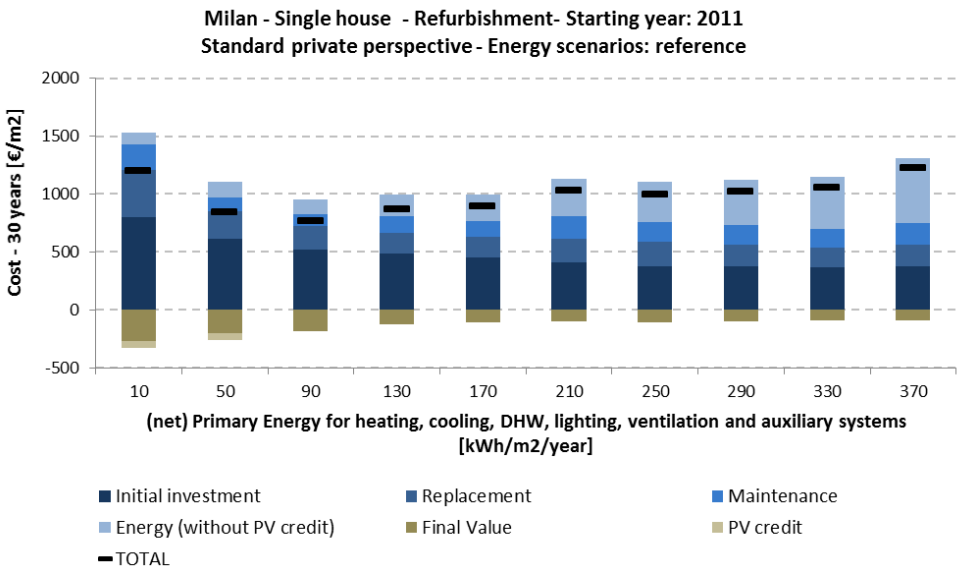

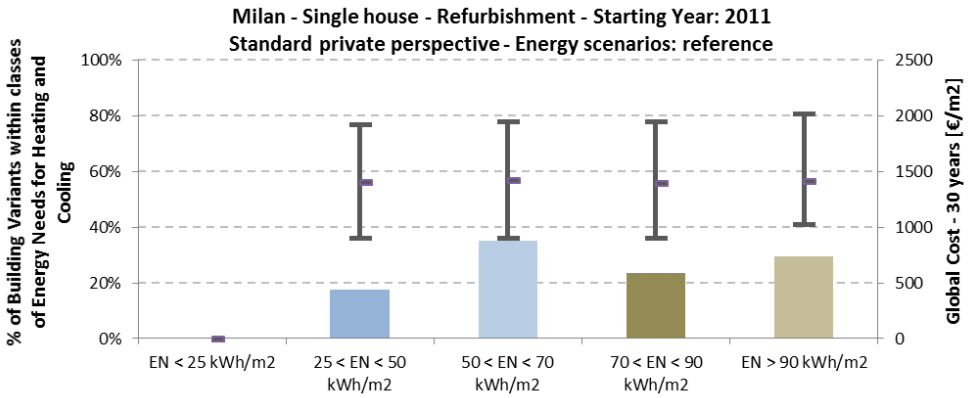

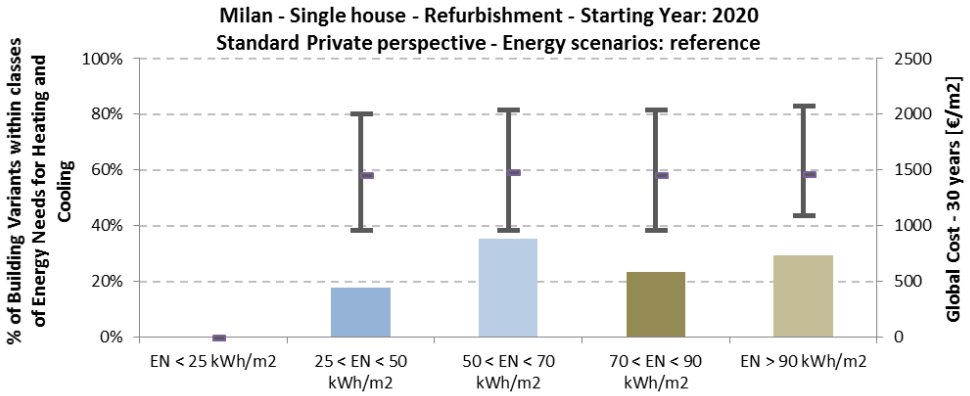

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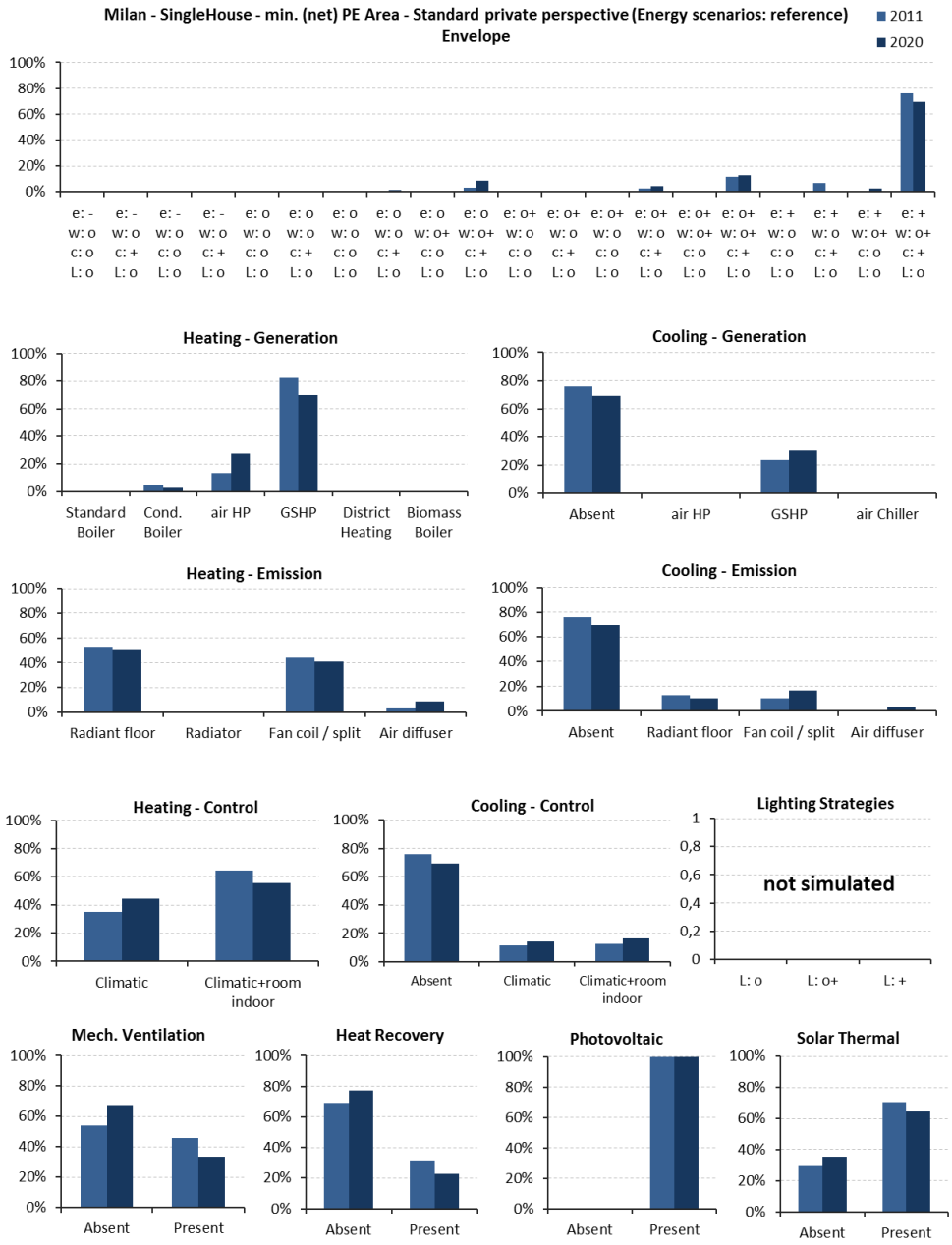
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	10	30	9	30
Range of Global Costs [€/m^2]:	1244	1493	1234	1461
Number of Building Variants:	150		150	



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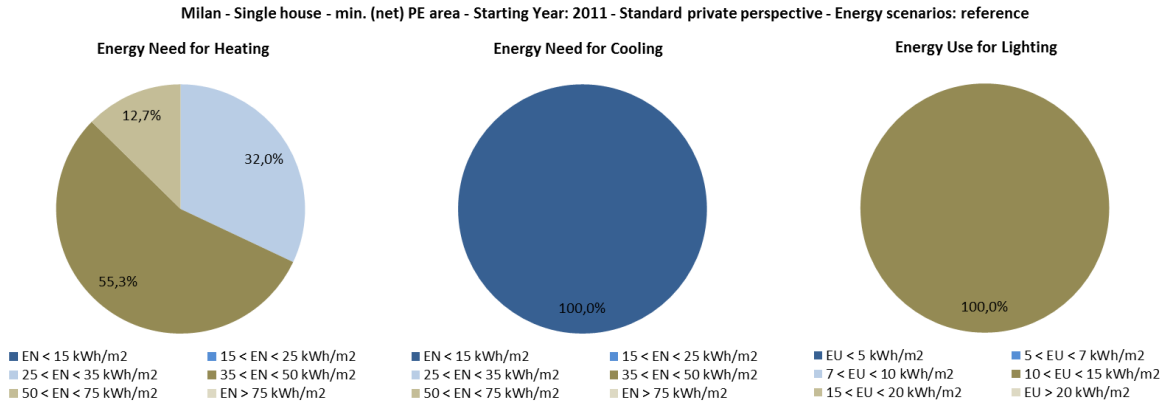

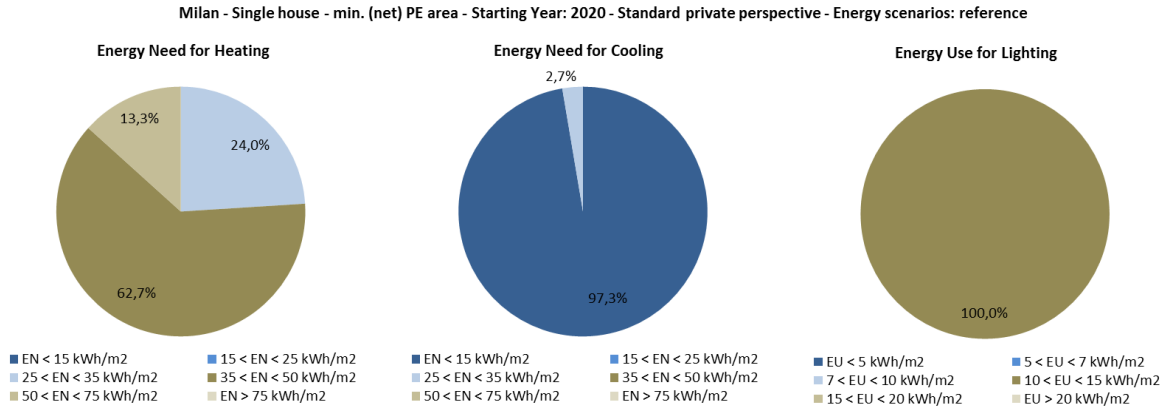

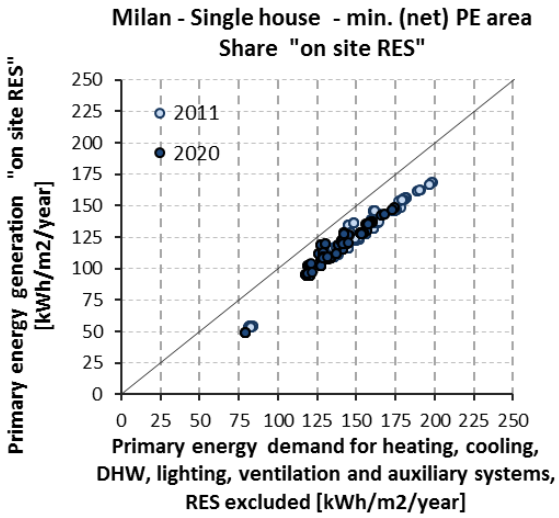

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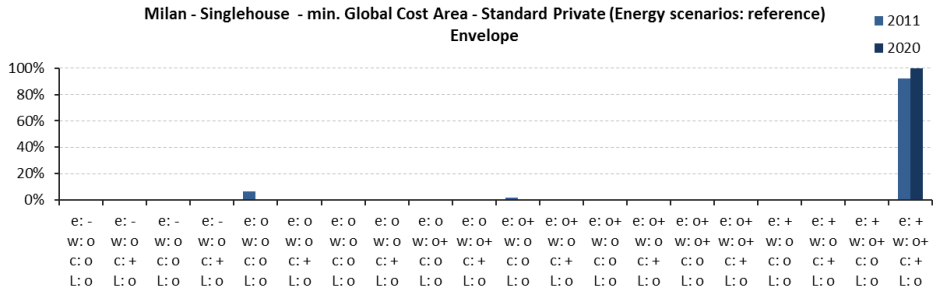
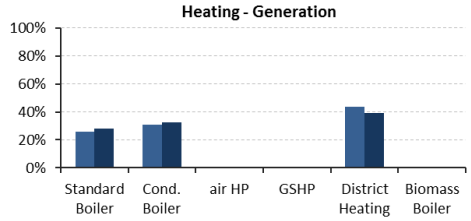
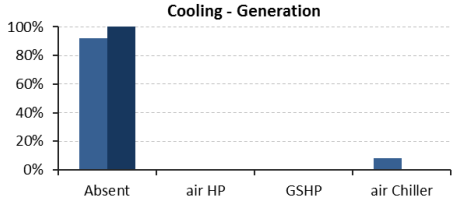
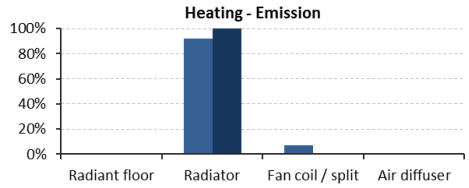
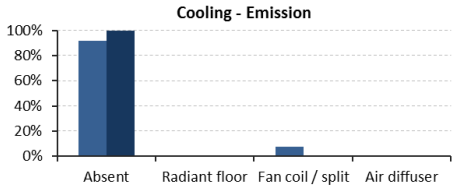
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	10	190	30	170
Range of Global Costs [€/m^2]:	904	1040	965	1091
Number of Building Variants:	124		122	

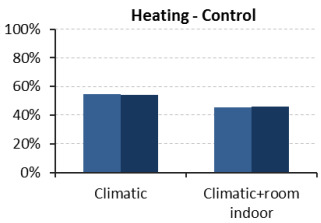


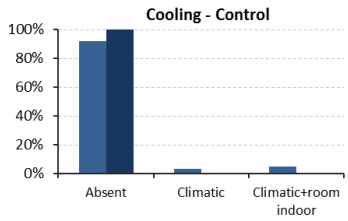


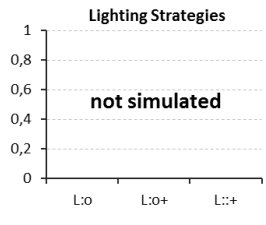


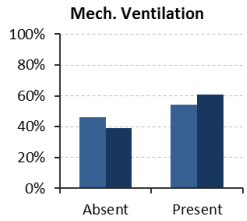


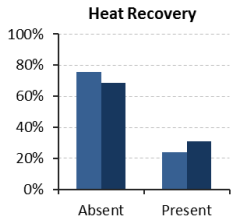


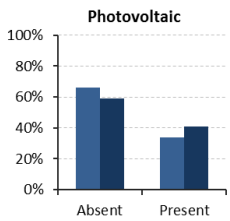


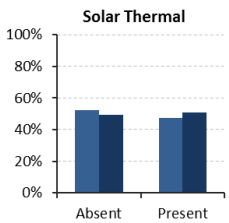












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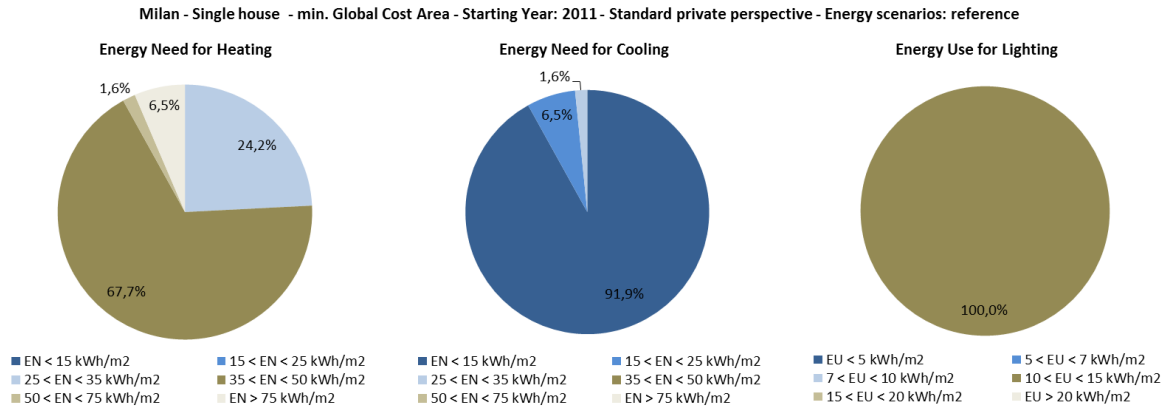

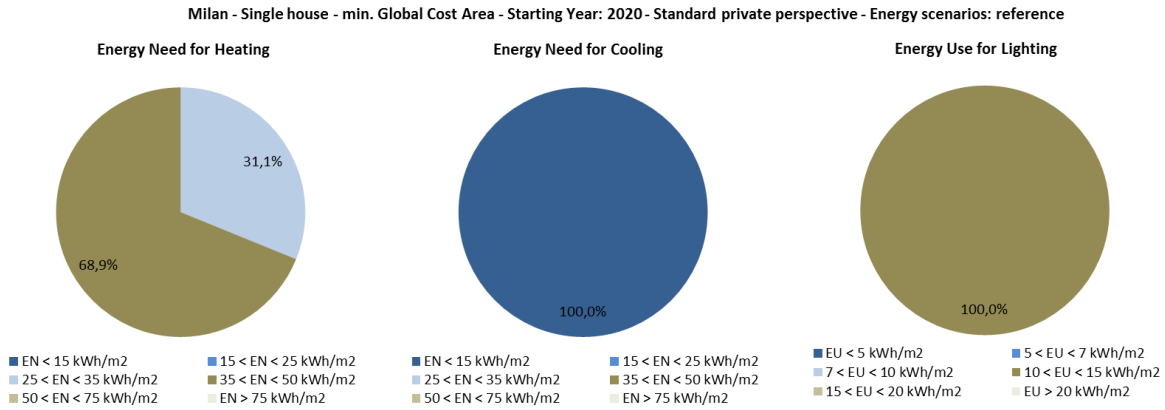

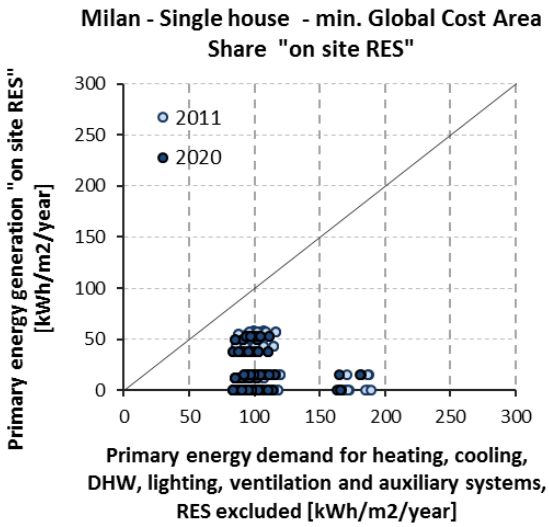

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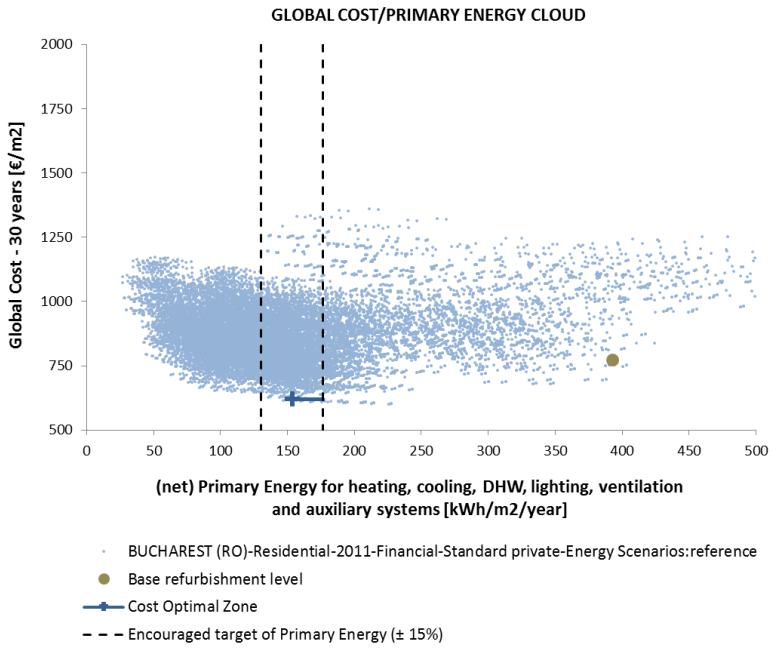
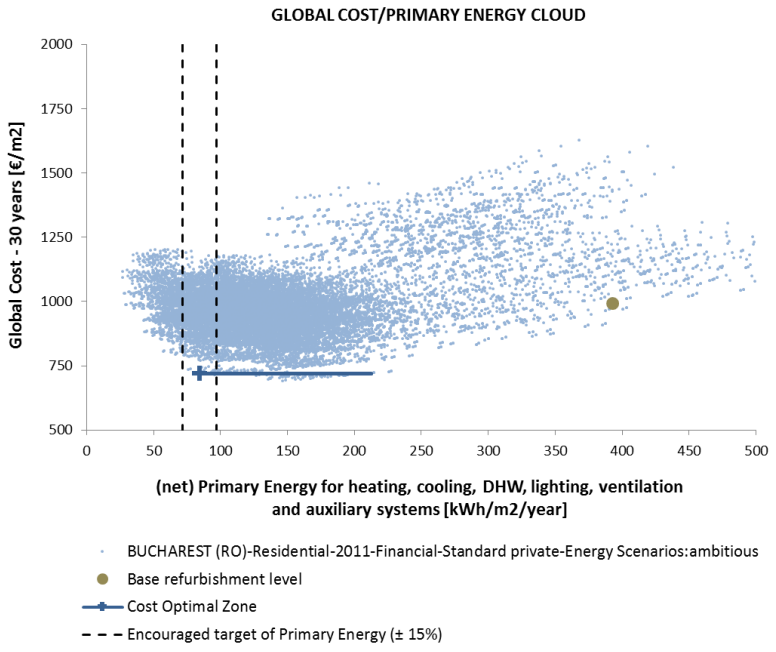
8.1.1.5 Bucharest





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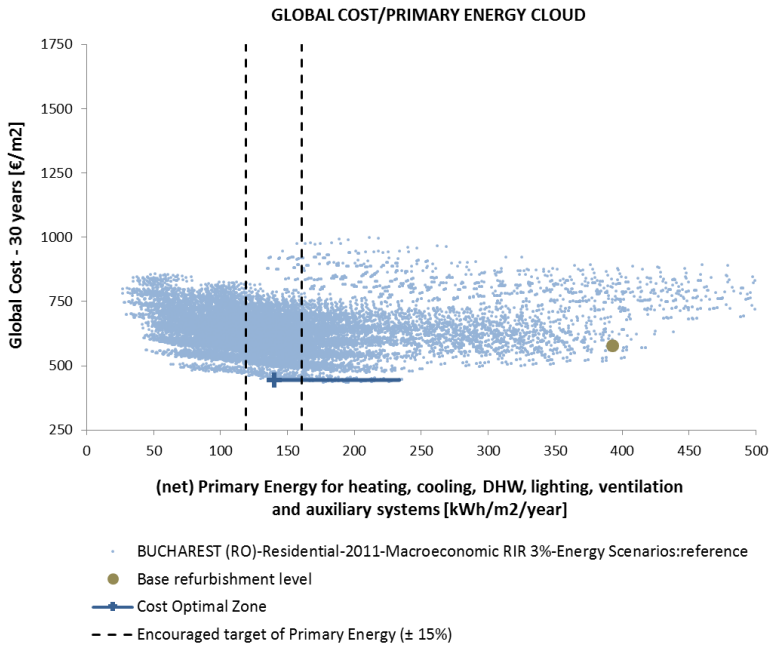

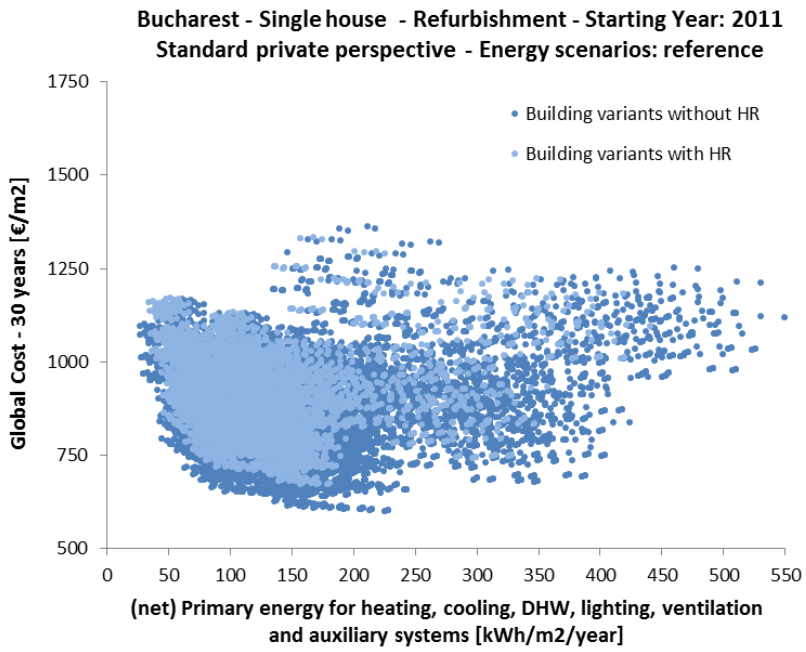

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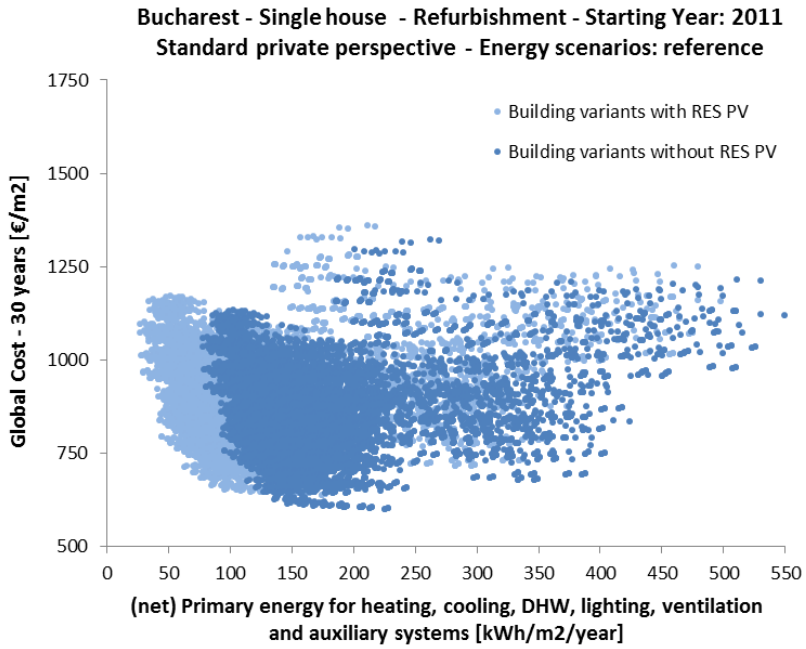

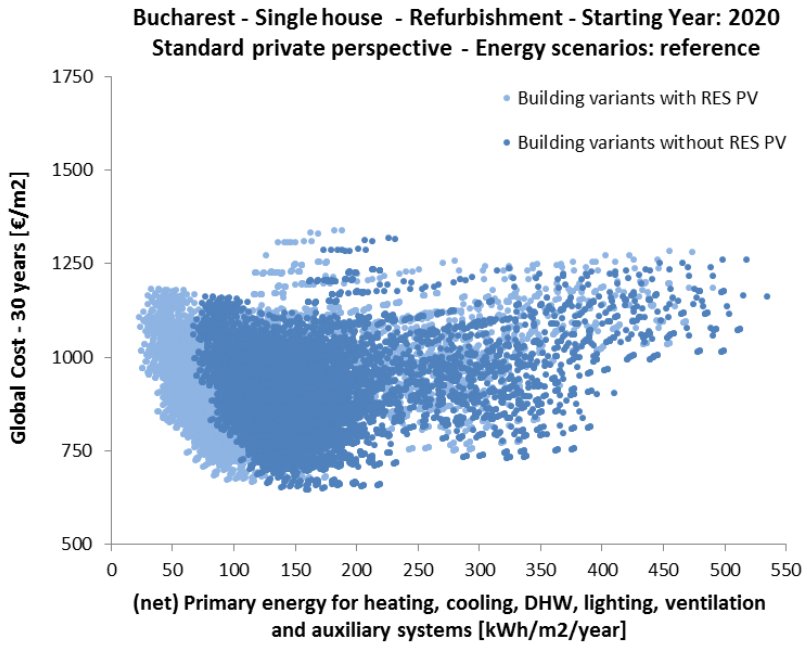

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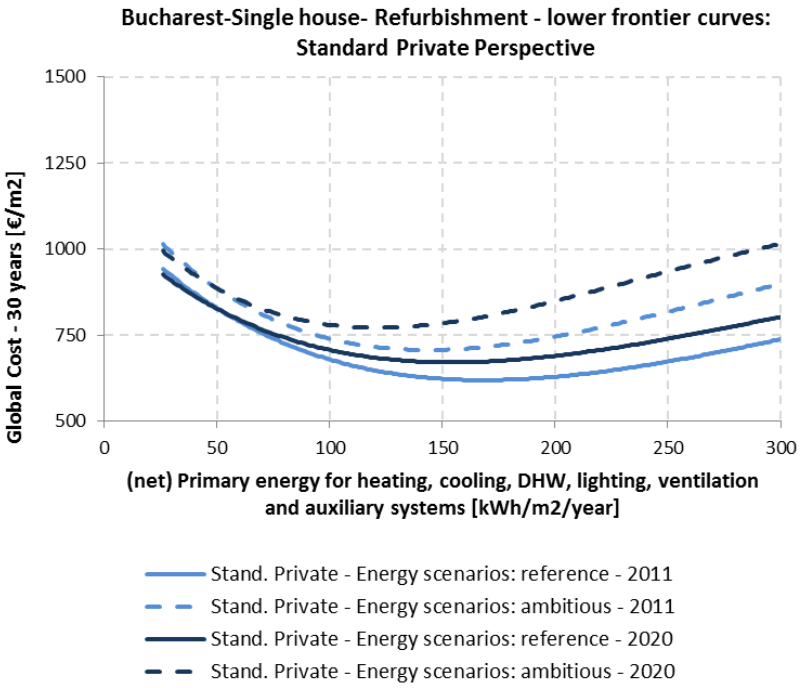

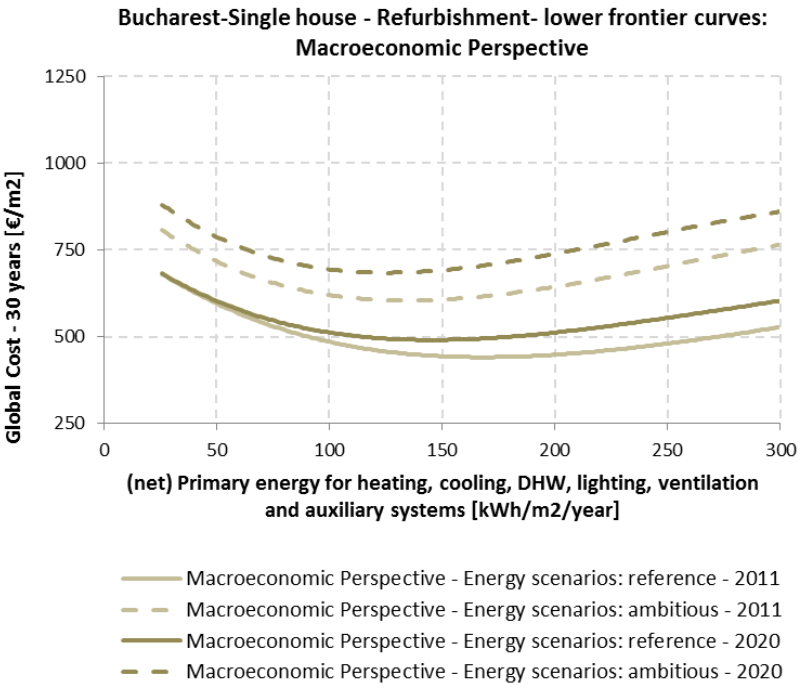

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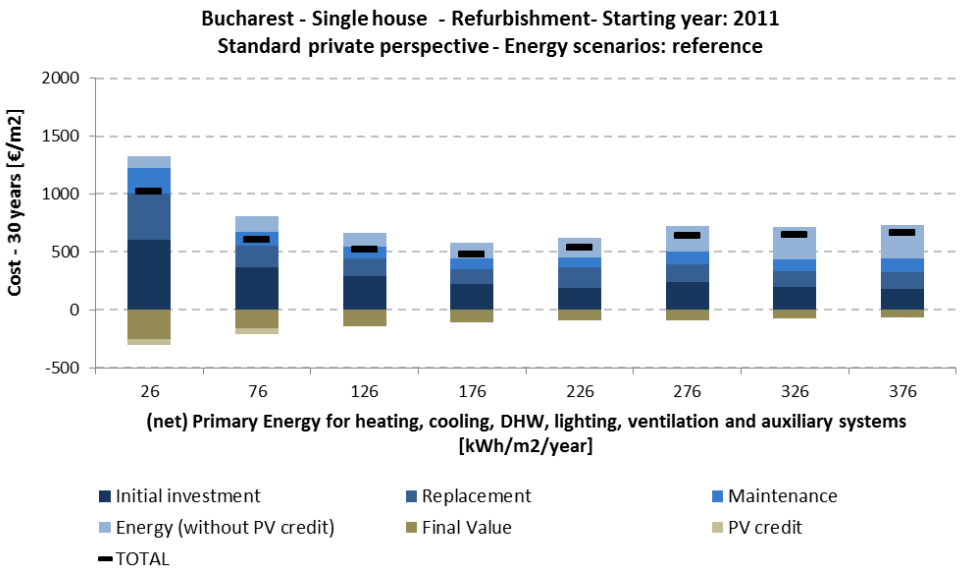

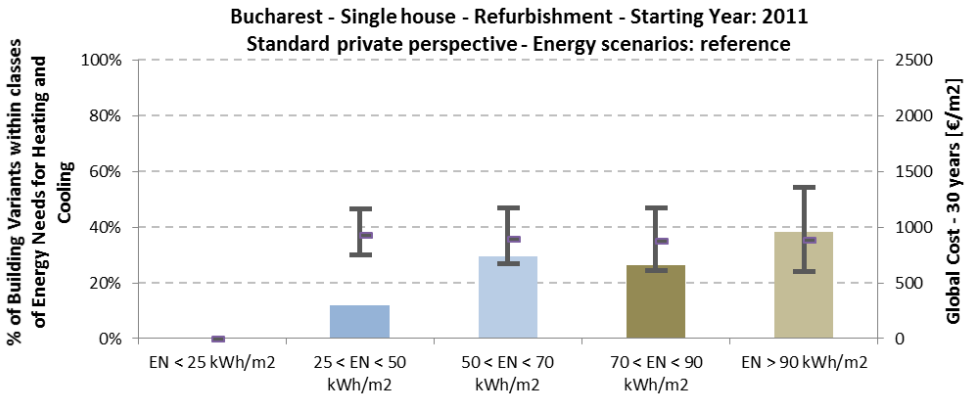

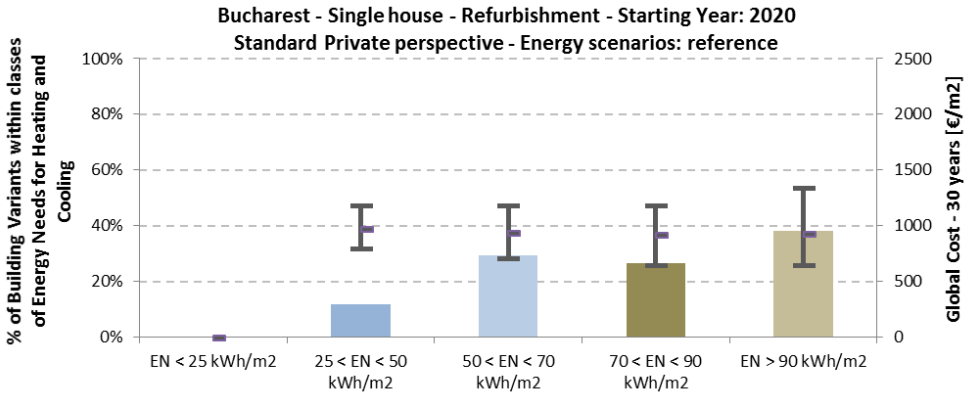

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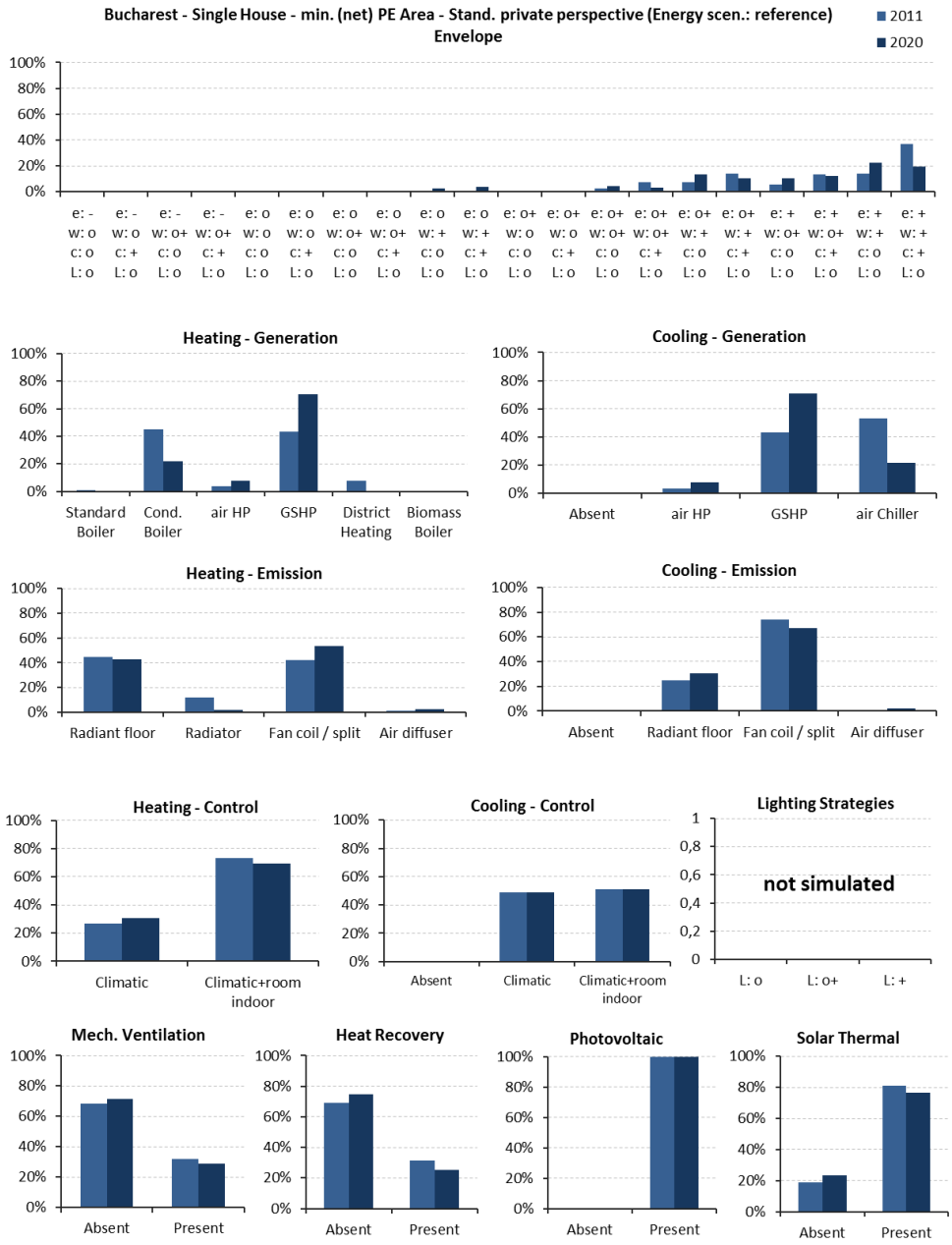
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	27	56	23	52
Range of Global Costs [€/m^2]:	774	968	811	976
Number of Building Variants:	167		167	



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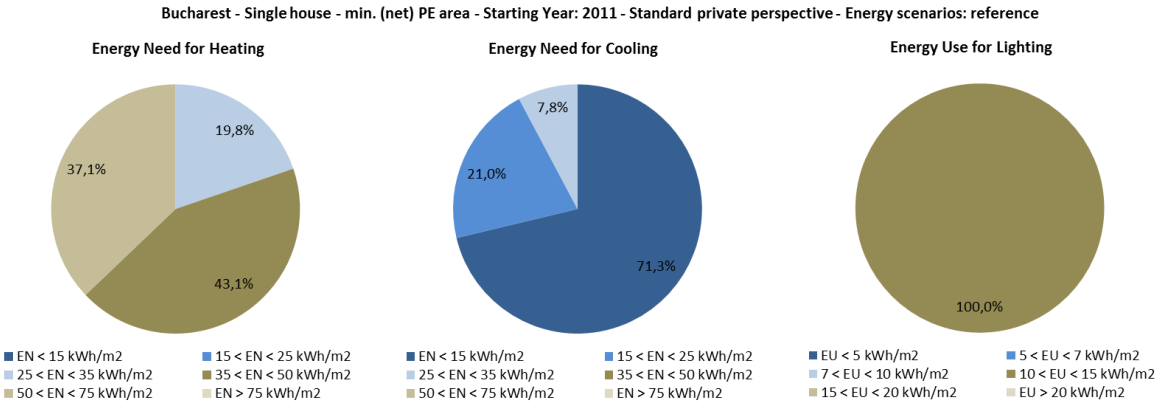

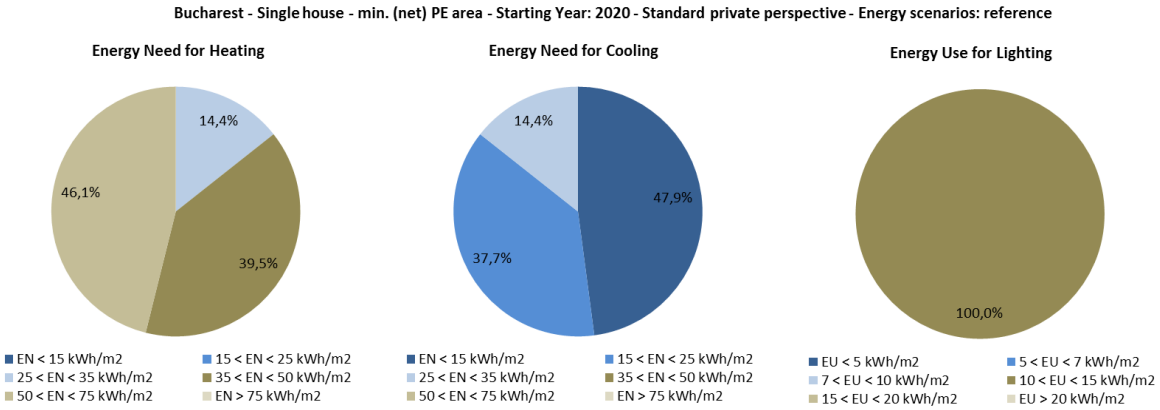

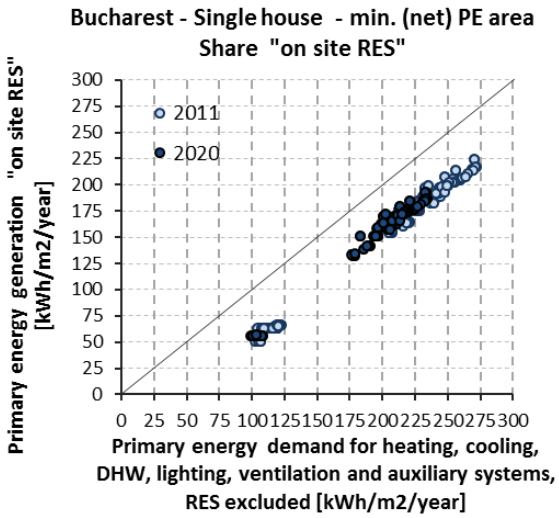

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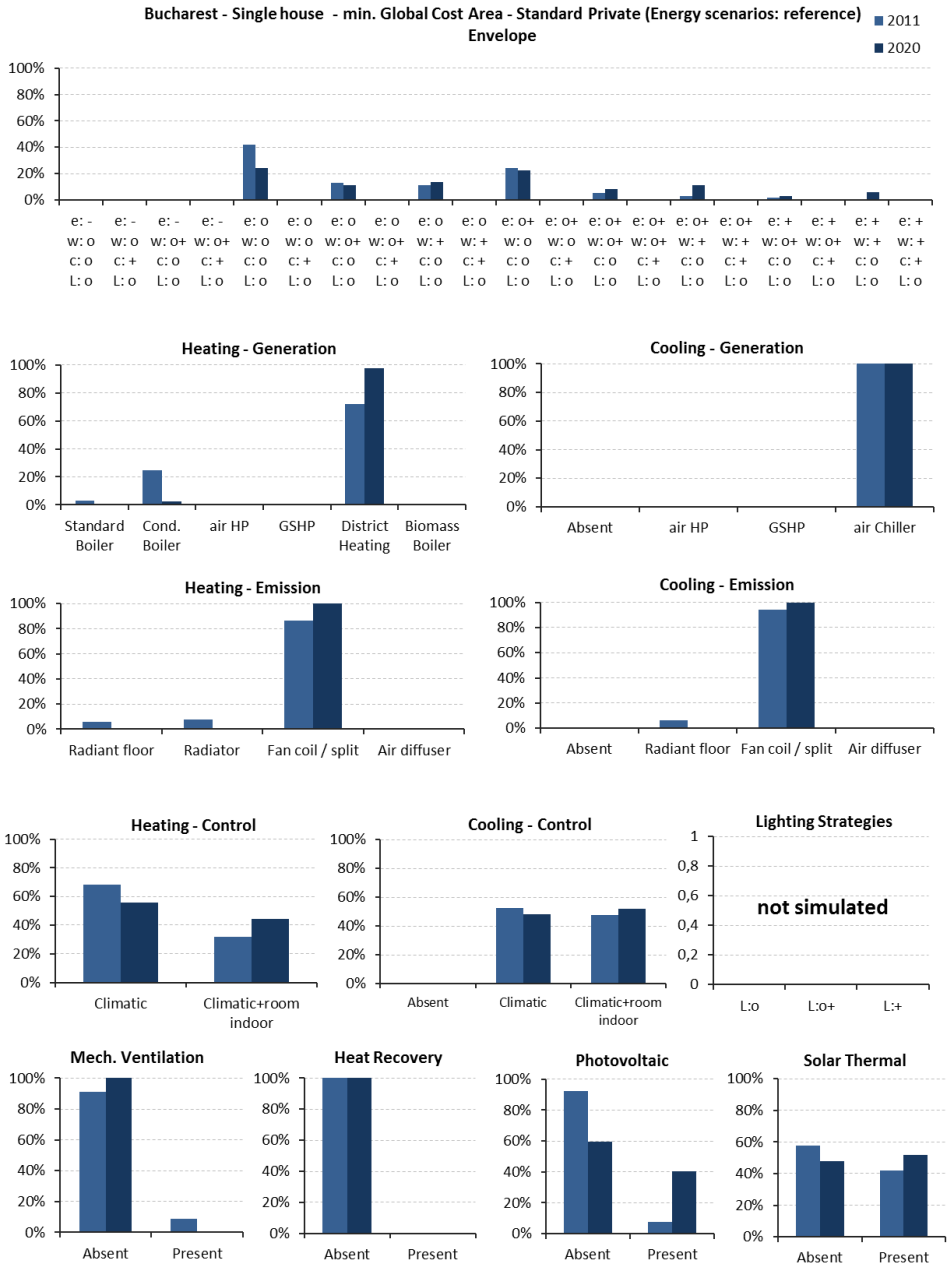
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	156	311	88	243
Range of Global Costs [€/m^2]:	602	662	645	693
Number of Building Variants:	133		133	



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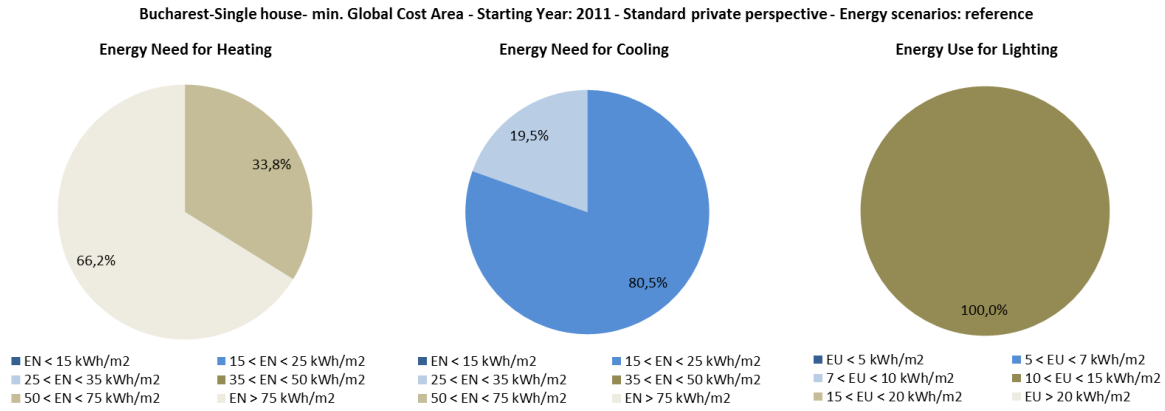

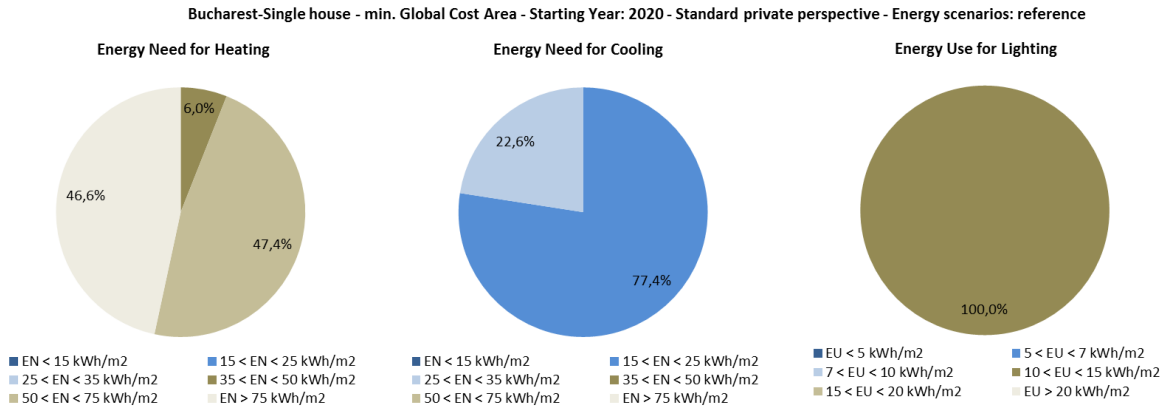

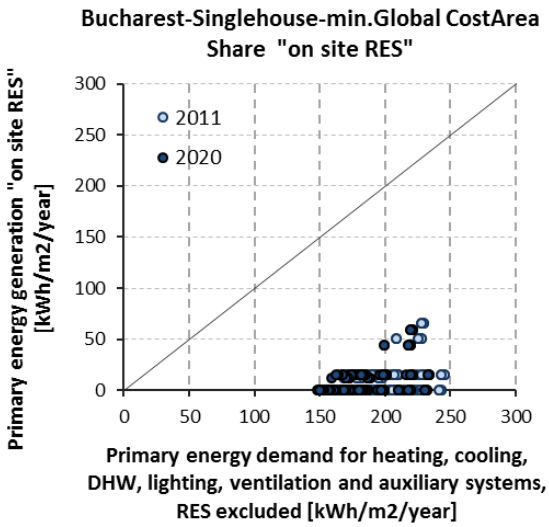

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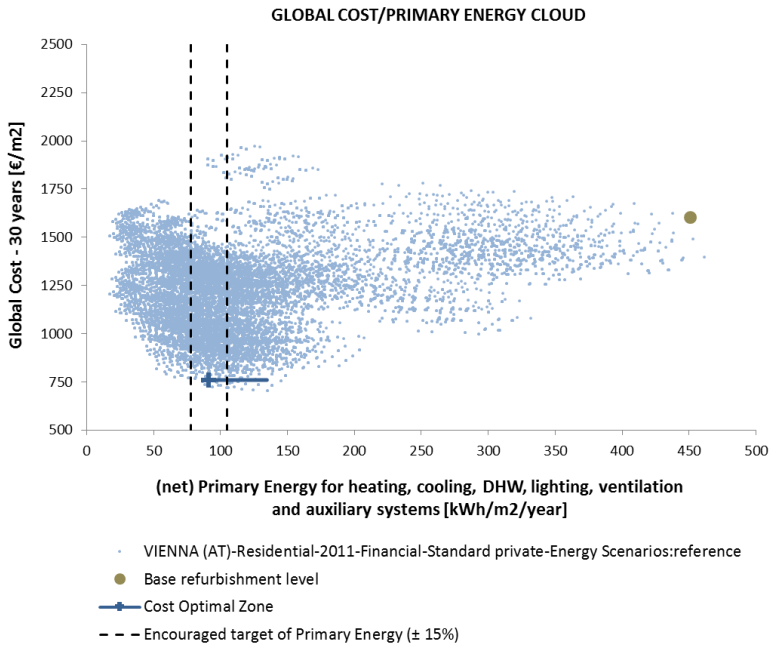
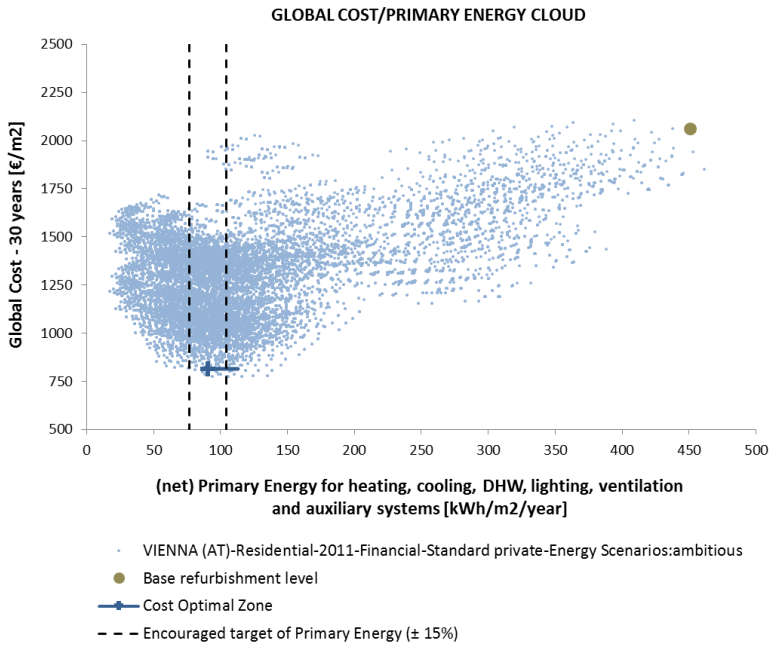
8.1.1.6 Vienna





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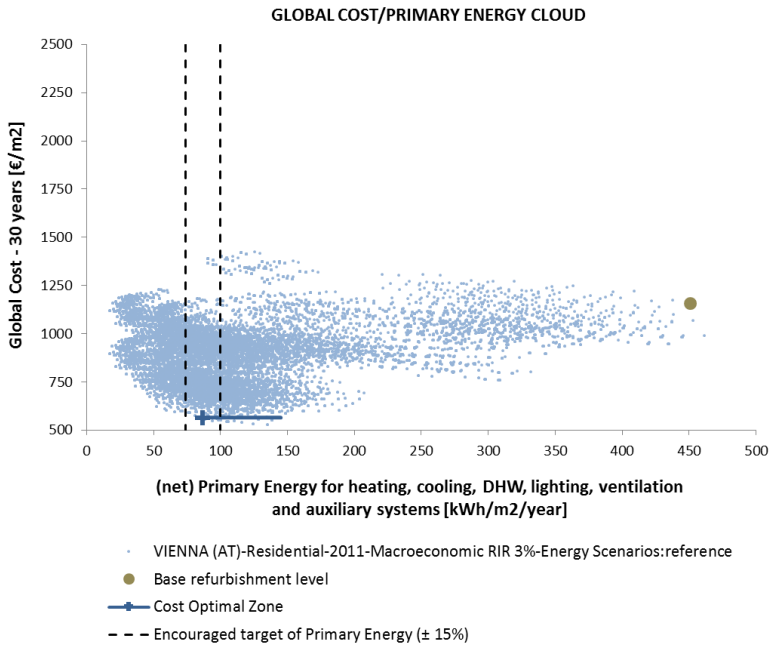

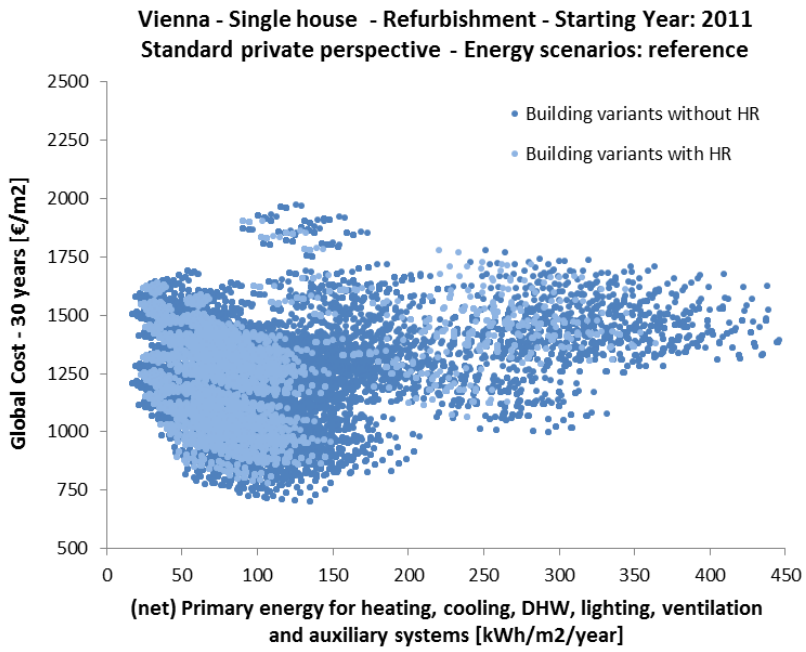

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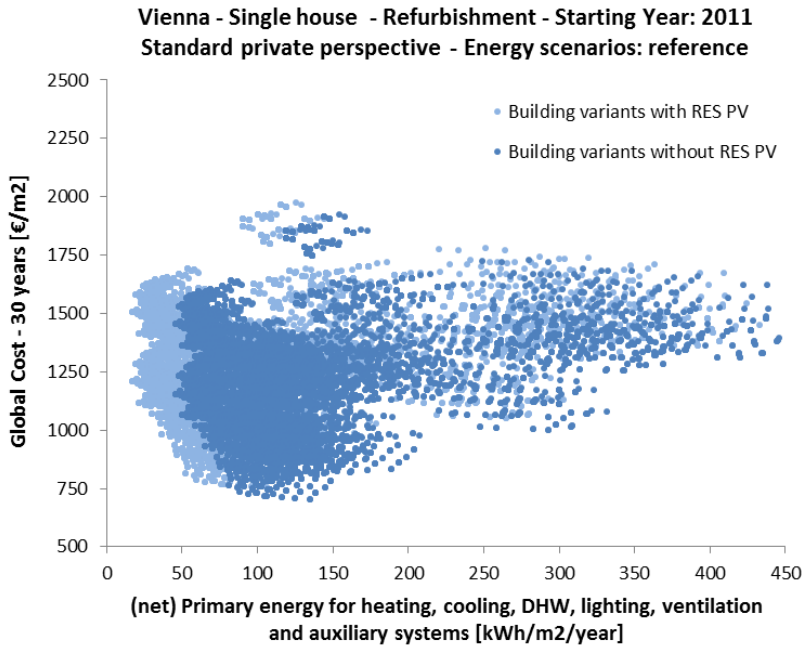

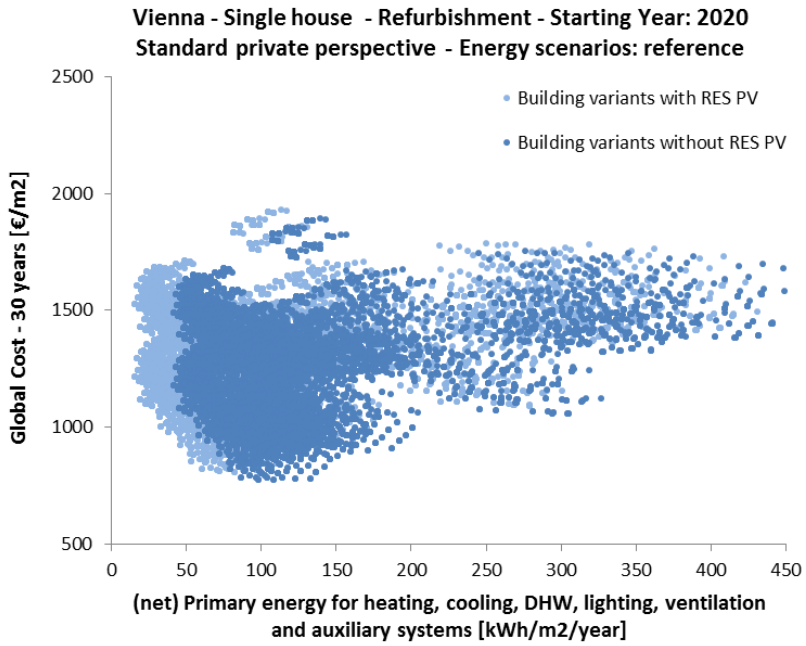

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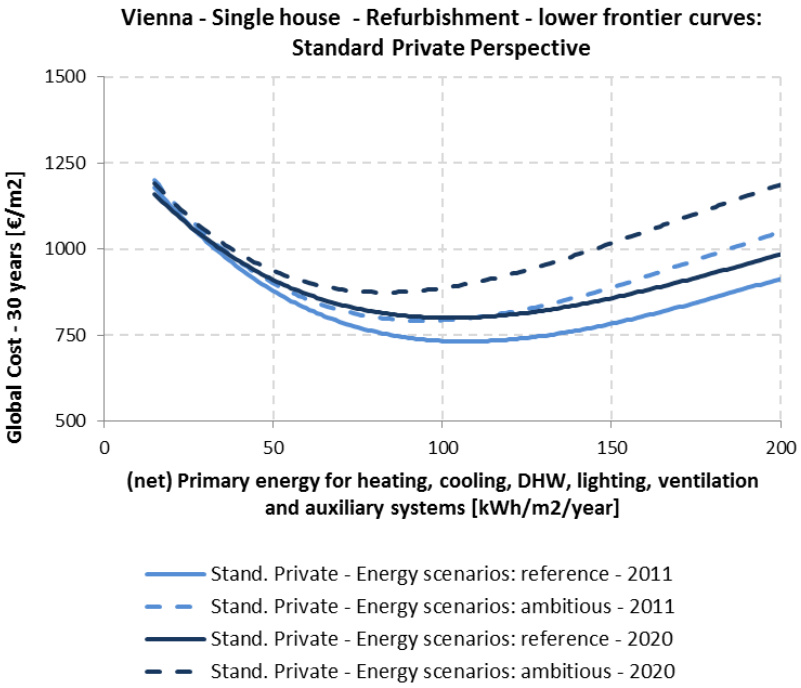

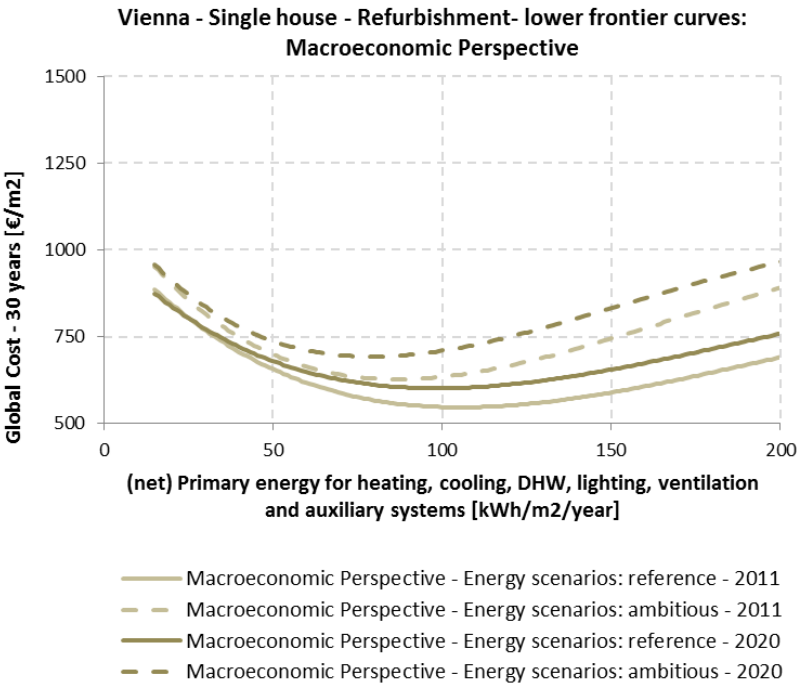

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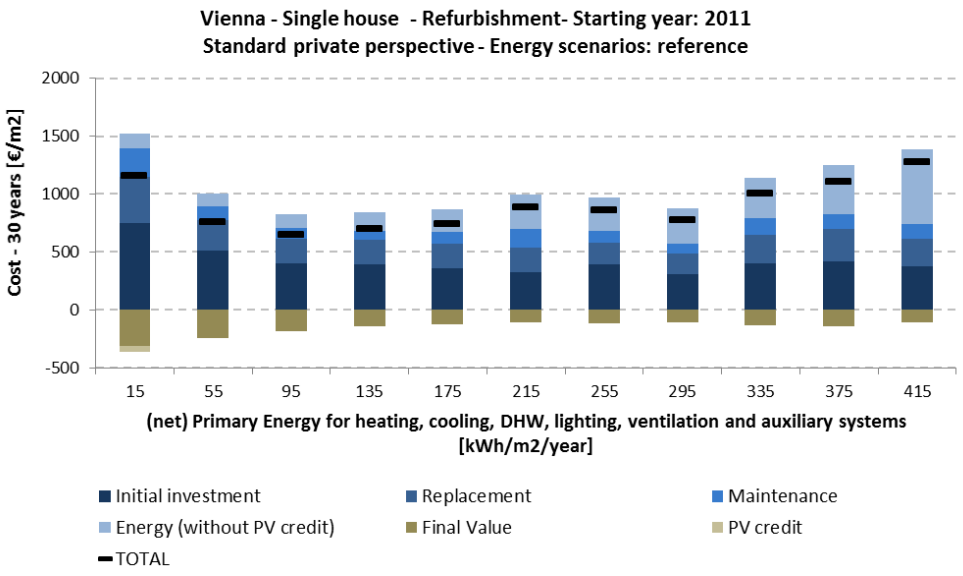

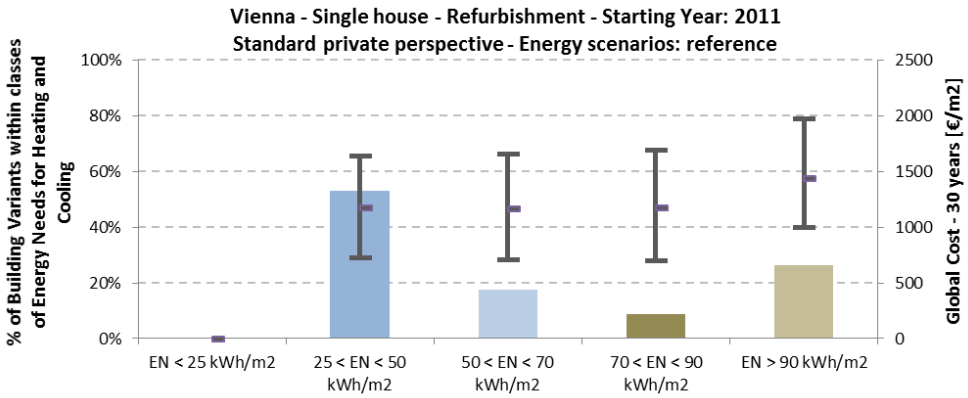

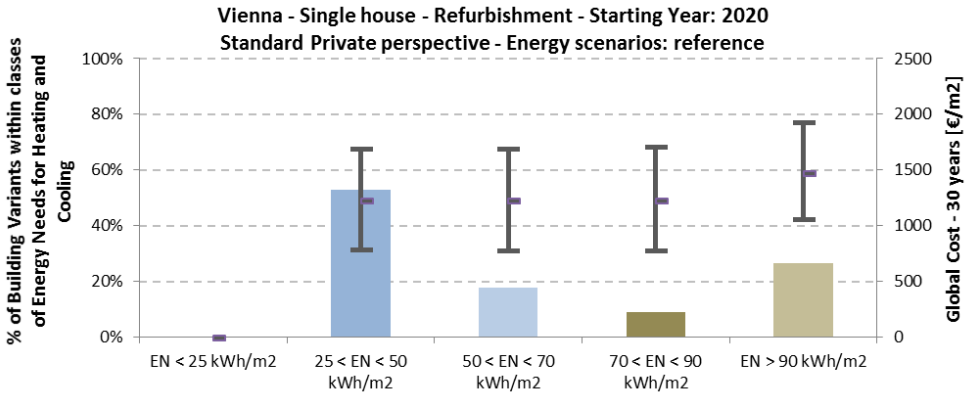

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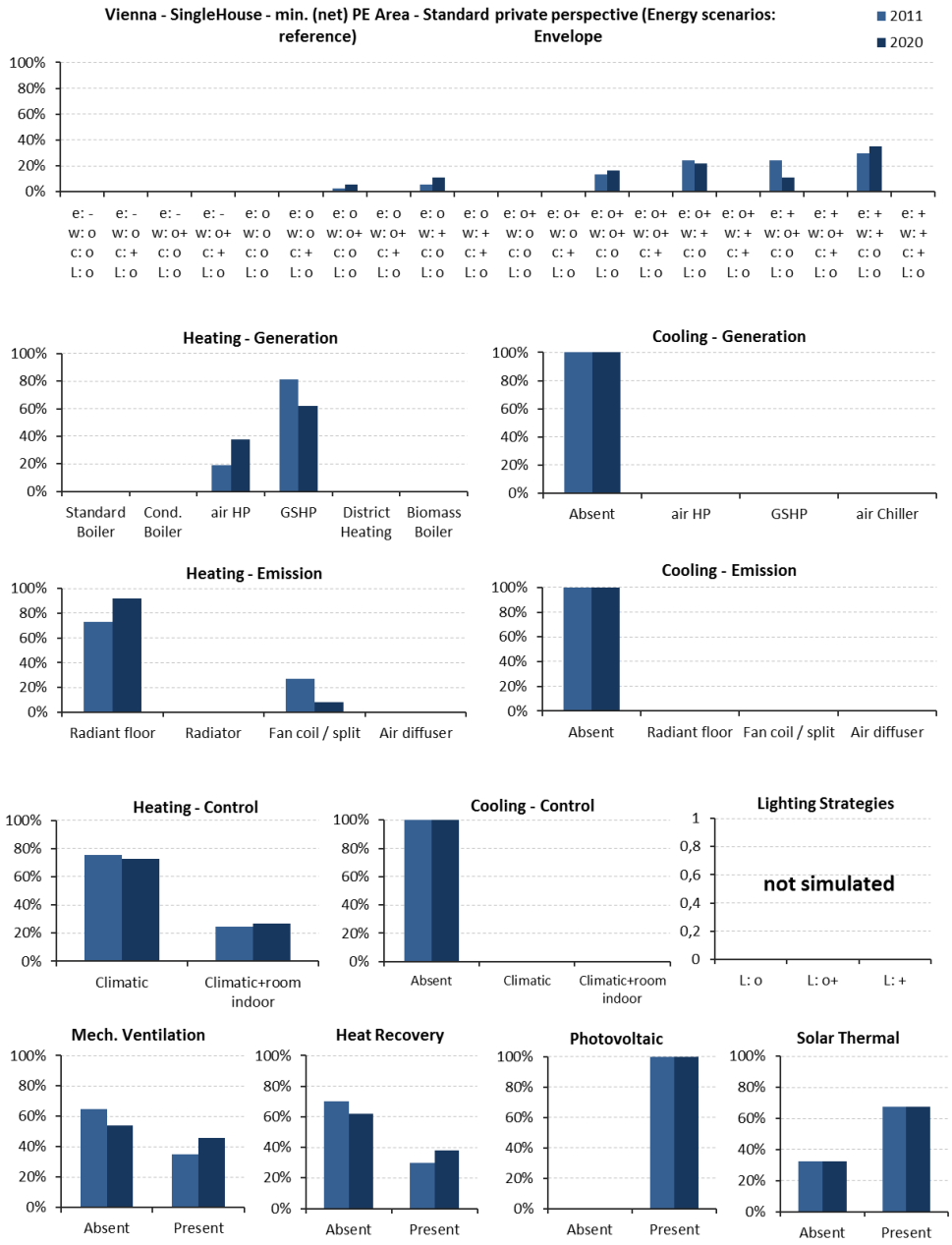
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	17	35	16	35
Range of Global Costs [€/m²]:	984	1201	1001	1171
Number of Building Variants:	148		148	



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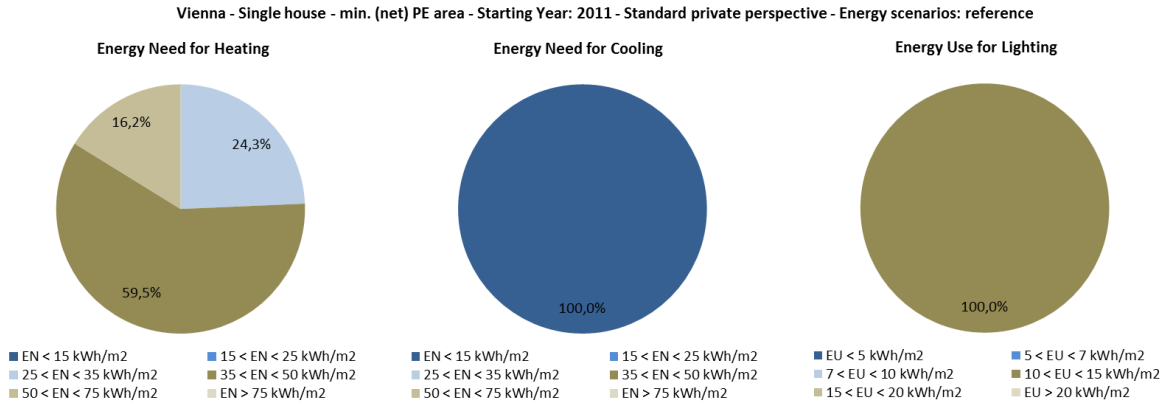

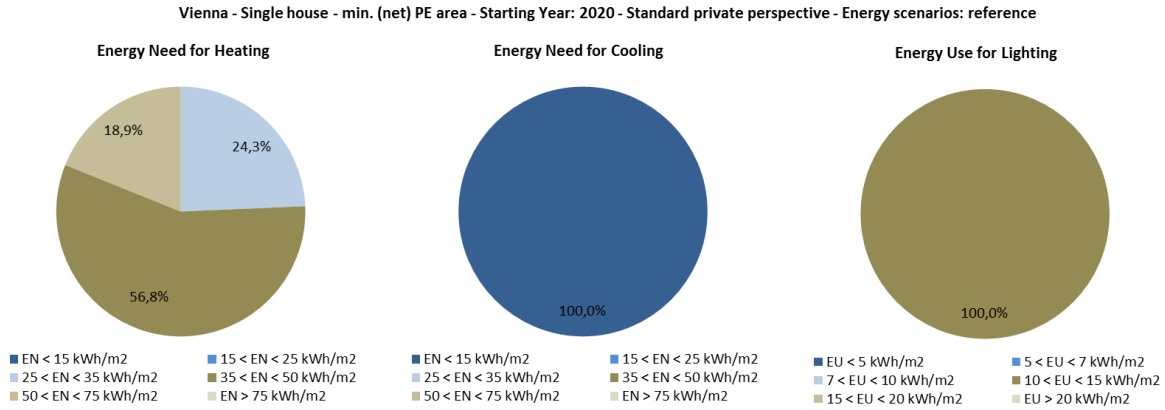

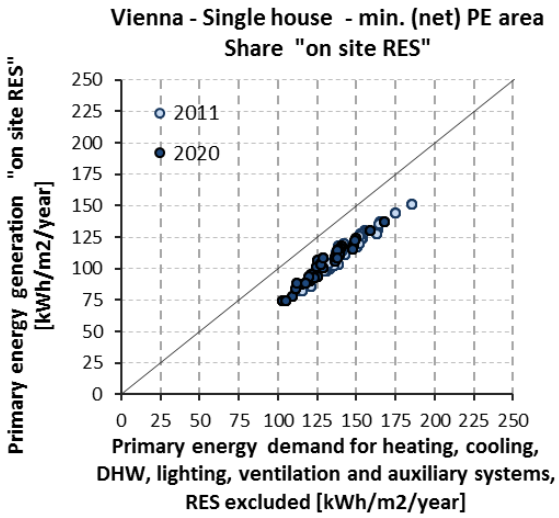

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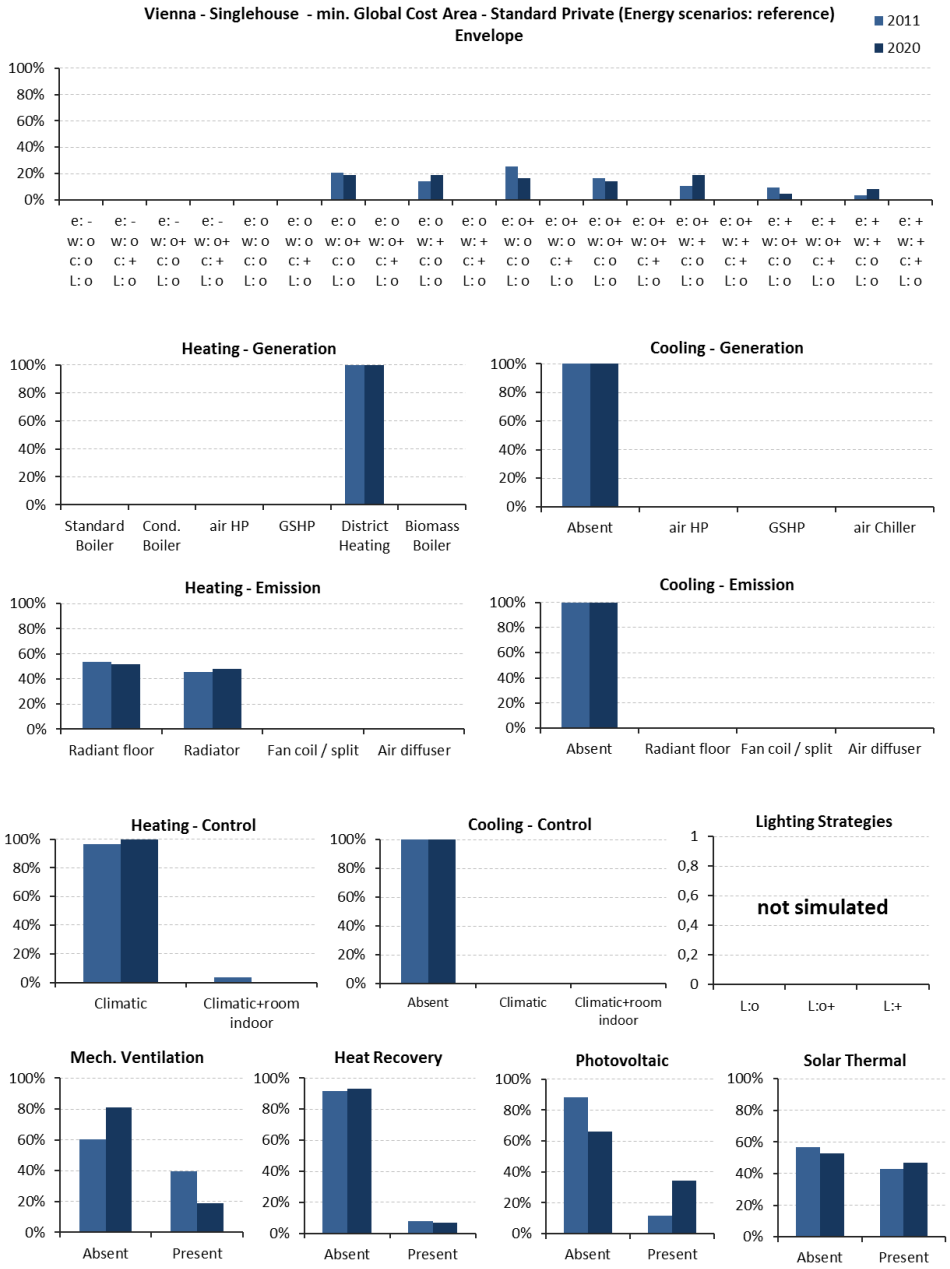
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	85	185	60	160
Range of Global Costs [€/m^2]:	703	809	776	856
Number of Building Variants:	172		172	



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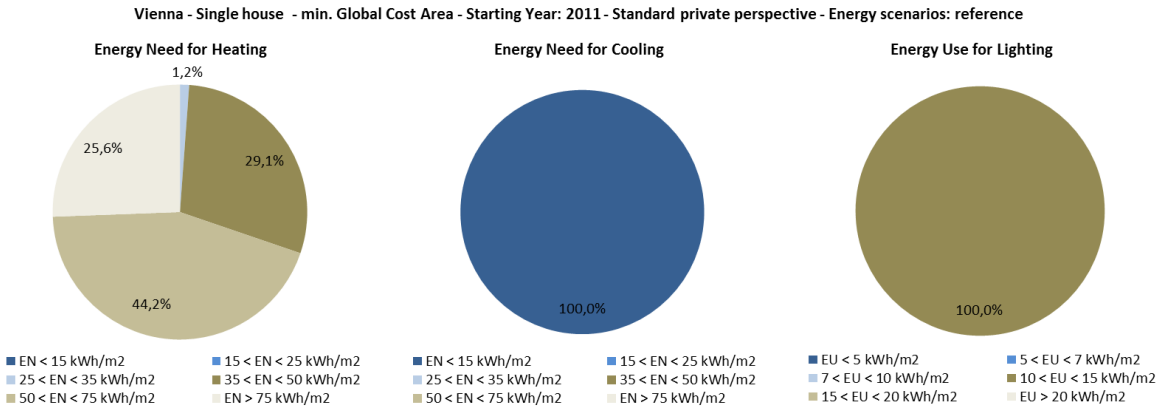

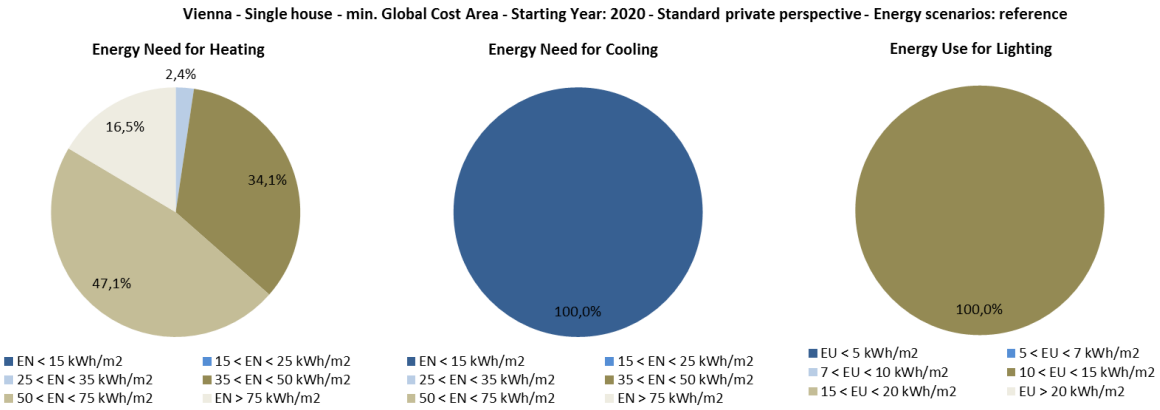

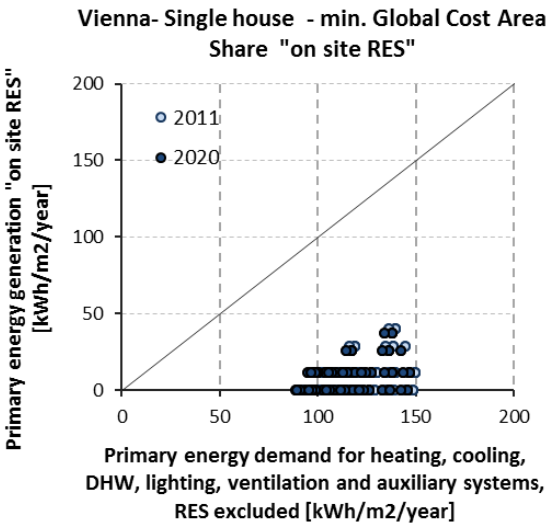

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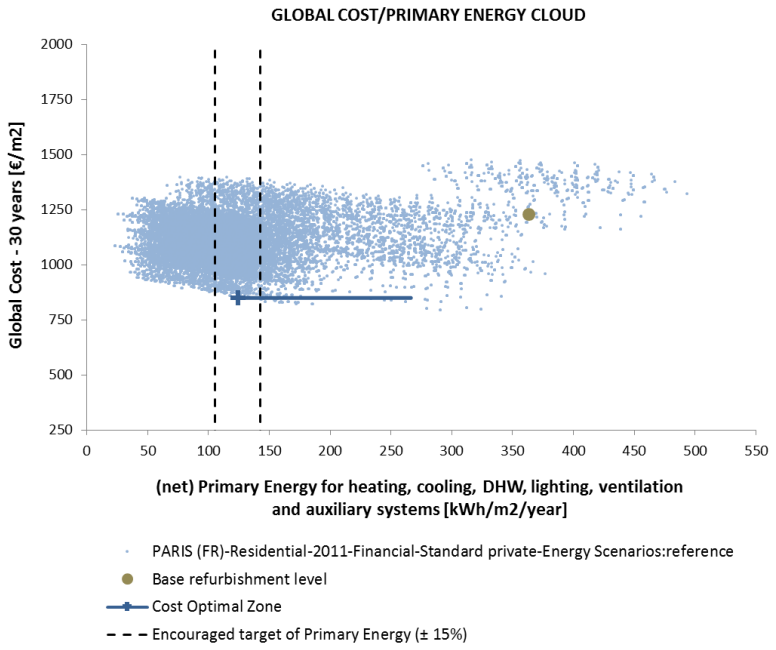
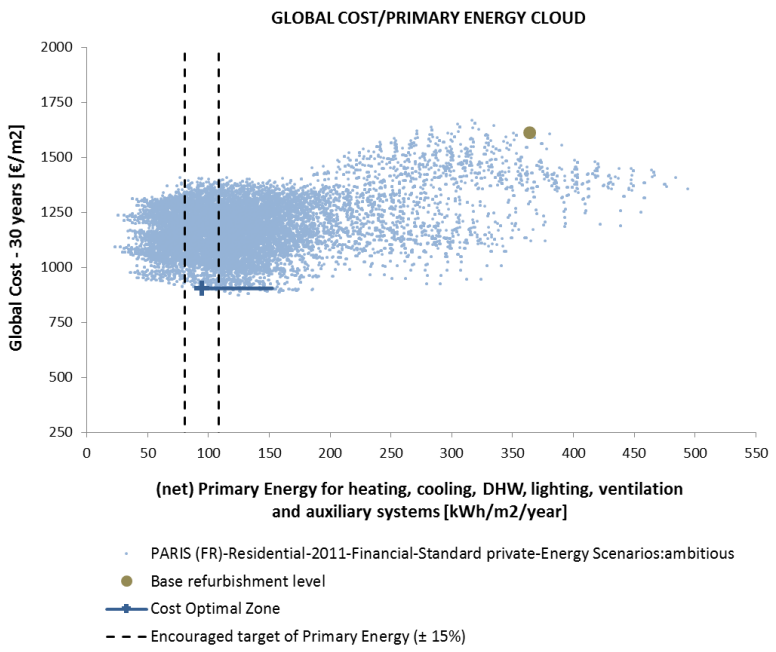
8.1.1.7 Paris





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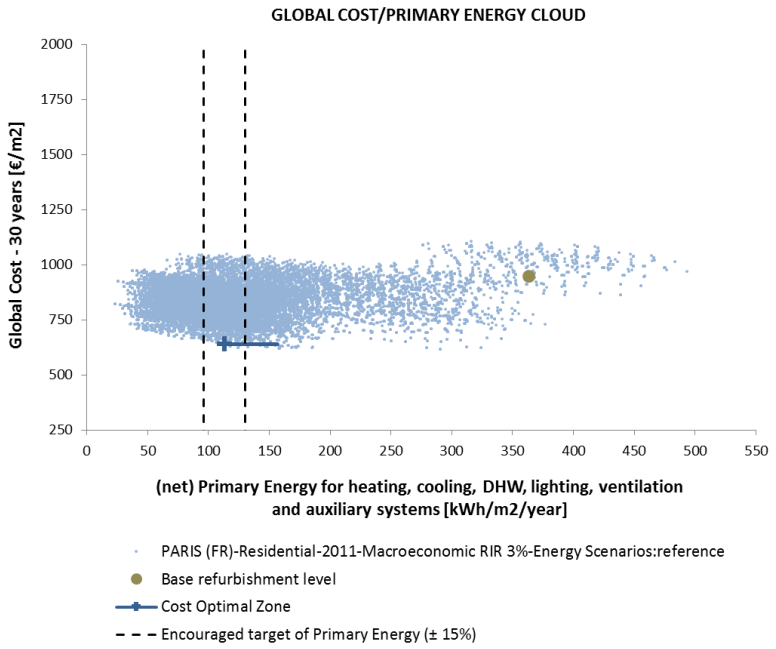

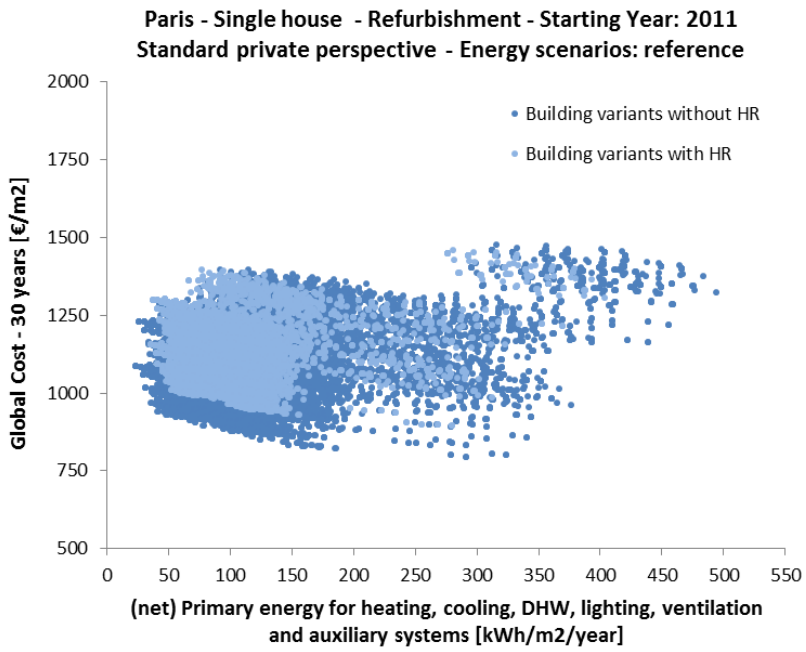

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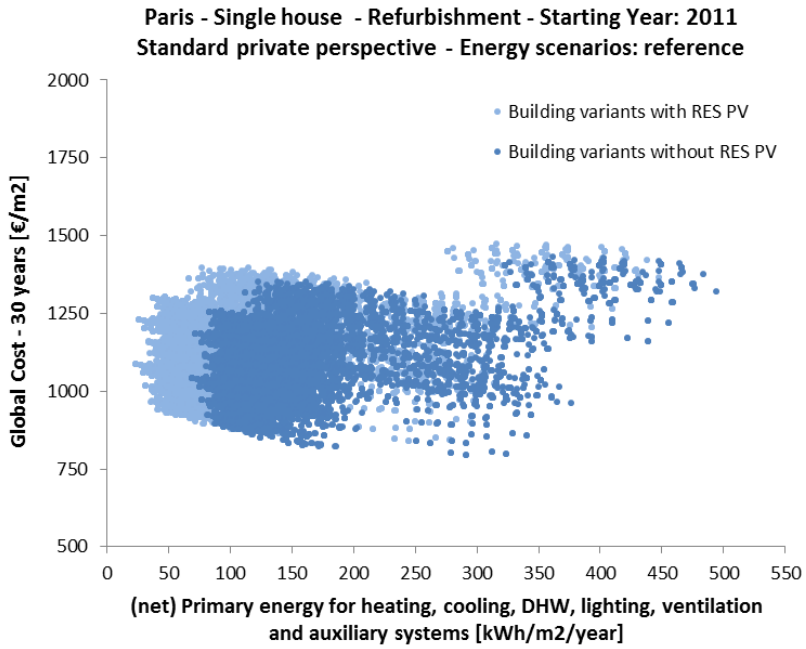

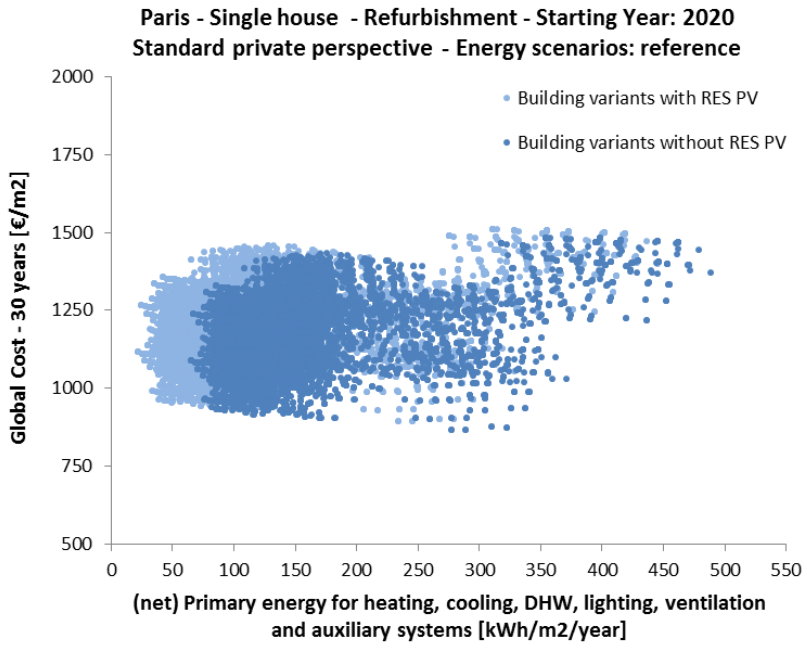

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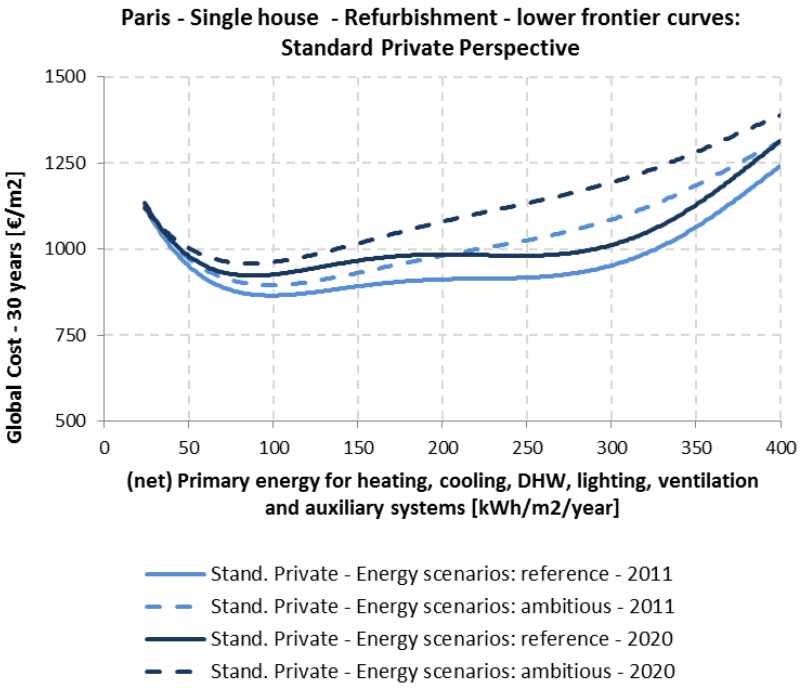

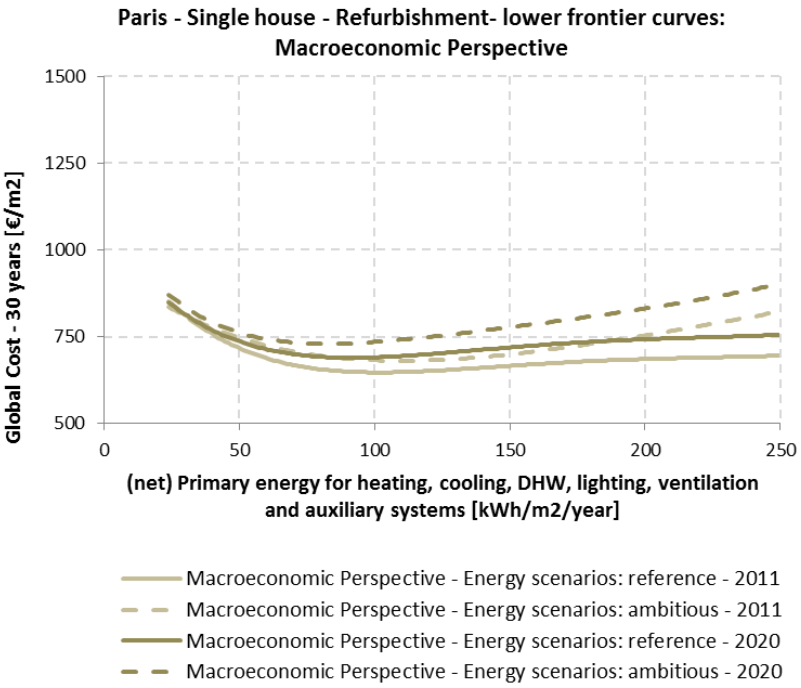

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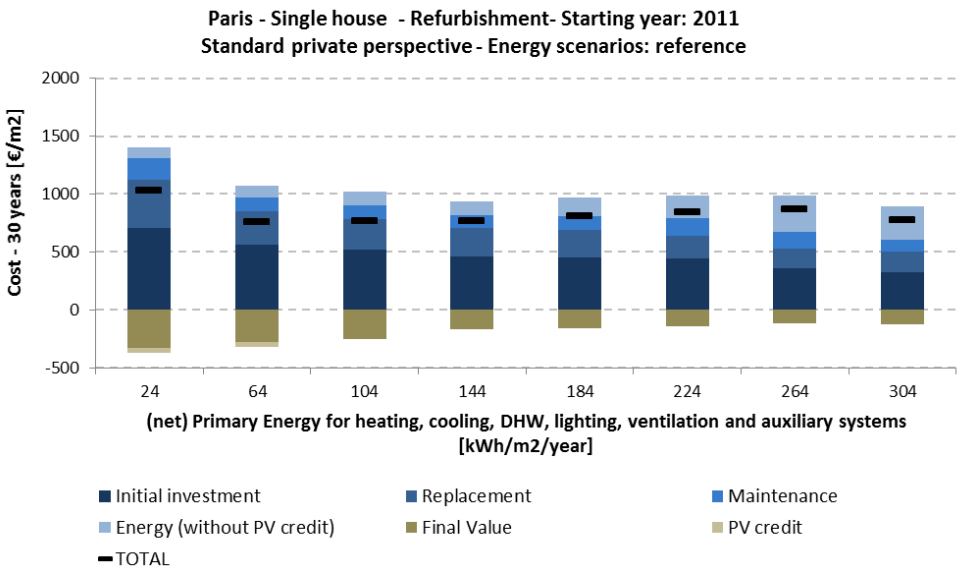

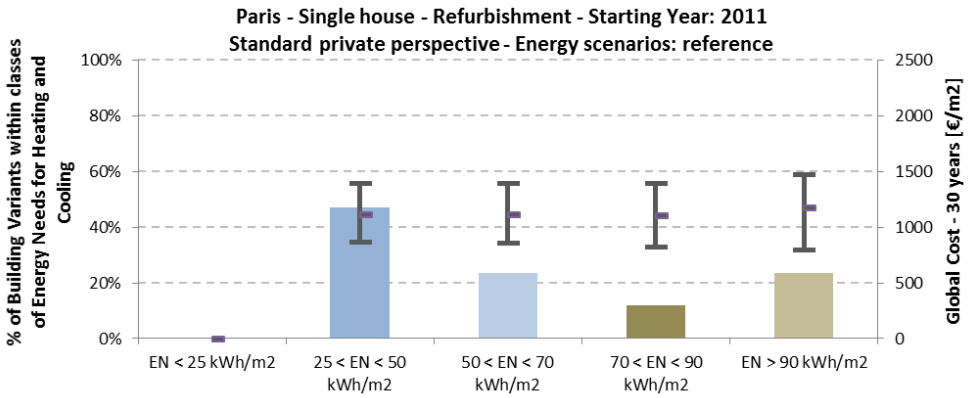

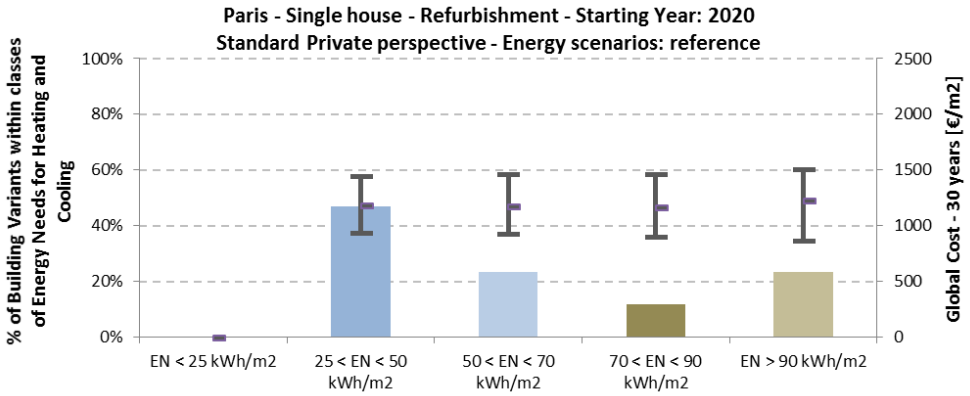

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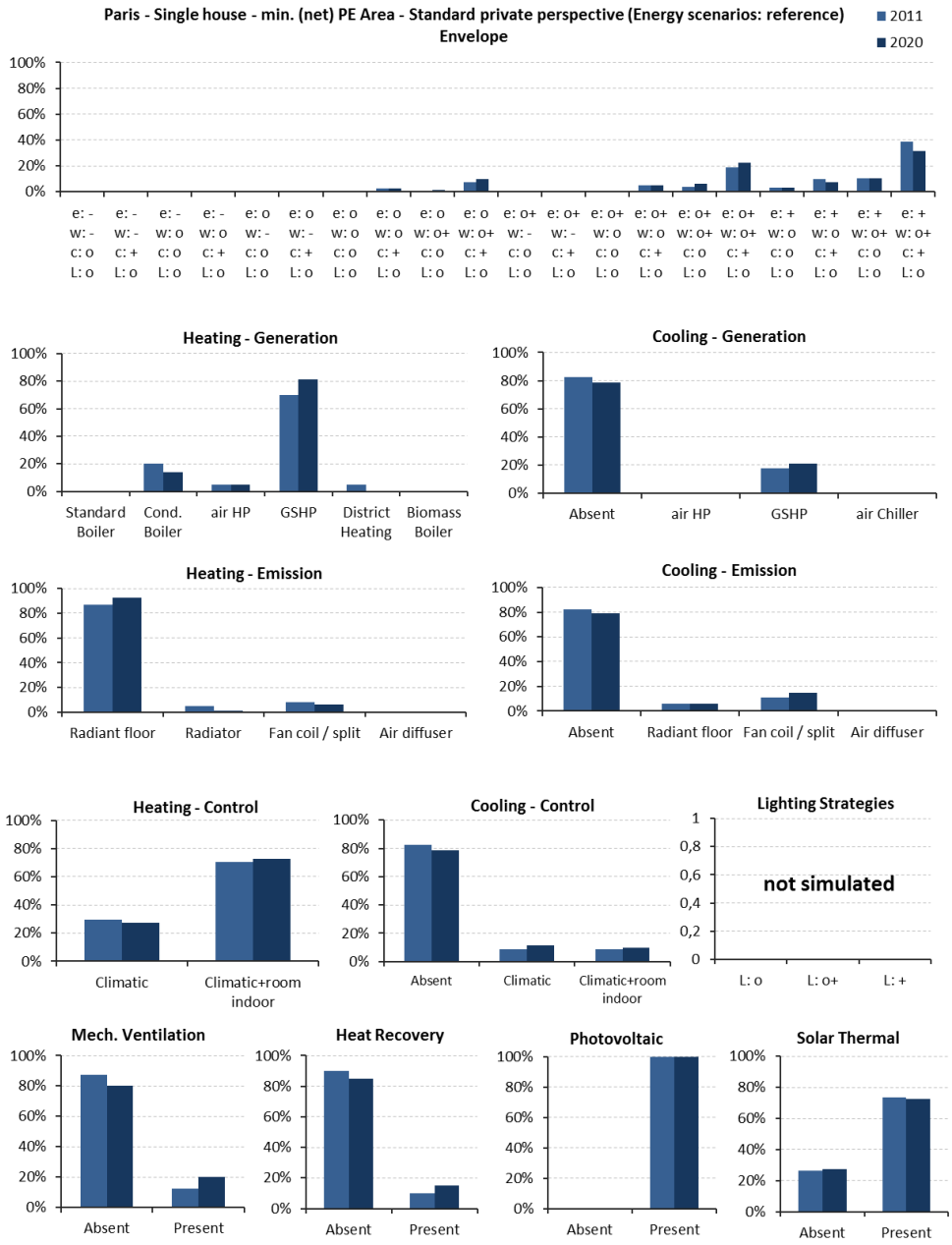
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	23	44	22	42
Range of Global Costs [€/m²]:	959	1151	961	1185
Number of Building Variants:	160		160	



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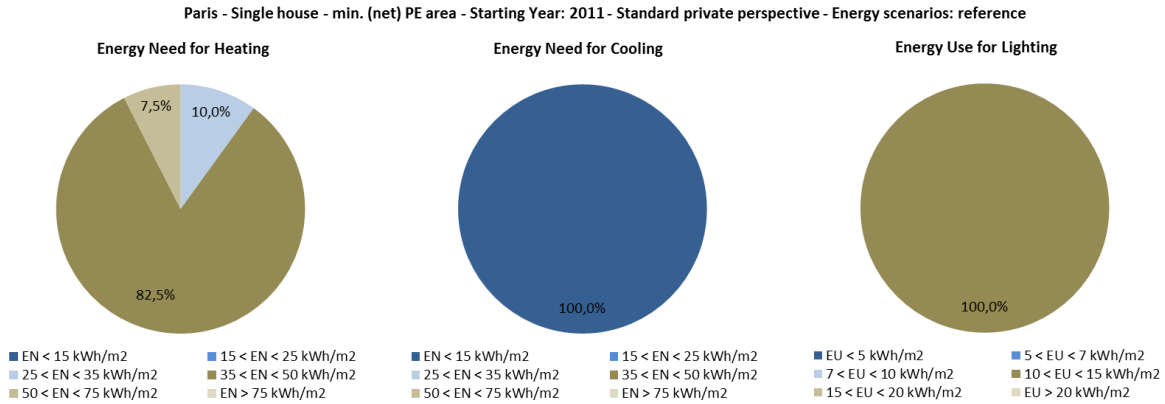
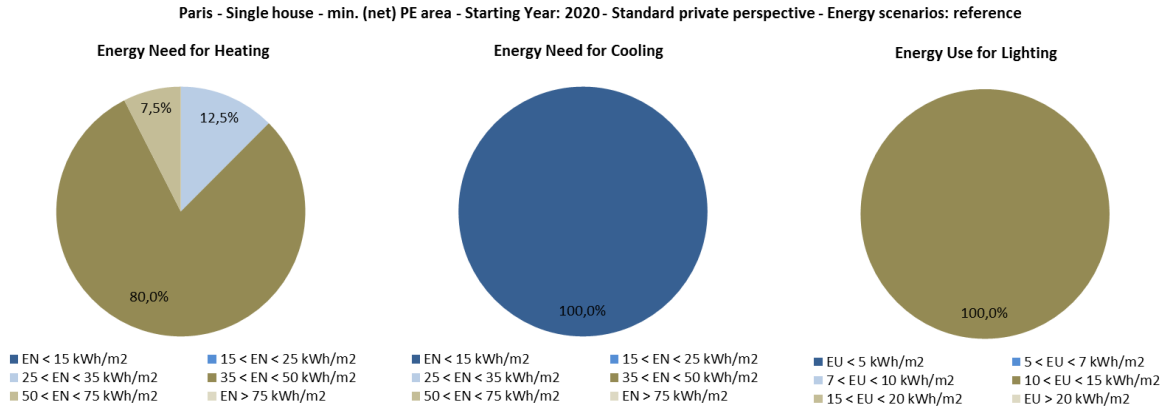
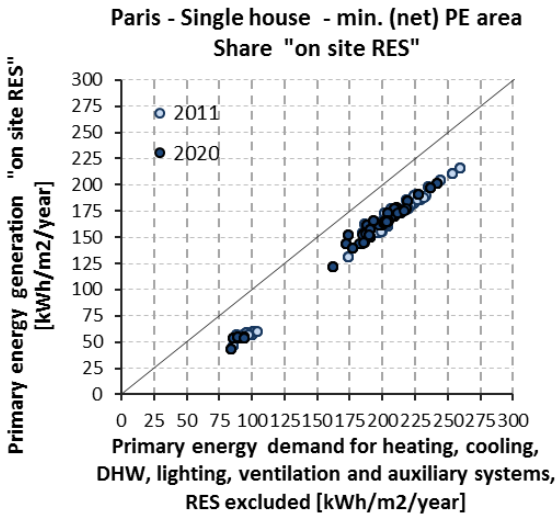
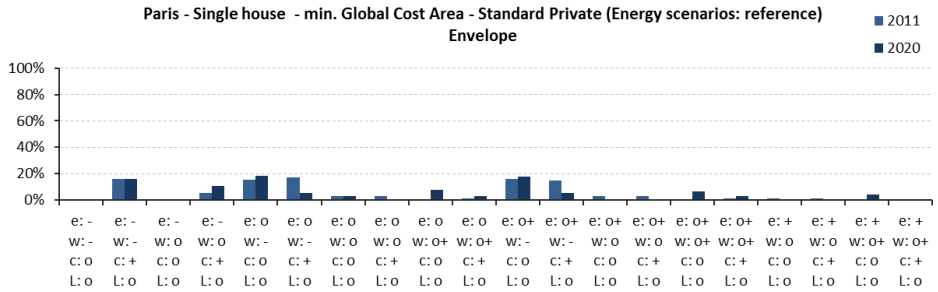
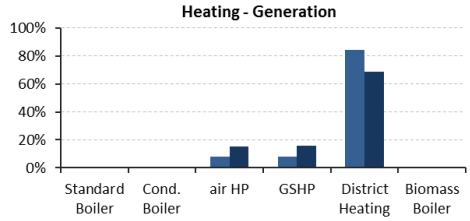

Paris - Single house - min. (net) PE area - Starting Year: 2011 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
Energy Need for Cooling
Energy Use for Lighting
7,5%
10,0%
82,5%
100,0%
100,0%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2

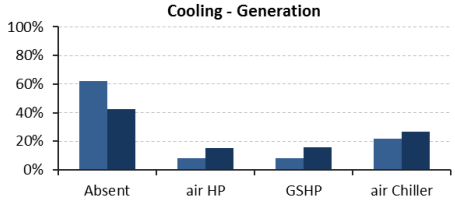

Paris - Single house - min. (net) PE area - Starting Year: 2020 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
Energy Need for Cooling
Energy Use for Lighting
7,5%
12,5%
80,0%
100,0%
100,0%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2

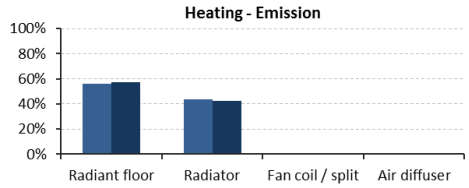

Paris - Single house - min. (net) PE area
Share "on site RES"
Primary energy generation "on site RES" [kWh/m2/year]
2011
2020
0
25
50
75
100
125
150
175
200
225
250
275
300
Primary energy demand for heating, cooling, DHW, lighting, ventilation and auxiliary systems, RES excluded [kWh/m2/year]

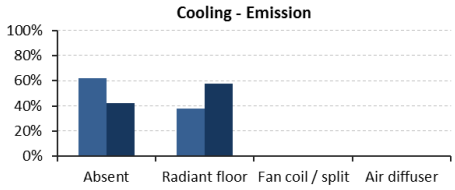
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	90	350	88	348
Range of Global Costs [€/m²]:	796	876	867	944
Number of Building Variants:	151		151	

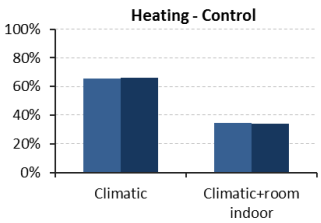


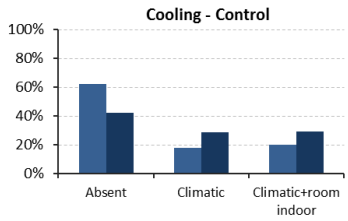


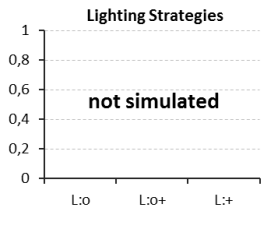


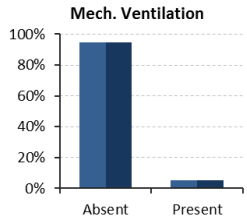


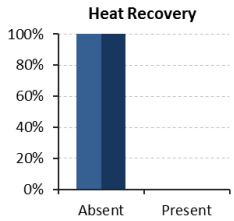


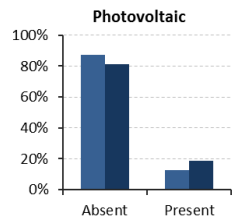


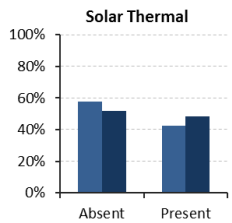












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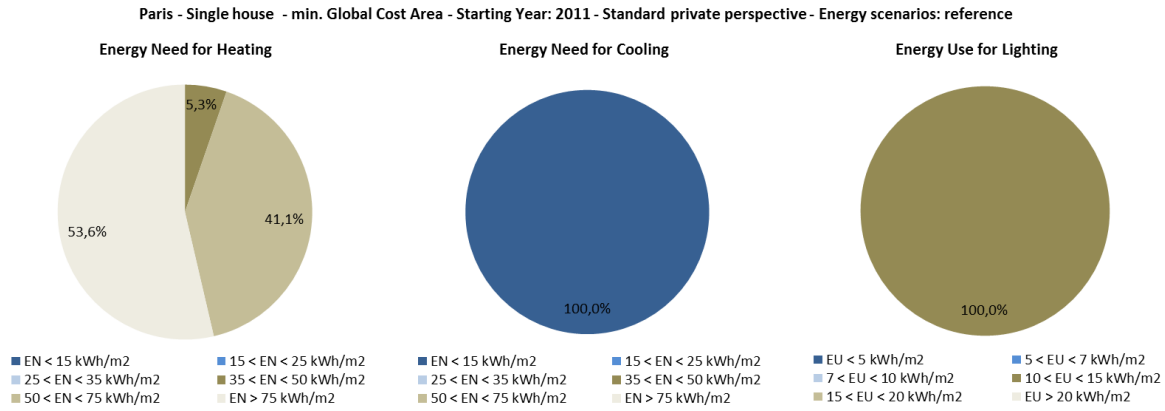

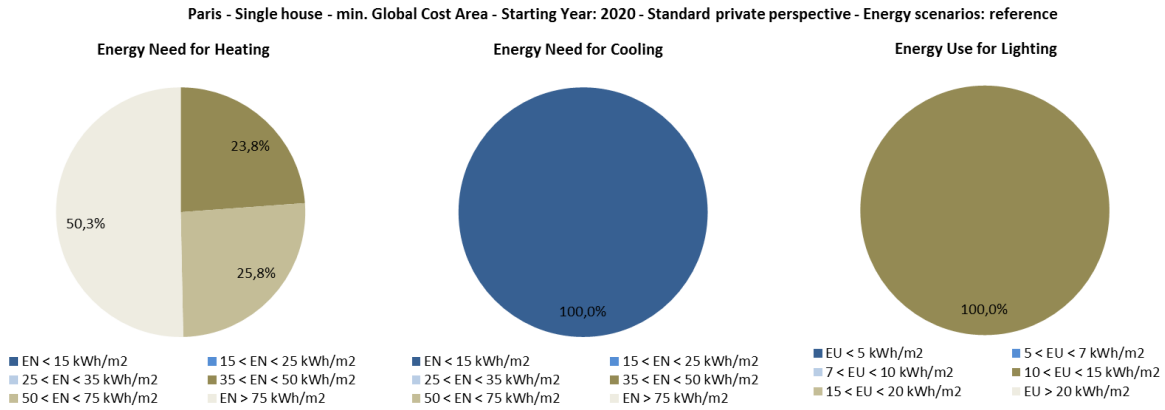

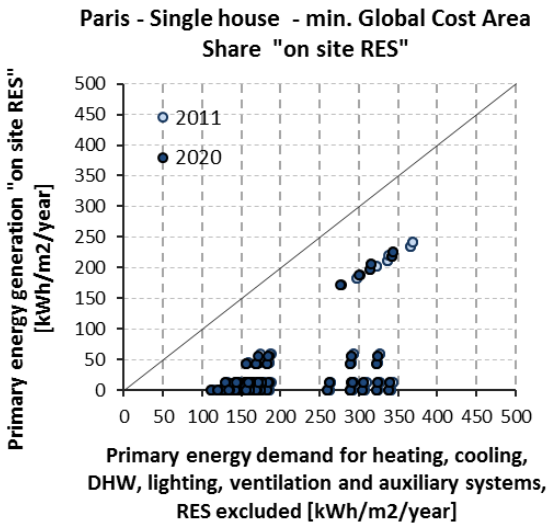

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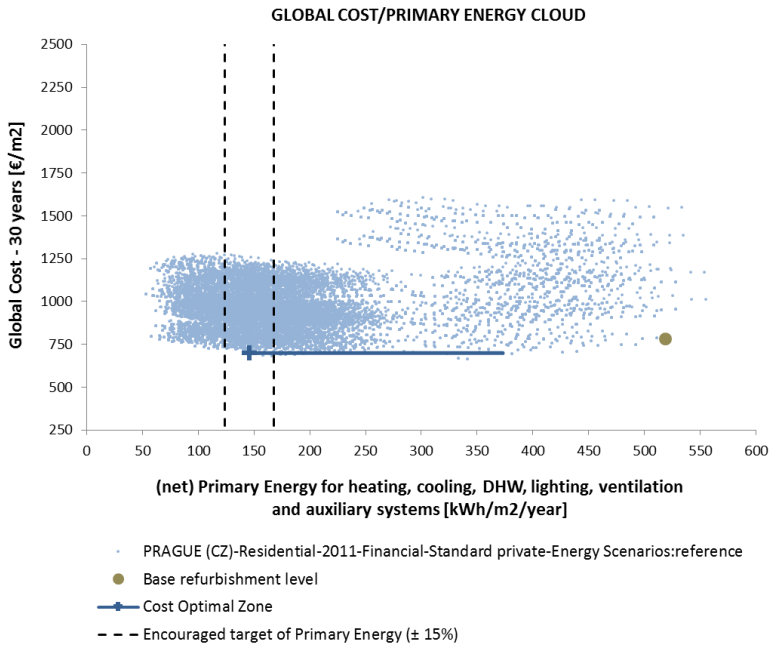
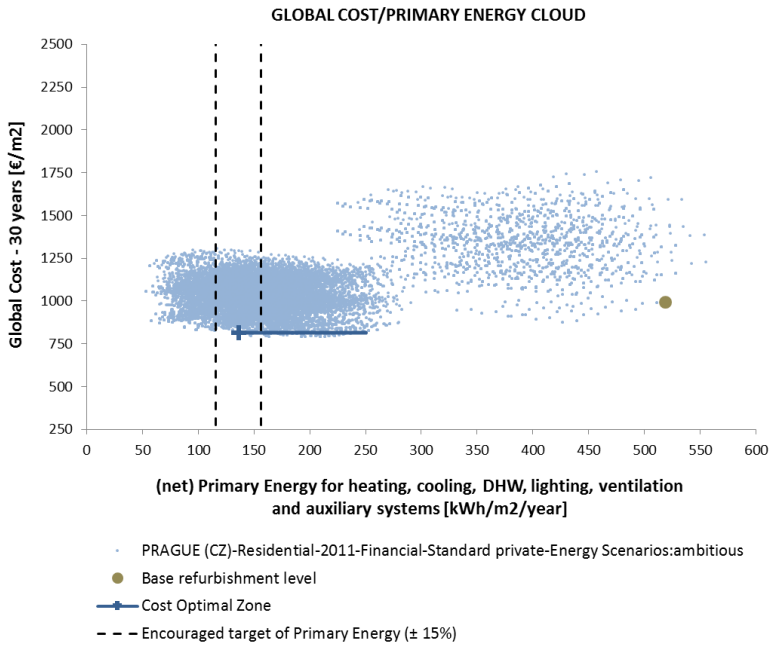
8.1.1.8 Prague





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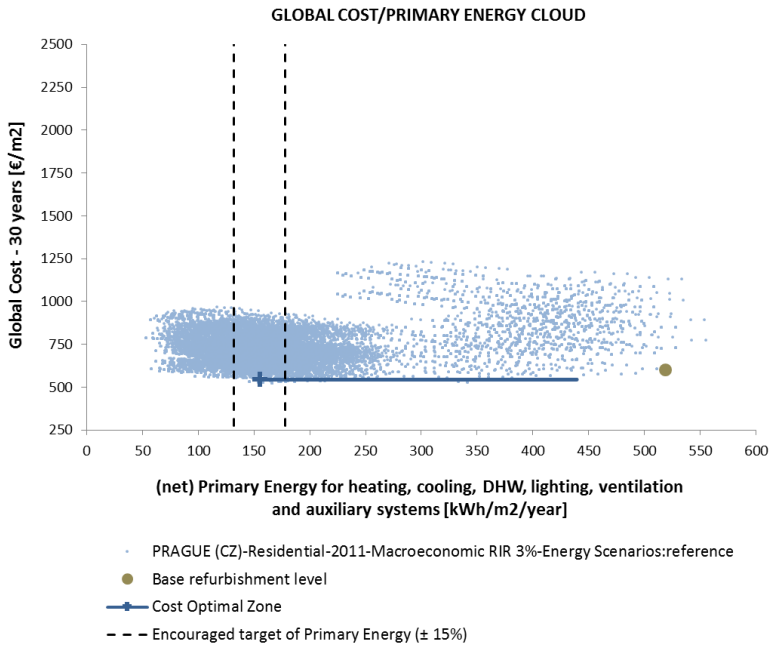

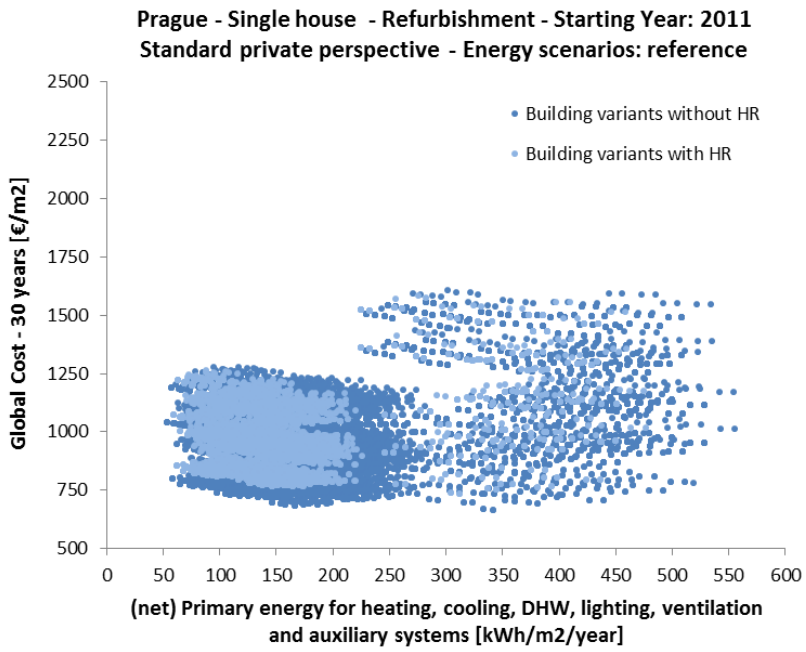

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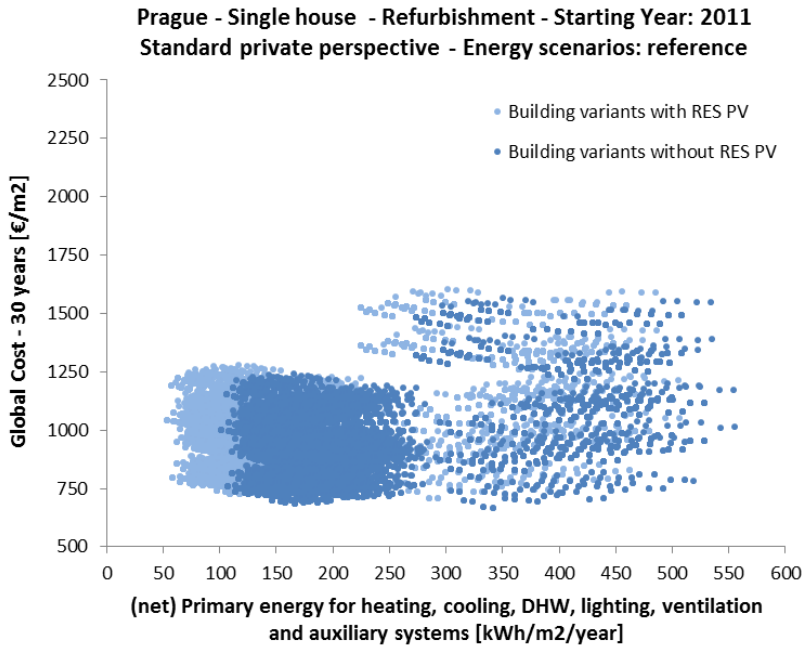

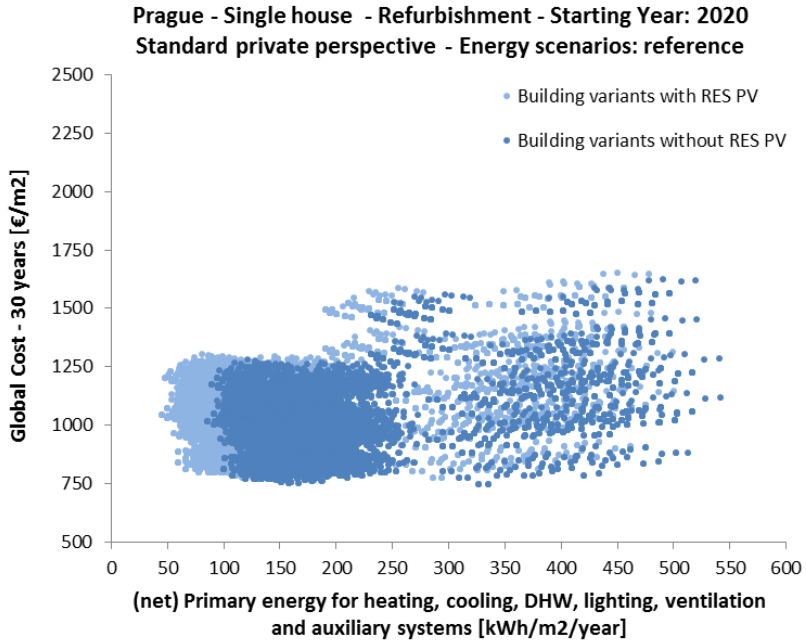

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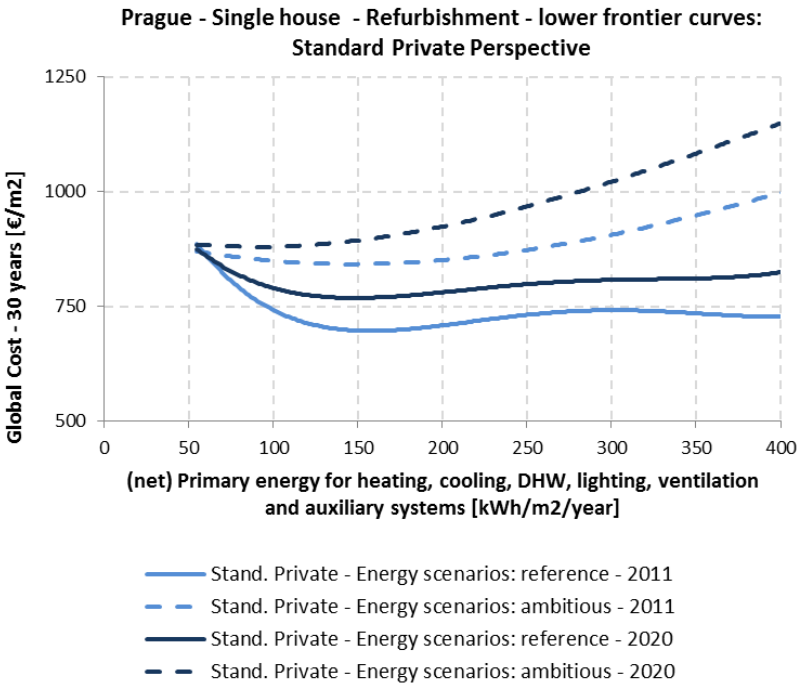

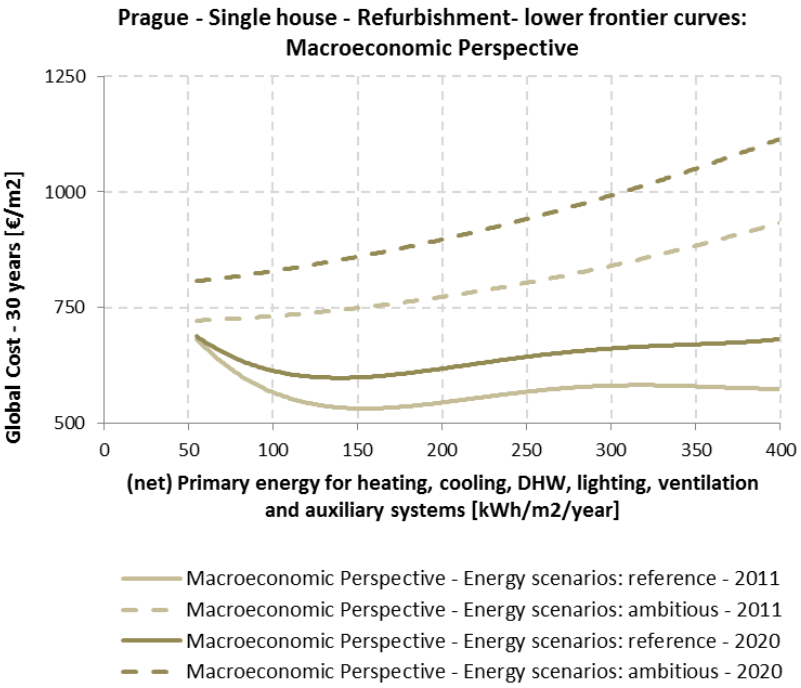

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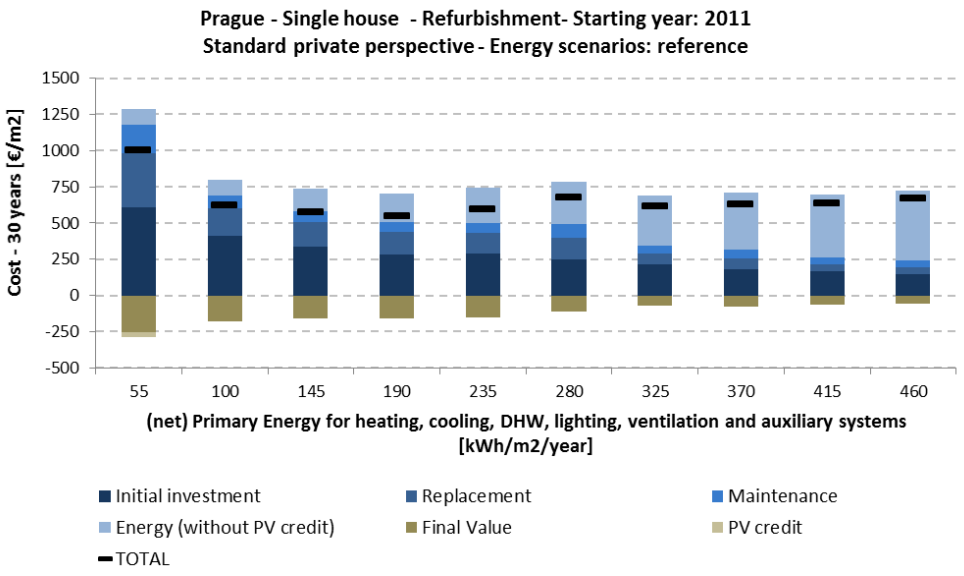

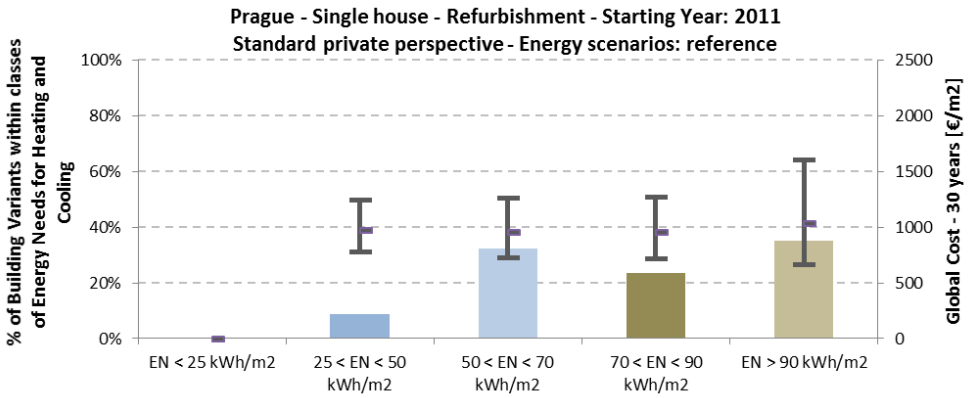

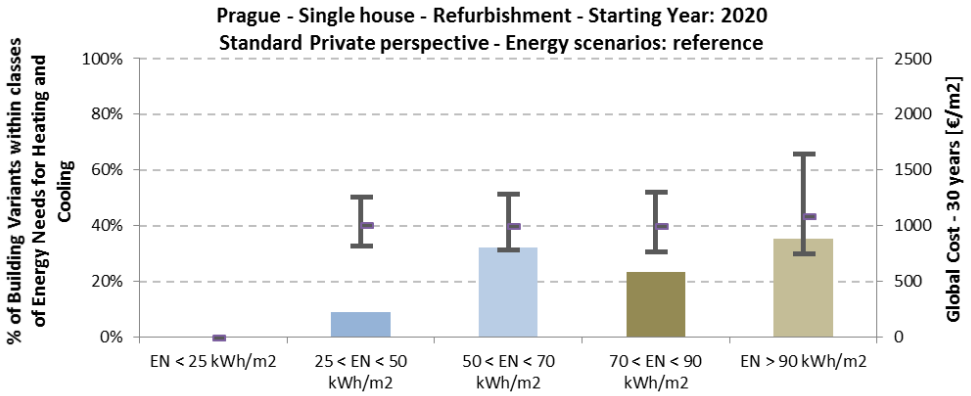

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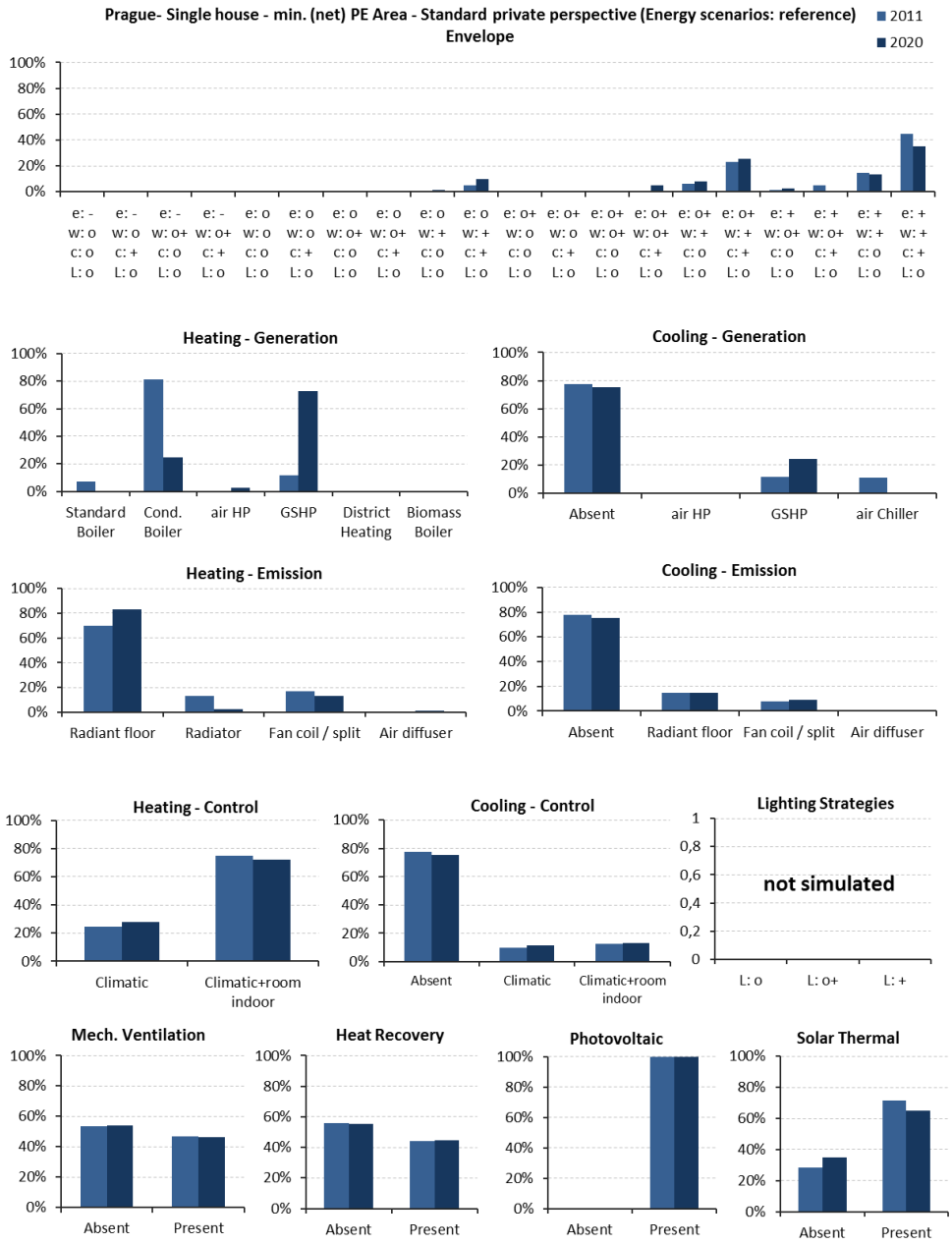
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	53	80	45	70
Range of Global Costs [€/m^2]:	772	1004	833	1066
Number of Building Variants:	165		165	



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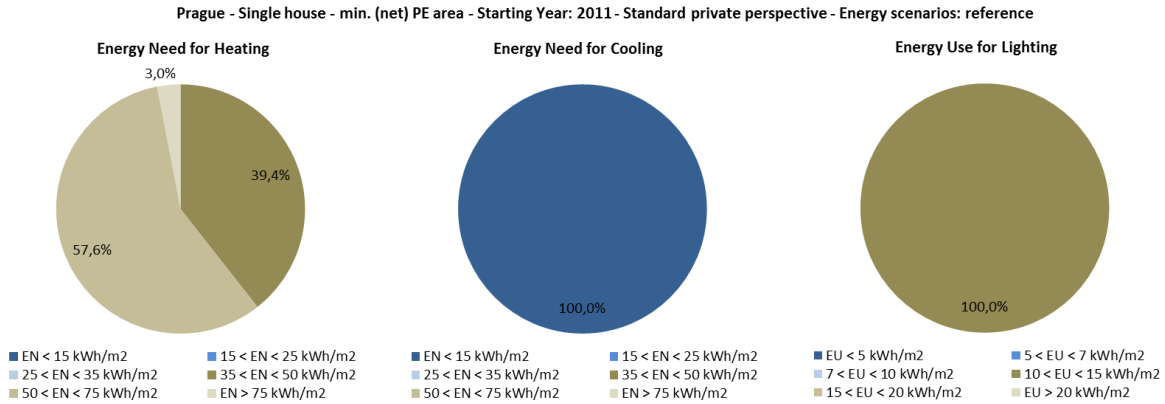

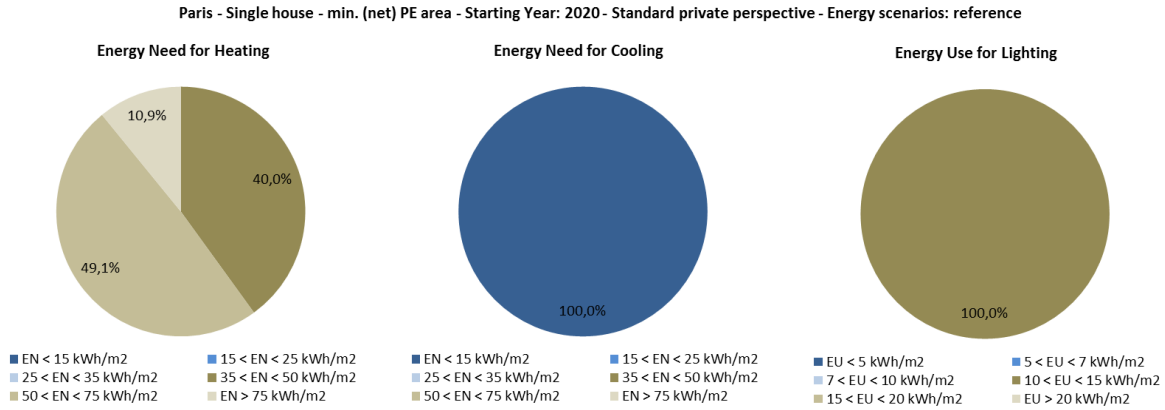

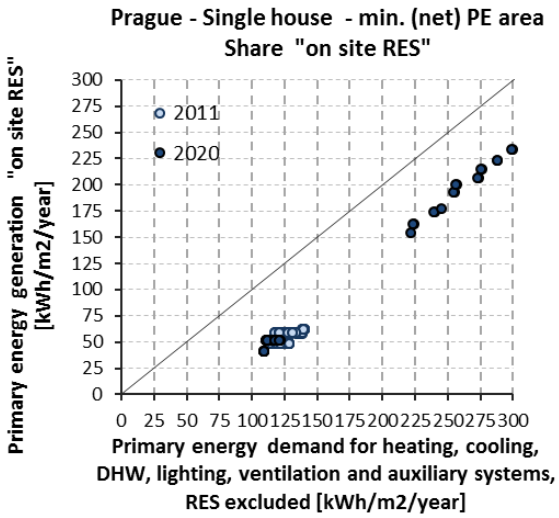

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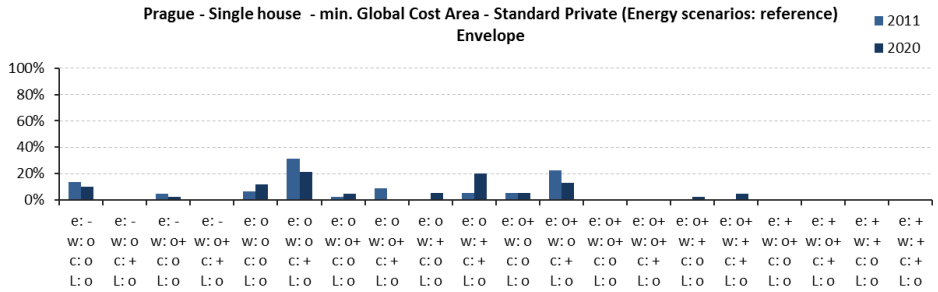
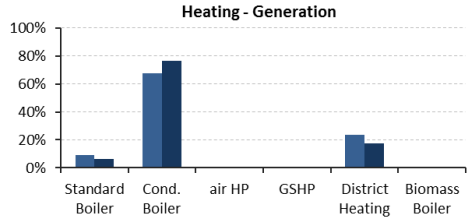
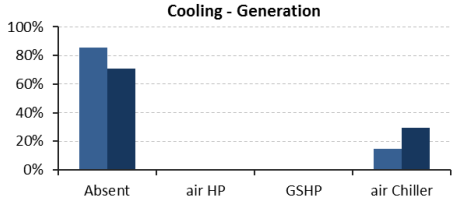
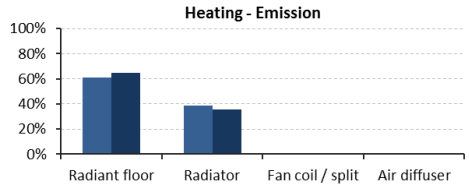
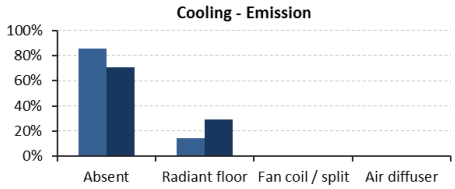
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	140	540	125	525
Range of Global Costs [€/m^2]:	666	726	748	791
Number of Building Variants:	180		180	

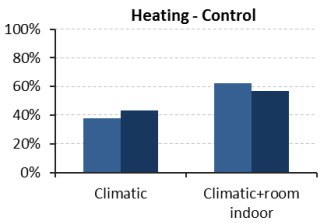


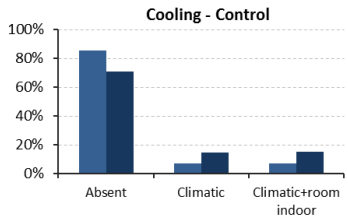


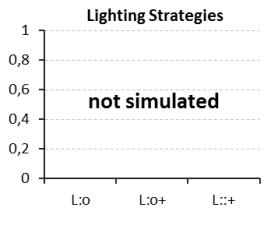


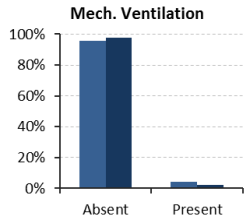


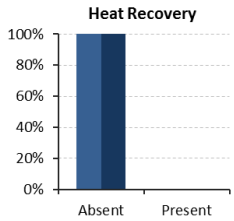


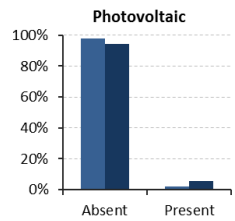


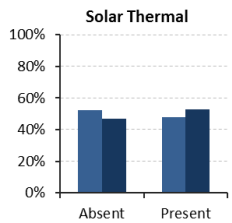












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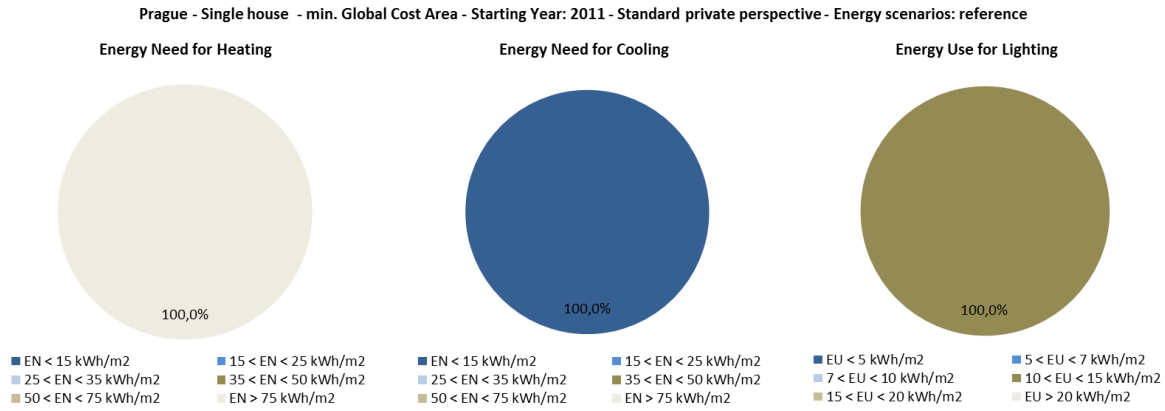

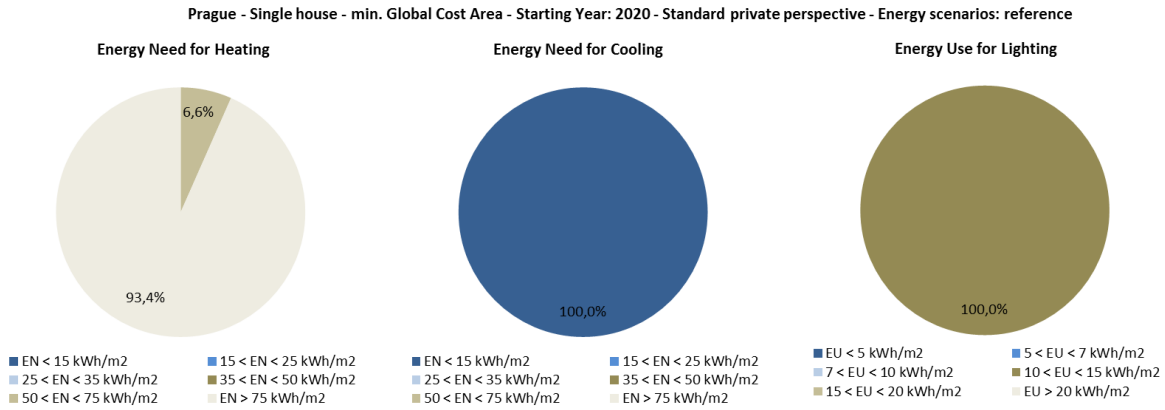

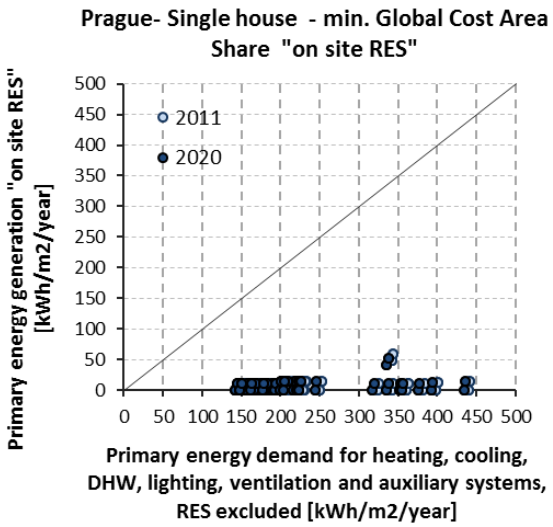

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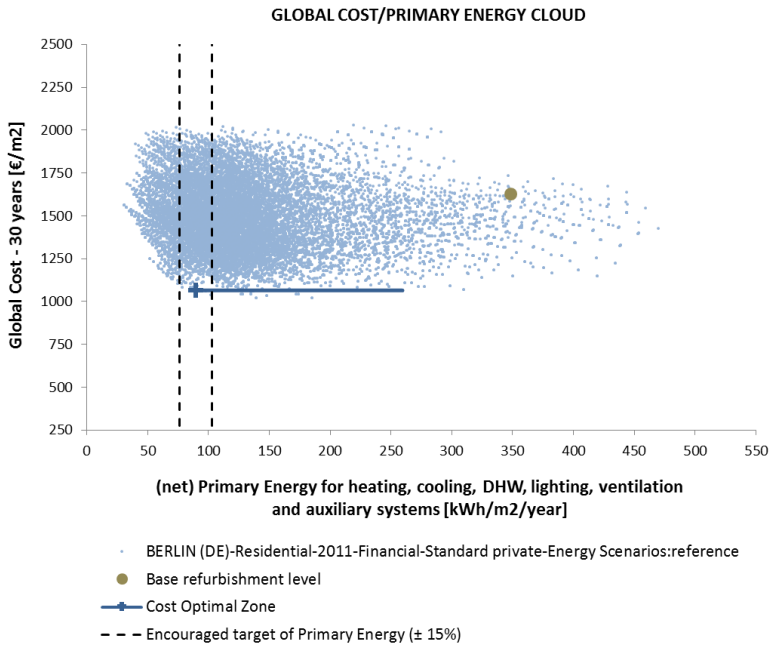
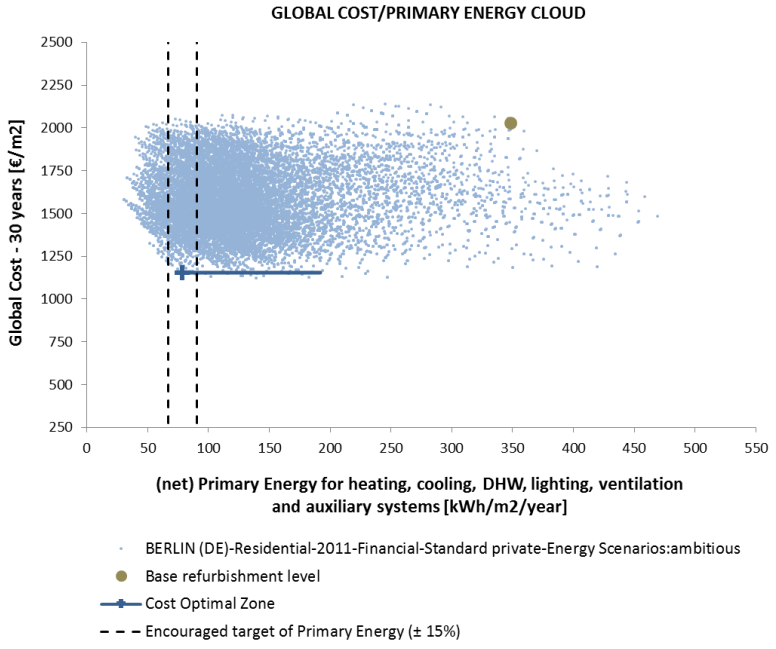
8.1.1.9 Berlin





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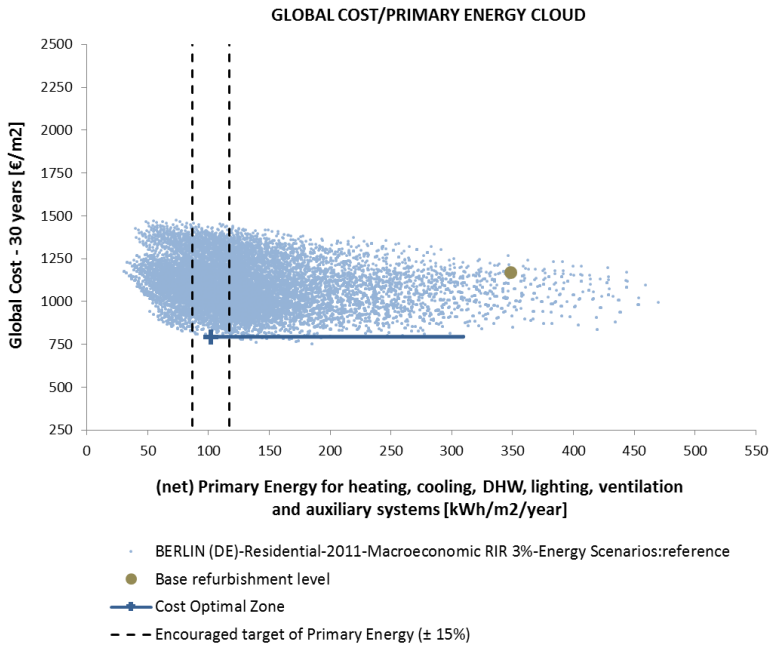

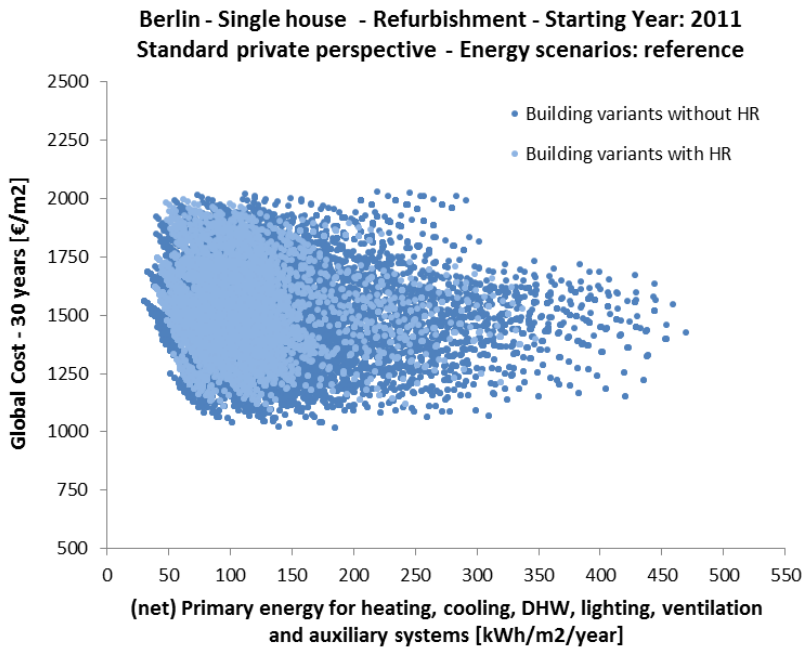

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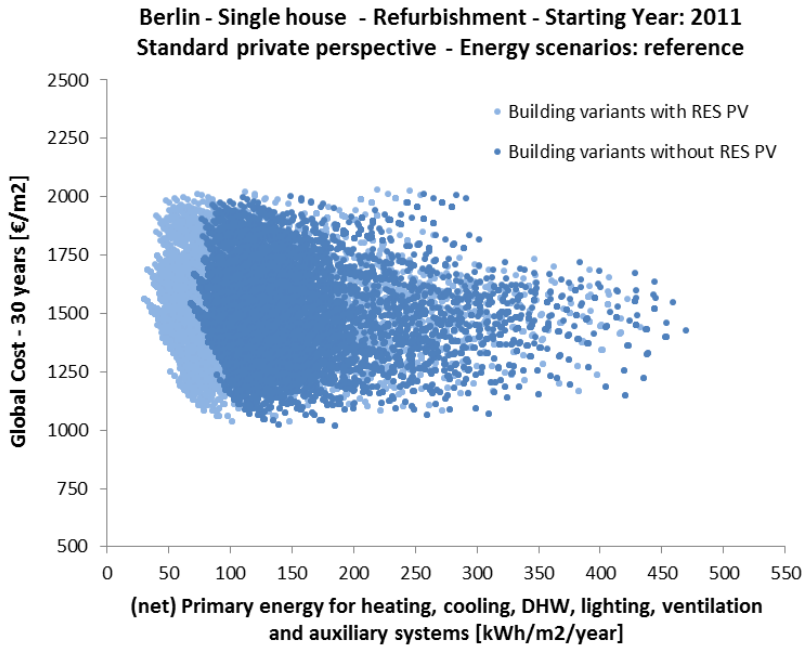

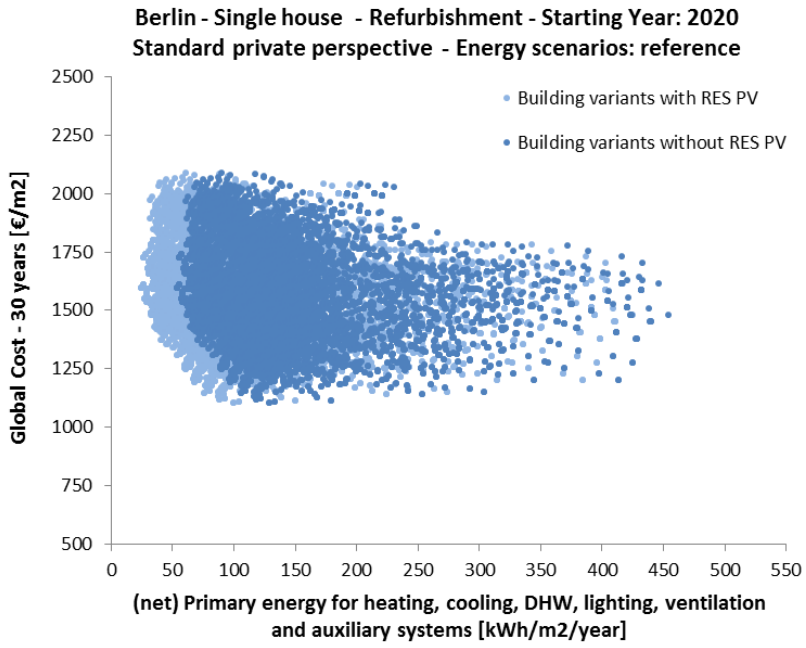

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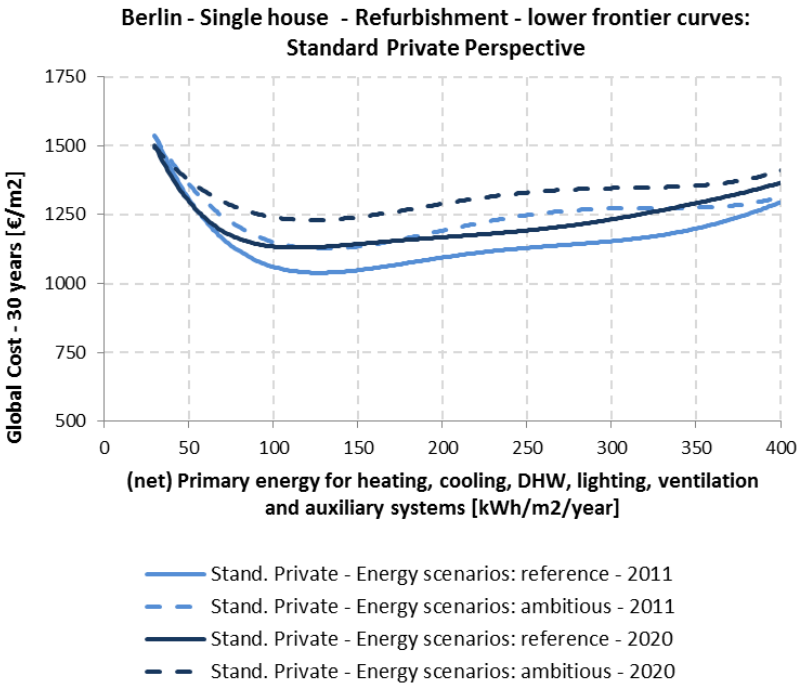

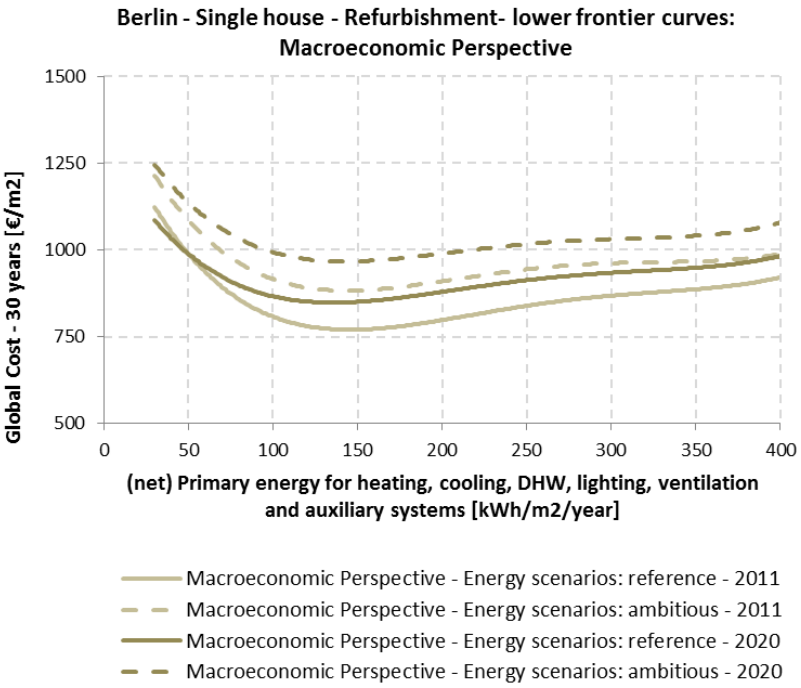

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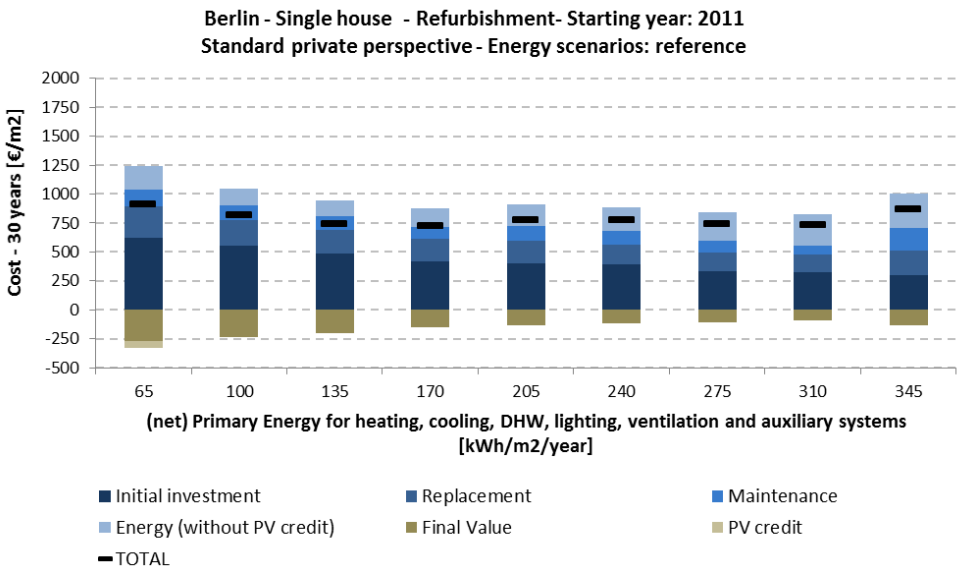

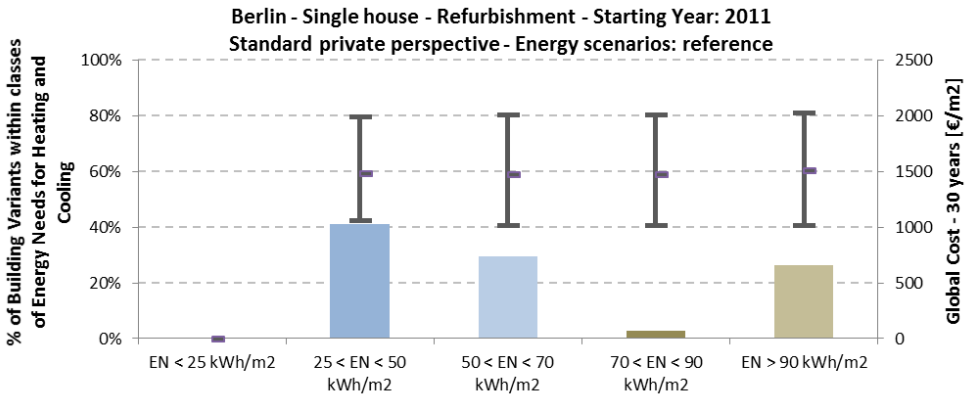

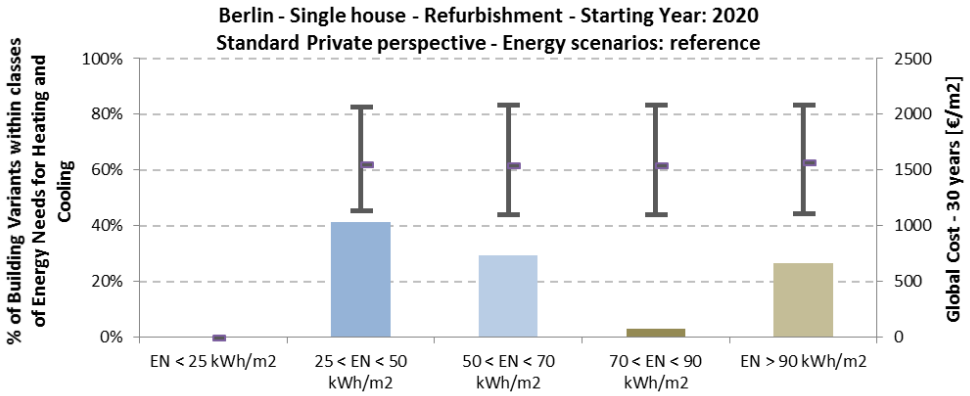

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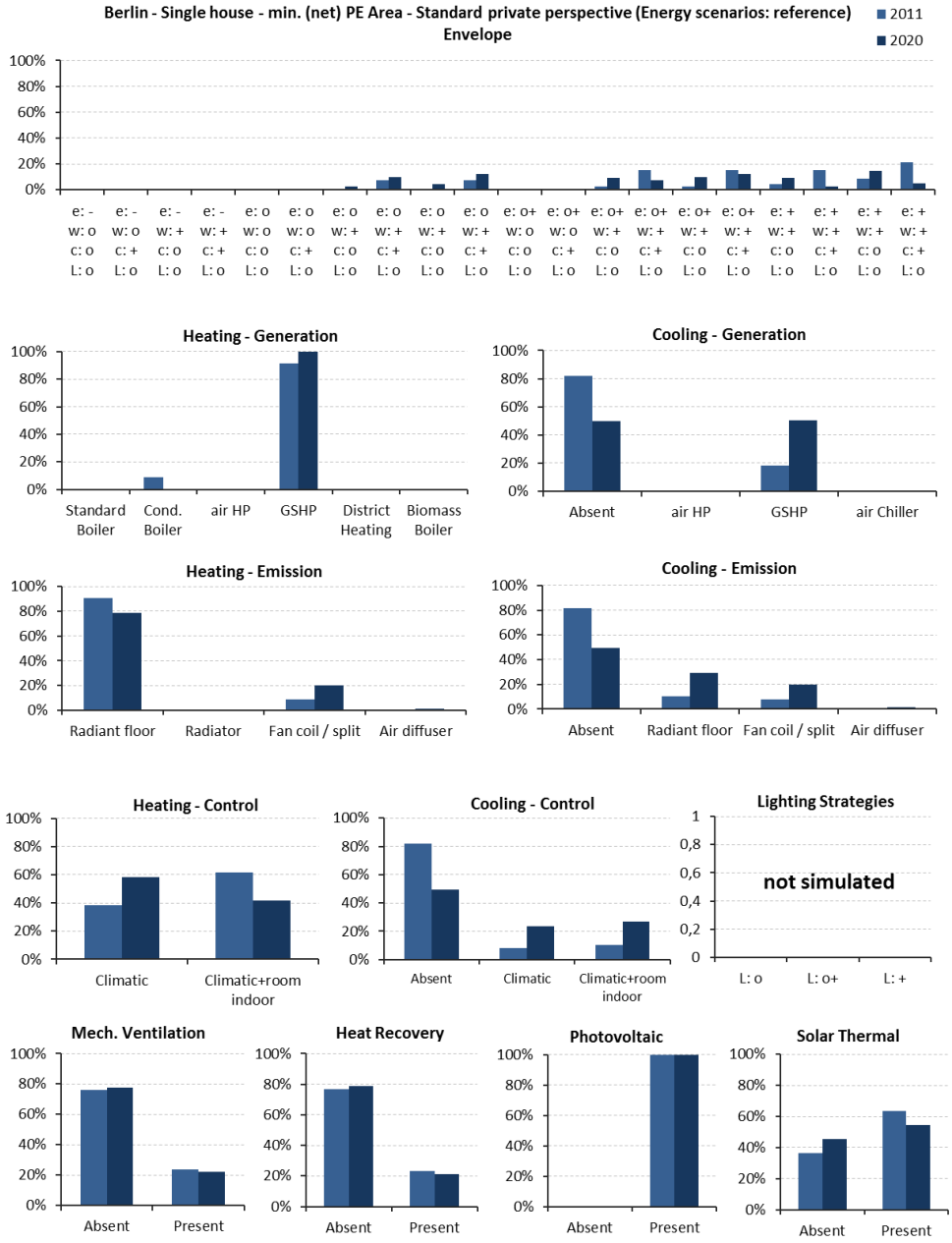
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	31	50	24	45
Range of Global Costs [€/m²]:	1252	1565	1357	1546
Number of Building Variants:	159		159	



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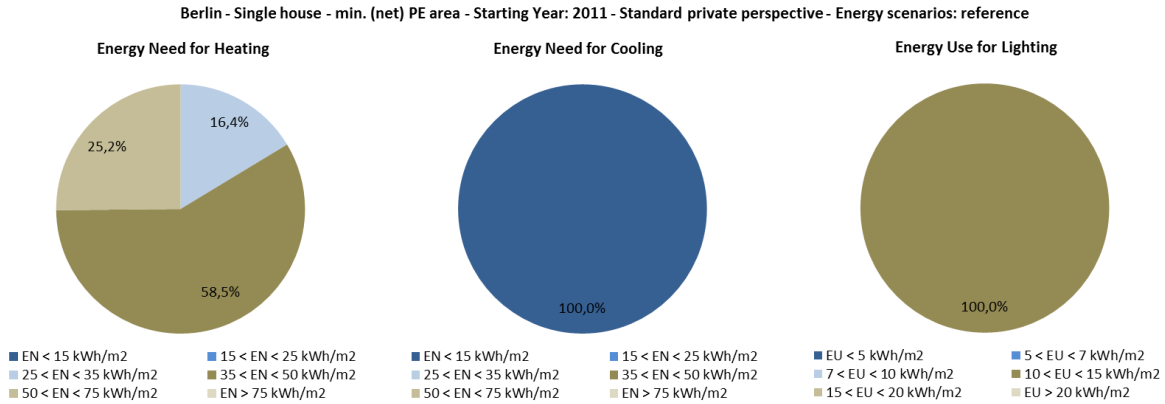

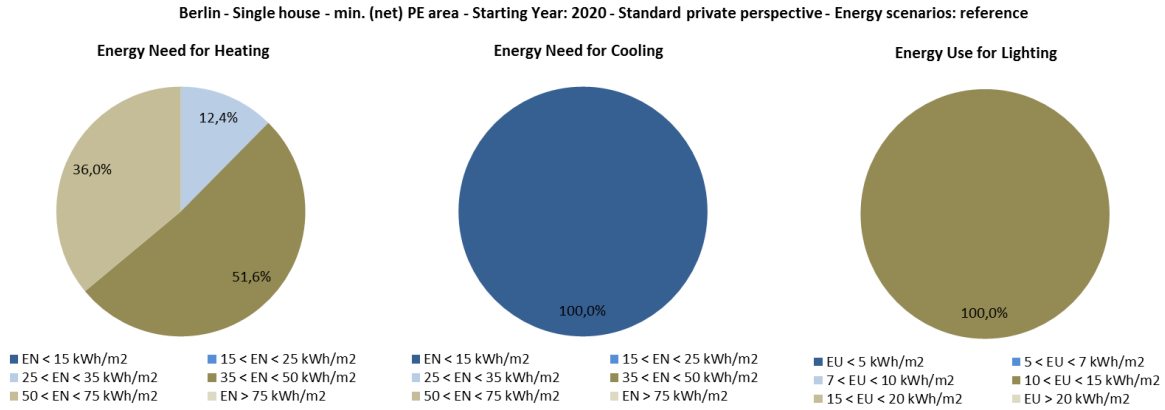

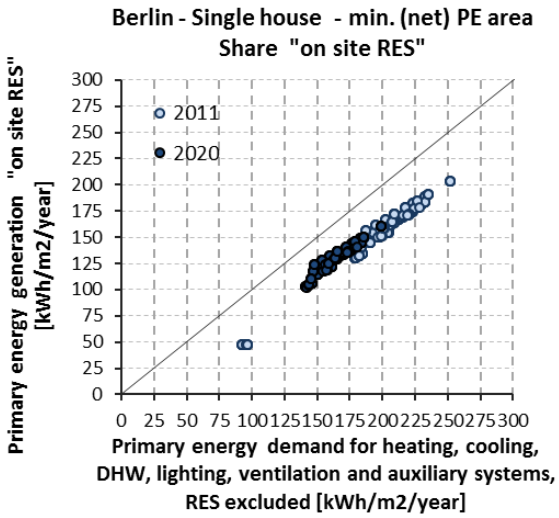

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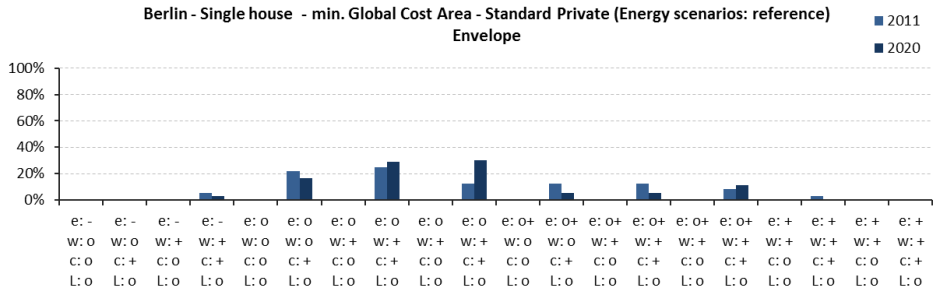
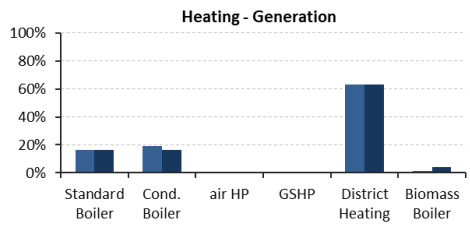
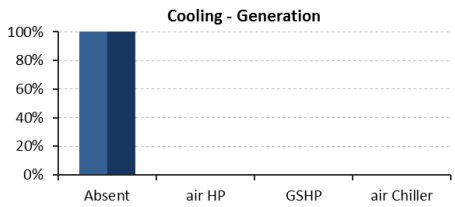
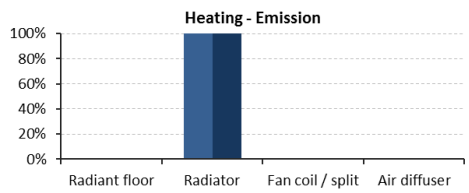
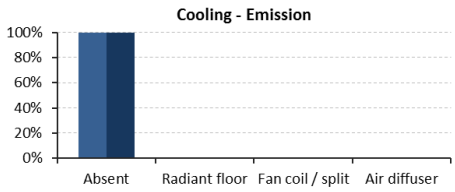
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	50	235	50	210
Range of Global Costs [€/m²]:	1020	1112	1105	1186
Number of Building Variants:	146		146	

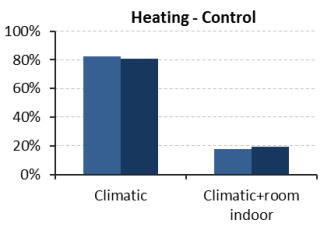


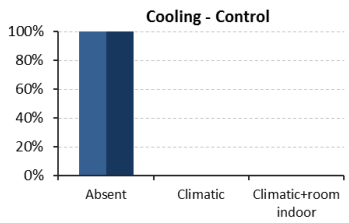


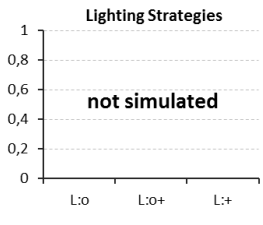


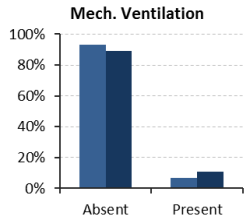


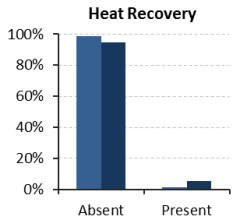


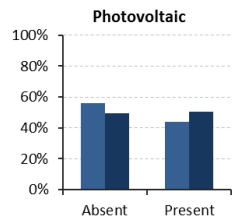


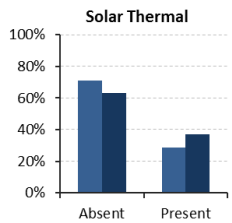












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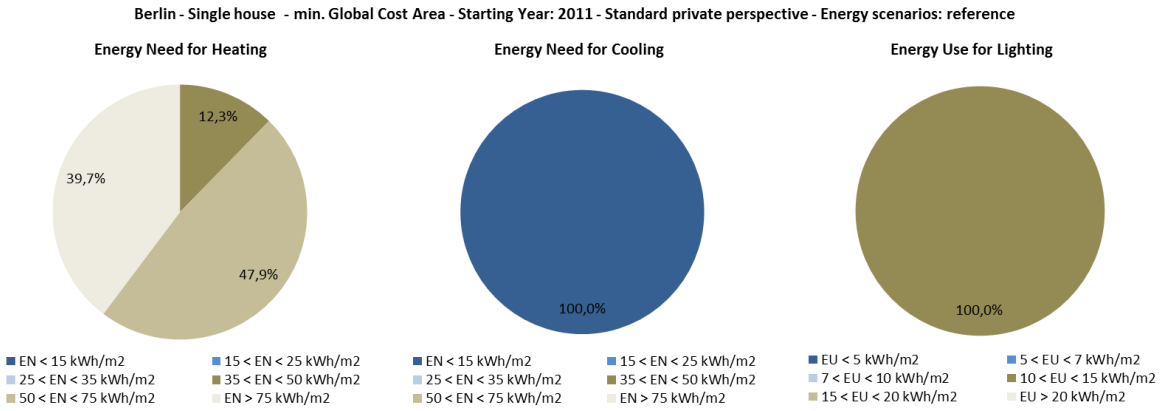

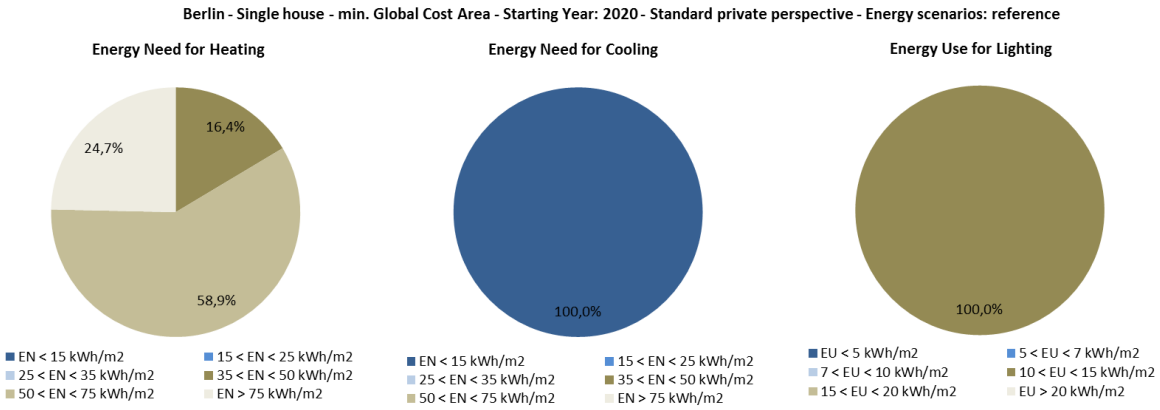

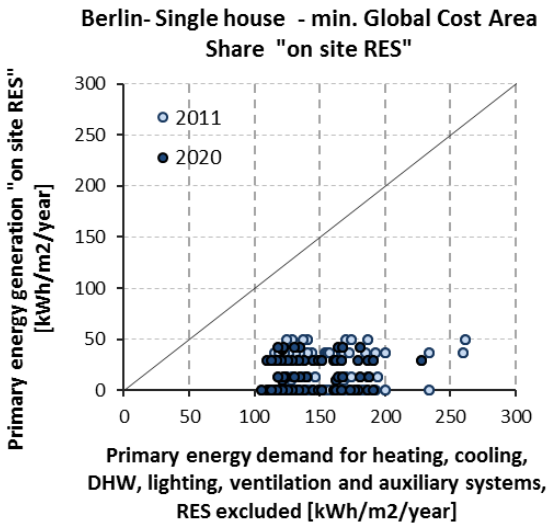

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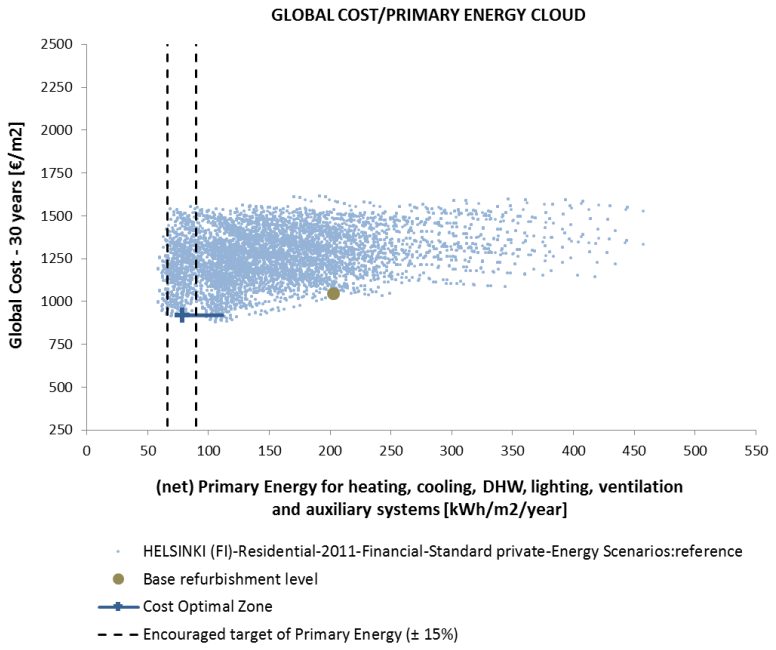
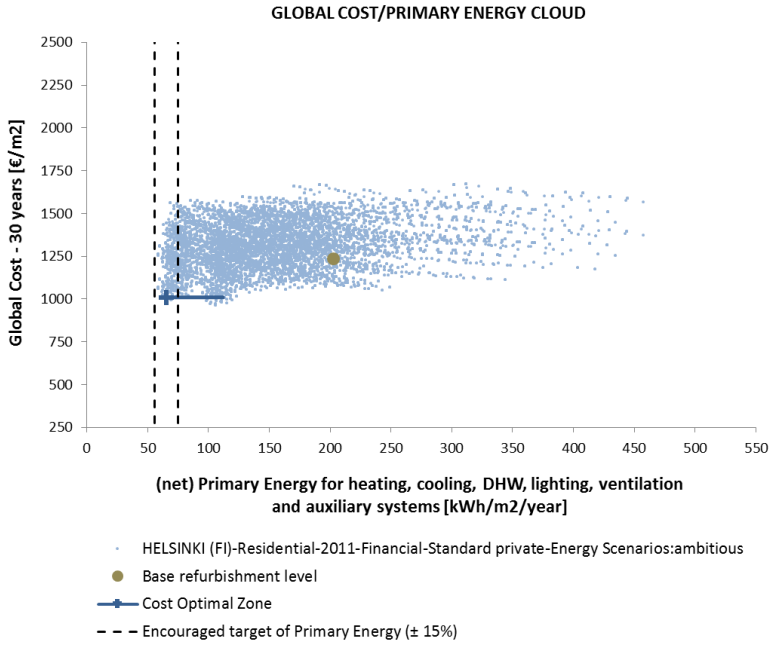
8.1.1.10 Helsinki





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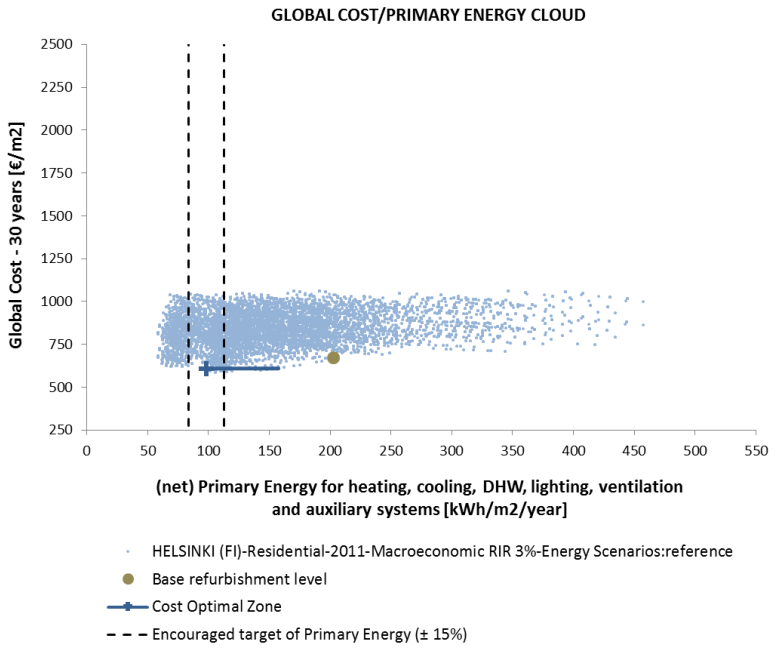

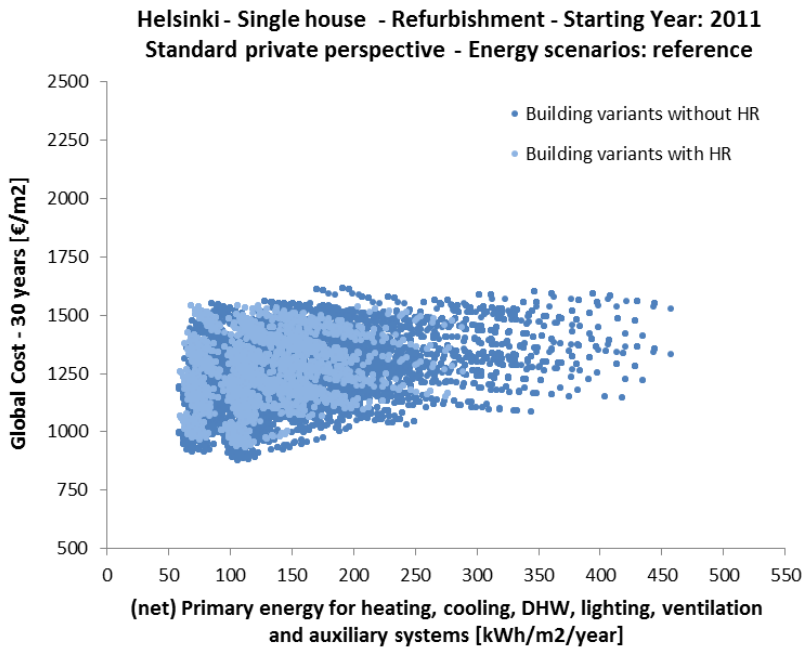

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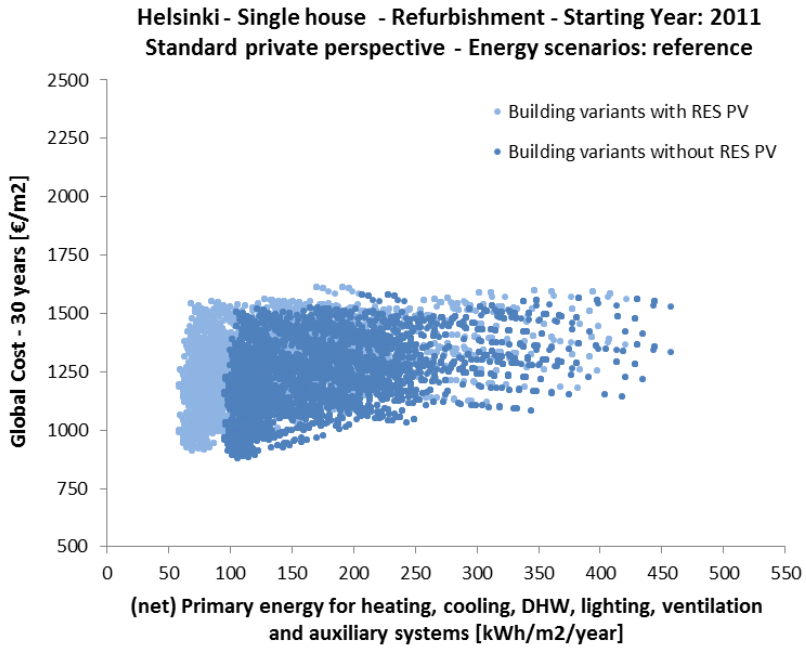

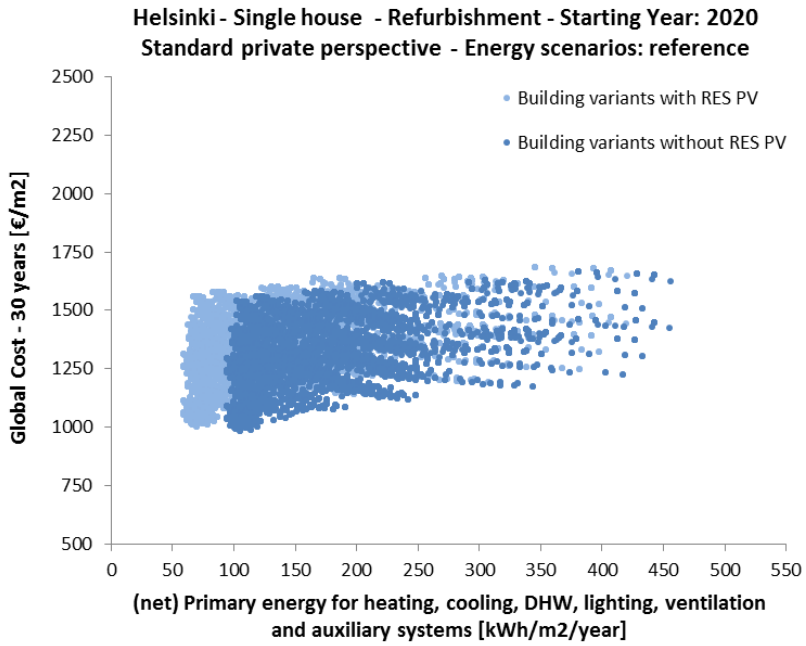

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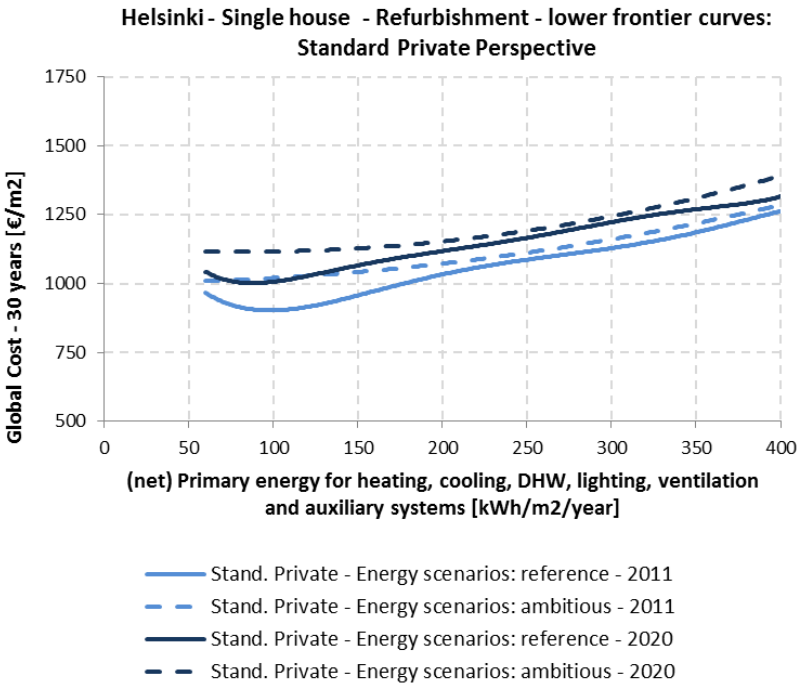

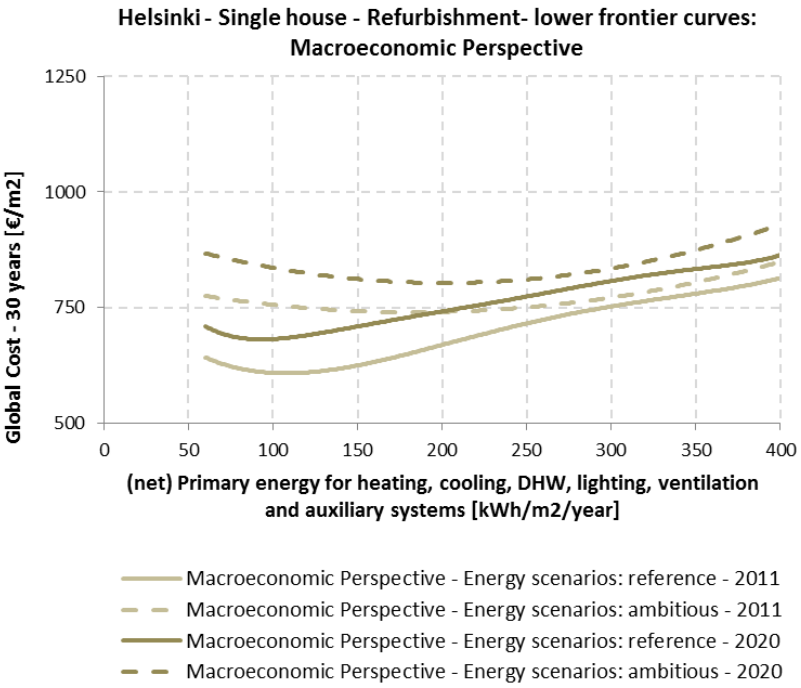

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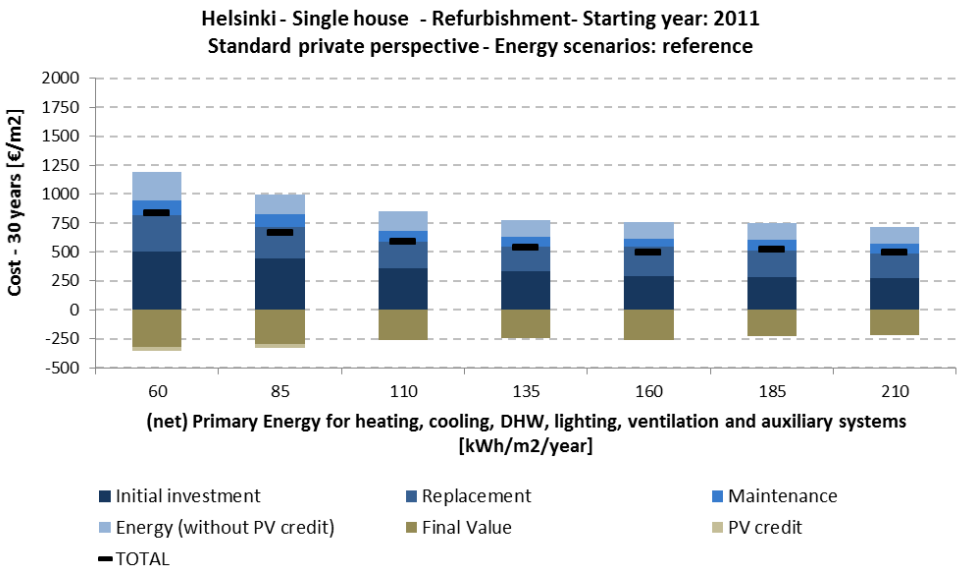

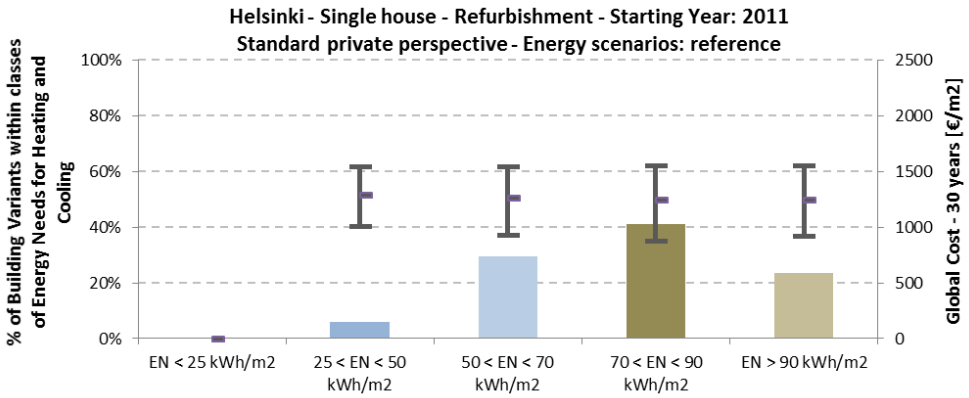

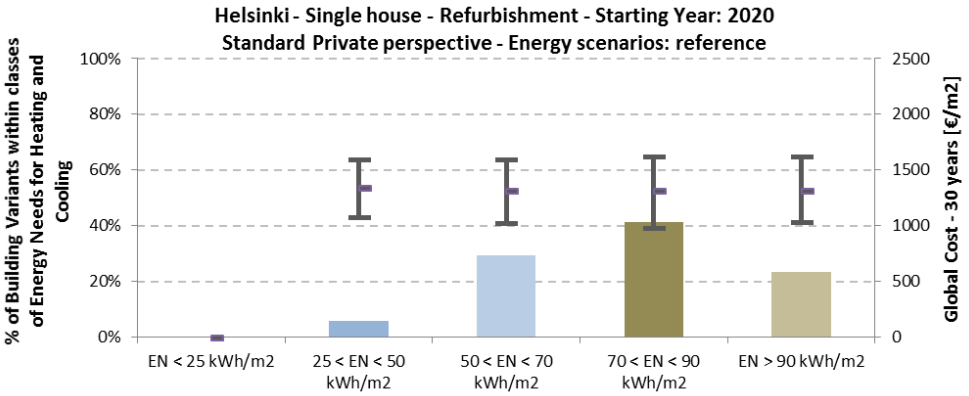

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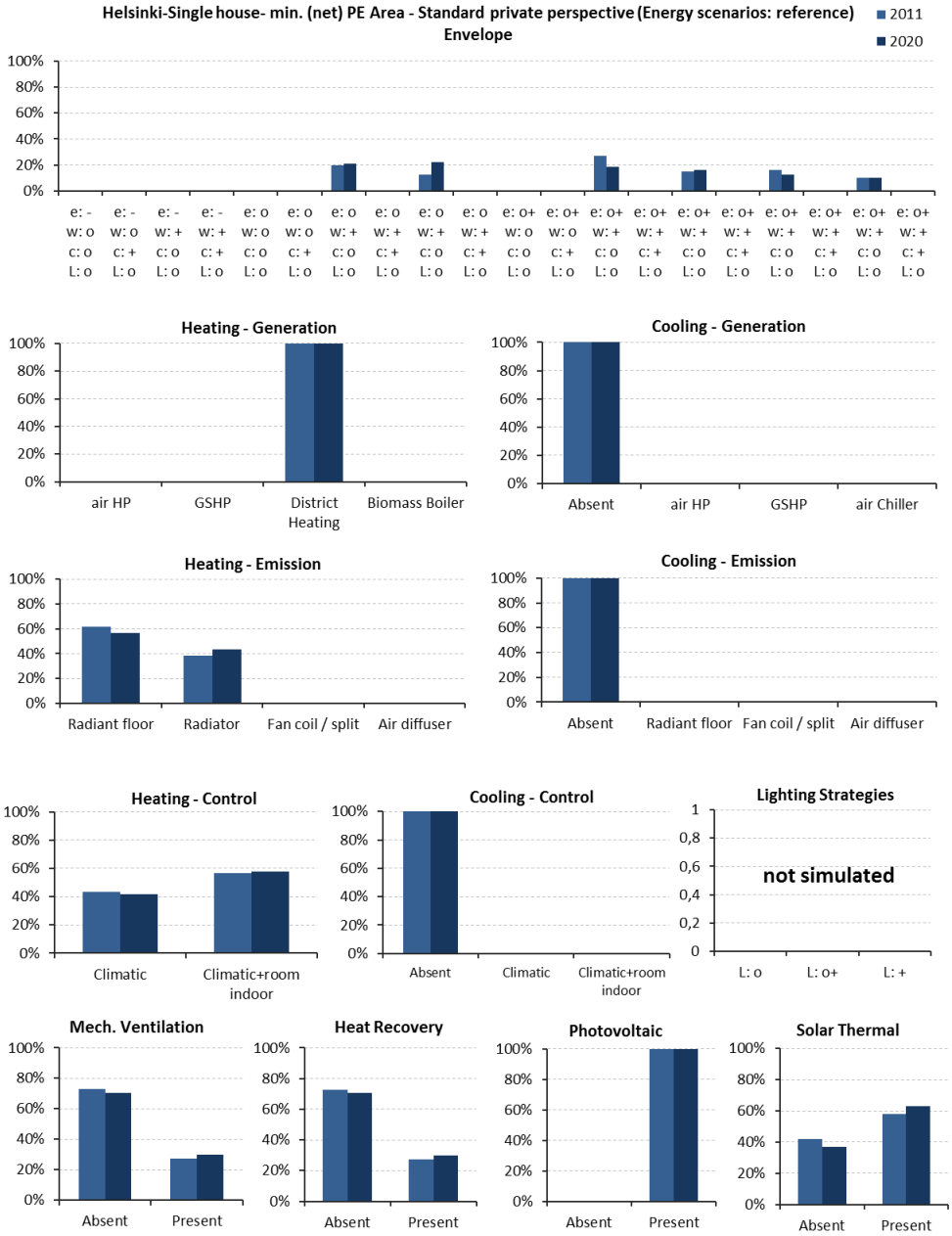
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	59	80	59	80
Range of Global Costs [€/m²]:	918	1010	1010	1076
Number of Building Variants:	162		162	



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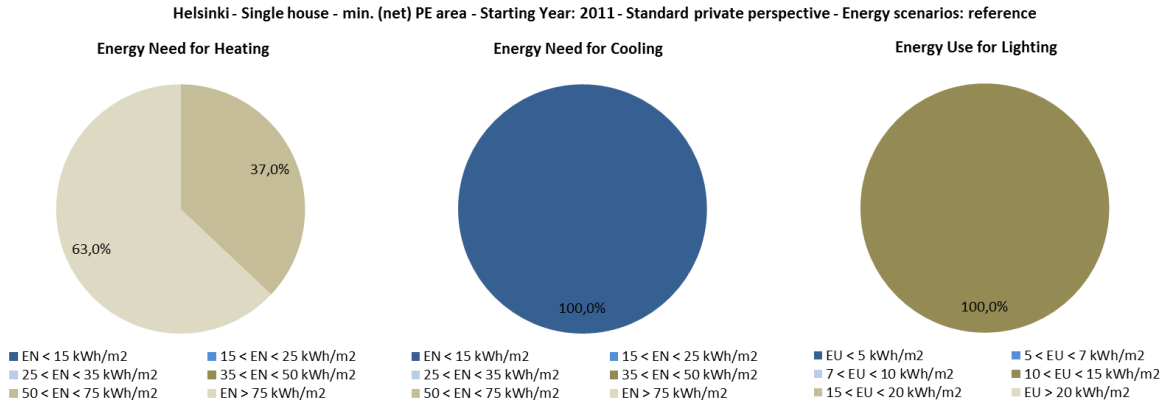

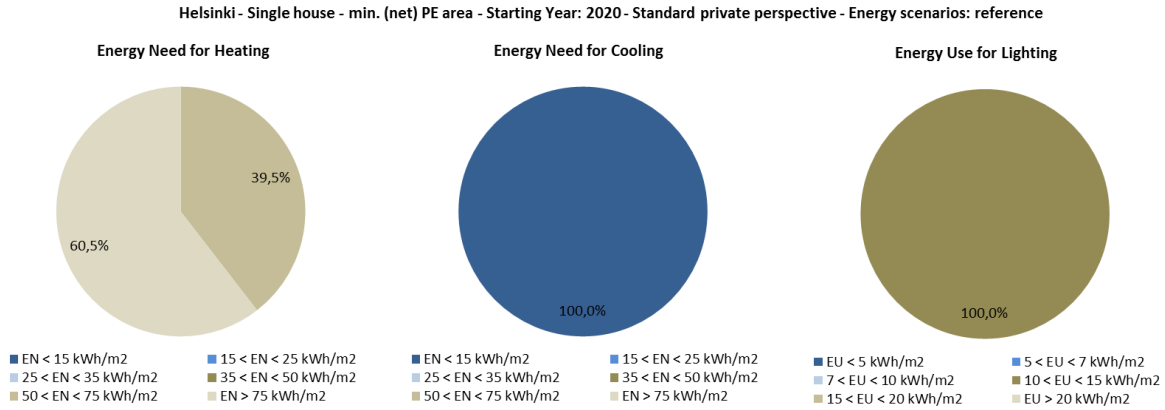

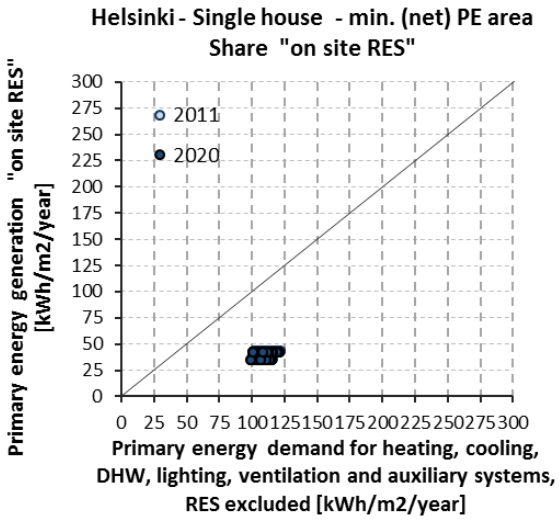

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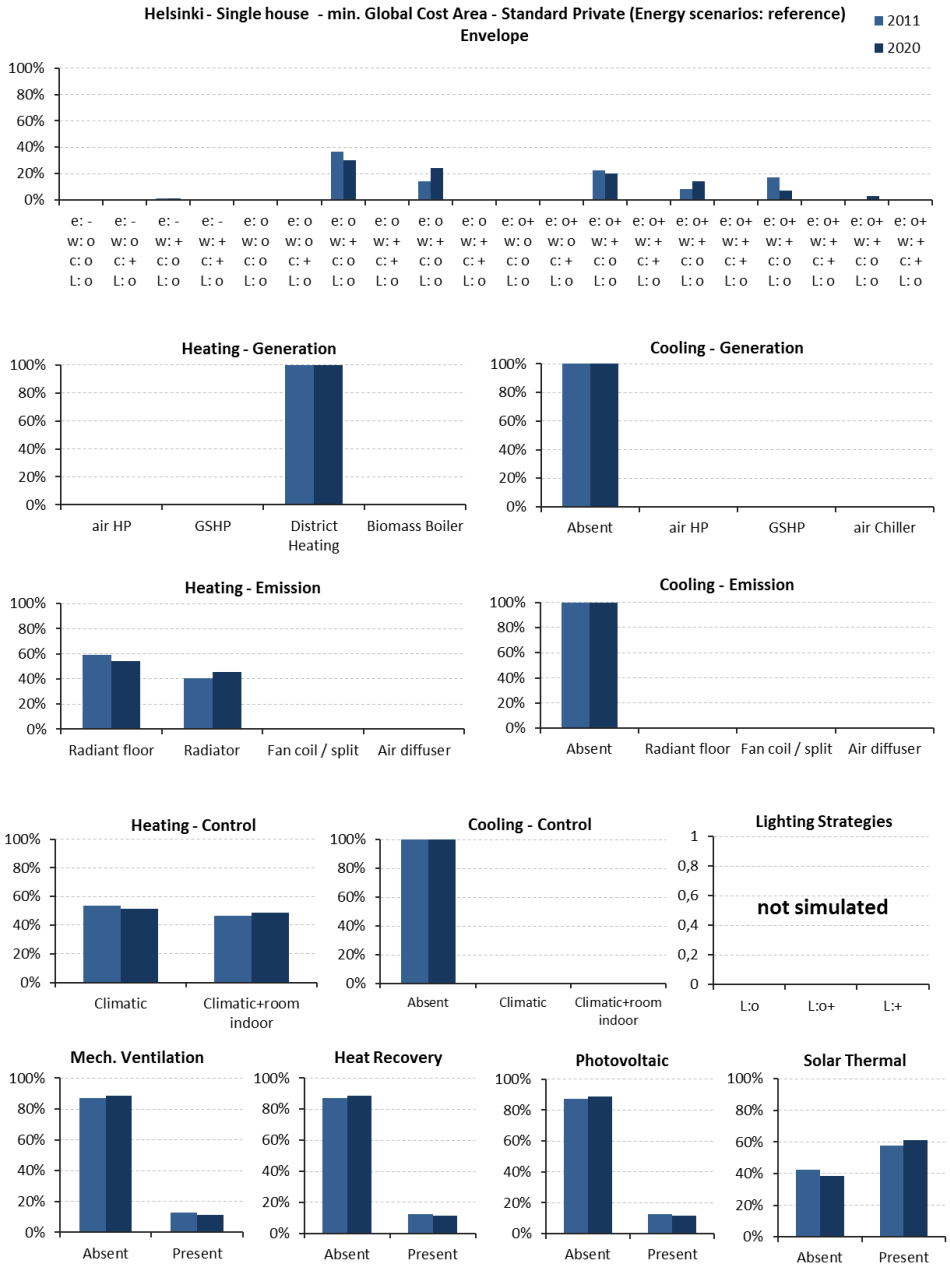
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	75	135	75	135
Range of Global Costs [€/m^2]:	880	951	983	1040
Number of Building Variants:	142		142	



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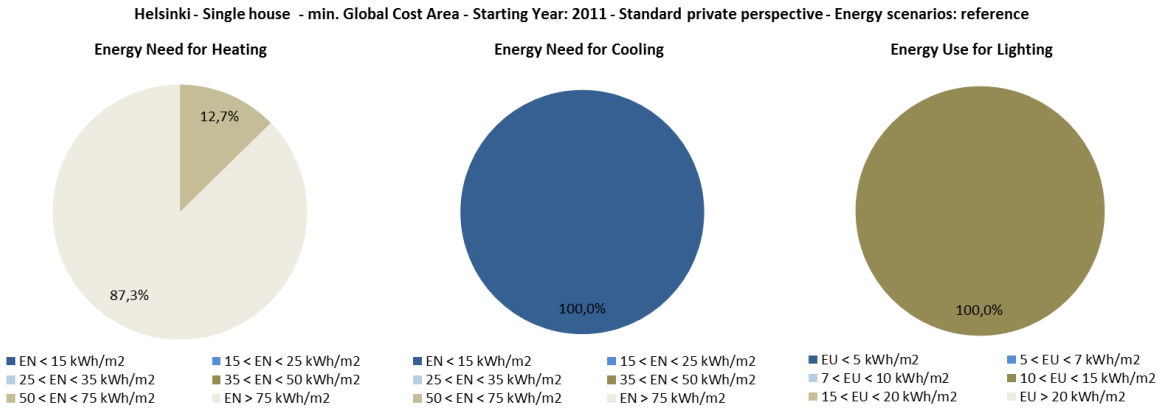

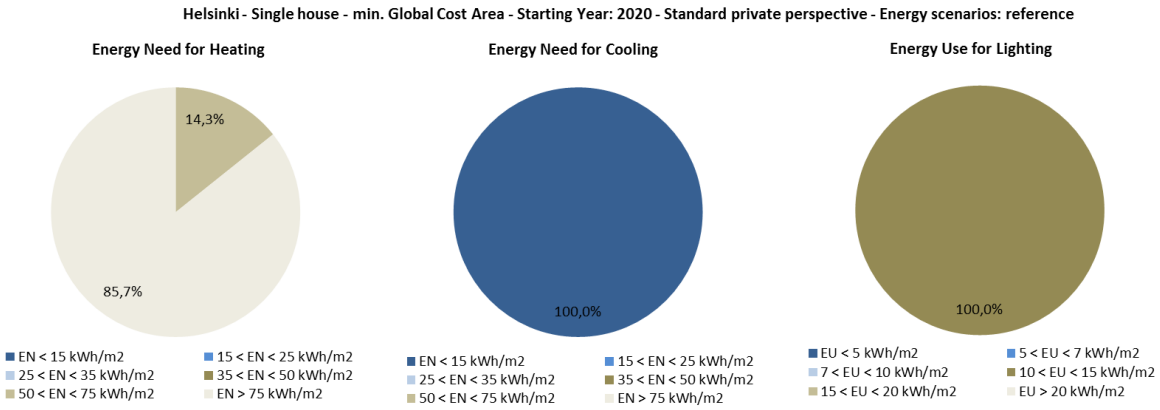

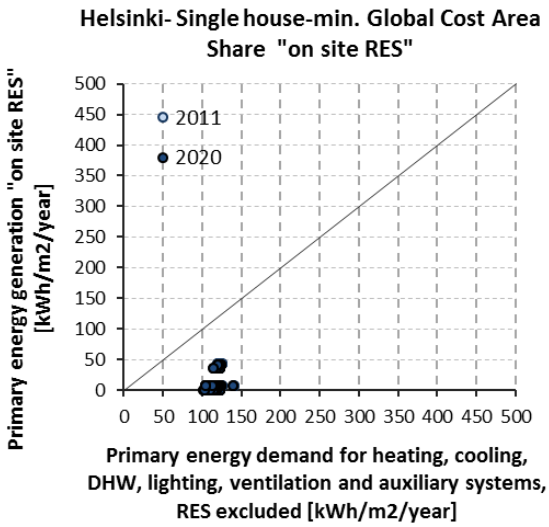

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8.1.2 Apartment block

Results about single family houses are presented in the following chapters.

About “Envelope Section” divided in these fields

- Opaque envelope Insulation **(e)**
- Windows (frame and glazing) **(w)**
- Cooling Strategies **(c)**
- Lighting efficiency (as internal gain) **(L)**

variants are expressed using this code with “-, o-, o, o+, +”, see table below

Tabella 4: variants codes for opaque envelope, windows, cooling strategies and lighting efficiency in Apartment block.

cod.	Opaque Envelope Insulation			Windows	Cooling strategies			
	Additional insulation compared to base case (in thickness of insulation "x" [cm])			number of glass + type of glass + "Air permeability Classification EN12207"	solar shading + control systems - natural night ventilation	lighting load + control system		
	Wall	Roof	Basement			cod	efficiency of lighting	control
-	0	0	0	single glass standard glass Class 0	solar shading ABSENT natural night ventilation ABSENT	o	standard	manual
o-	5	5	5	***	solar shading PRESENT + MANUAL Control Automatised natural ventilation ABSENT	o	standard	manual
o	10	10 ÷ 15	5 ÷ 10	double glass standard glass Class 2	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation ABSENT	o	standard	manual
o+	15	15 ÷ 20	10 ÷ 15	double glass low-e glass Class 3	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT medium performance	o	standard	manual
+	20	30	15	triple glass low-e glass Class 4	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT high performance	o	standard	manual

*** There aren’t variant that can be assigned to this code

Additional notes:

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For Helsinki and Berlin calculations, the variant number 2 and 3 of windows strategies correspond respectively at a triple glass with high performance and one's with very high performance. Both are classified with the code "+". For more deep analysis of results in the bar plot graph "Envelope" the columns n. 3-4-7-8-13-14-17-18 correspond at the variant n. 2 of window substitution and the column 9-10-15-16-19-20 at the variant n. 3.

For Helsinki, for insulation of basement, it wasn't simulated any renovation package for every level of refurbishment.

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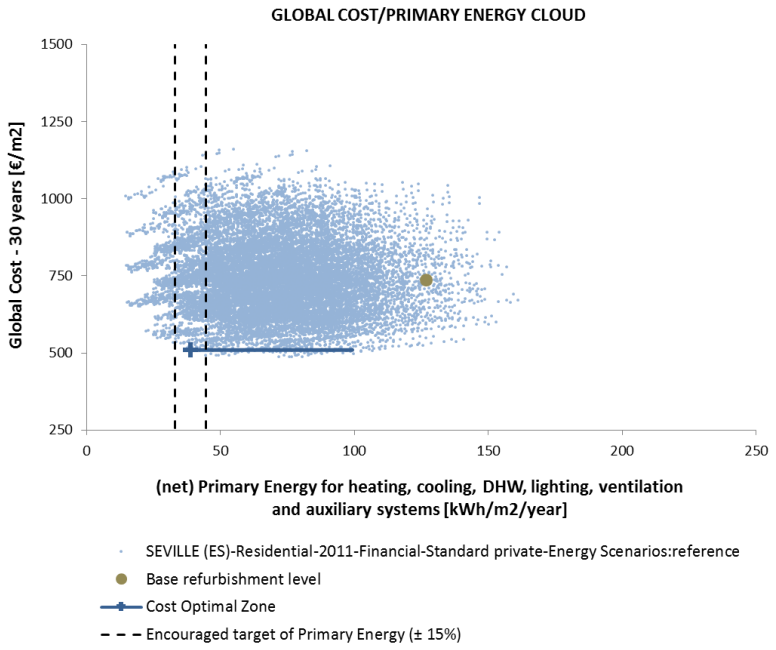
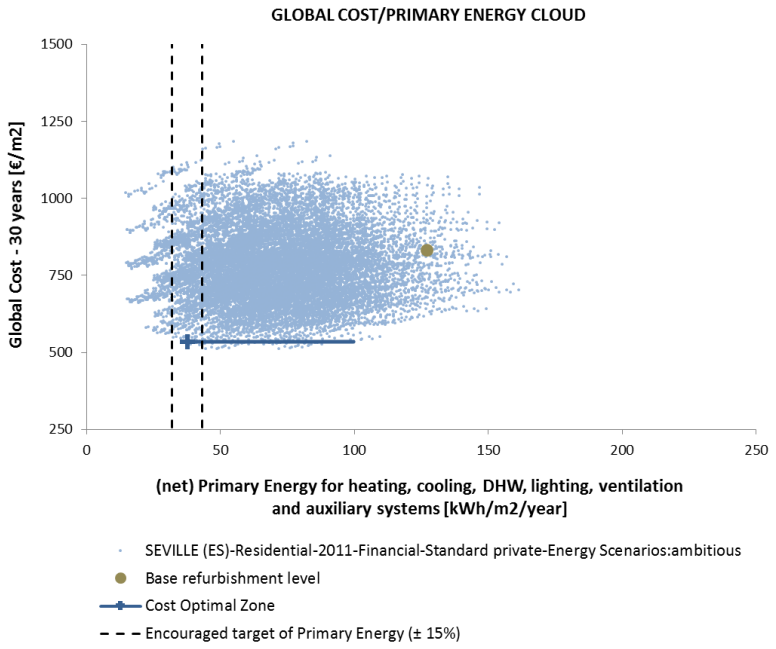
8.1.2.1 Seville





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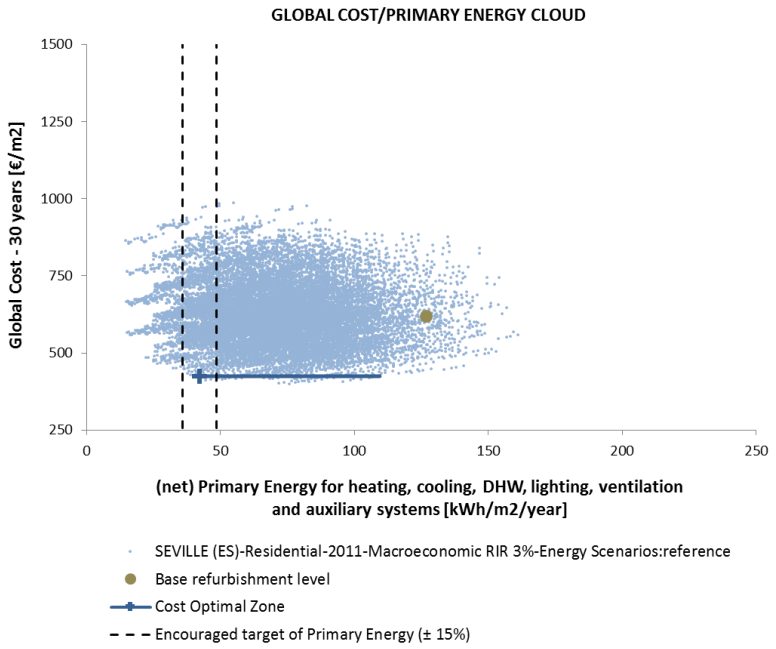

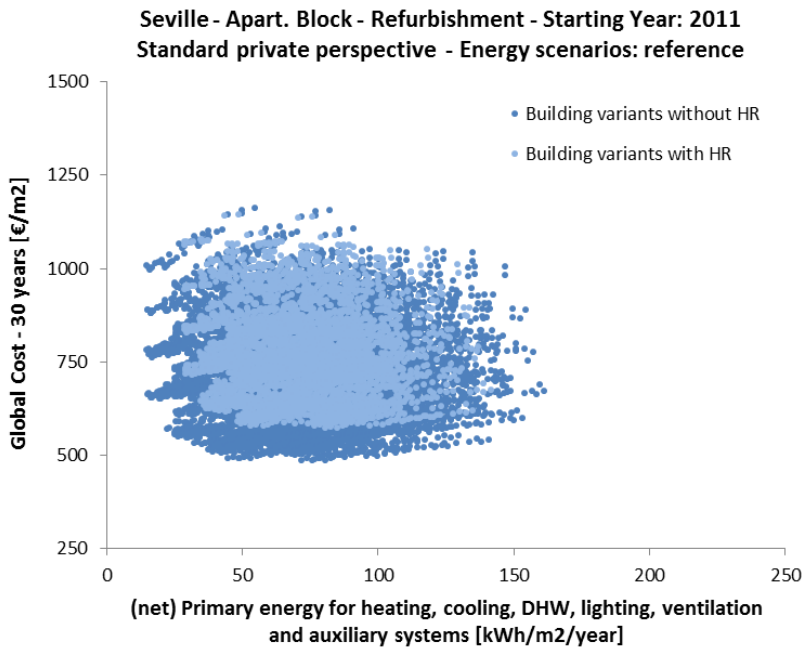

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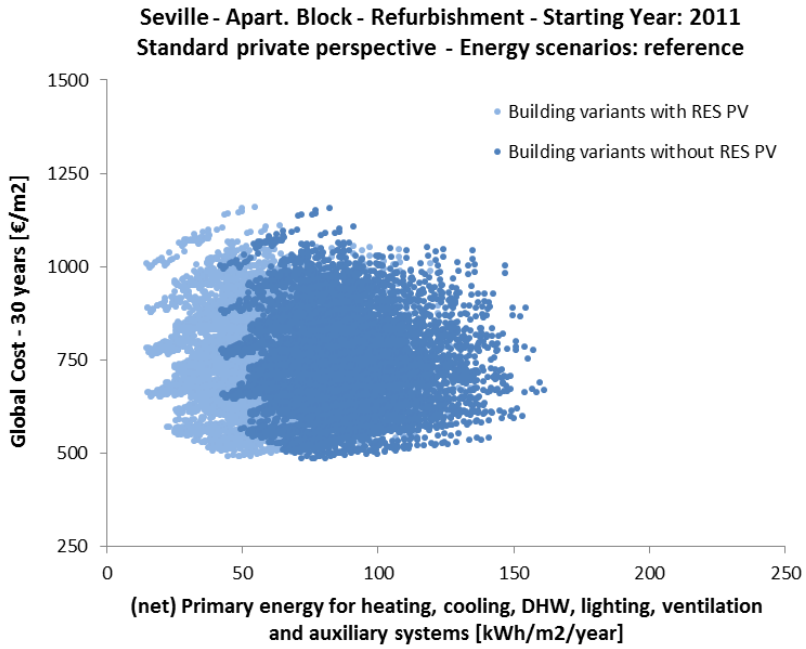

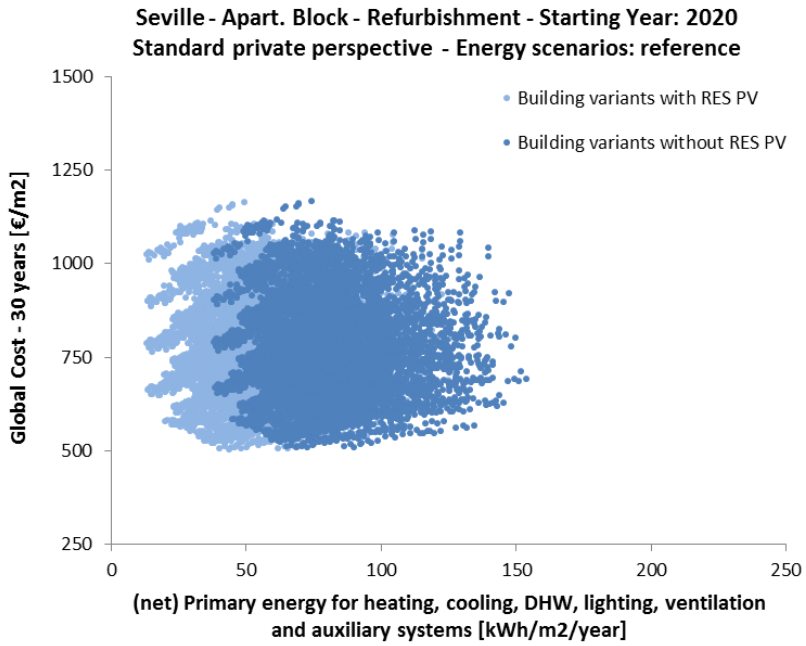

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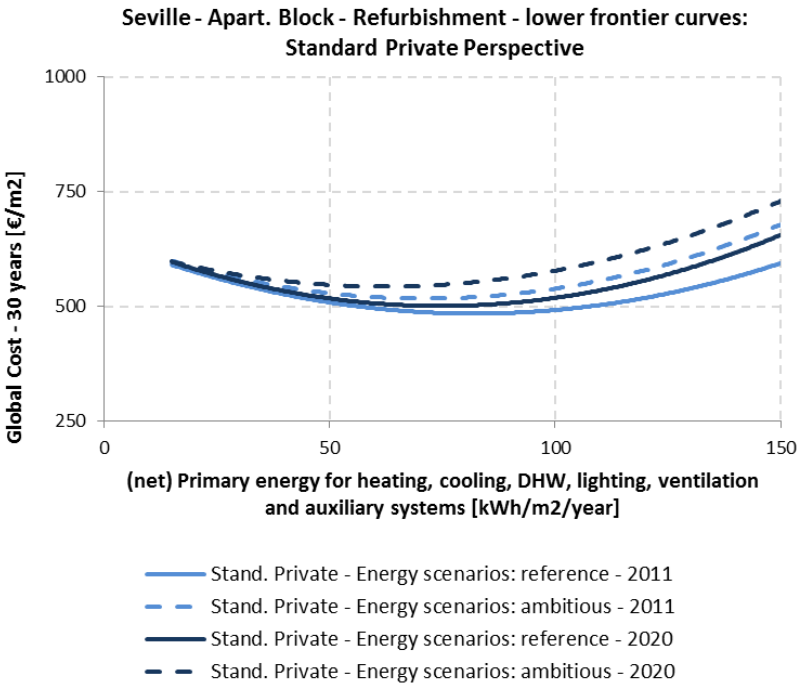

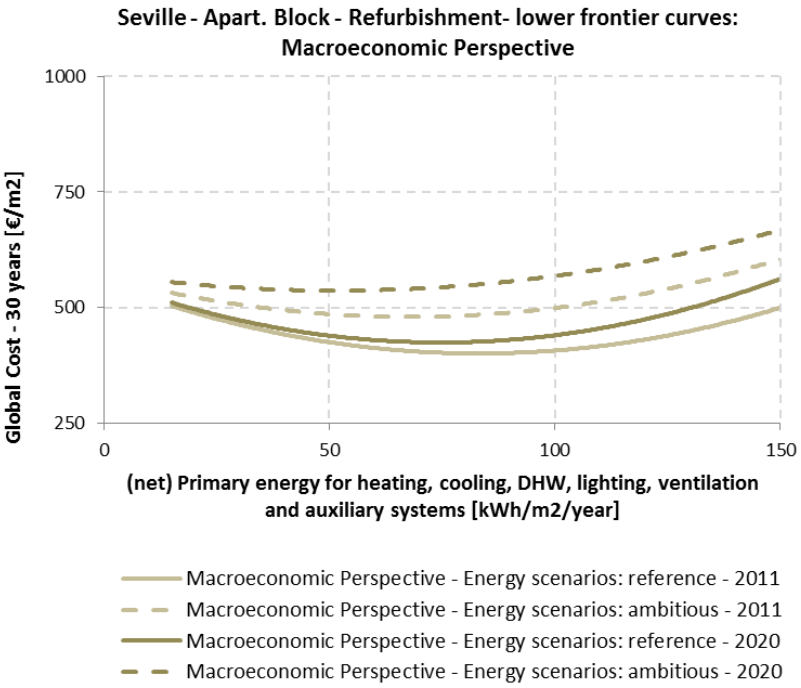

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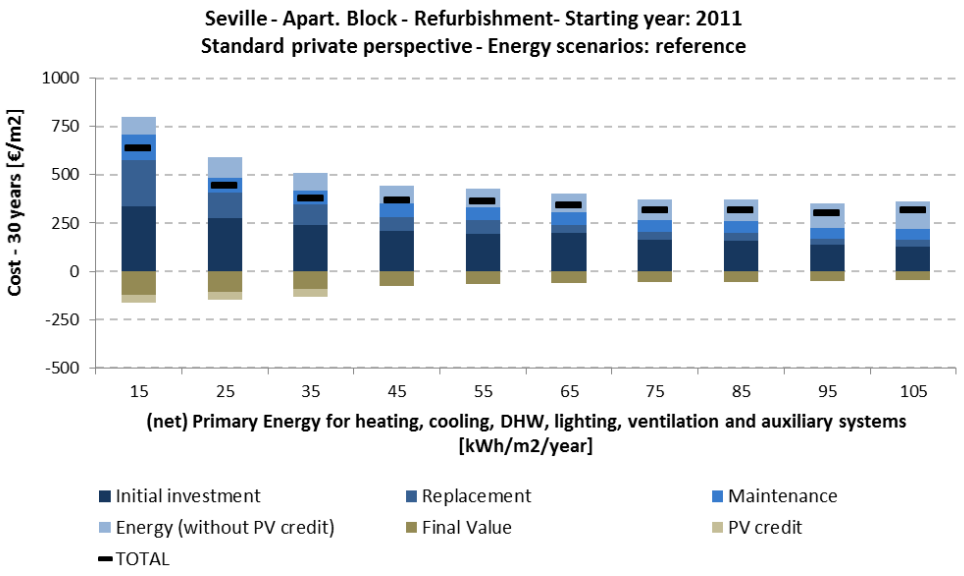

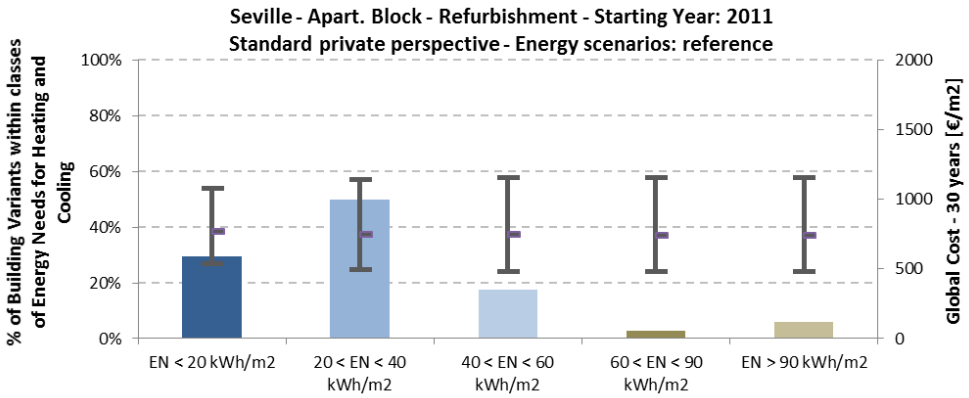

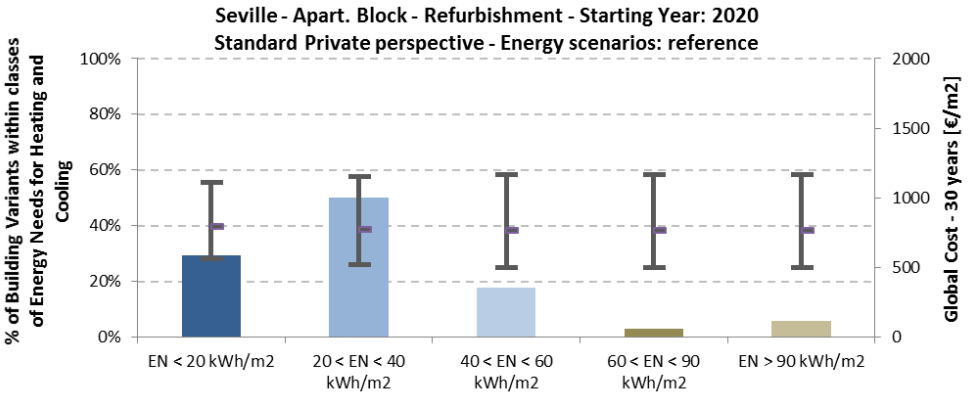

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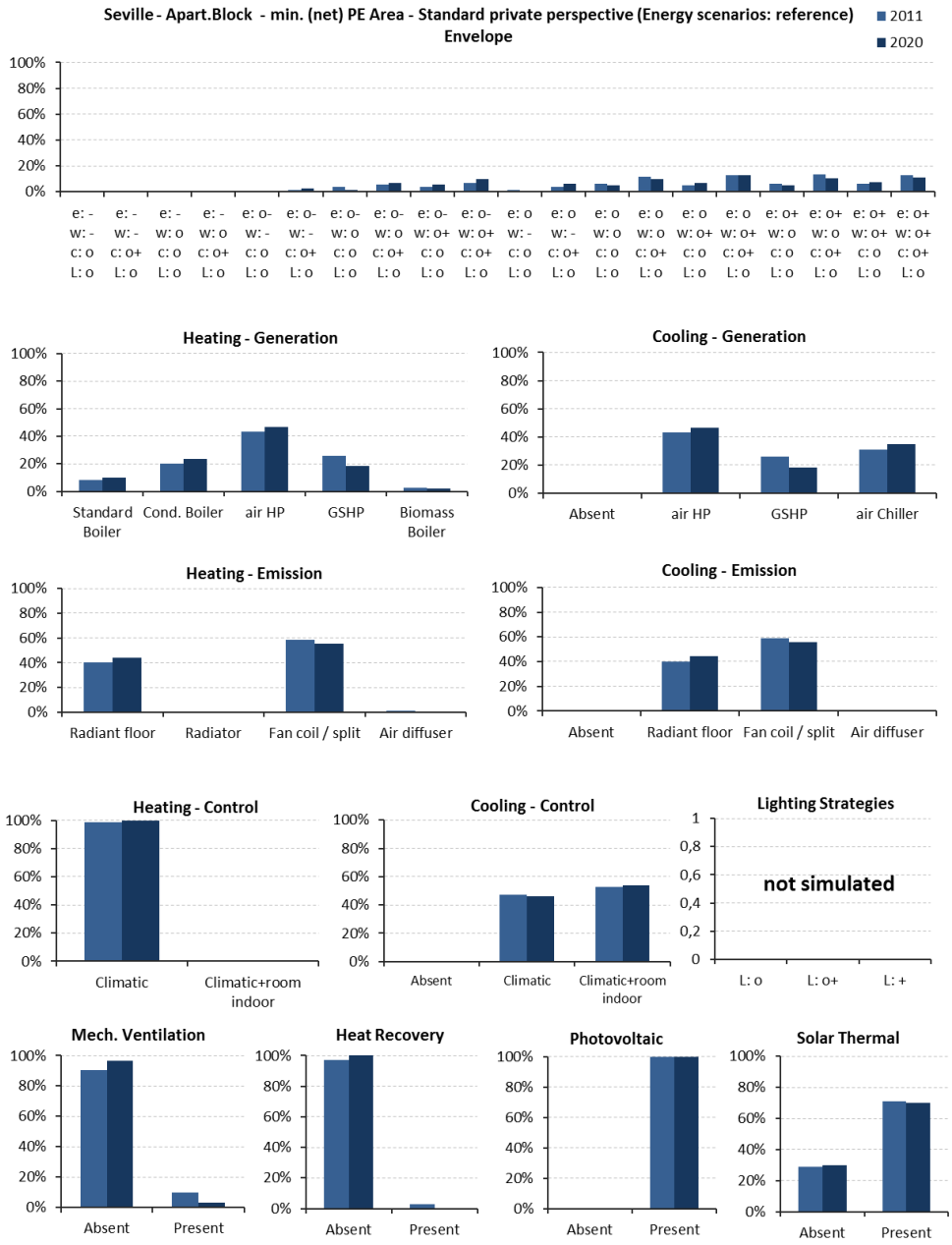
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	15	40	13	40
Range of Global Costs [€/m^2]:	507	633	508	626
Number of Building Variants:	185		185	



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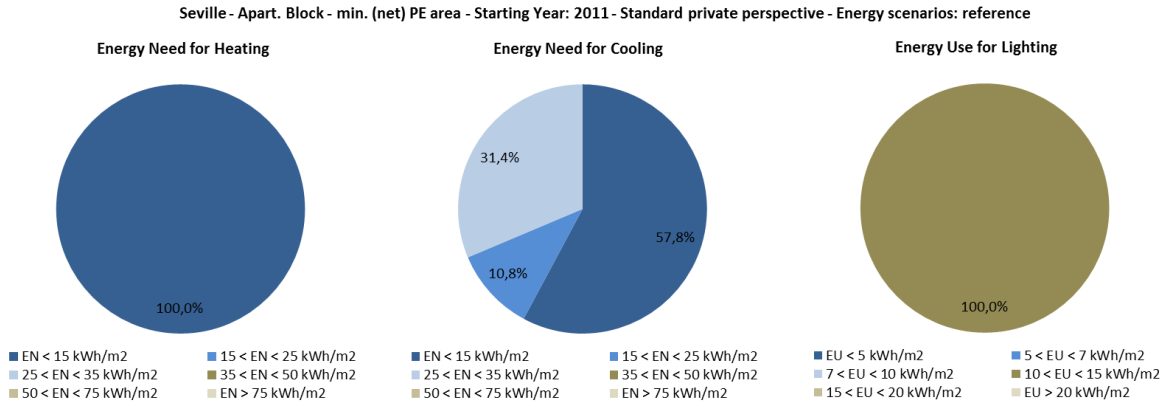

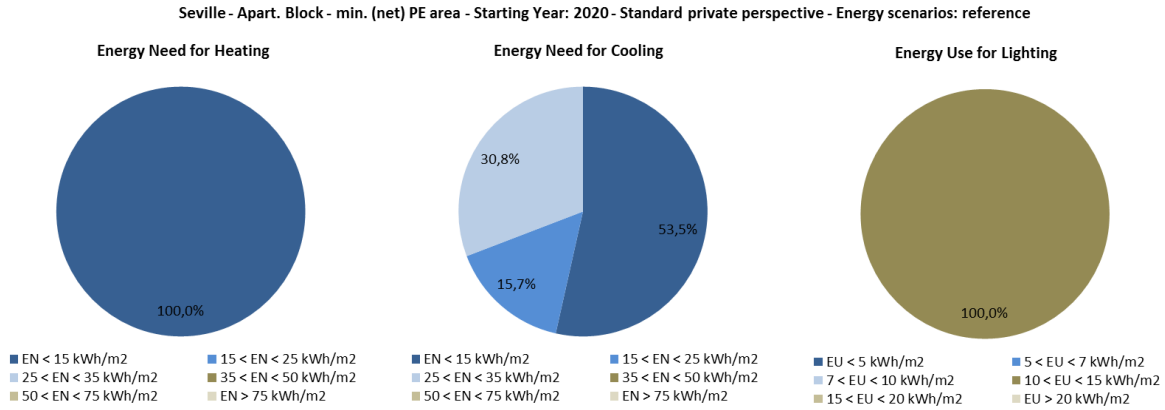

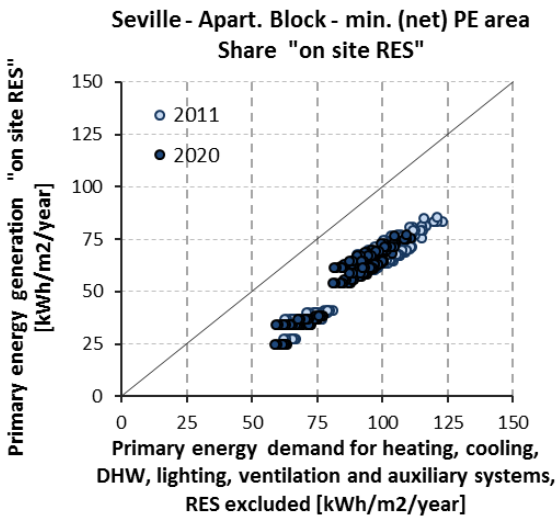

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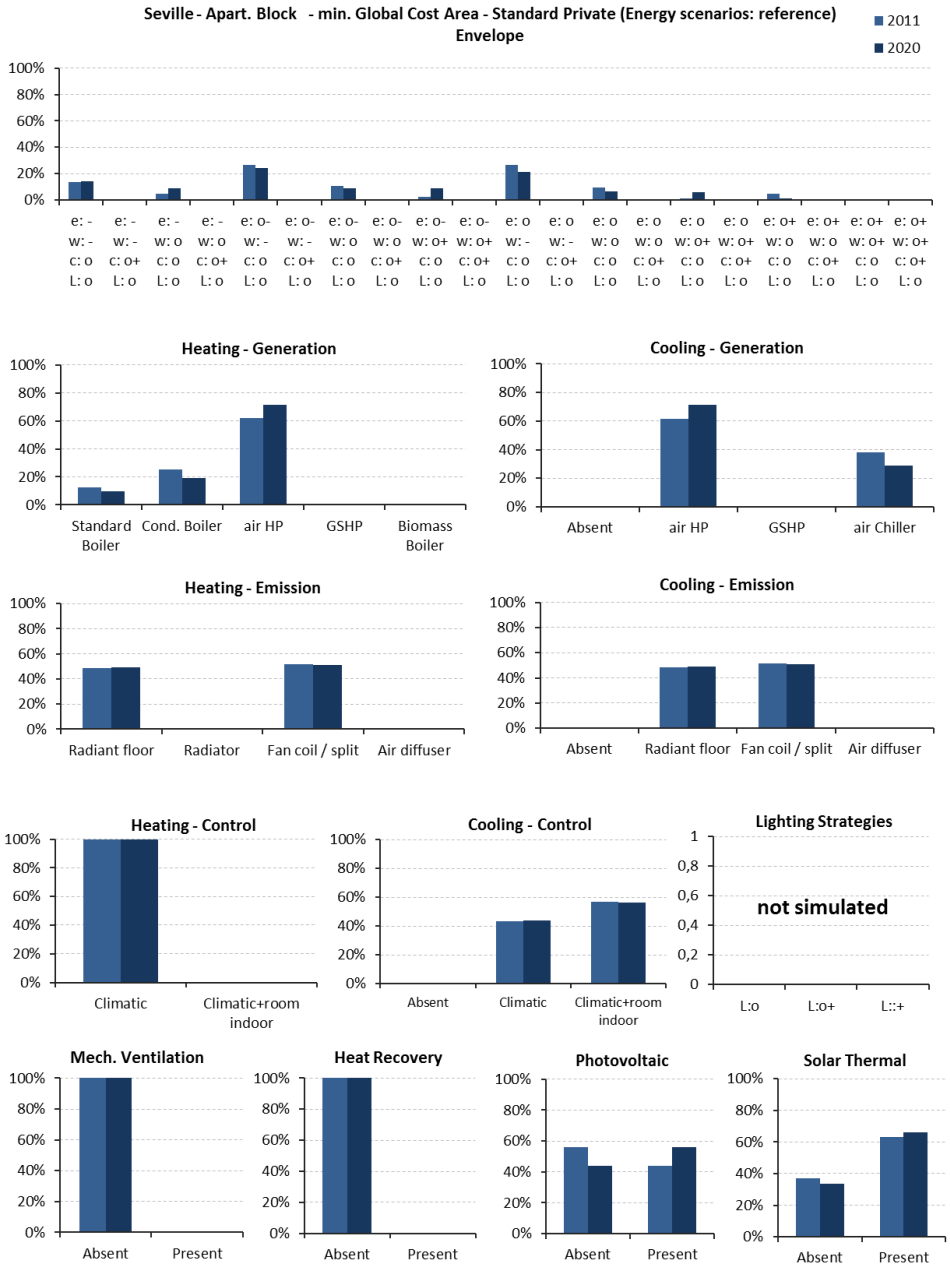
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	25	125	25	125
Range of Global Costs [€/m^2]:	487	521	505	540
Number of Building Variants:	157		157	



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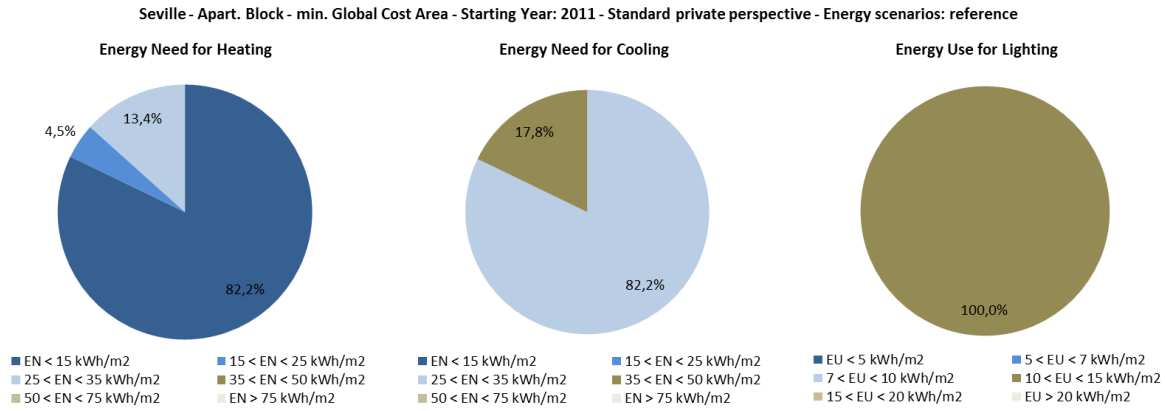

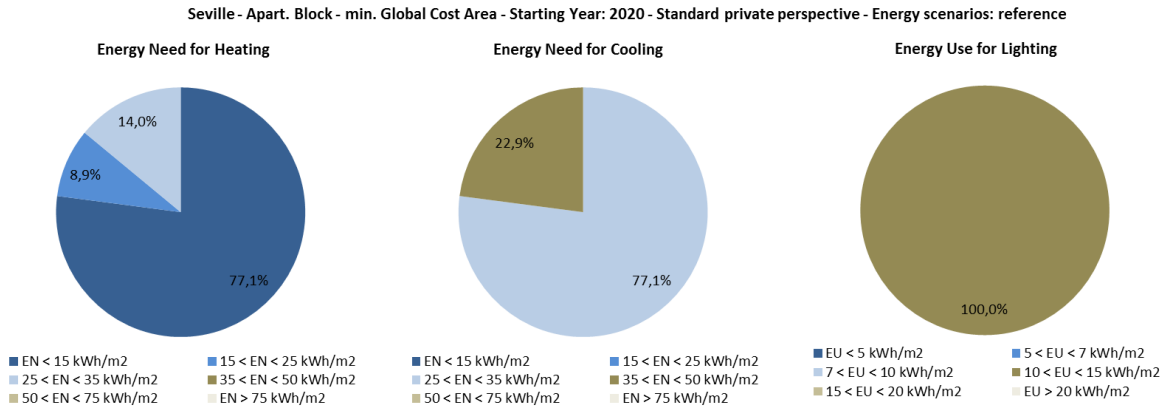

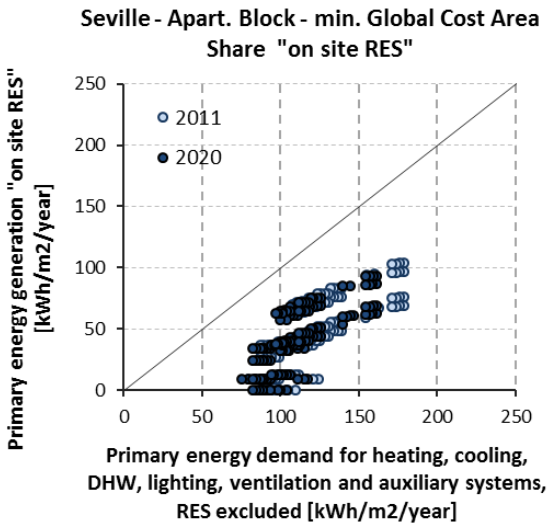

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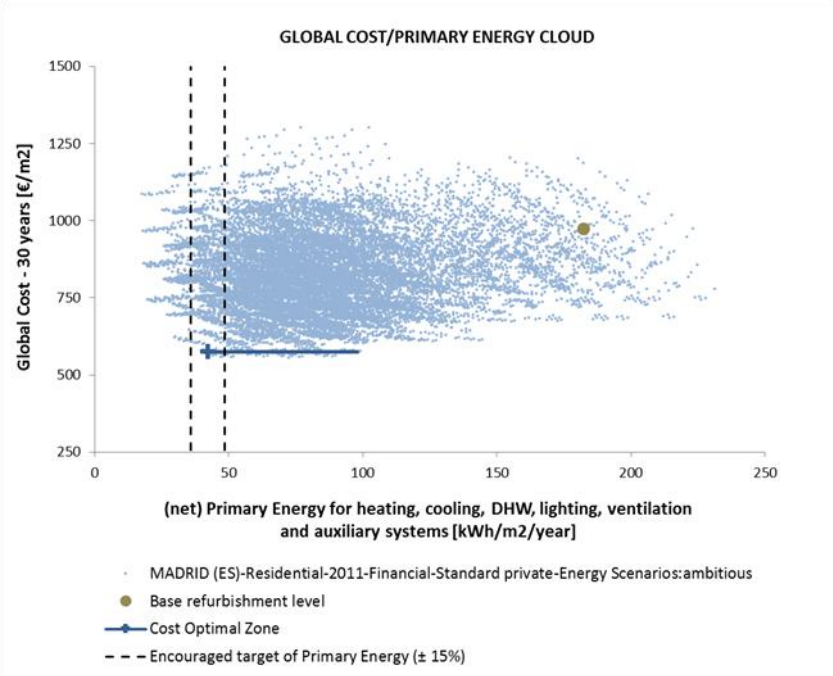
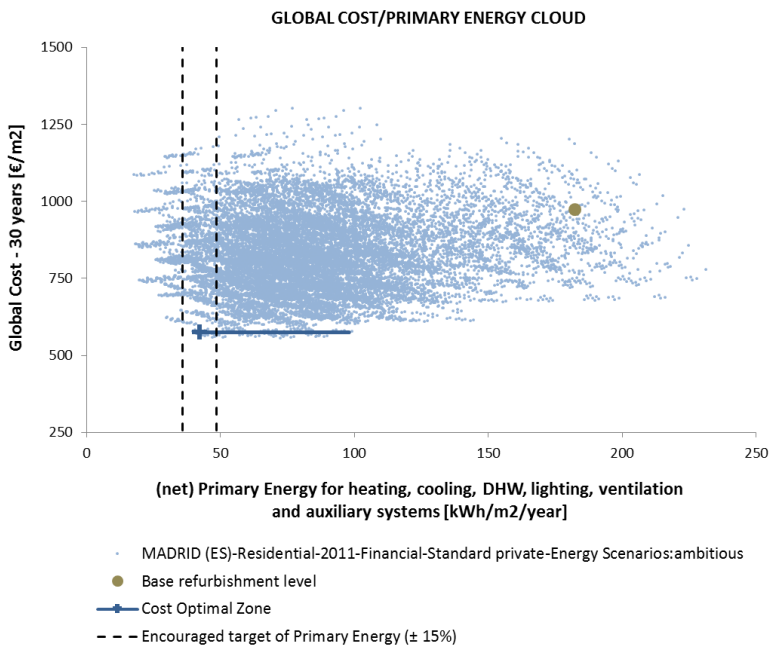
8.1.2.2 Madrid





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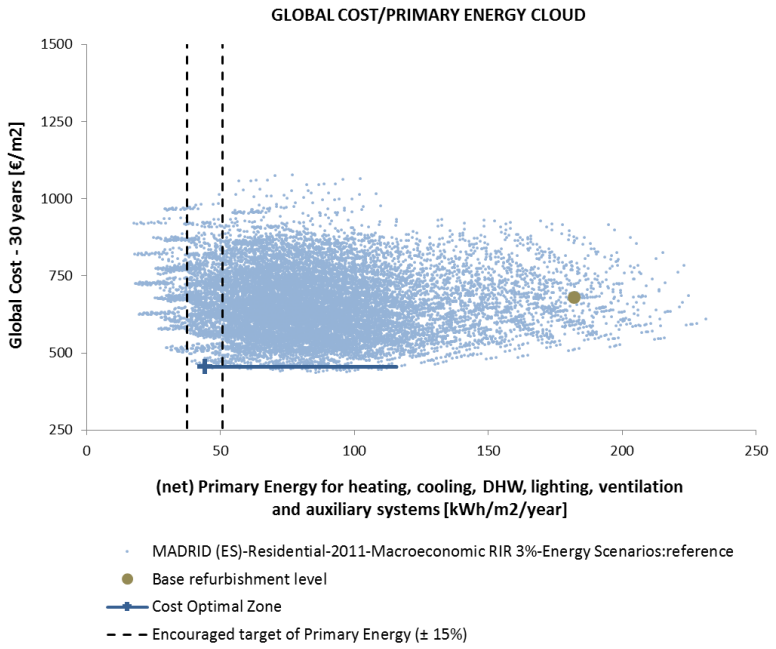

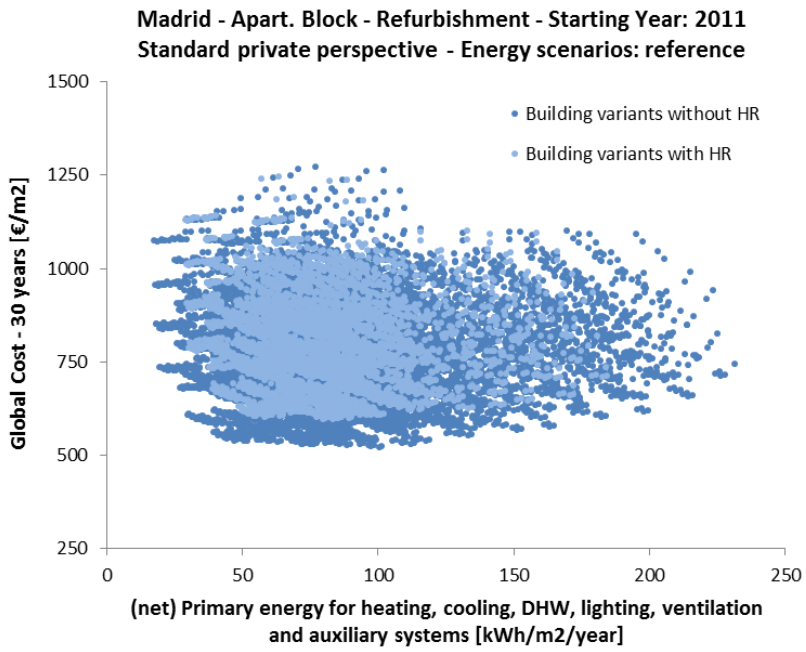

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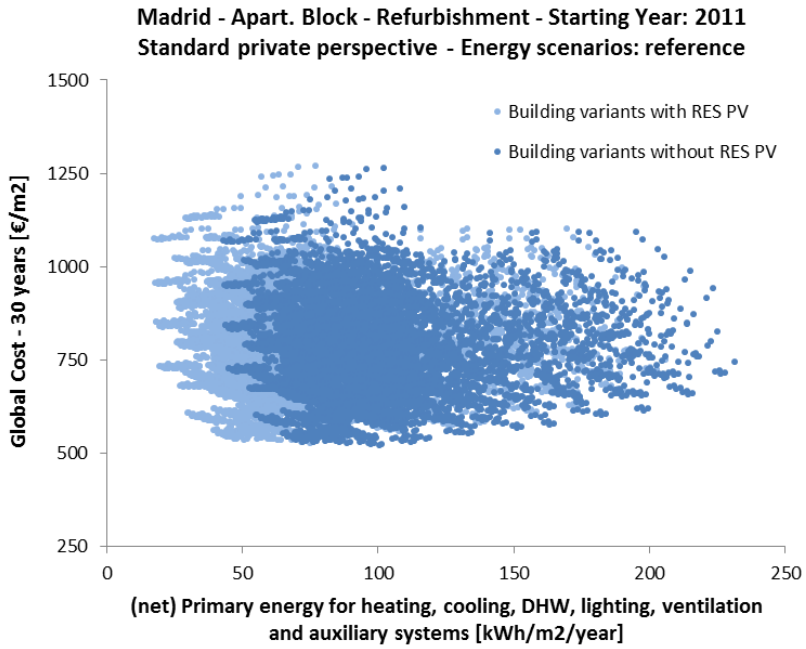

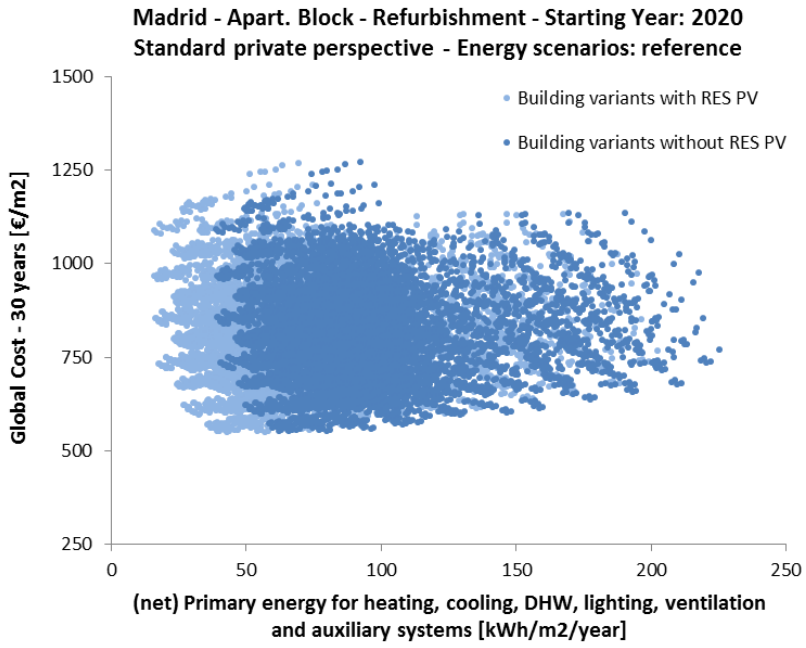

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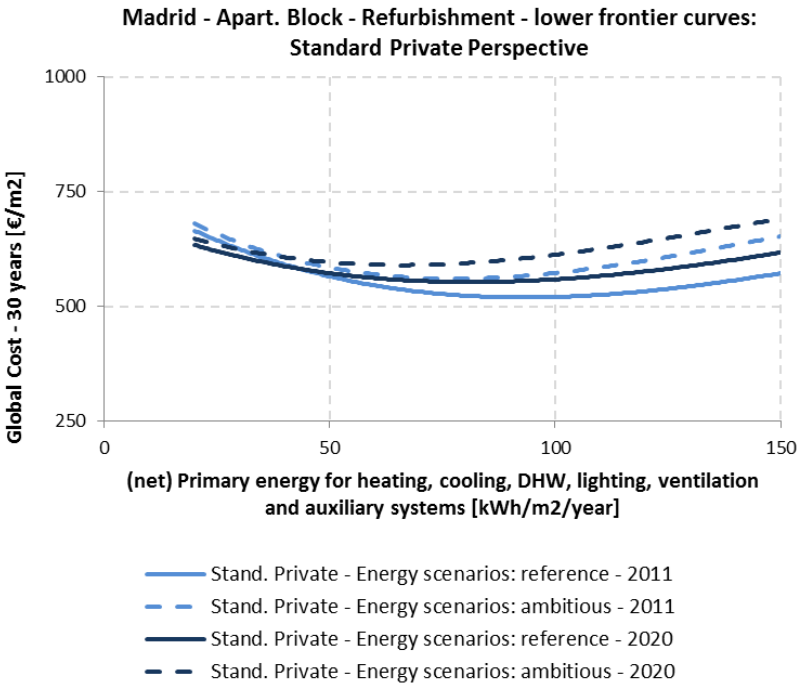

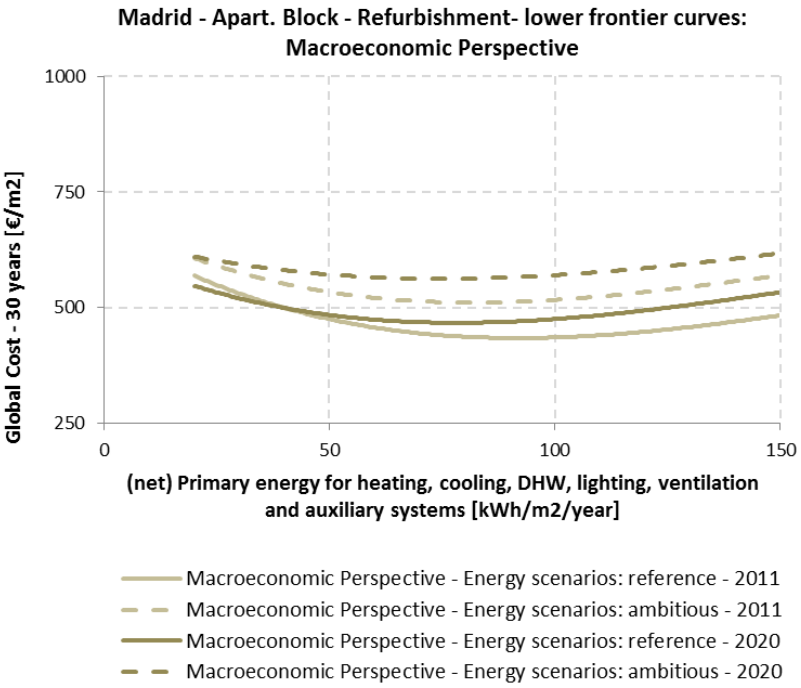

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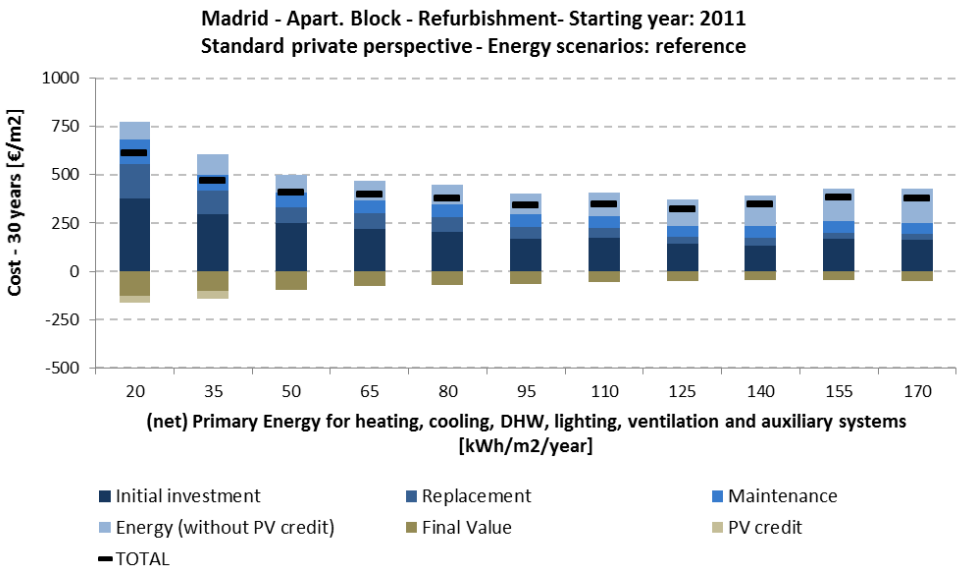

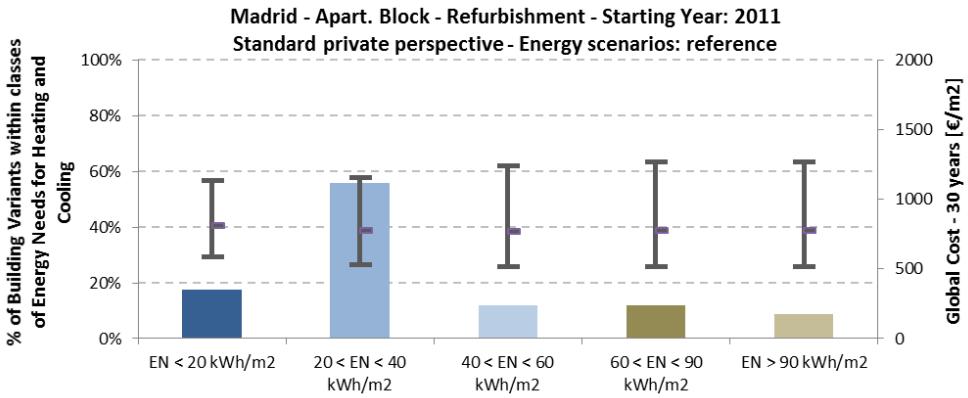

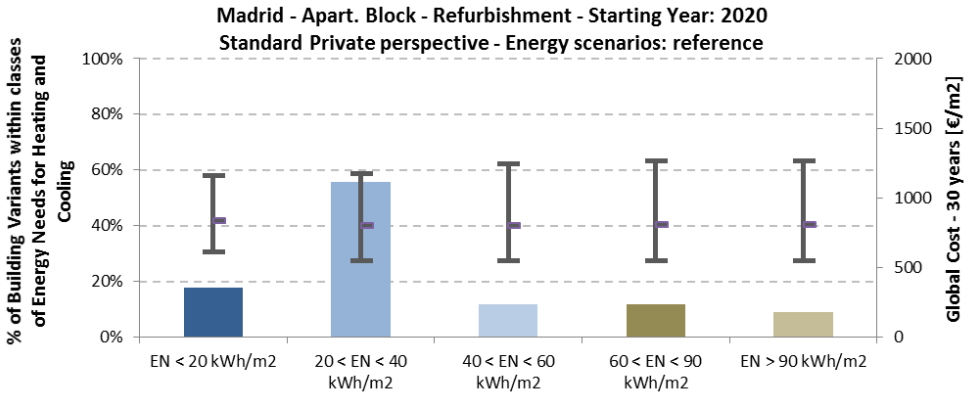

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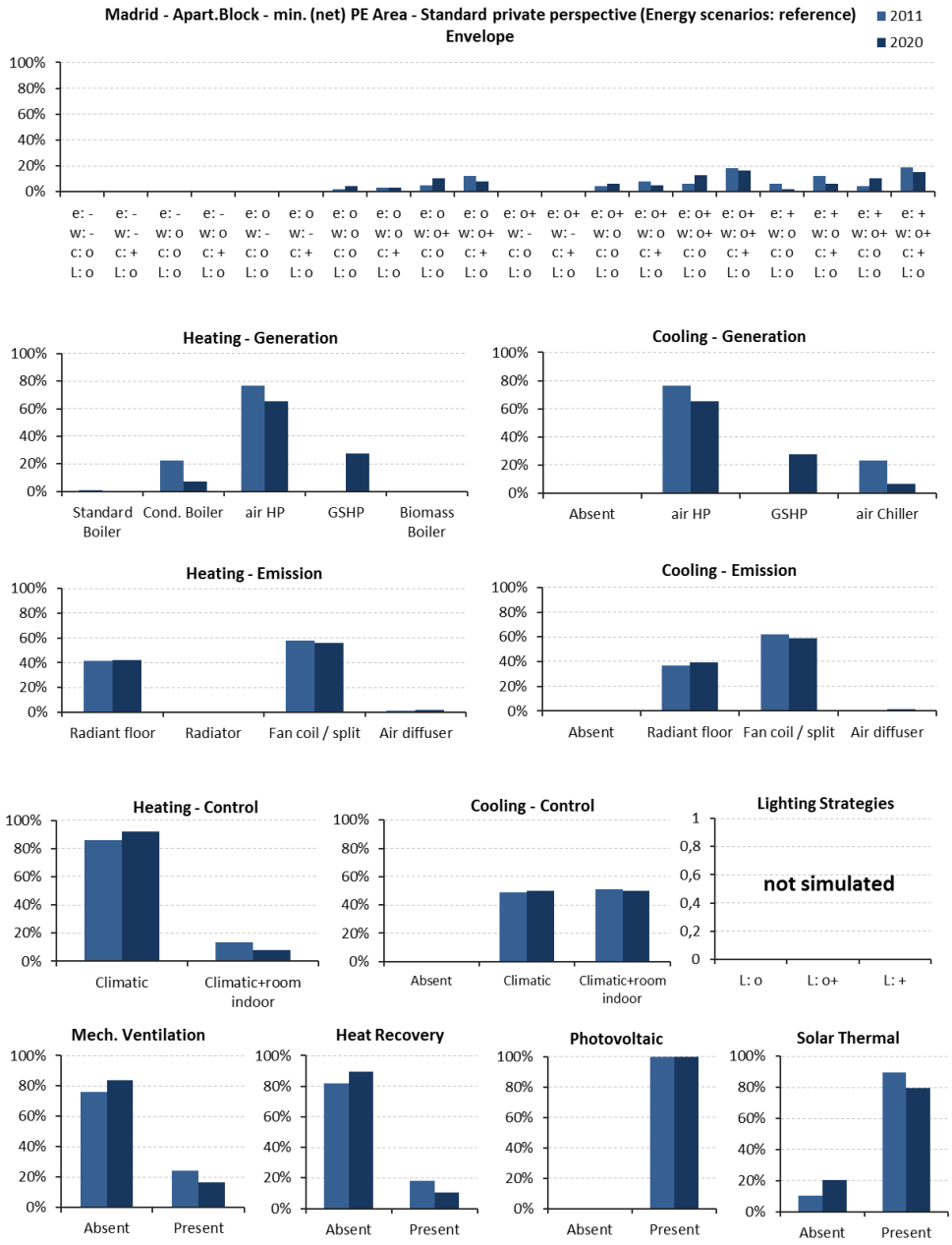
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	18	45	16	40
Range of Global Costs [€/m^2]:	539	673	551	686
Number of Building Variants:	116		116	



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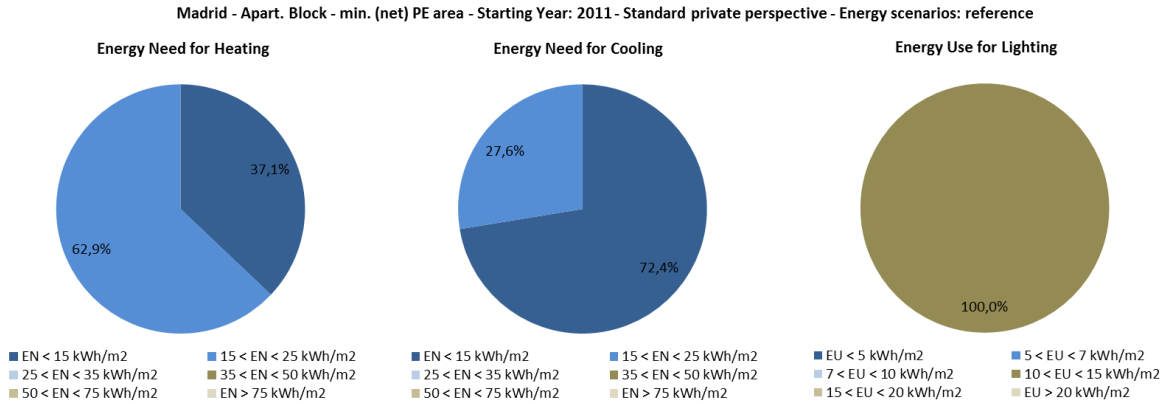

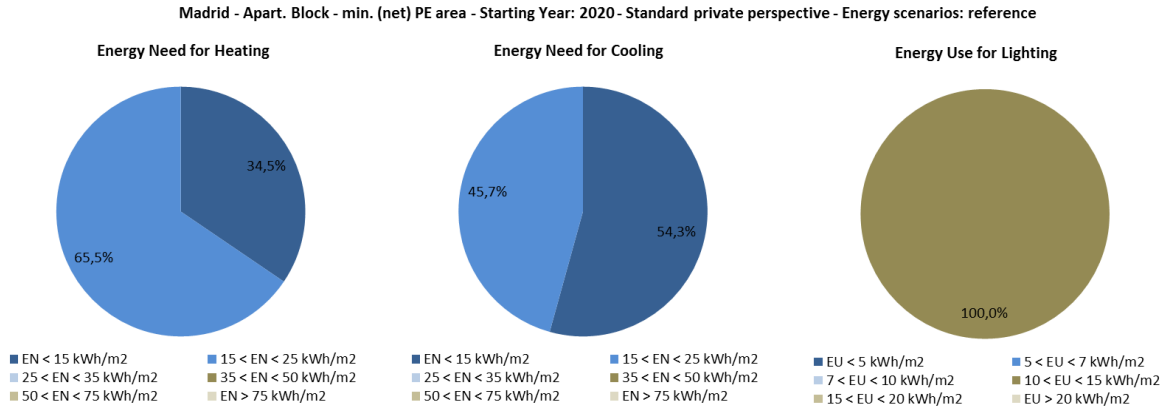

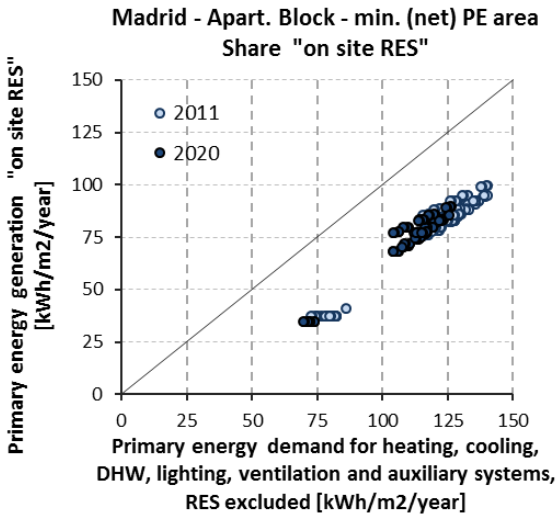

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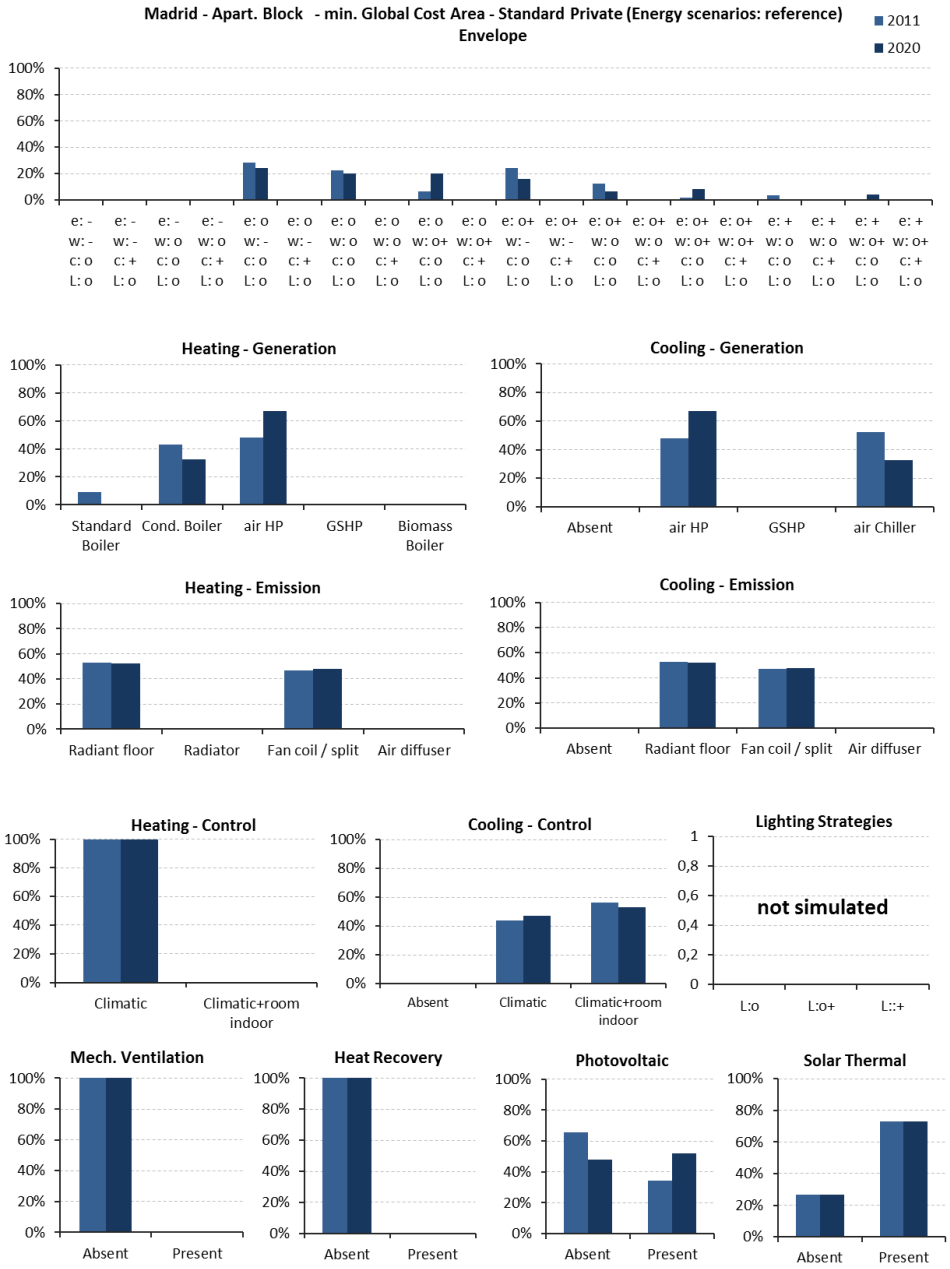
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	25	150	35	150
Range of Global Costs [€/m^2]:	522	548	550	574
Number of Building Variants:	119		119	



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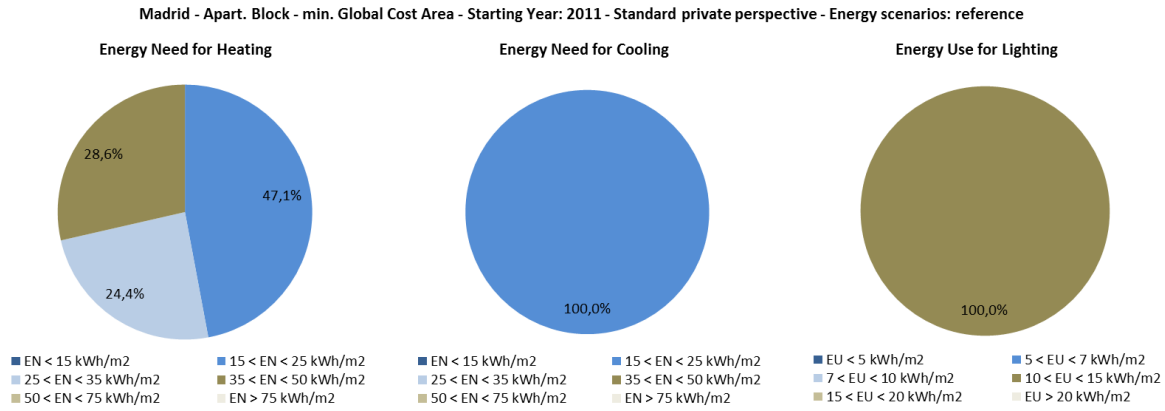

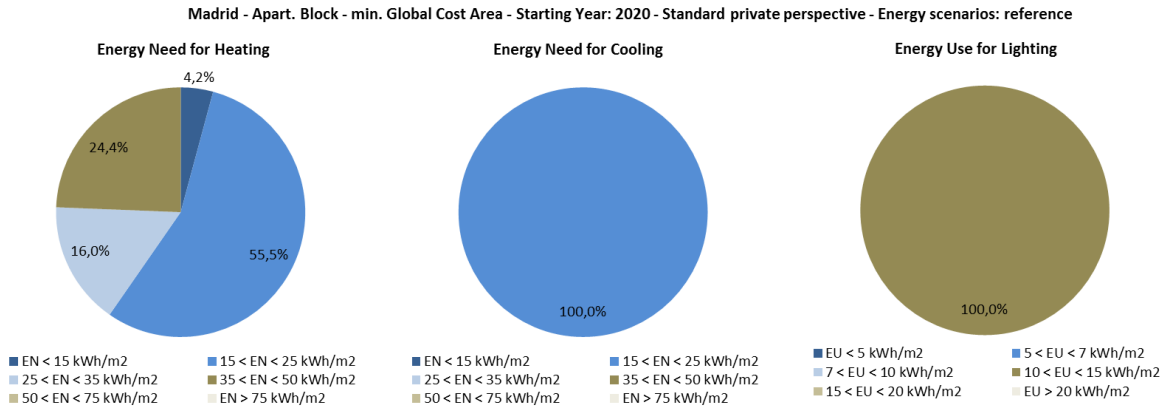

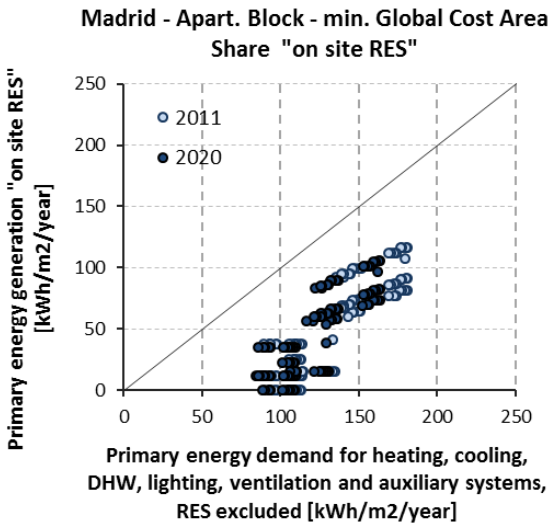

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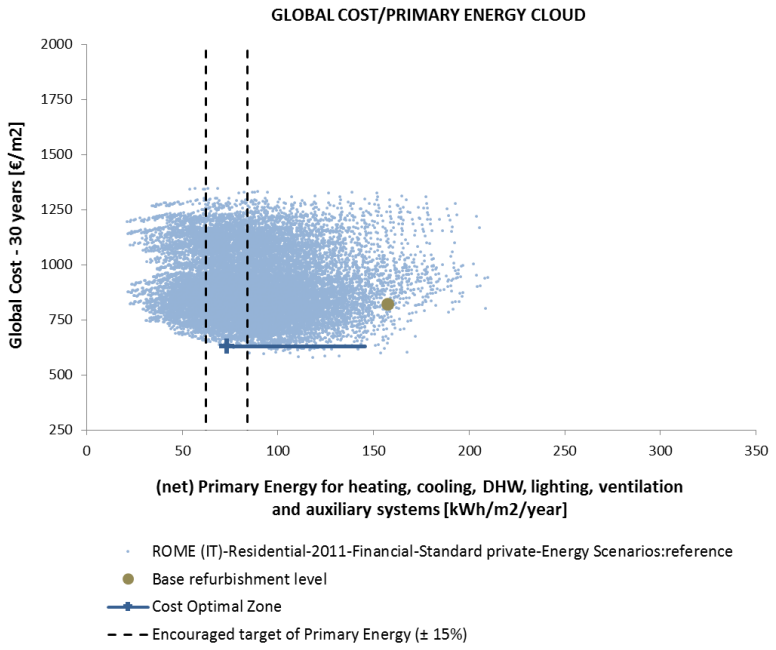
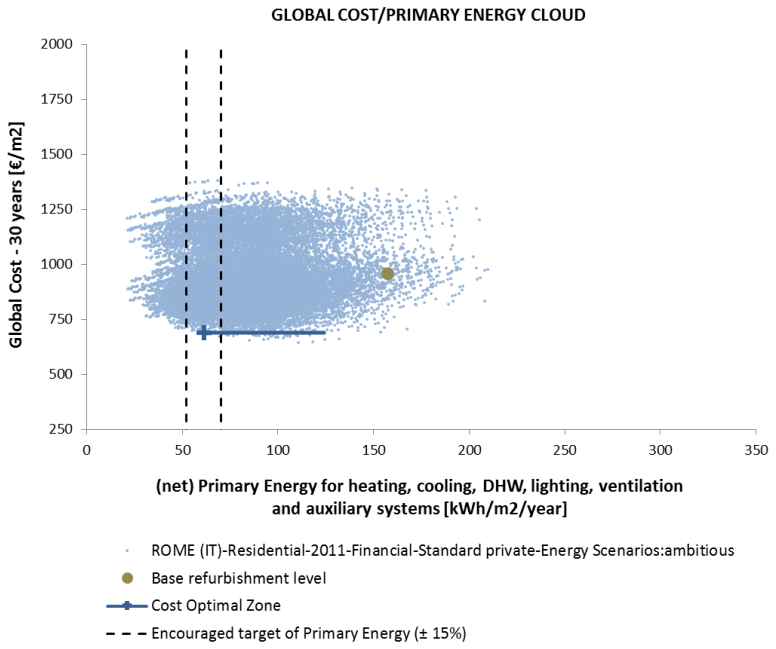
8.1.2.3 Rome





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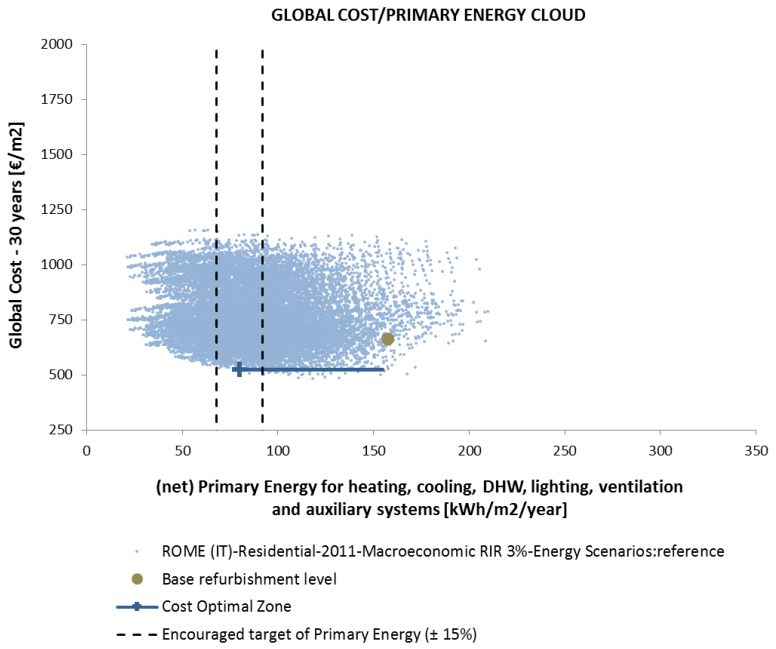

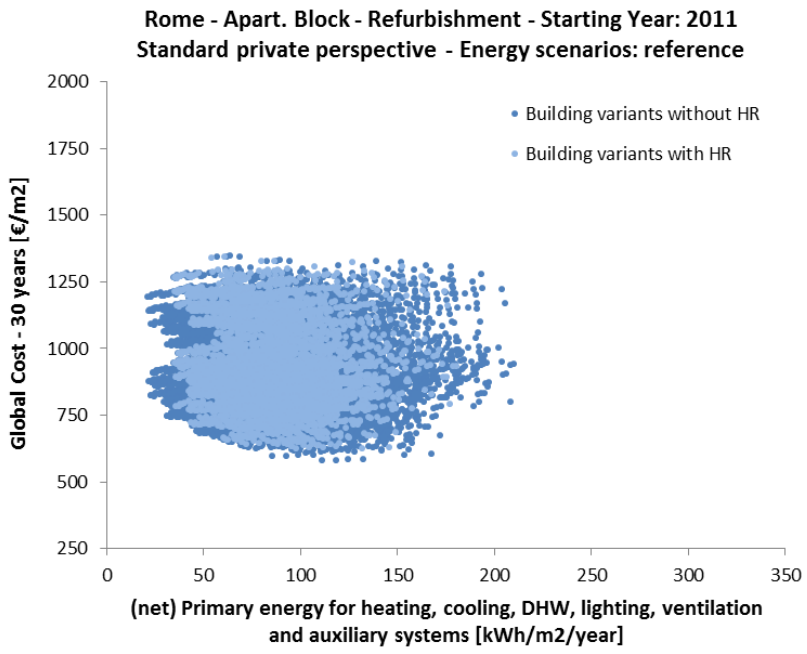

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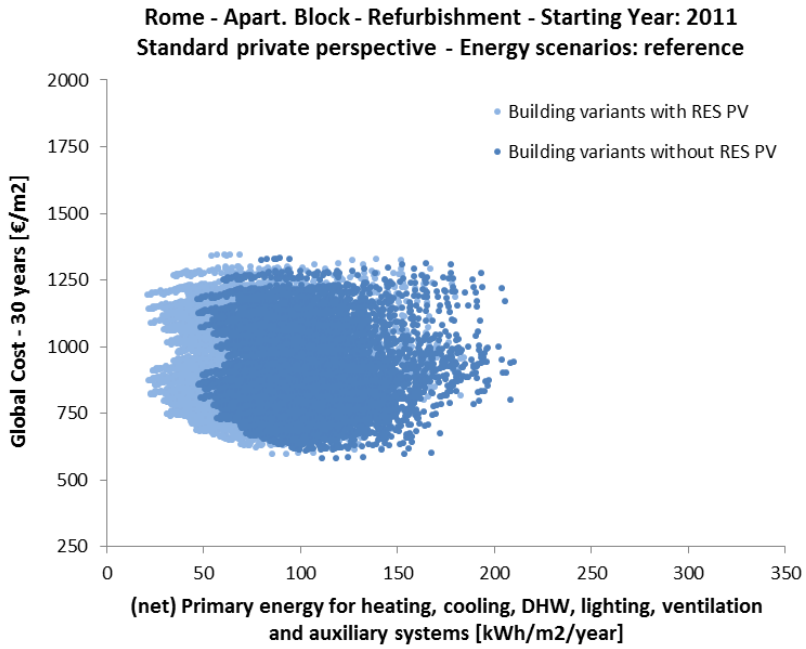

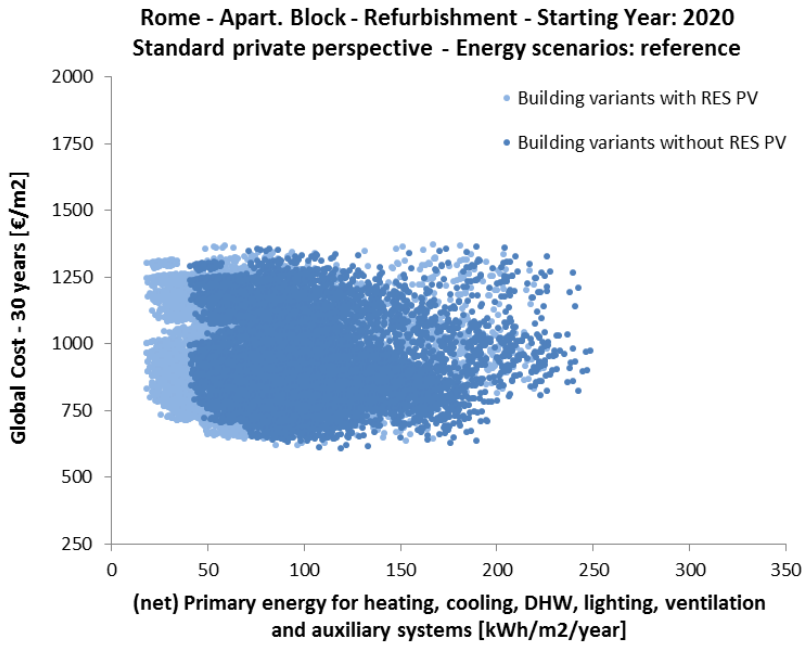

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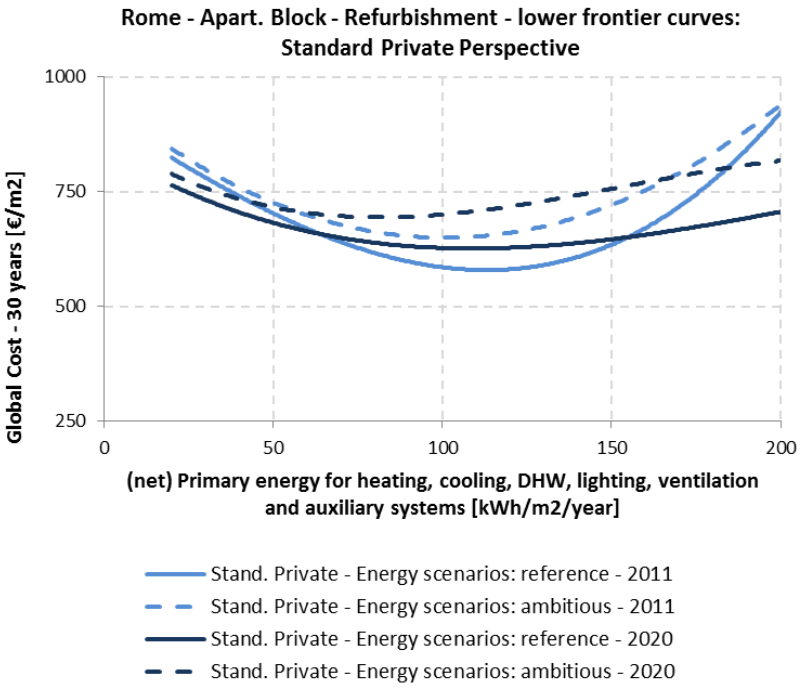

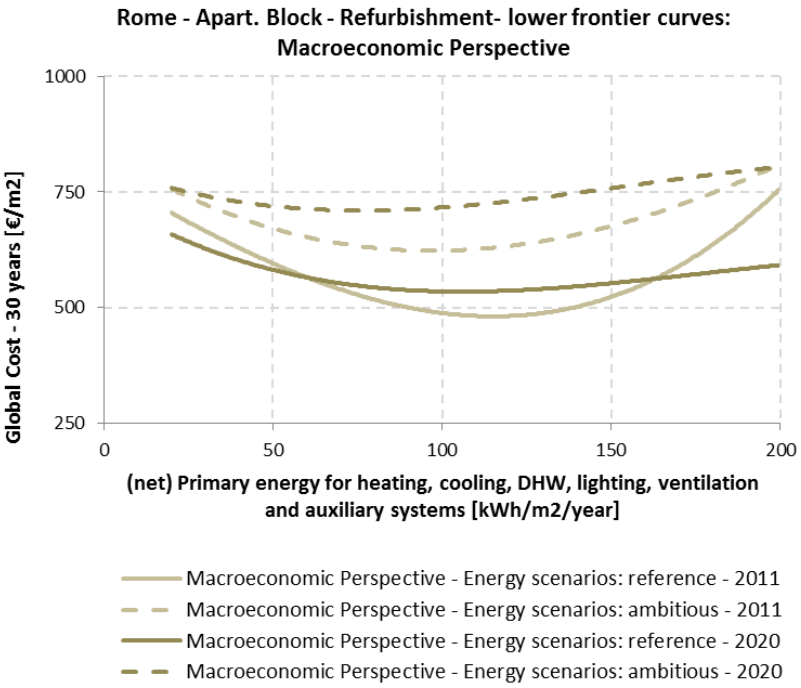

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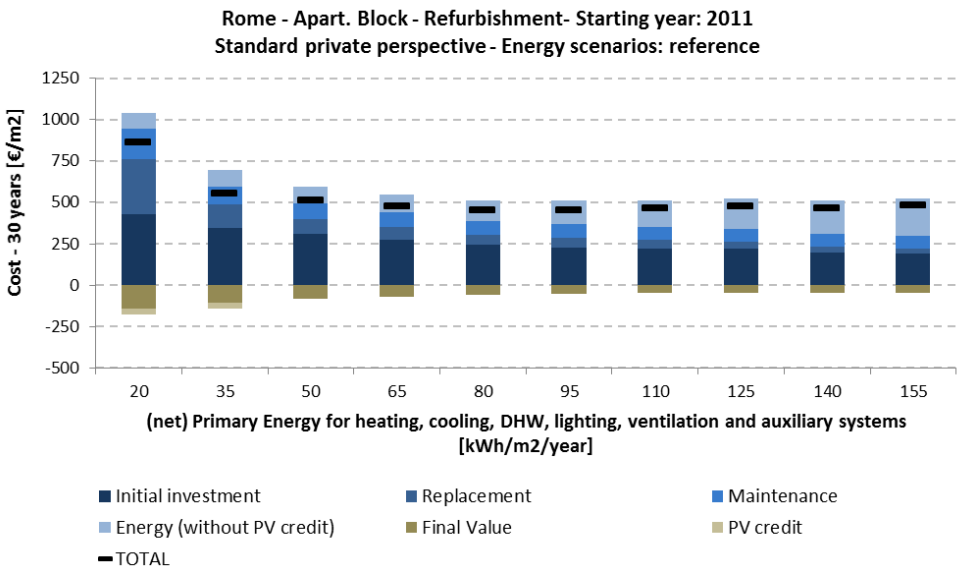

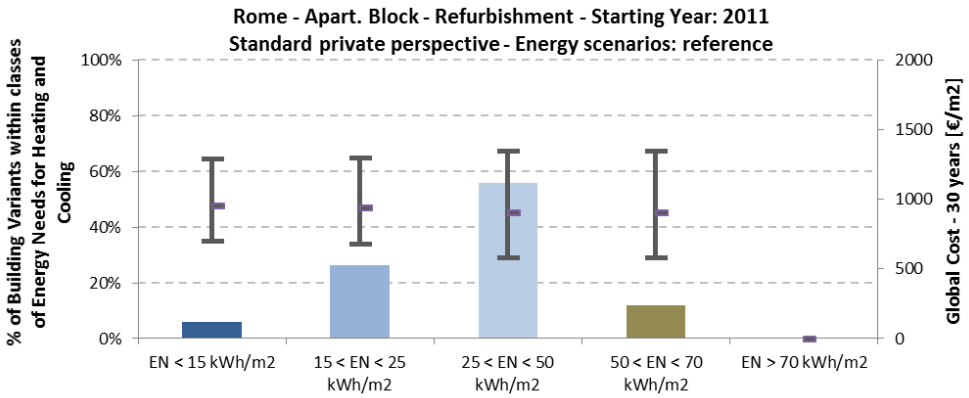

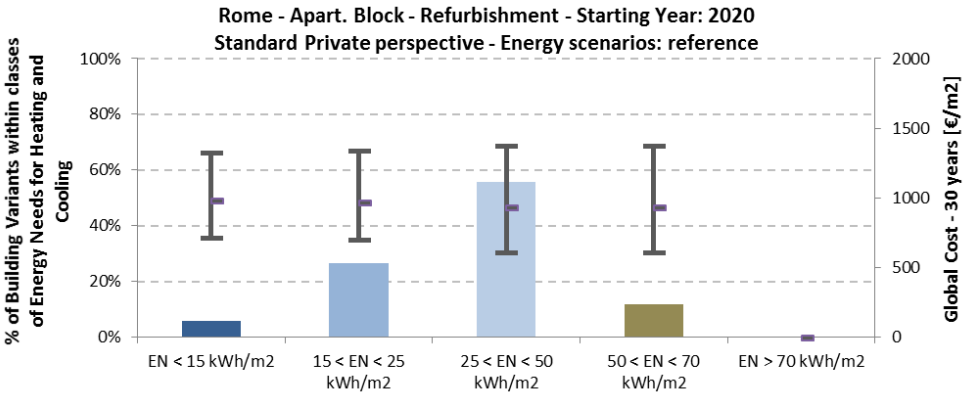

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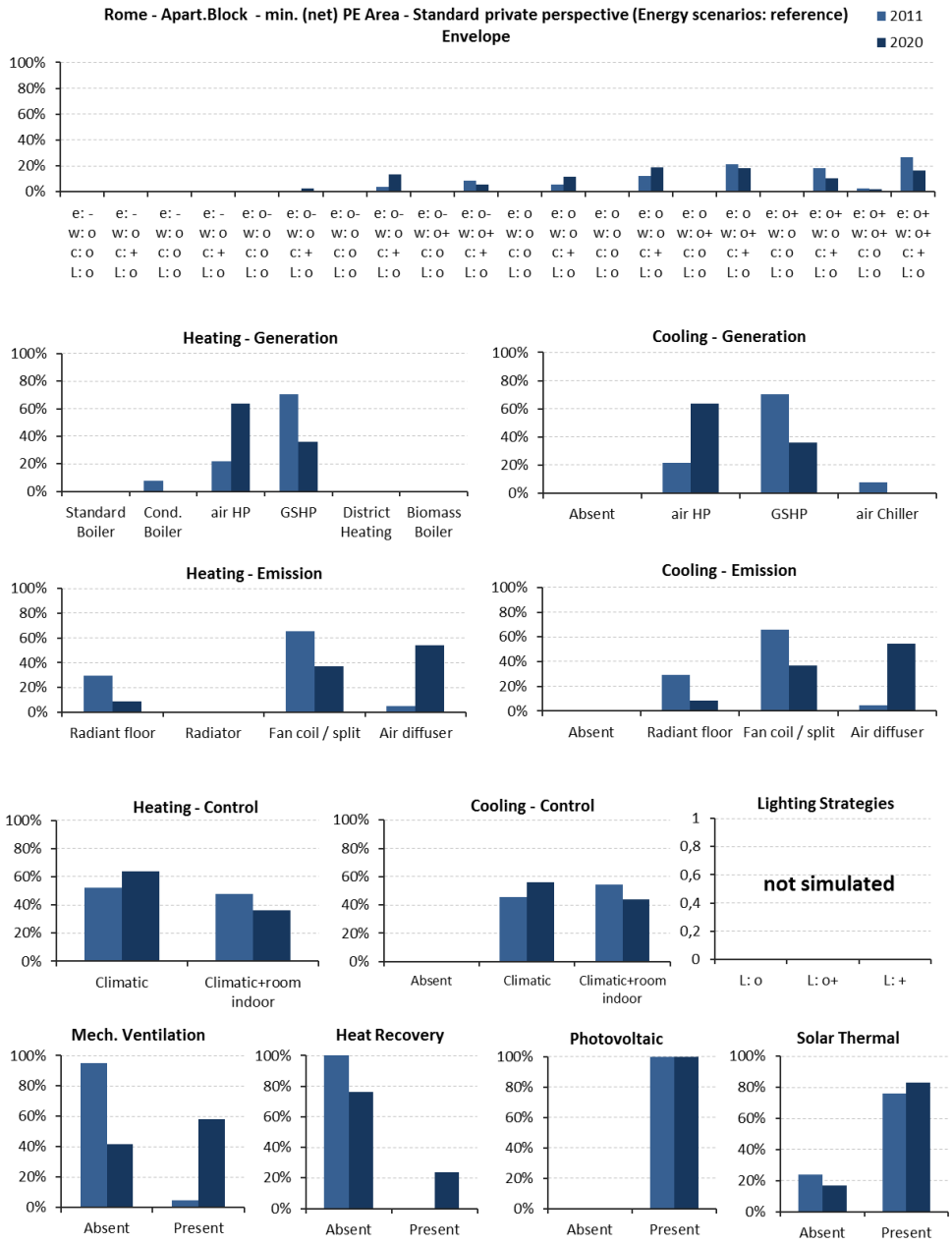
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	21	35	18	35
Range of Global Costs [€/m^2]:	743	891	715	831
Number of Building Variants:	105		105	



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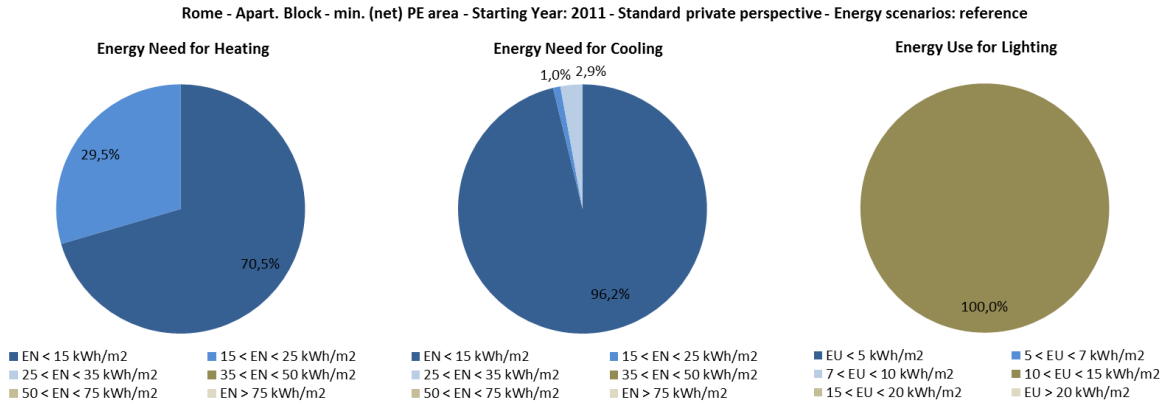

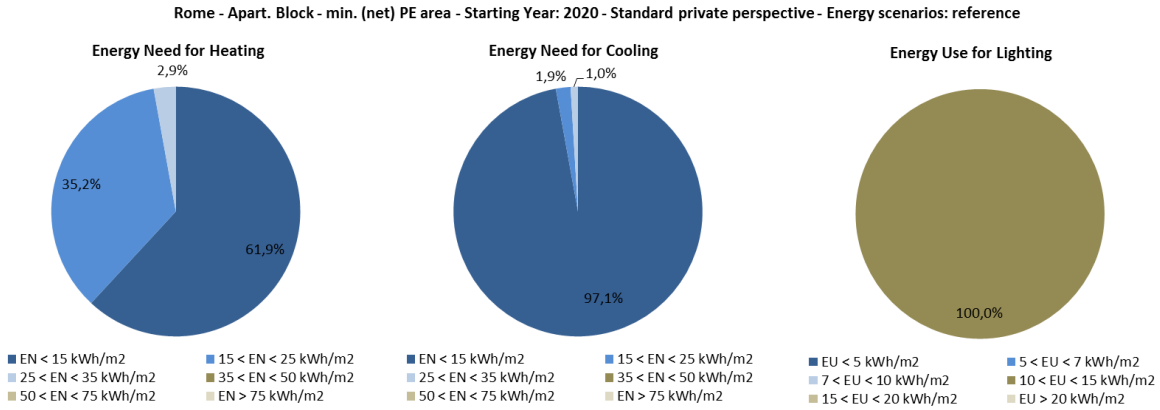

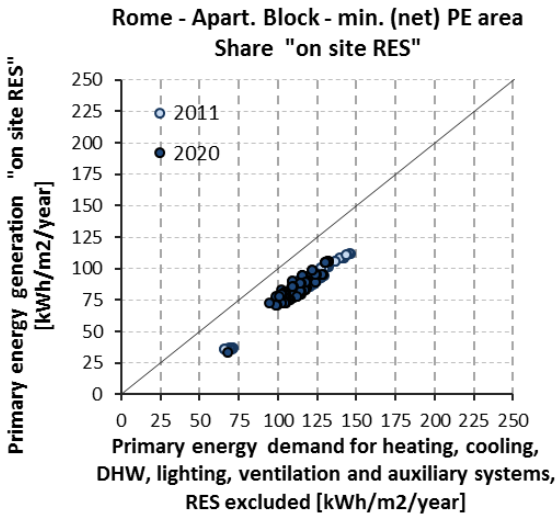

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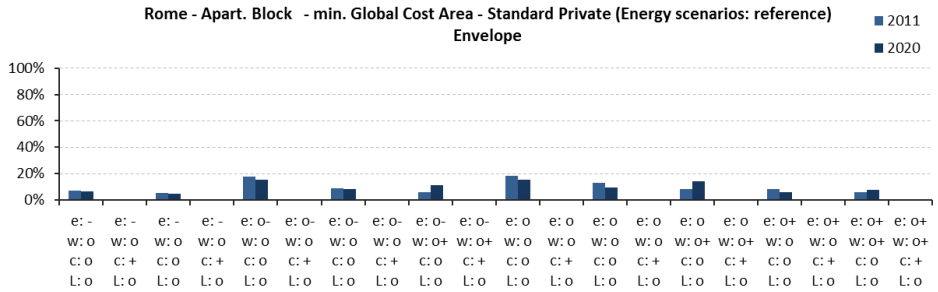
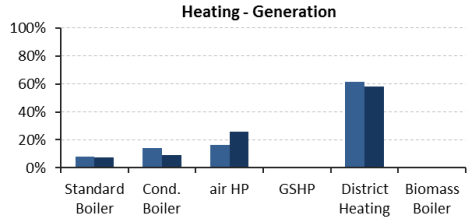
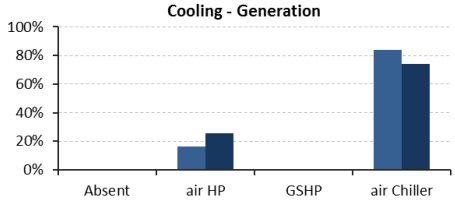
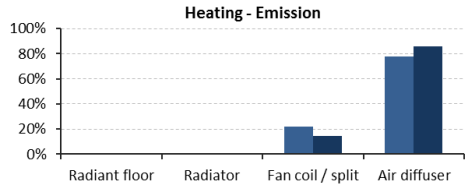
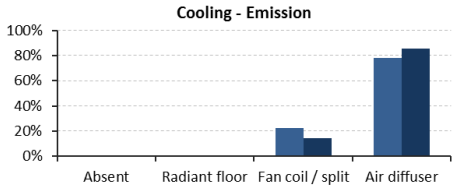
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	50	190	50	190
Range of Global Costs [€/m^2]:	581	651	611	674
Number of Building Variants:	167		167	

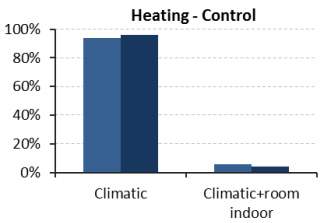


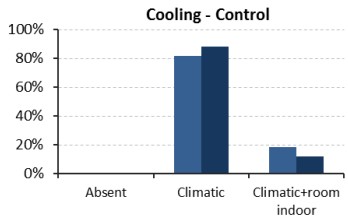


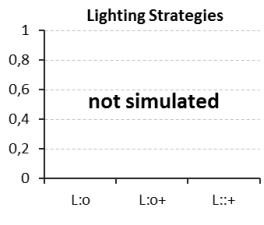


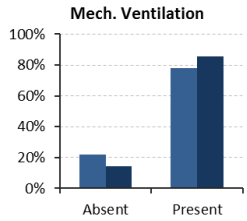


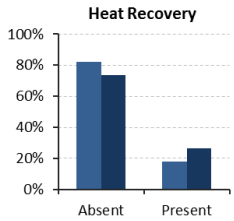


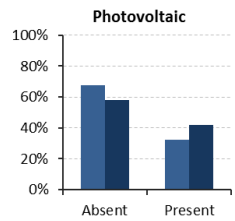


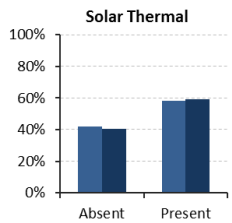












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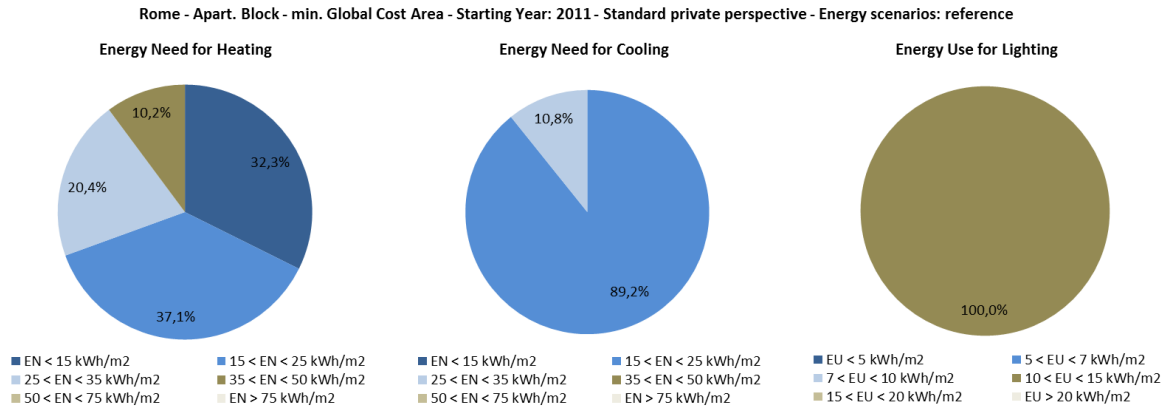

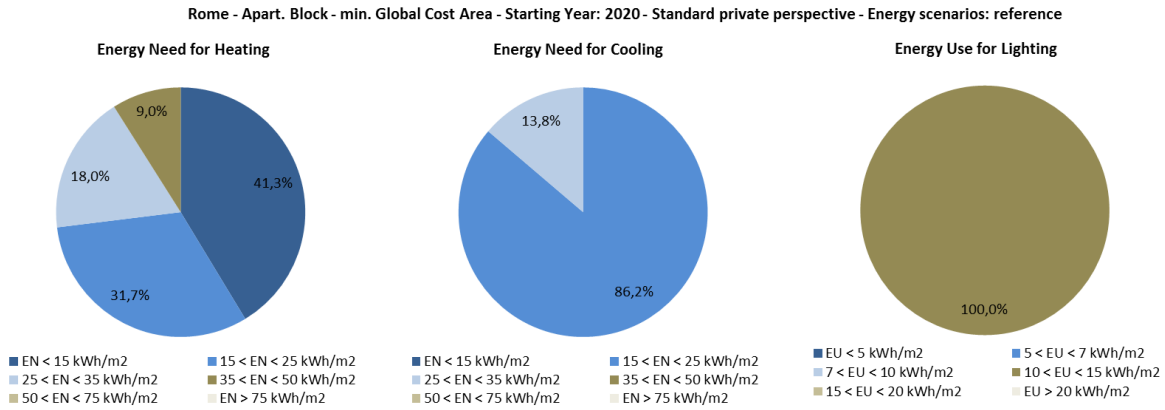

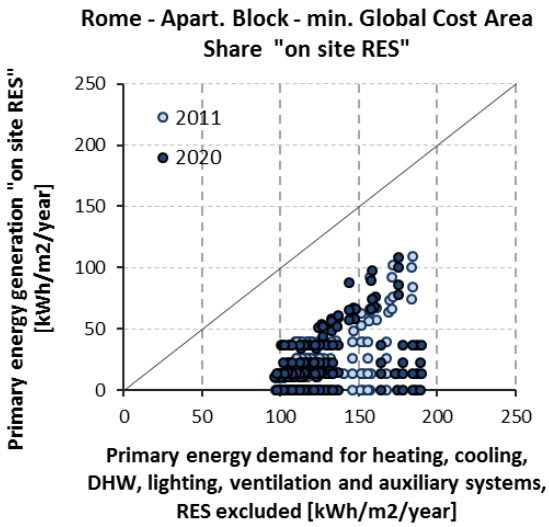

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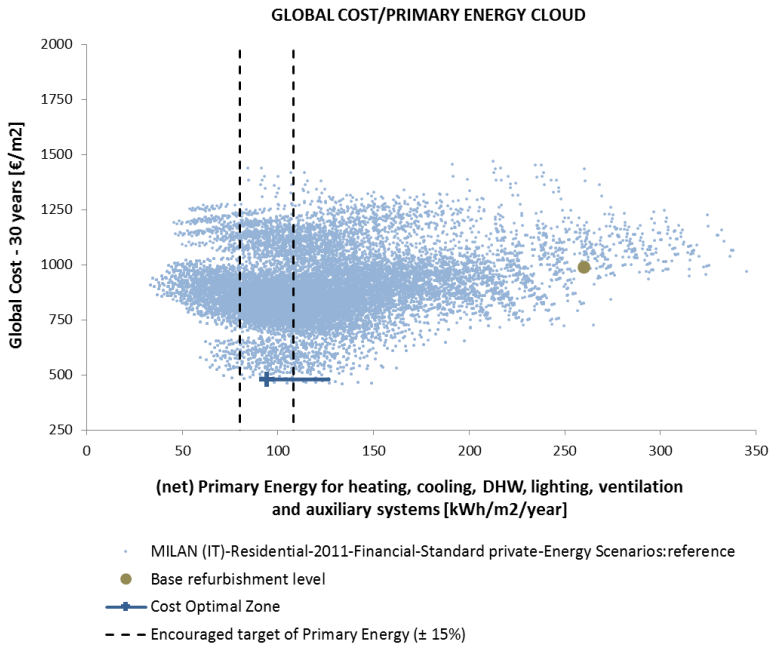
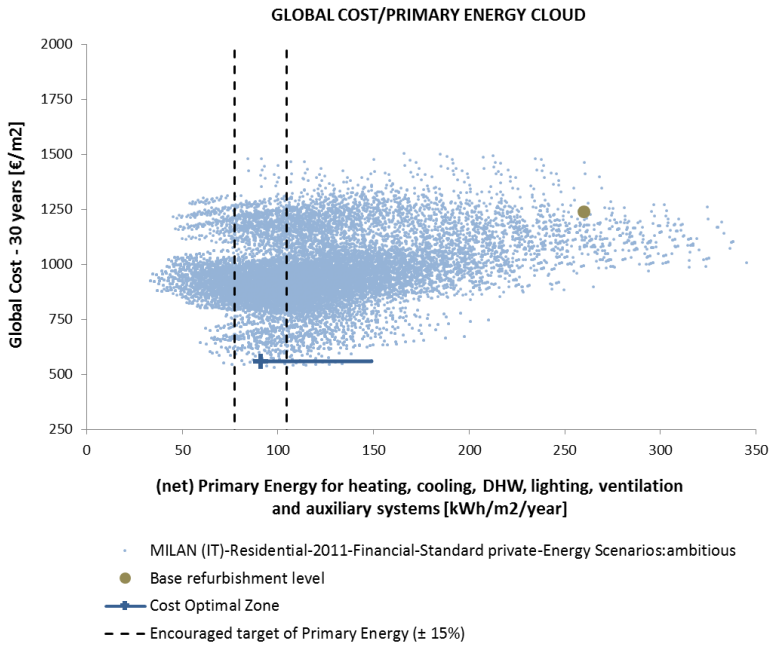
8.1.2.4 Milan





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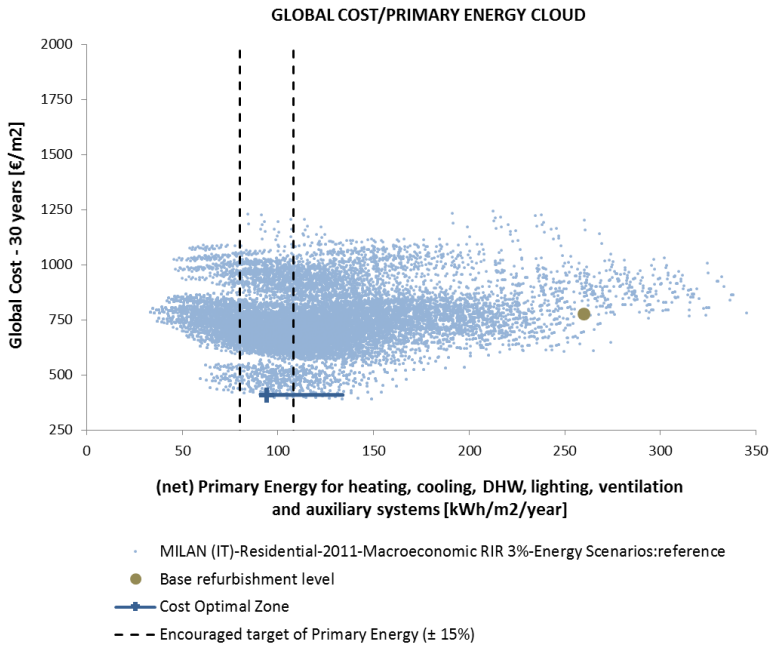

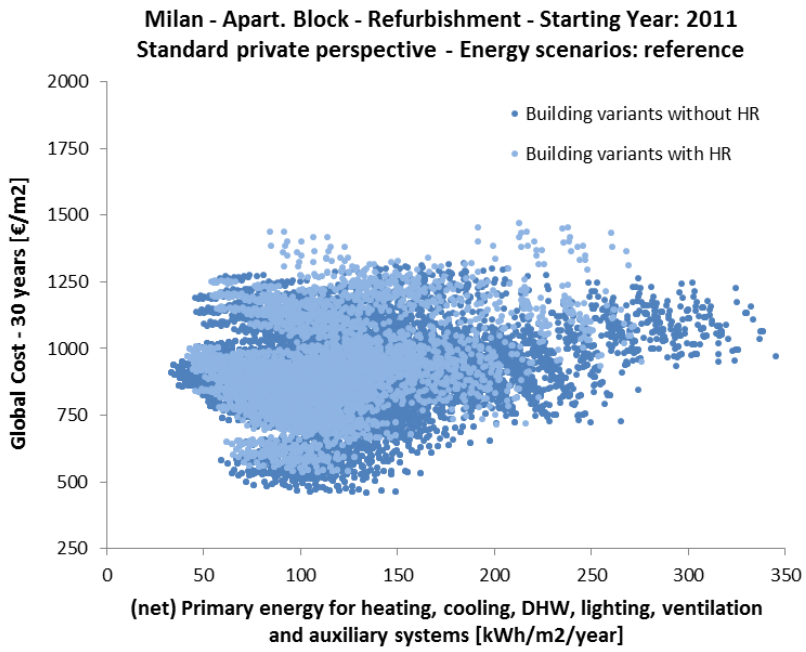

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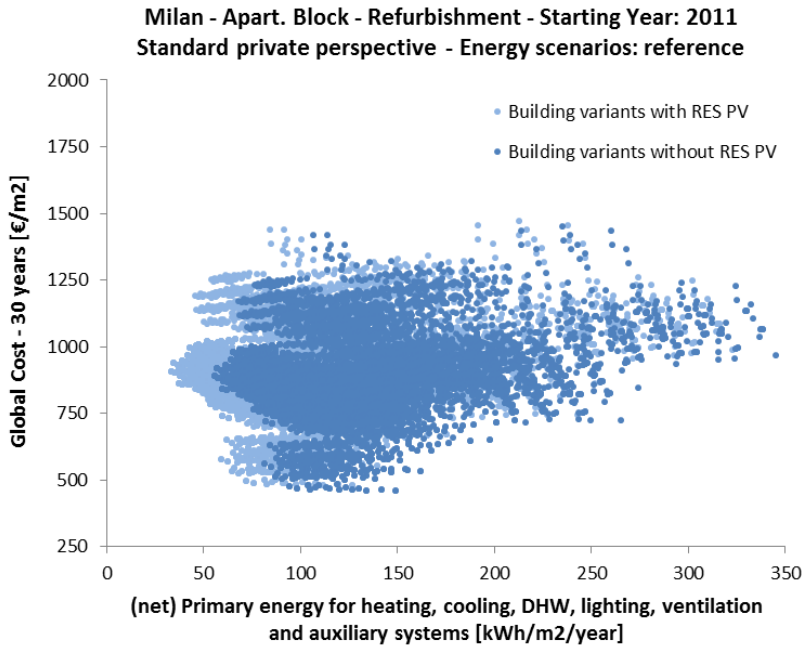

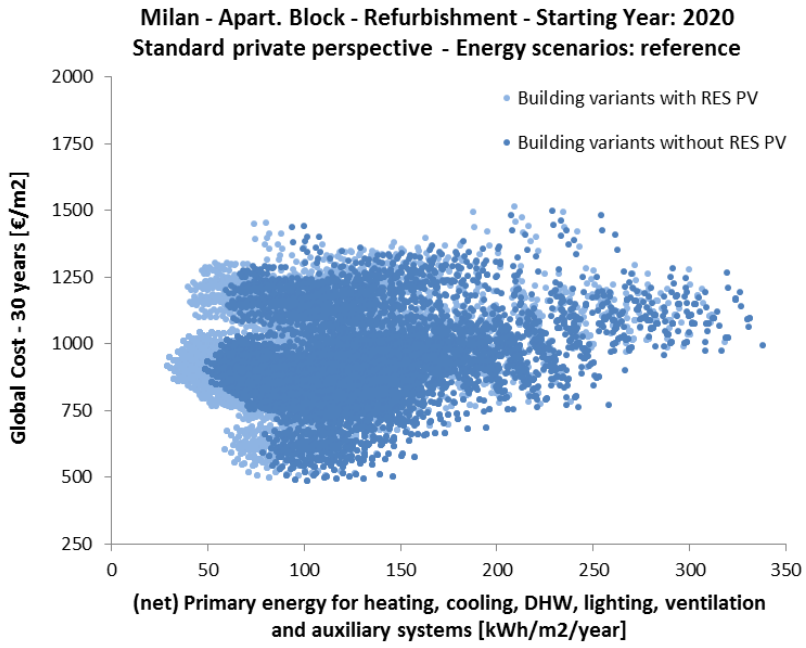

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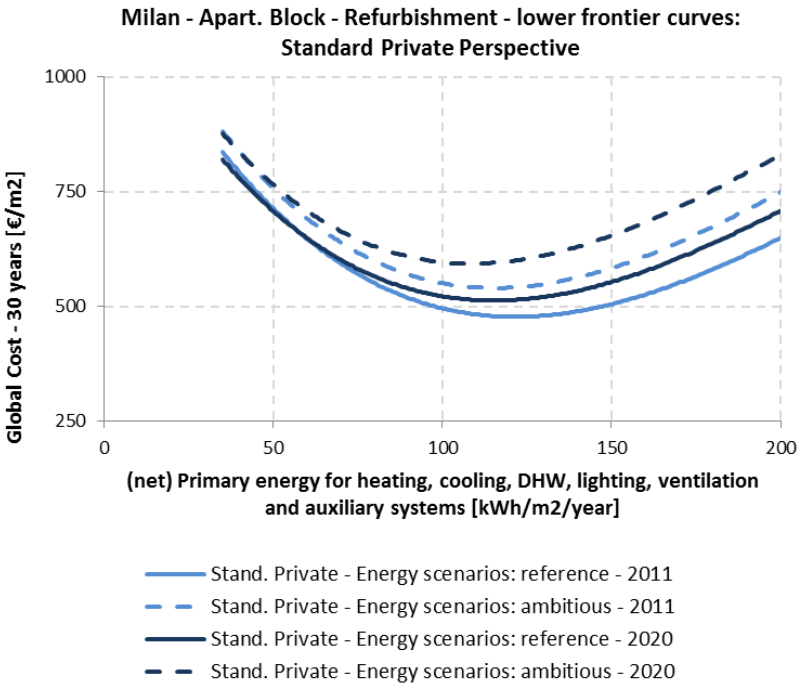

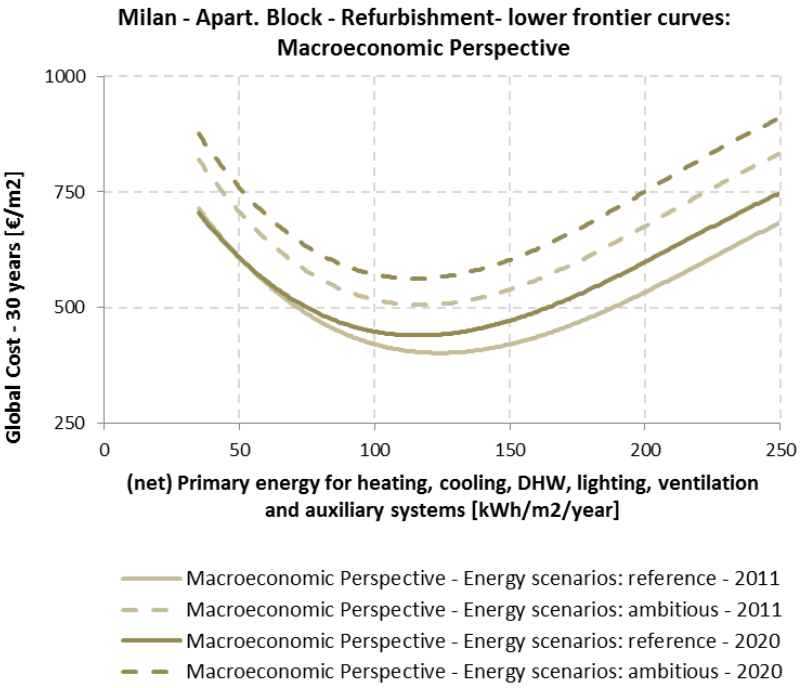

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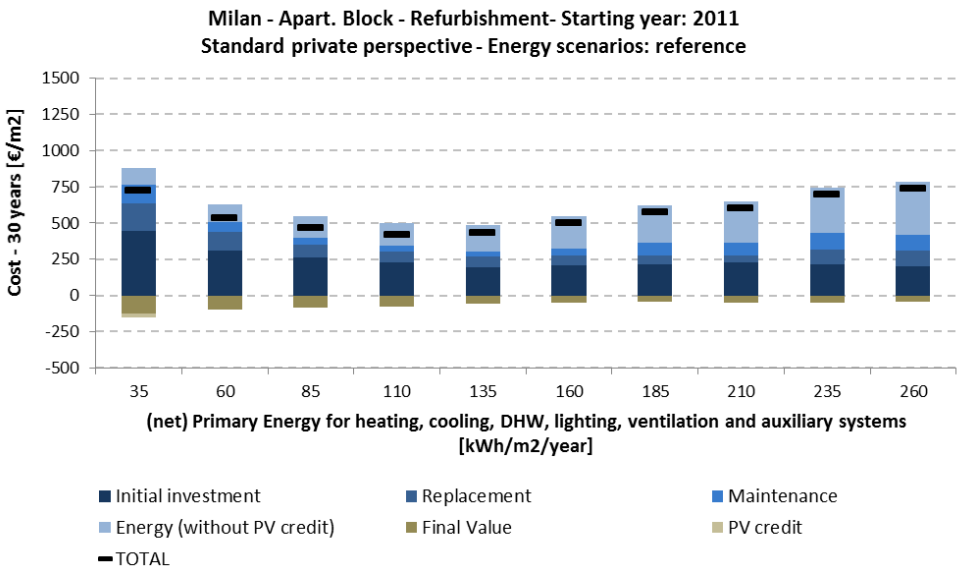

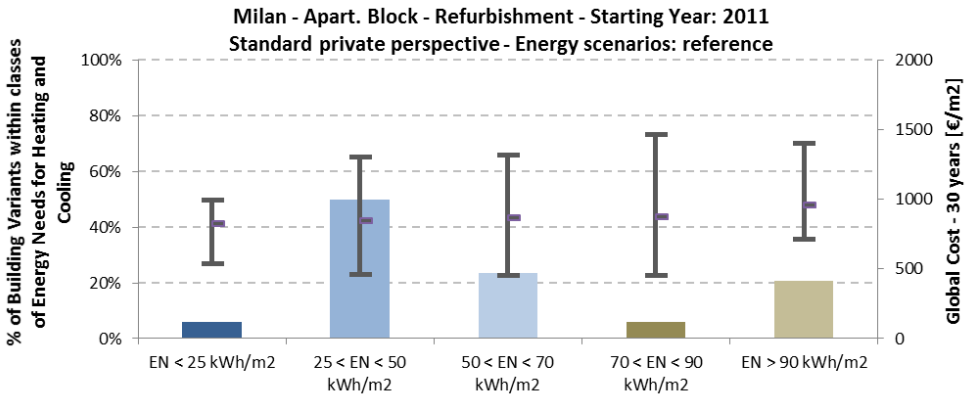

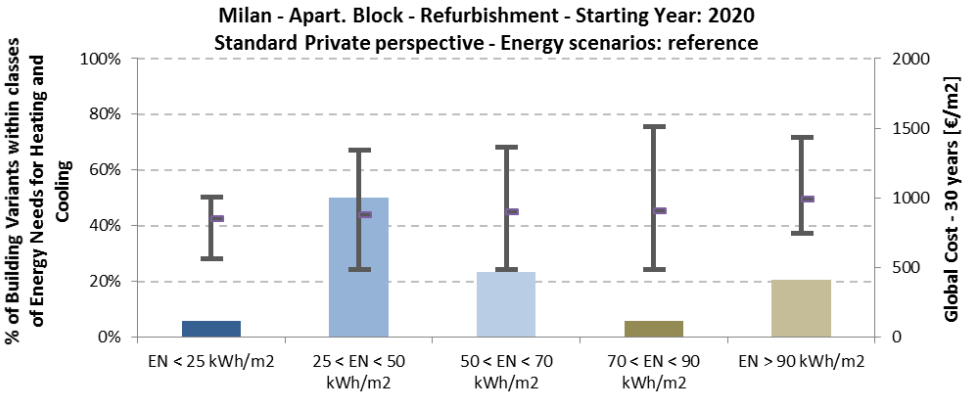

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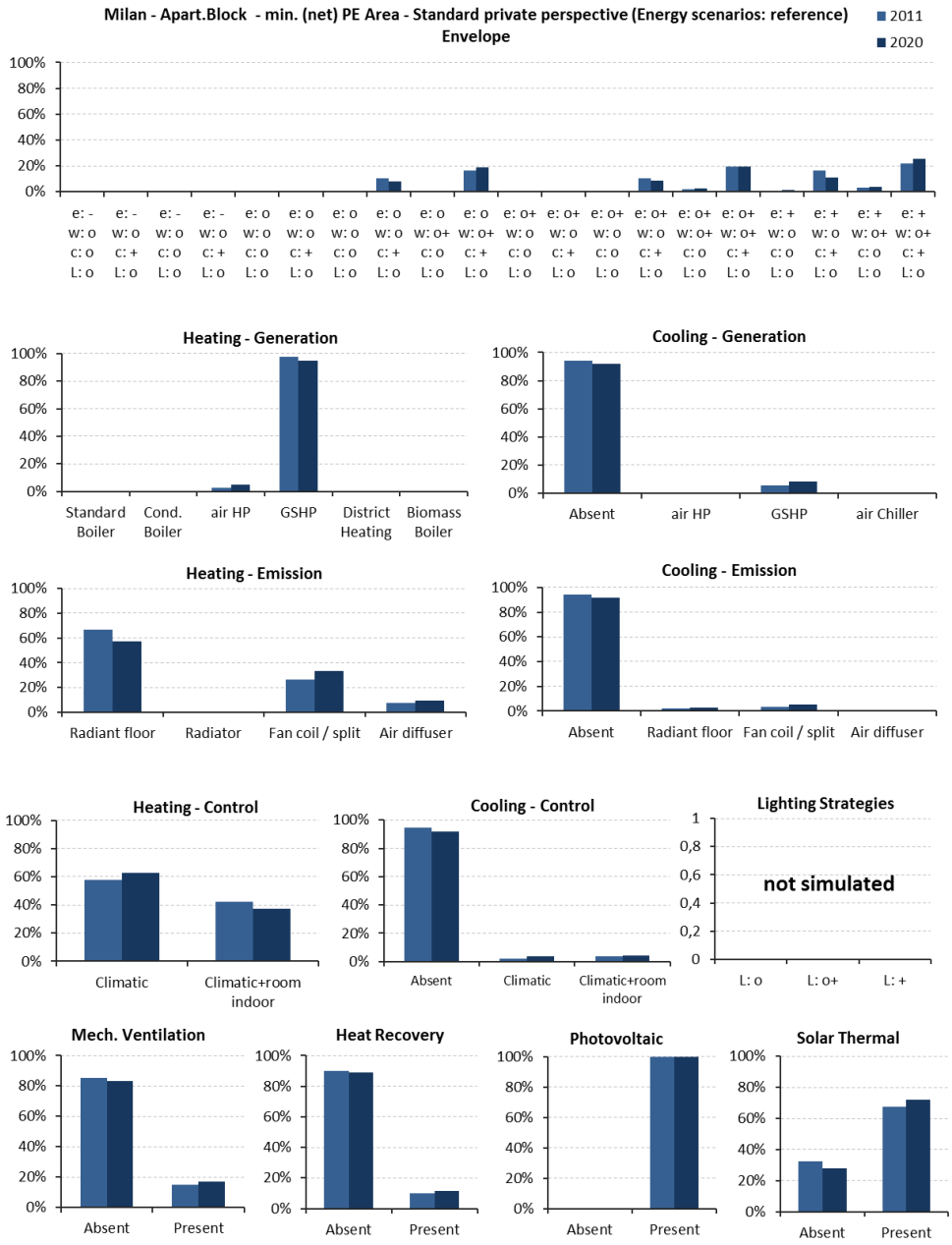
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	33	50	29	45
Range of Global Costs [€/m^2]:	801	921	796	930
Number of Building Variants:	161		160	



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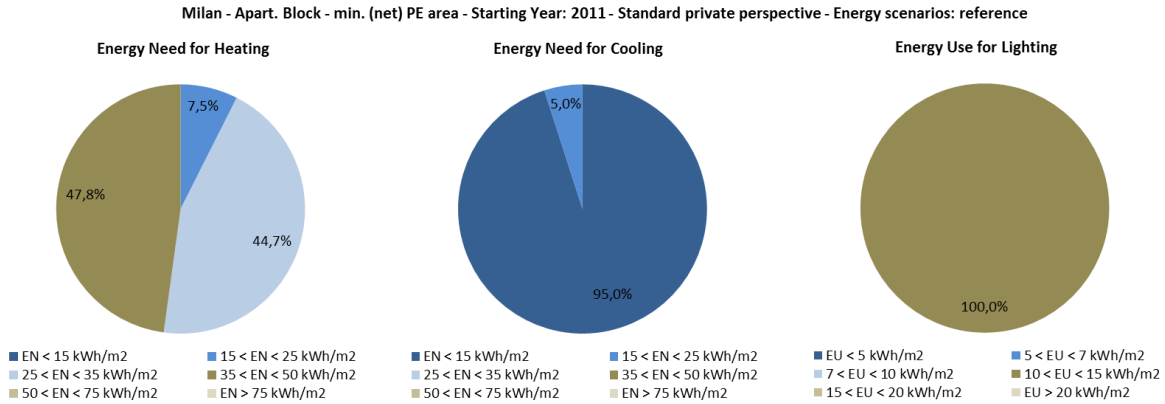
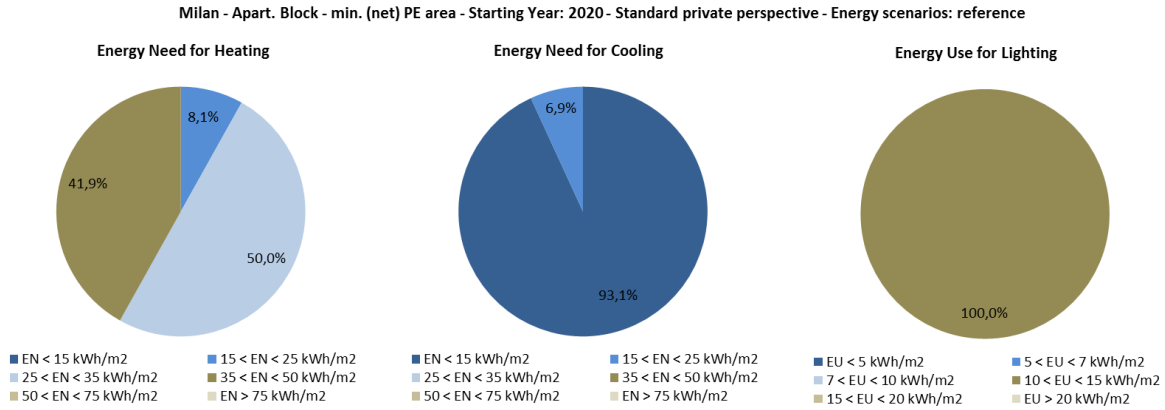
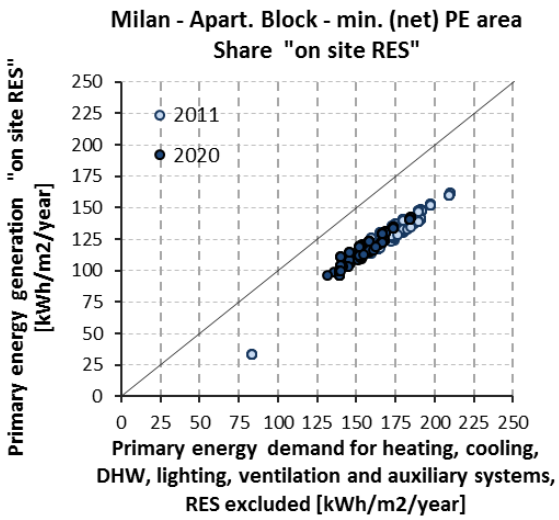
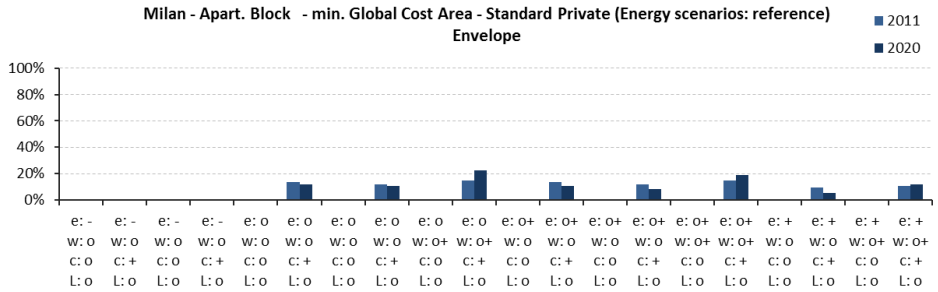
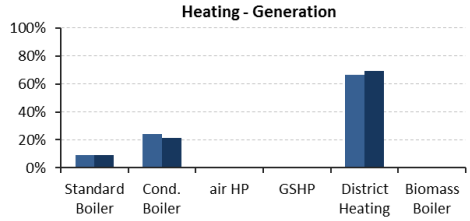

Milan - Apart. Block - min. (net) PE area - Starting Year: 2011 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
7,5%
47,8%
44,7%
Energy Need for Cooling
5,0%
95,0%
Energy Use for Lighting
100,0%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2

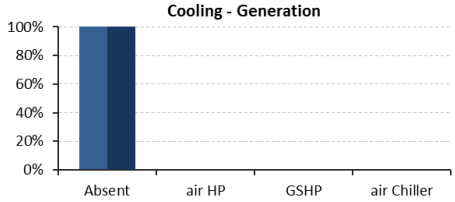

Milan - Apart. Block - min. (net) PE area - Starting Year: 2020 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
8,1%
41,9%
50,0%
Energy Need for Cooling
6,9%
93,1%
Energy Use for Lighting
100,0%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2

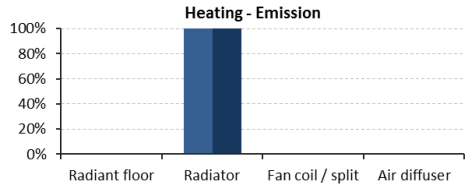

Milan - Apart. Block - min. (net) PE area
Share "on site RES"
Primary energy generation "on site RES" [kWh/m2/year]
250
225
200
175
150
125
100
75
50
25
0
2011
2020
0 25 50 75 100 125 150 175 200 225 250
Primary energy demand for heating, cooling, DHW, lighting, ventilation and auxiliary systems, RES excluded [kWh/m2/year]

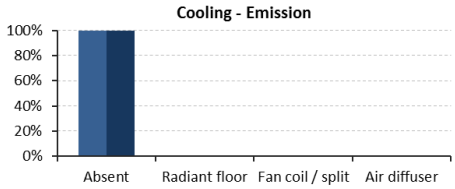
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	50	180	50	180
Range of Global Costs [€/m^2]:	460	529	487	561
Number of Building Variants:	150		150	

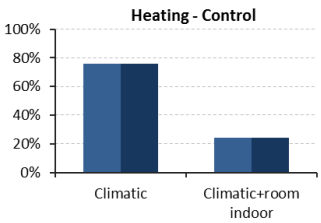


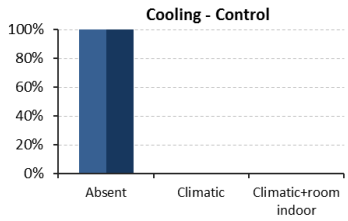


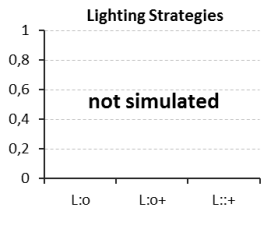


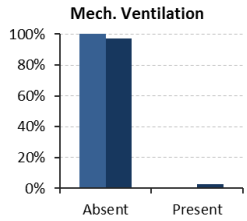


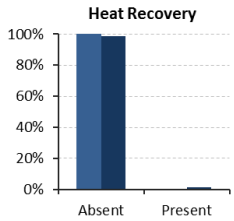


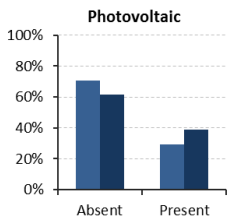


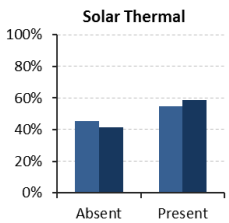












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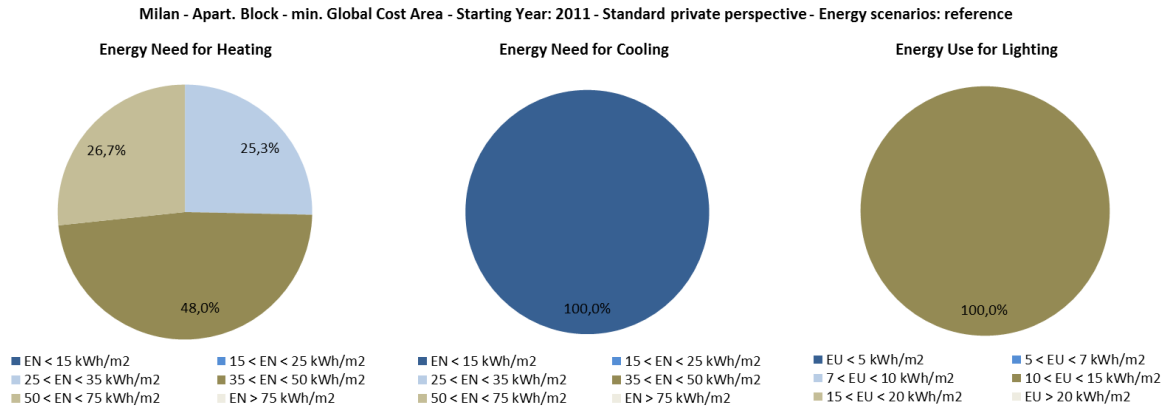
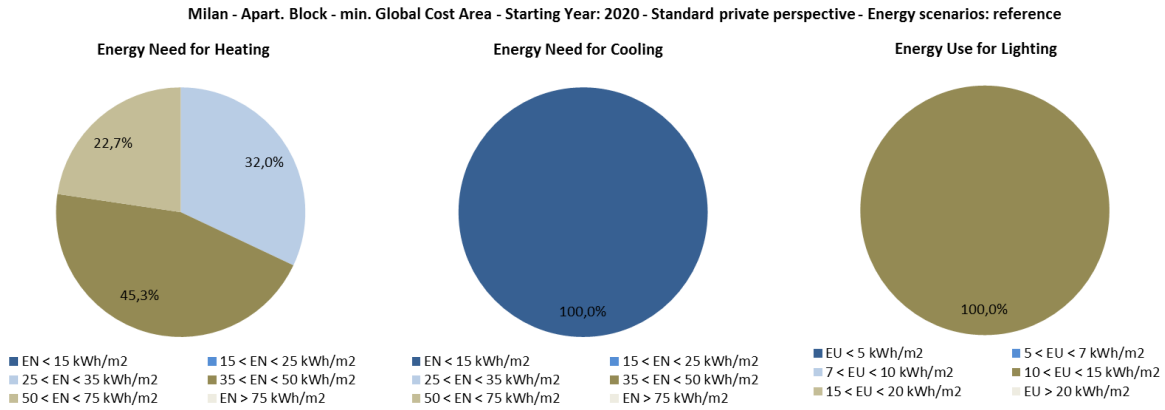
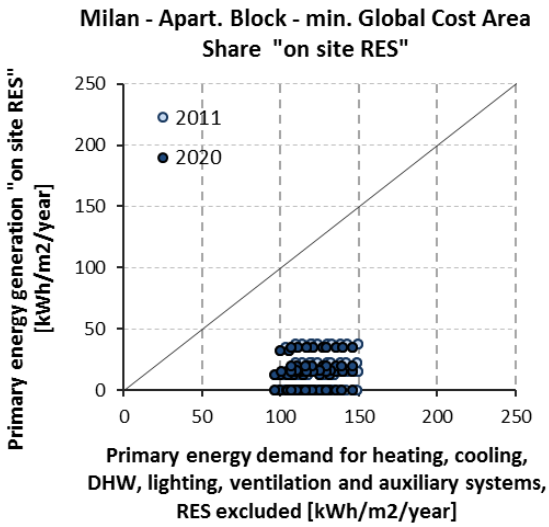
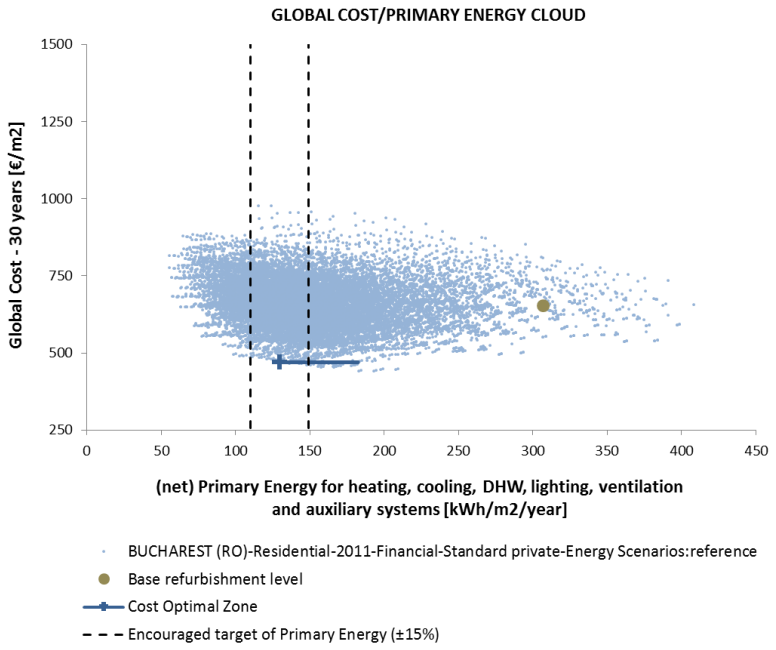
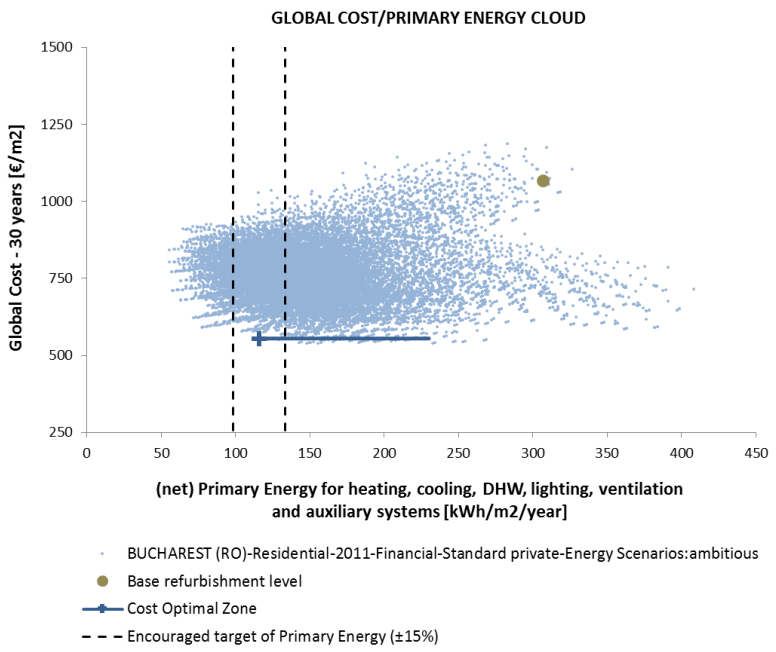

Milan - Apart. Block - min. Global Cost Area - Starting Year: 2011 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
26,7%
25,3%
48,0%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Need for Cooling
100,0%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Use for Lighting
100,0%
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2


Milan - Apart. Block - min. Global Cost Area - Starting Year: 2020 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
22,7%
32,0%
45,3%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Need for Cooling
100,0%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
Energy Use for Lighting
100,0%
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2


Milan - Apart. Block - min. Global Cost Area
Share "on site RES"
Primary energy generation "on site RES" [kWh/m2/year]
250
200
150
100
50
0
2011
2020
0
50
100
150
200
250
Primary energy demand for heating, cooling, DHW, lighting, ventilation and auxiliary systems, RES excluded [kWh/m2/year]

8.1.2.5 Bucharest





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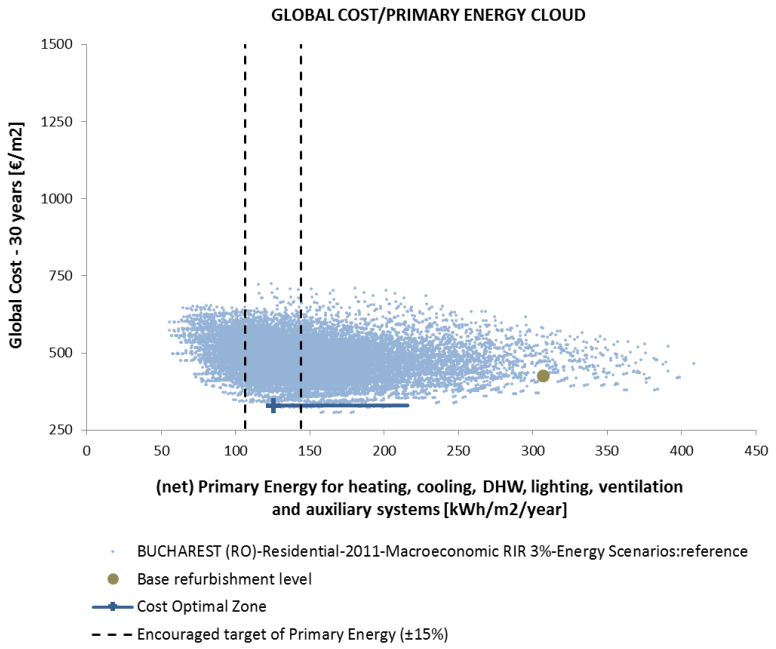

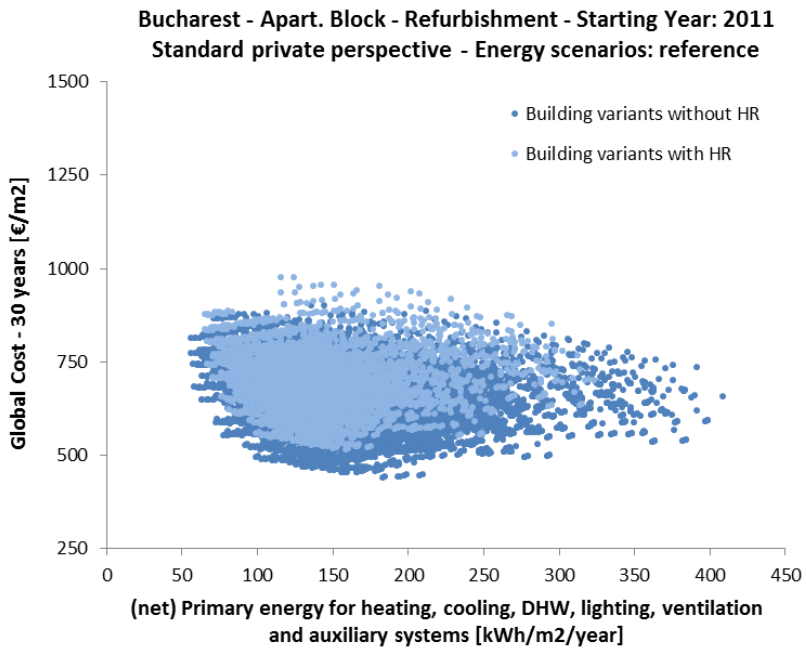

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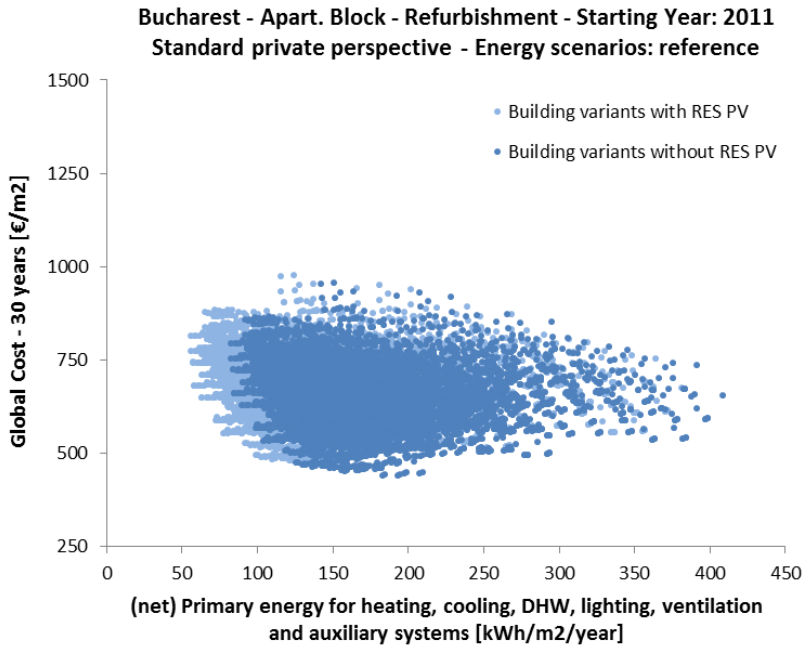

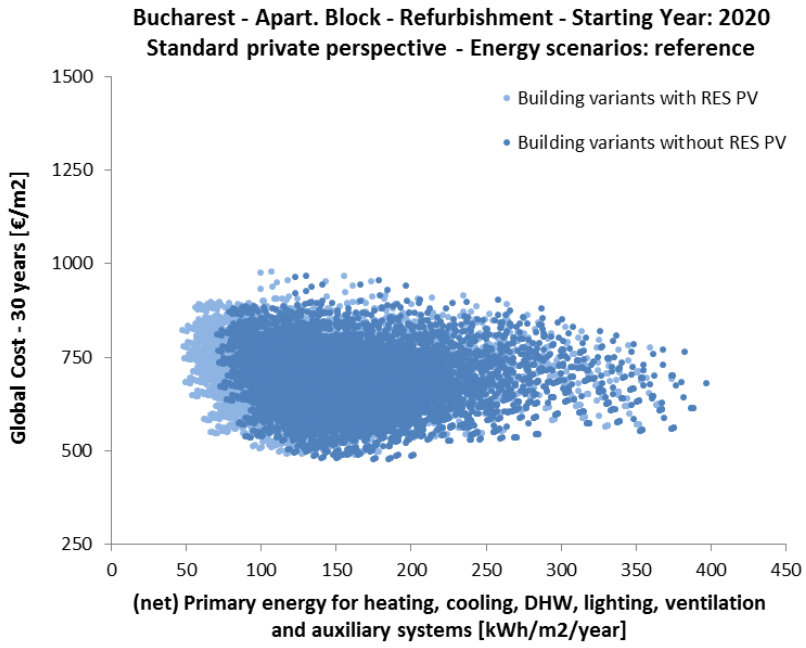

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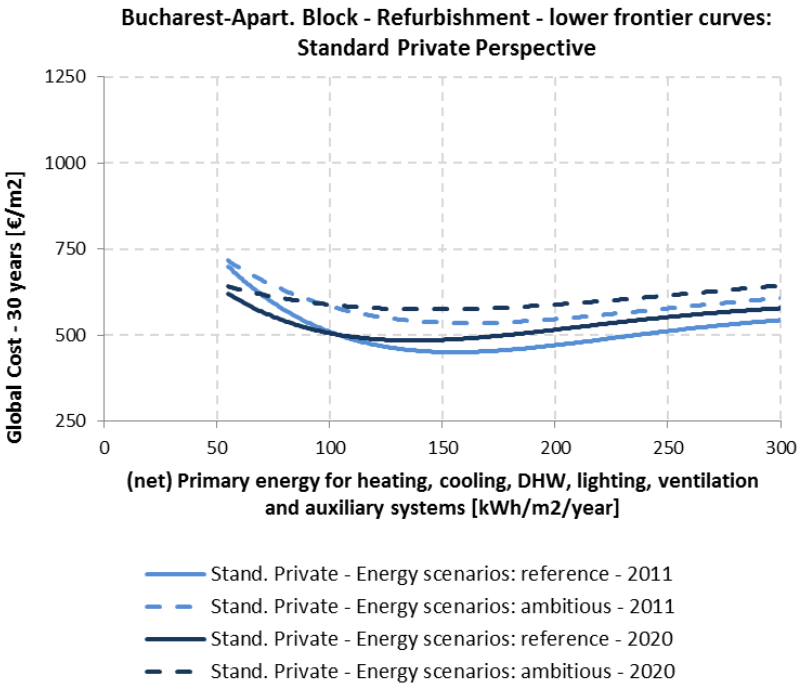

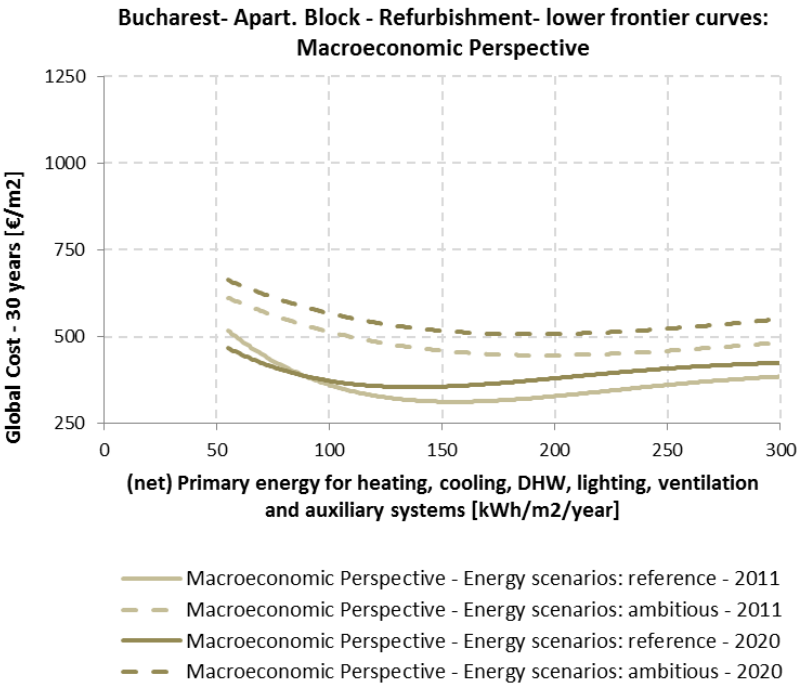

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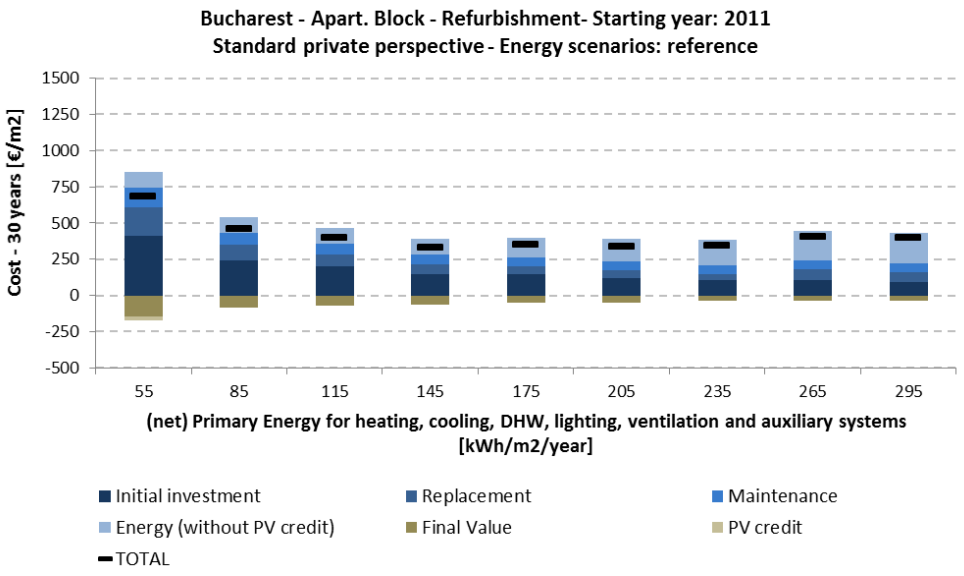

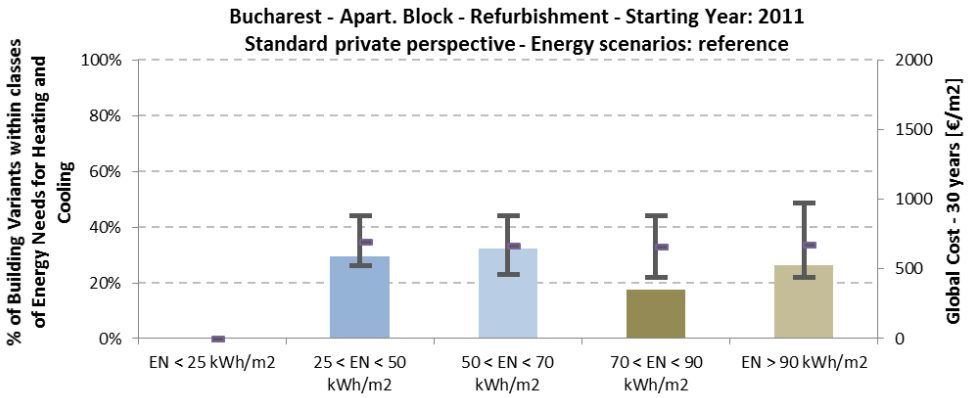

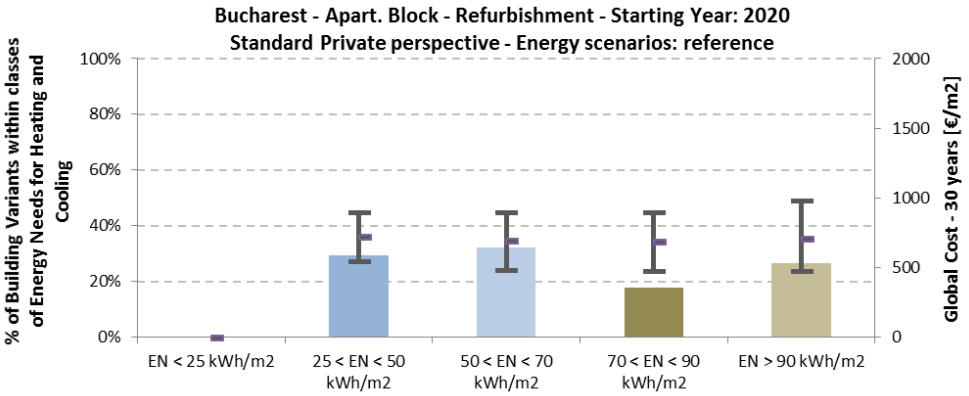

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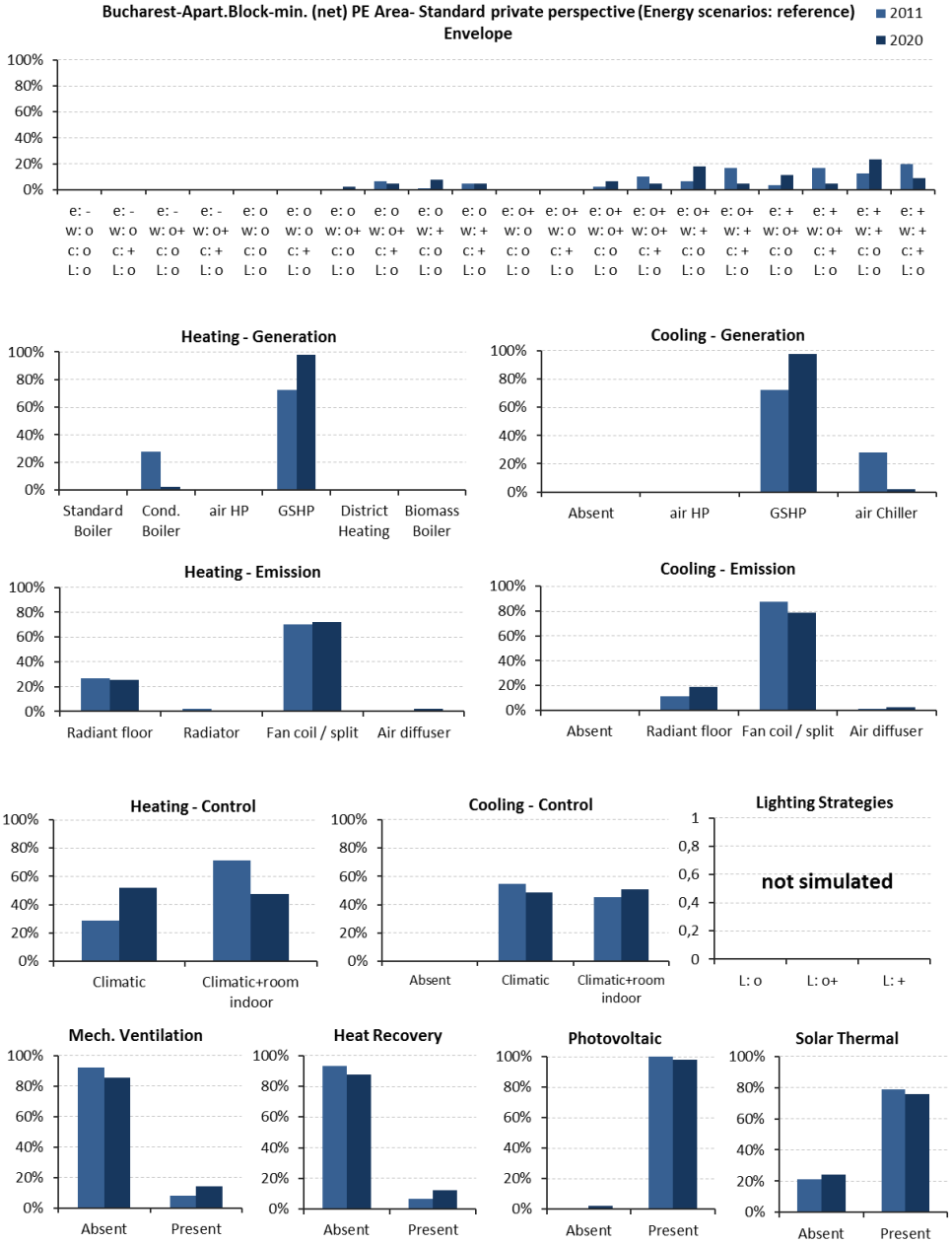
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	56	80	48	75
Range of Global Costs [€/m²]:	554	693	551	672
Number of Building Variants:	90		90	



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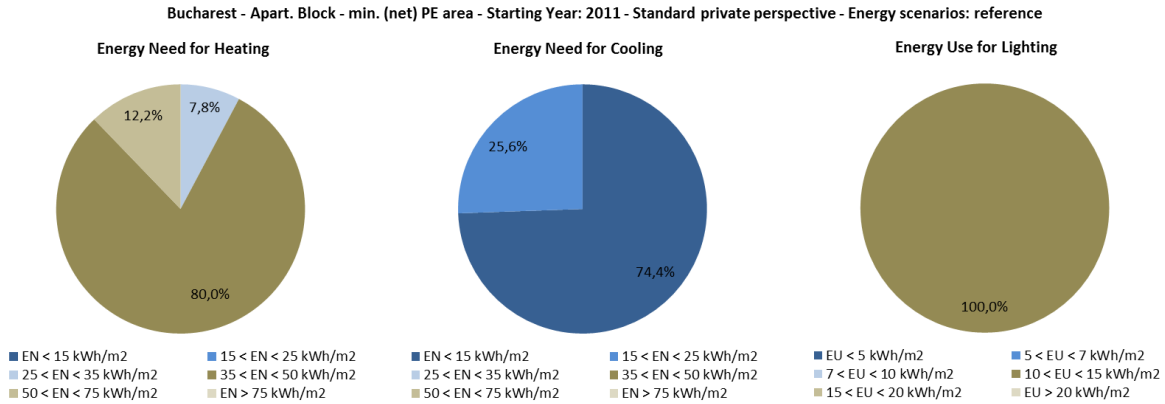

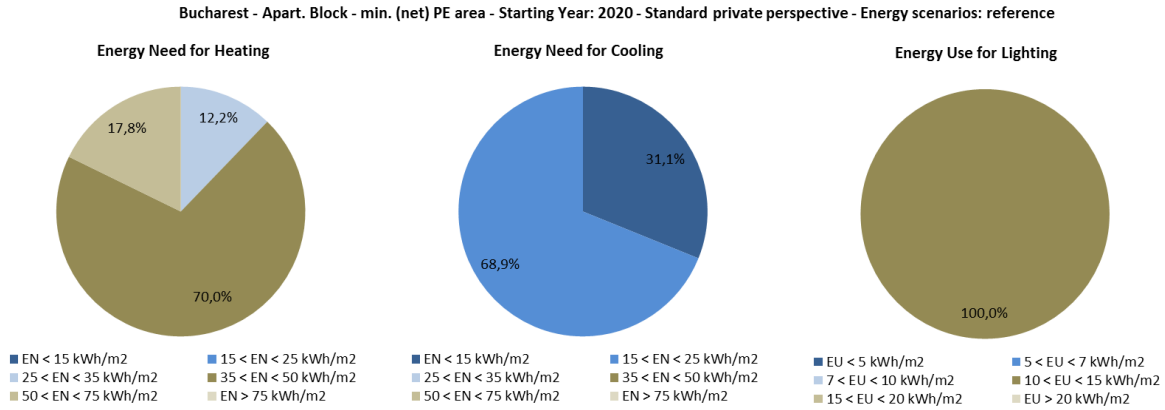

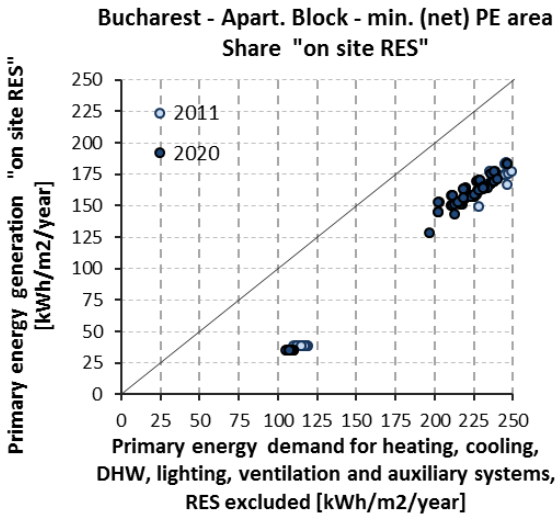

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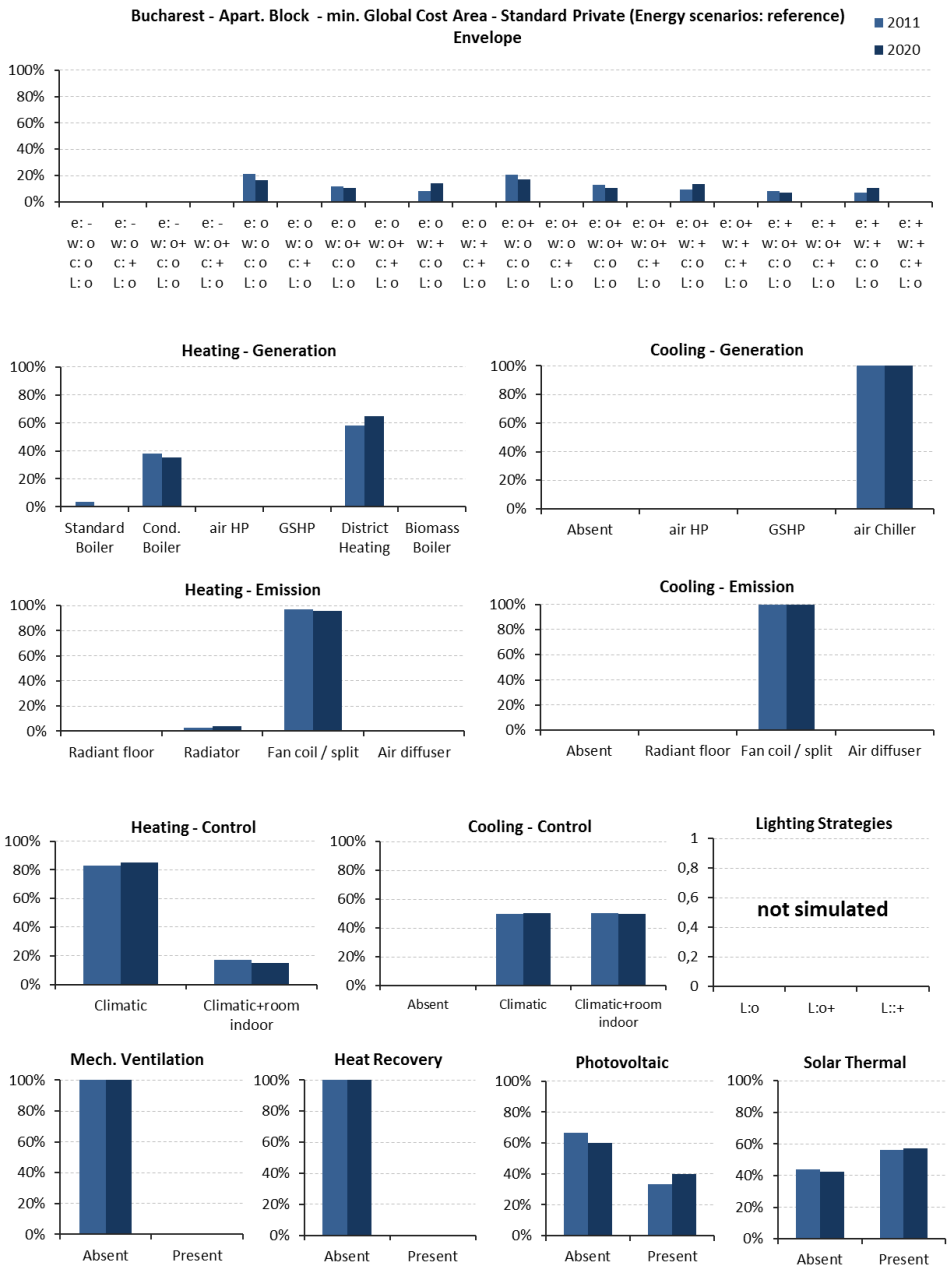
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	85	225	65	225
Range of Global Costs [€/m^2]:	442	490	477	520
Number of Building Variants:	141		141	



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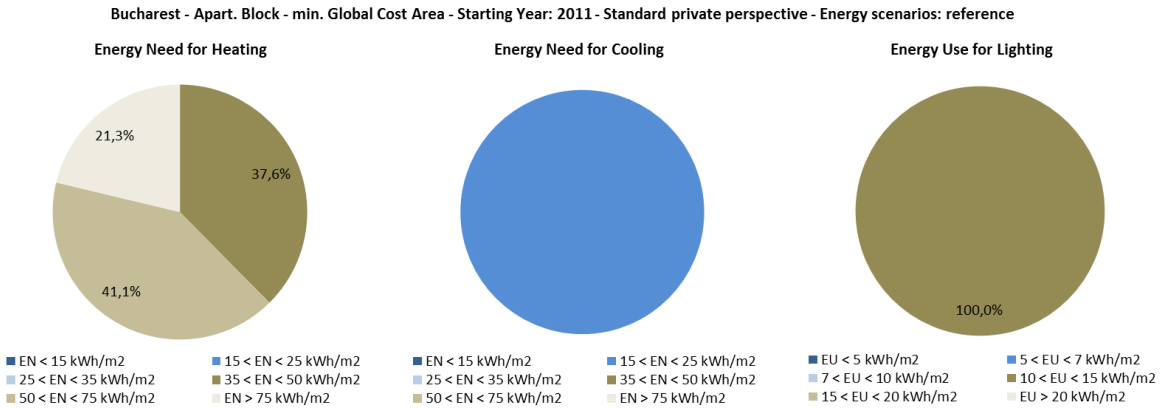

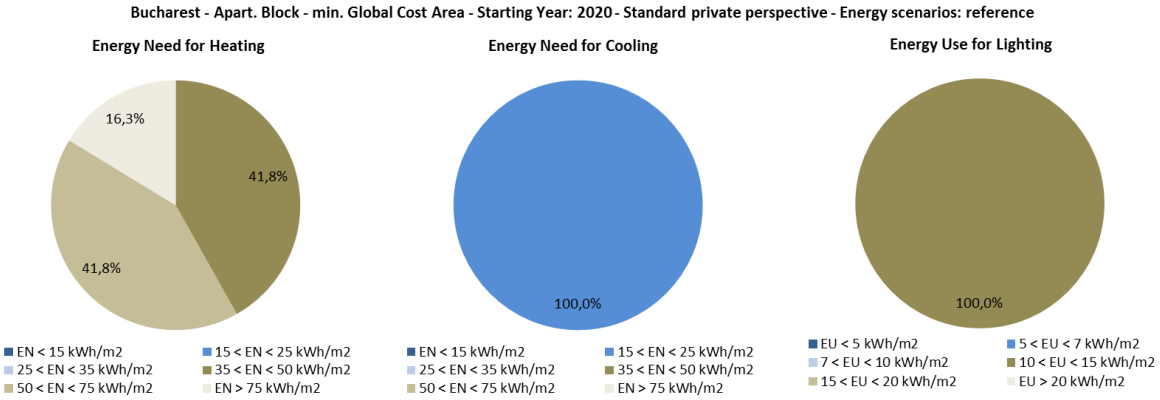

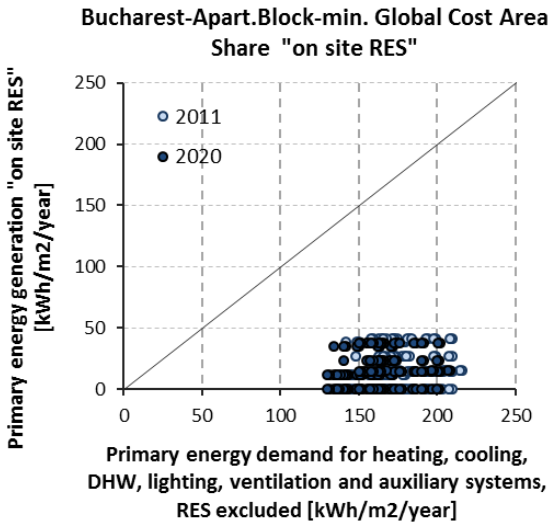

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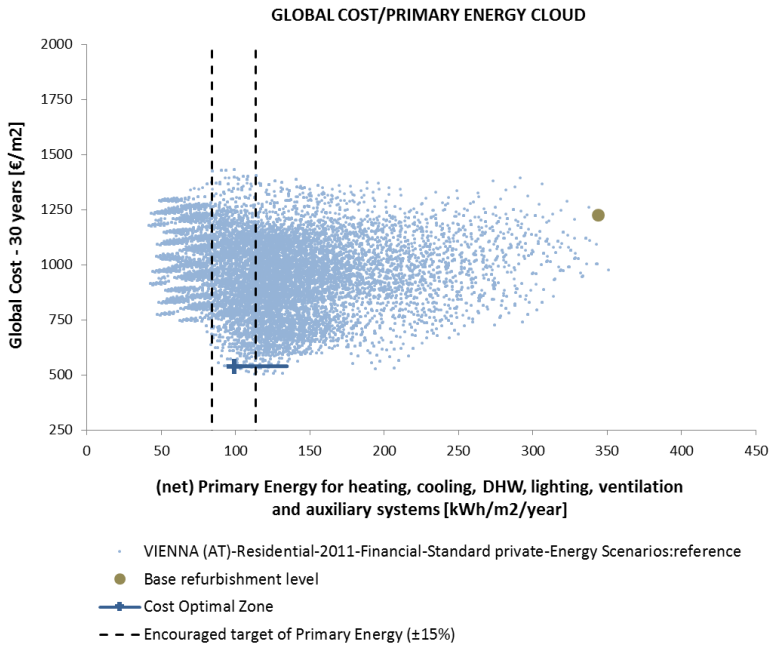
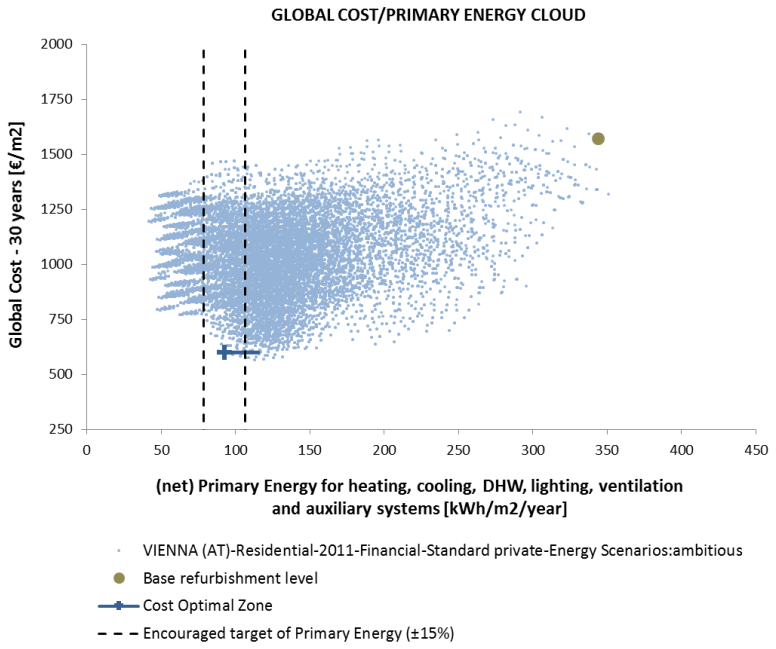
8.1.2.6 Vienna





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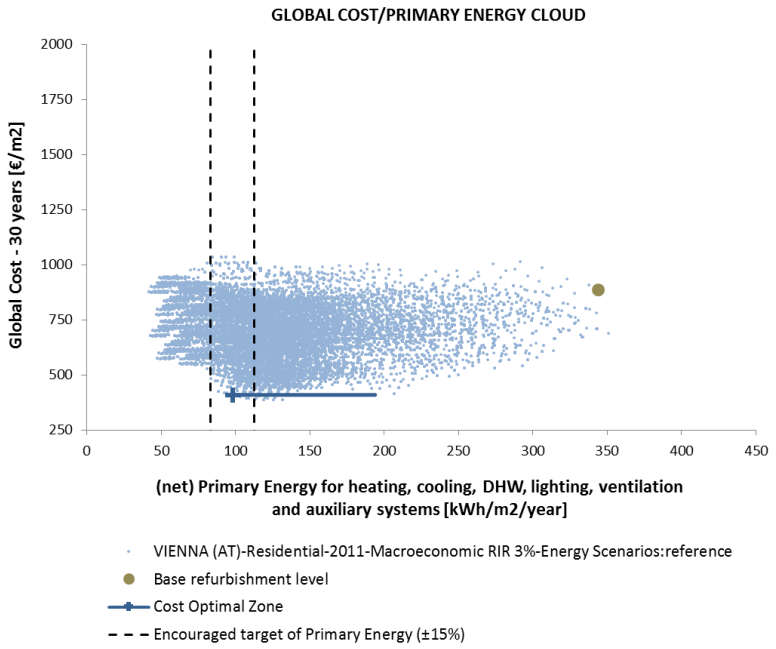

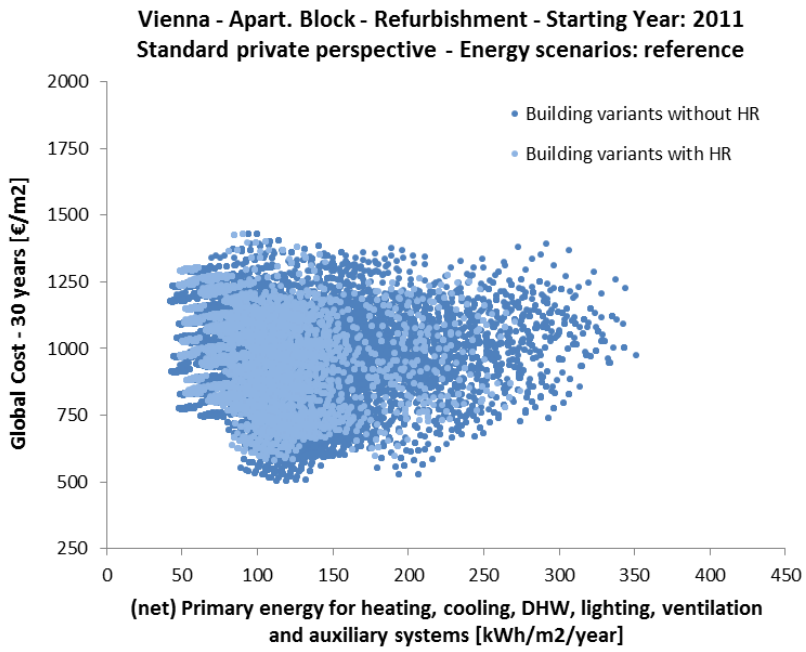

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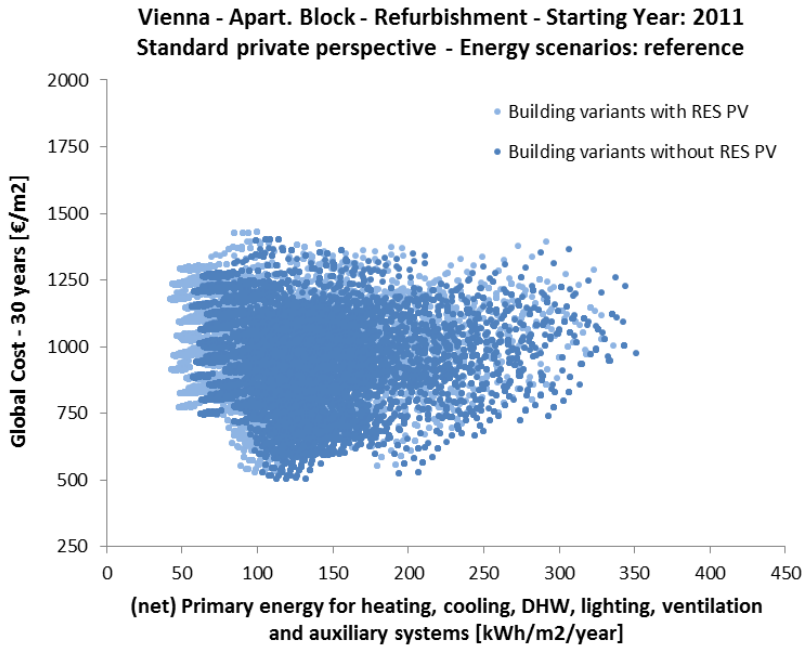

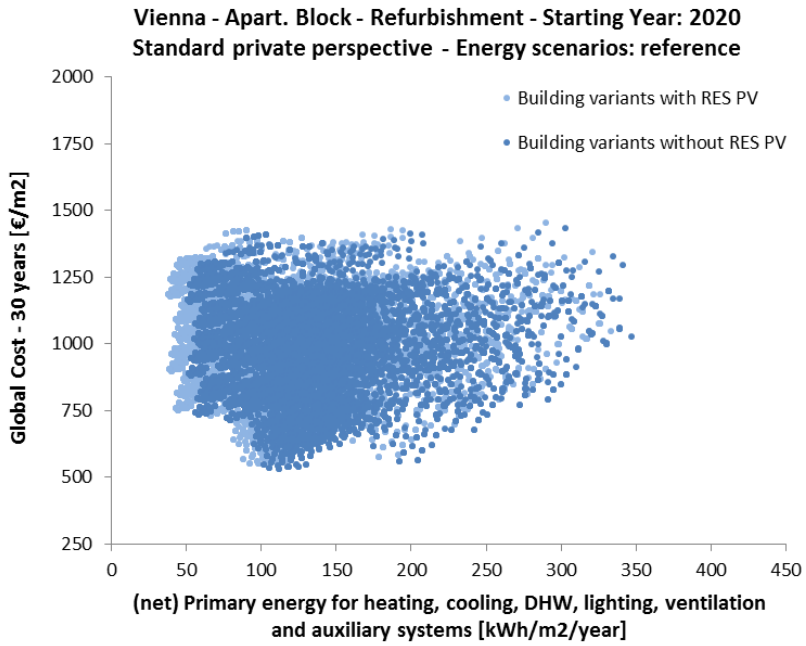

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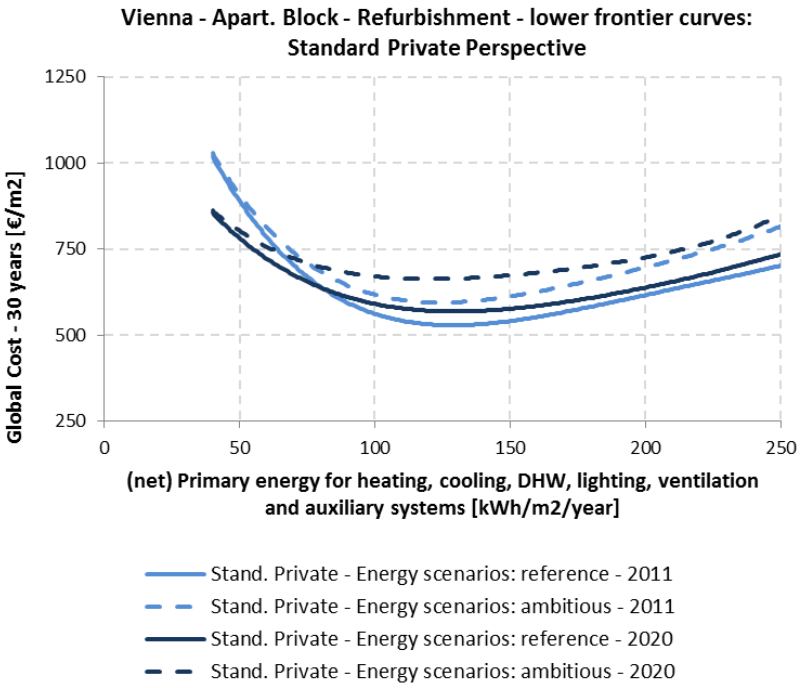

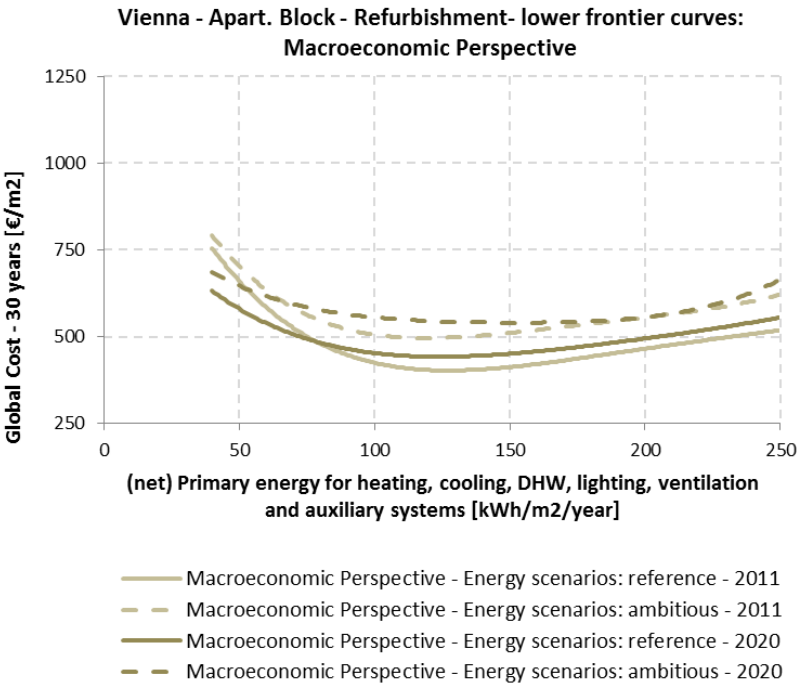

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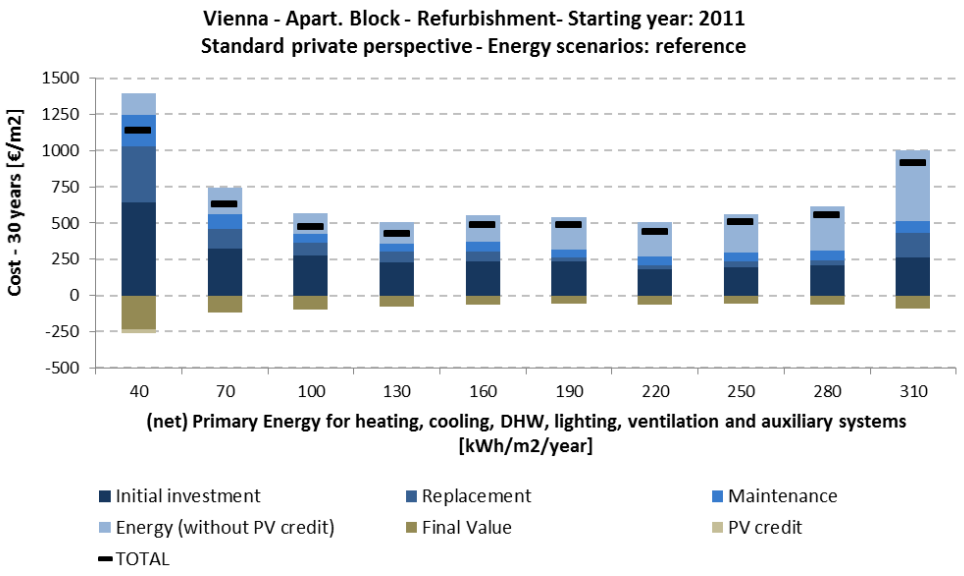

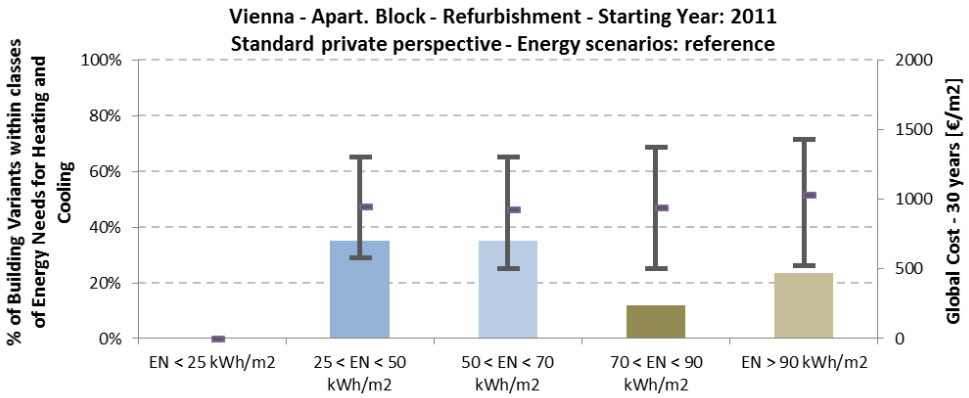

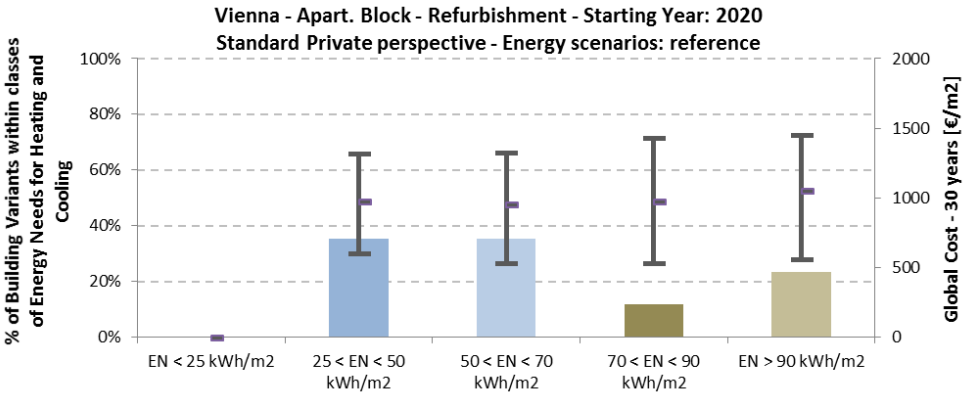

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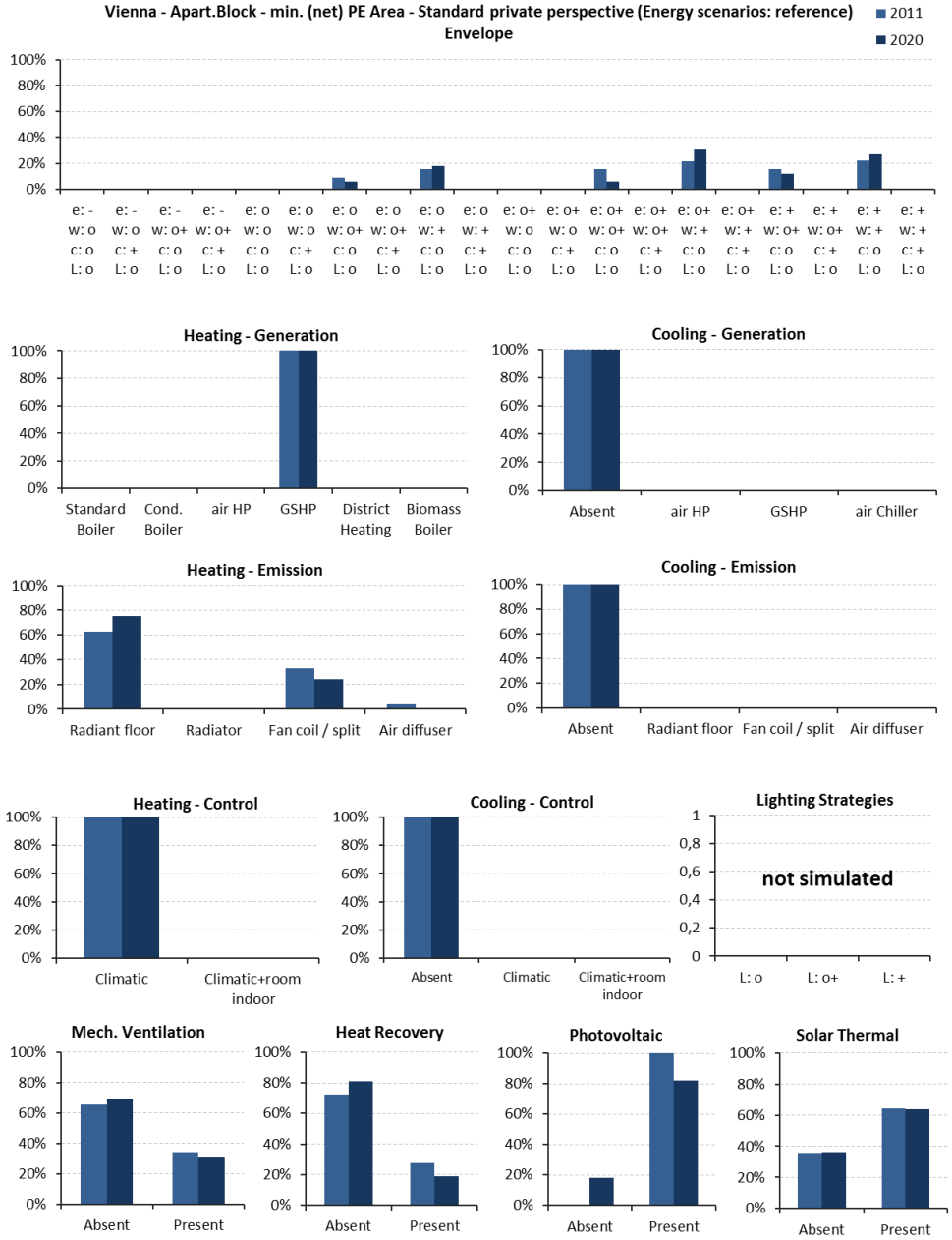
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	42	60	38	60
Range of Global Costs [€/m^2]:	748	861	735	822
Number of Building Variants:	134		134	



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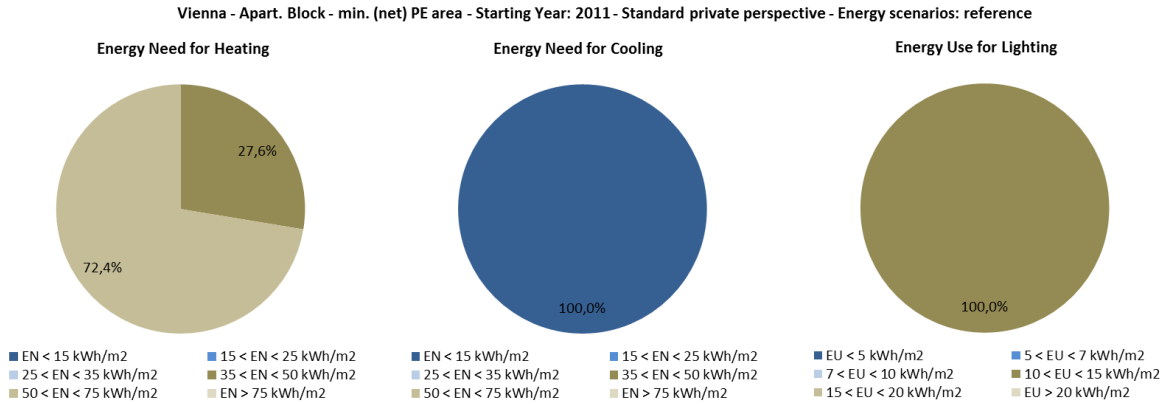

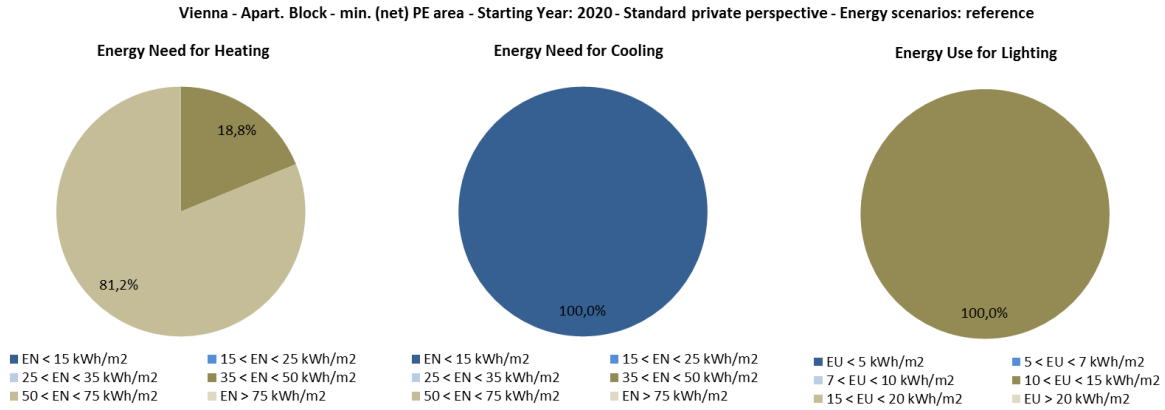

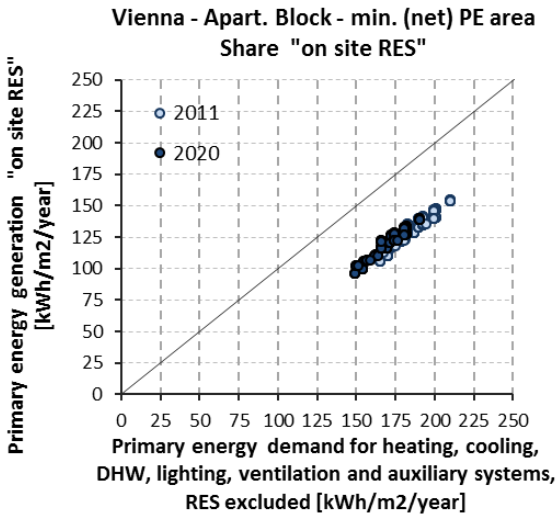

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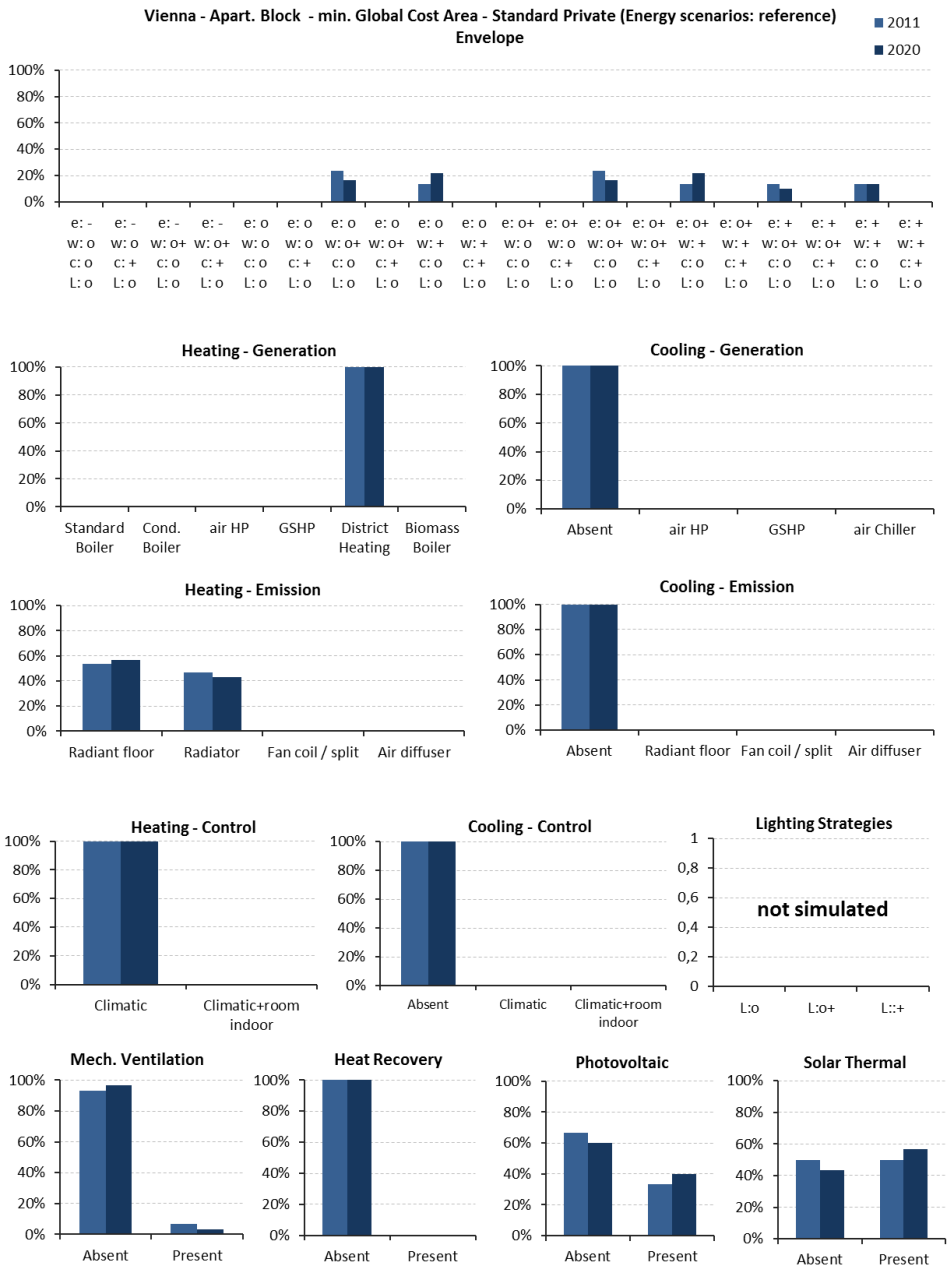
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	70	150	70	150
Range of Global Costs [€/m²]:	504	570	533	596
Number of Building Variants:	120		120	



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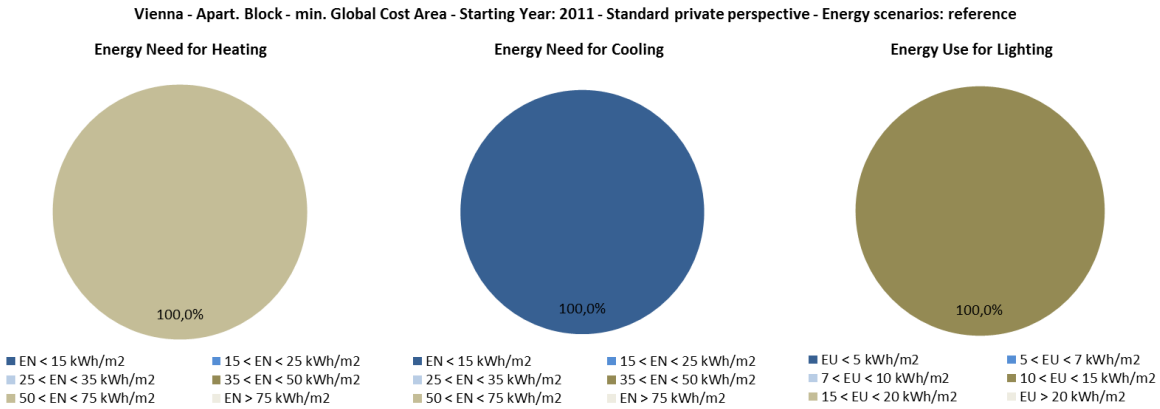

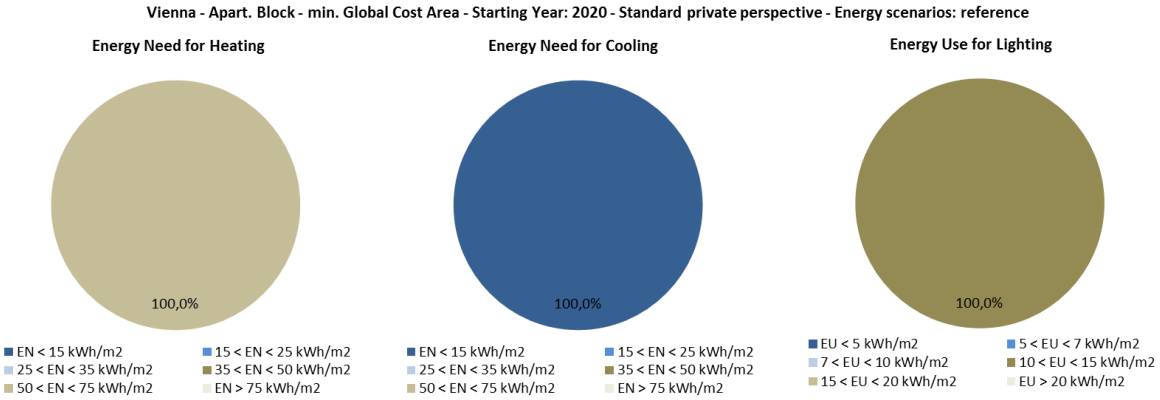

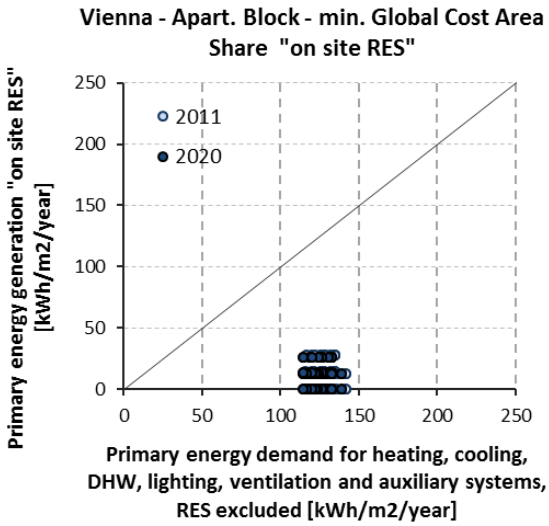

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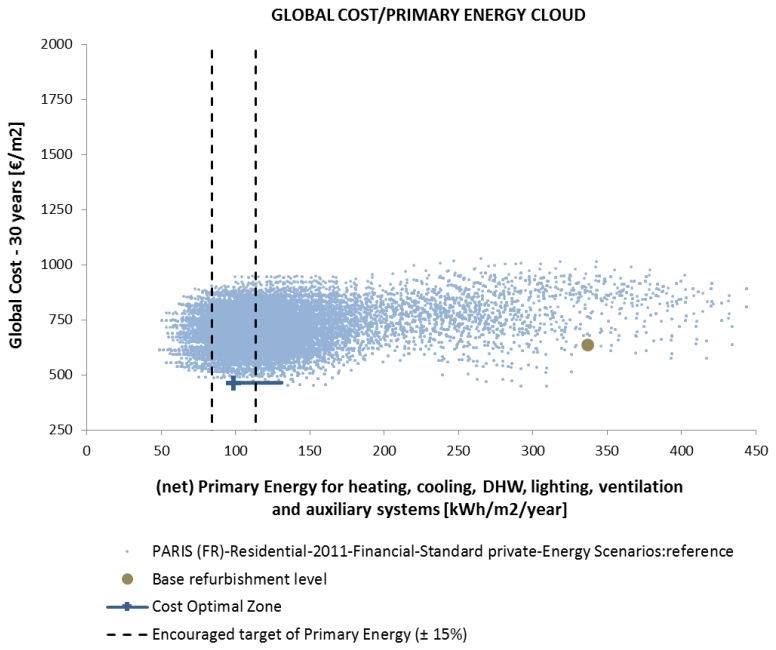
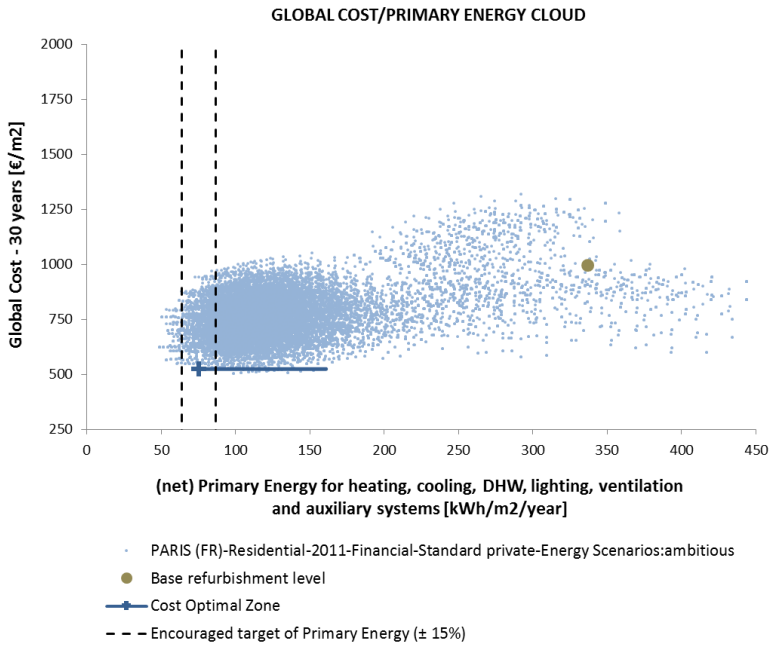
8.1.2.7 Paris





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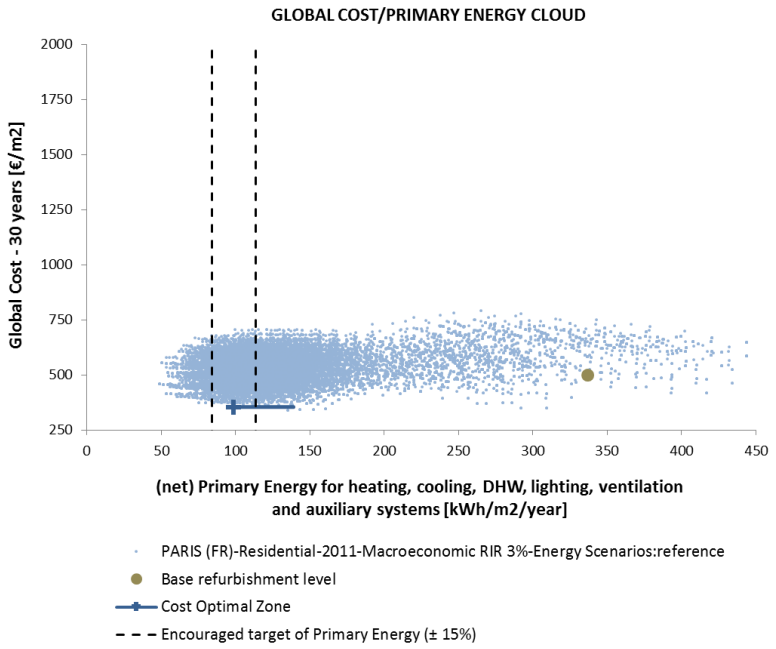

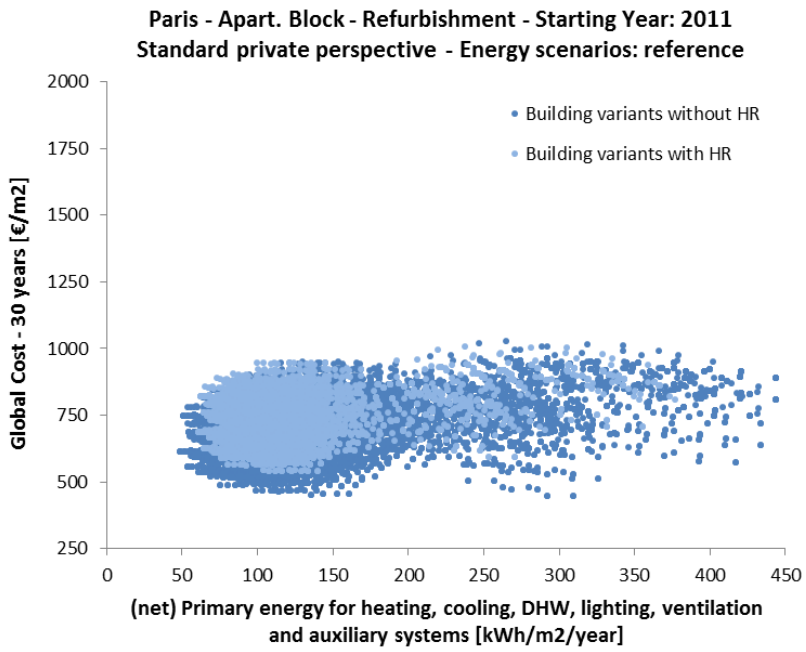

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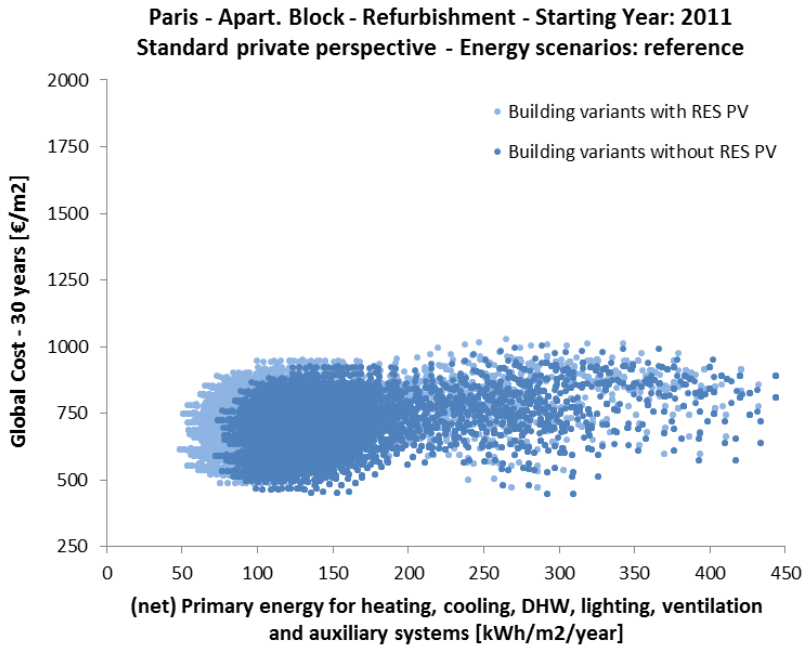

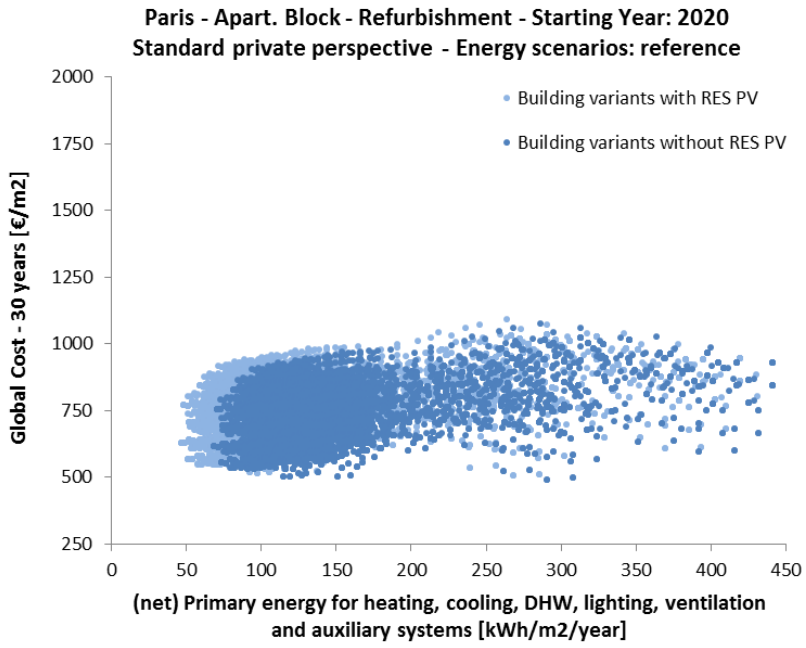

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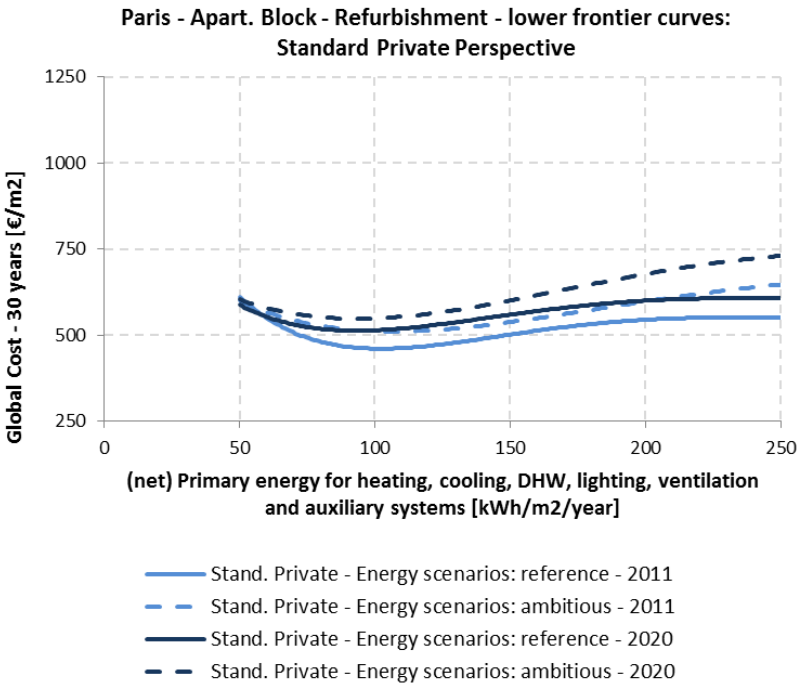

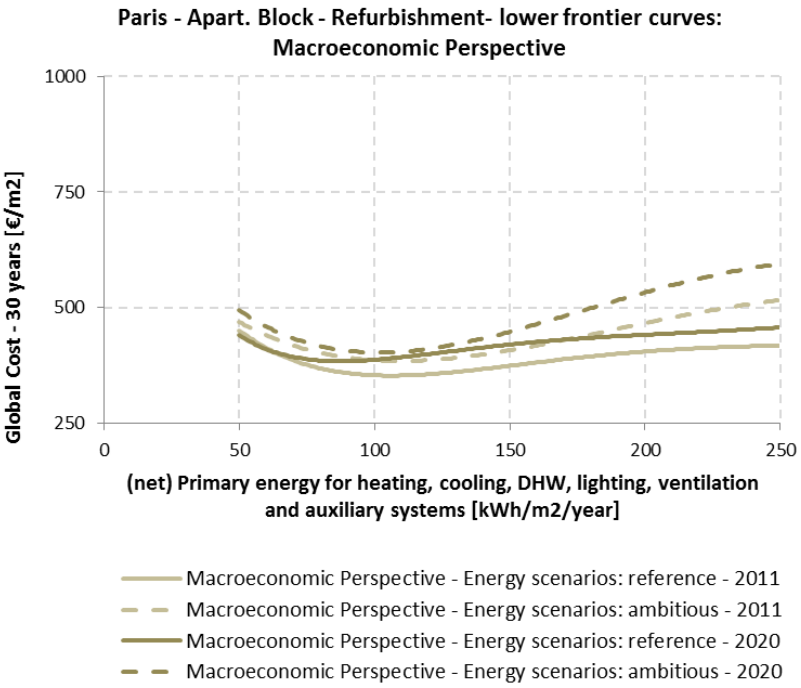

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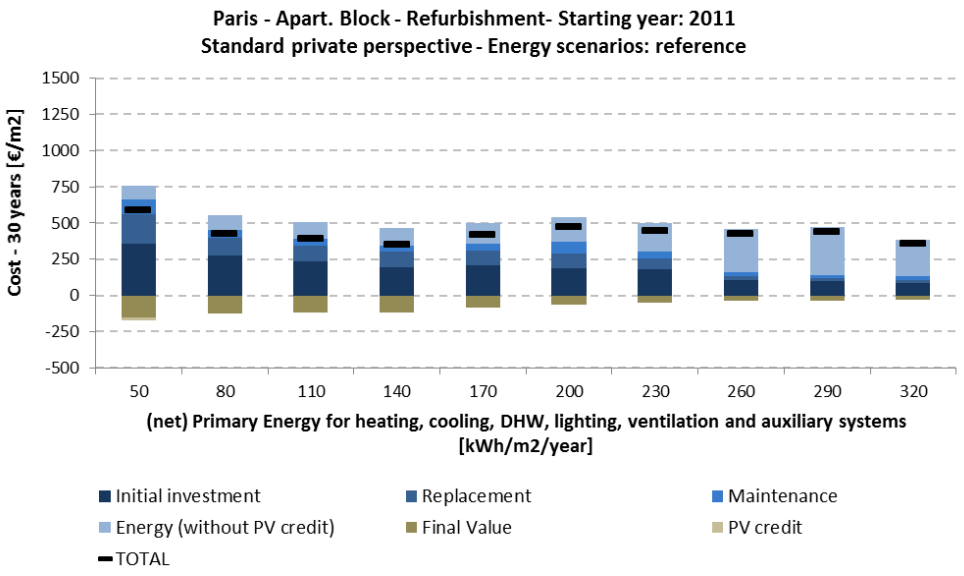

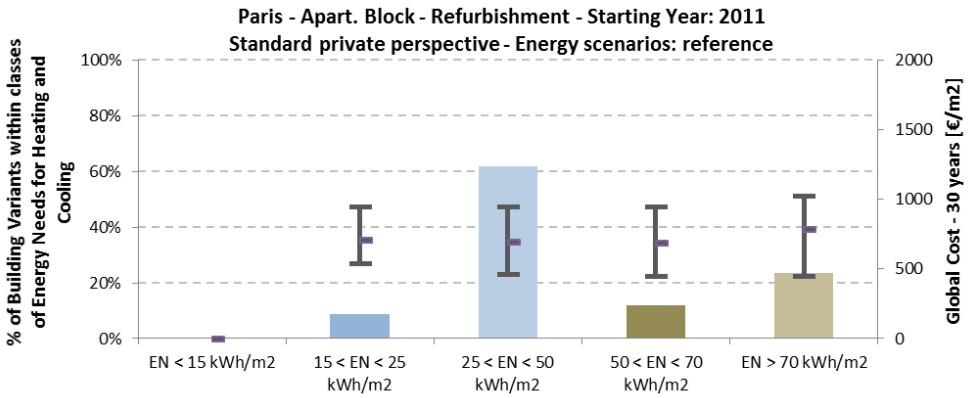

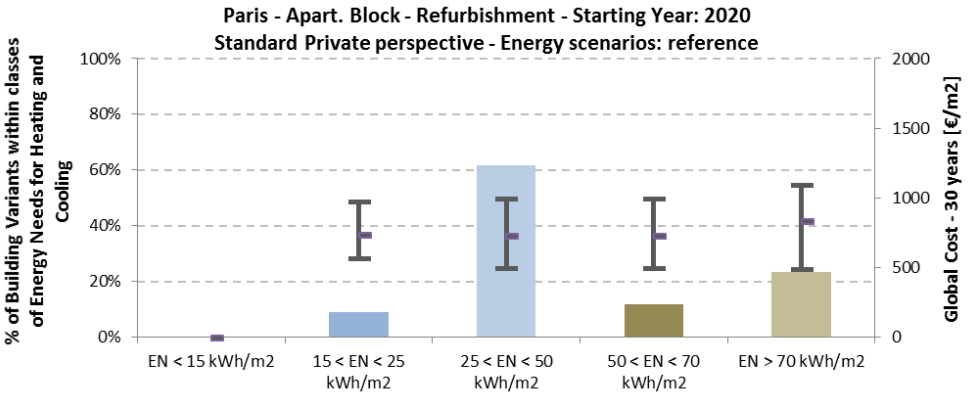

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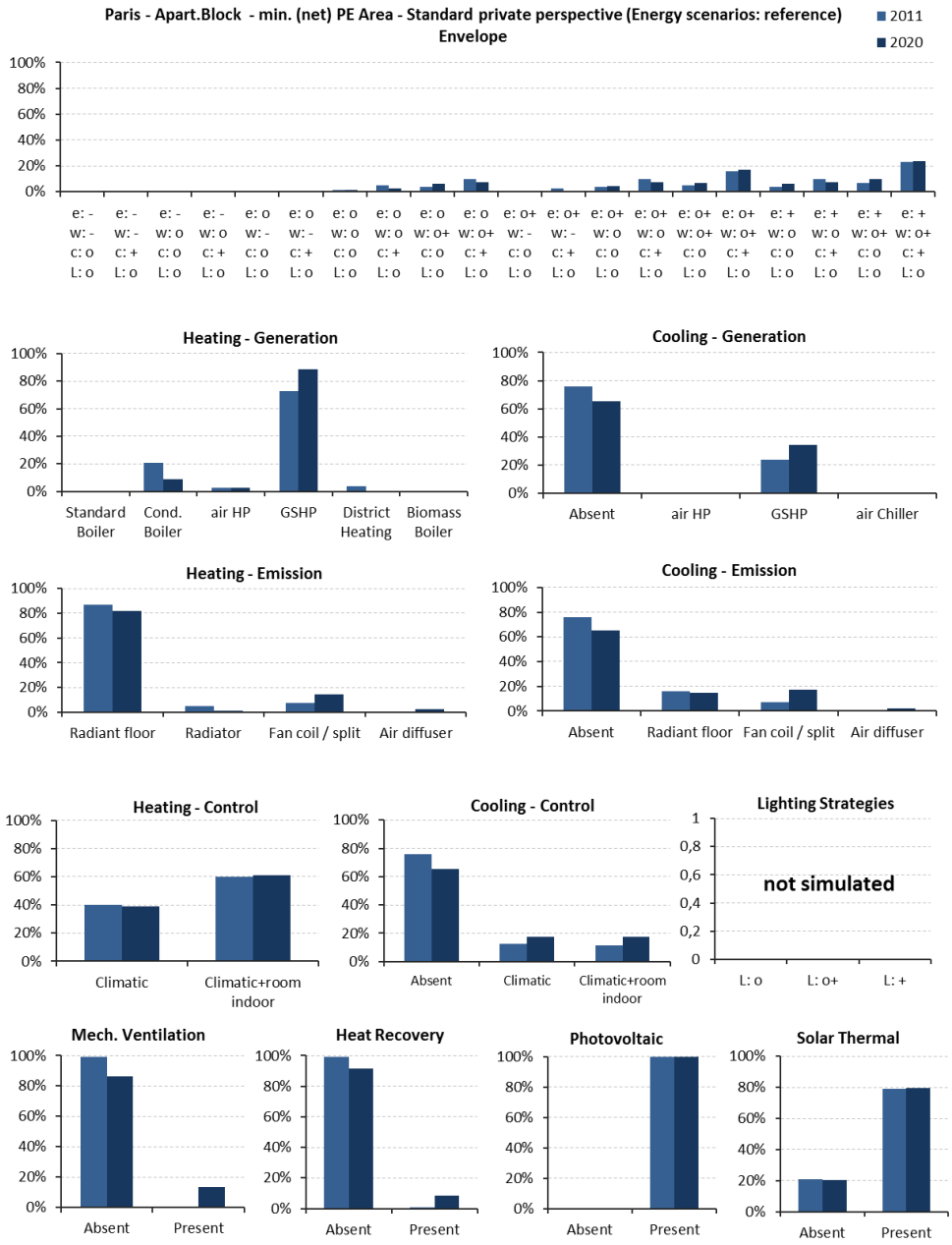
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	49	70	47	65
Range of Global Costs [€/m²]:	521	625	551	702
Number of Building Variants:	162		162	



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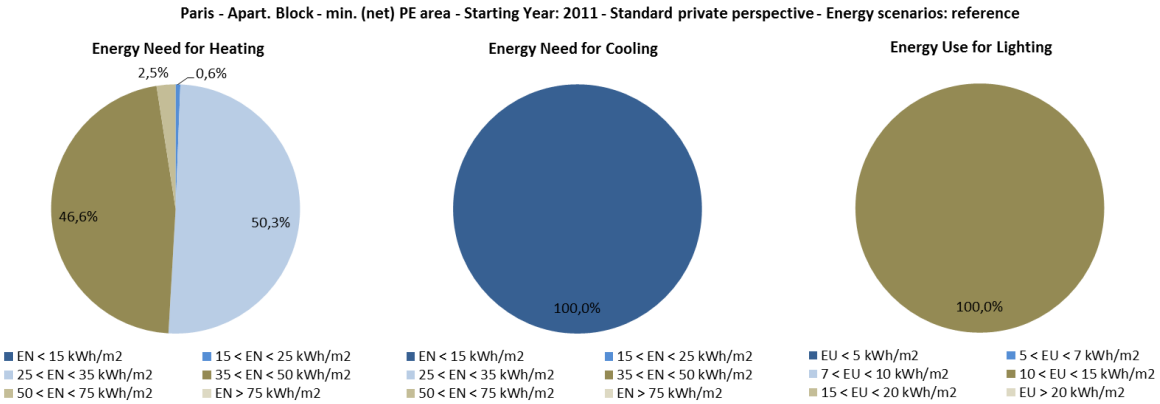

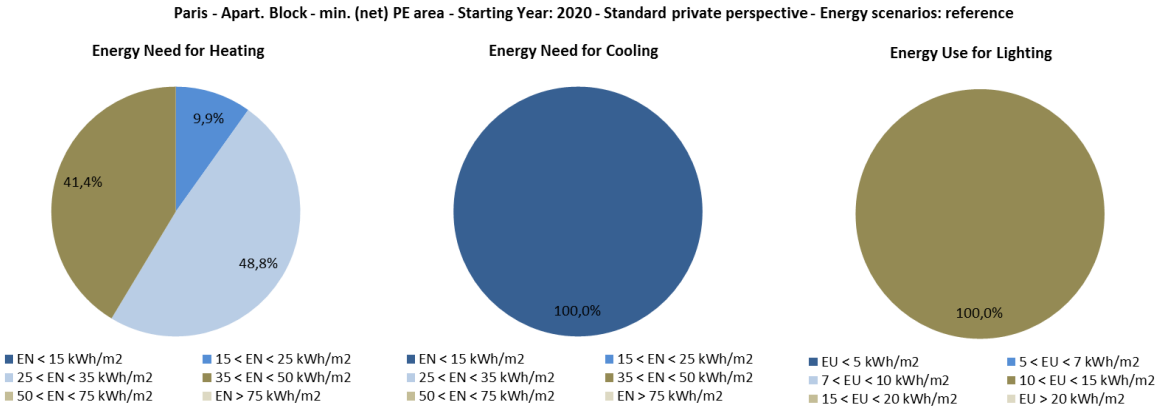

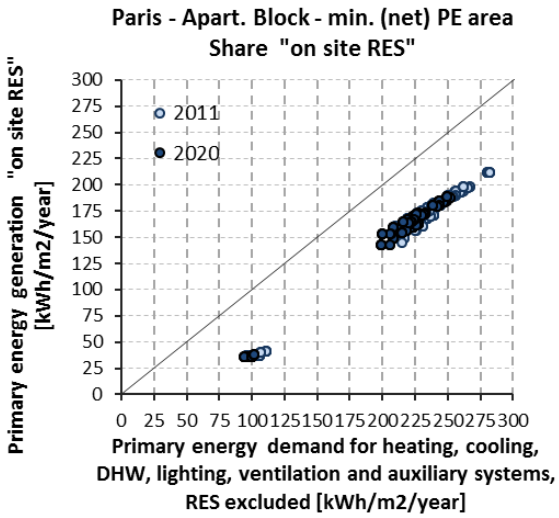

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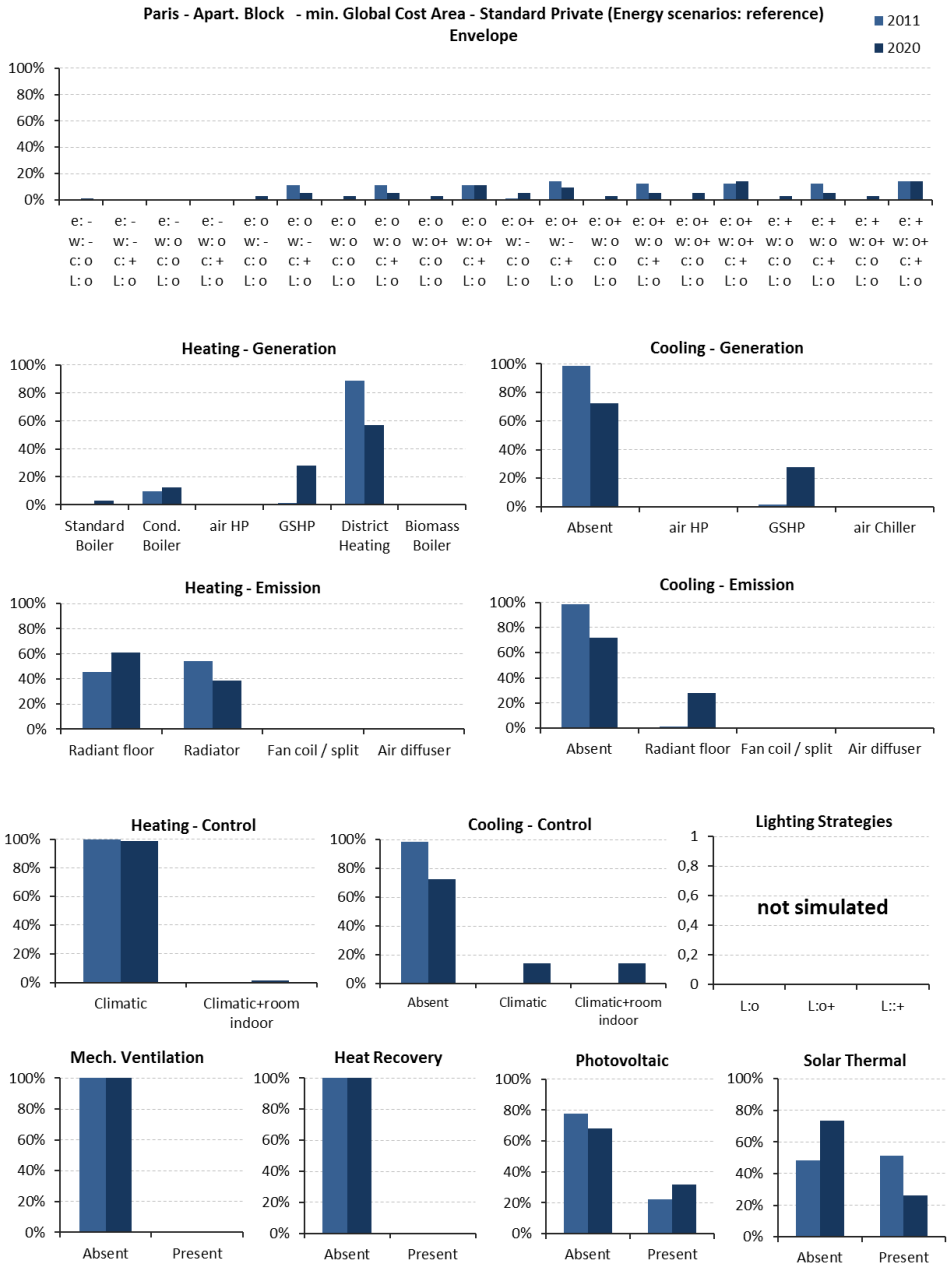
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	50	250	50	250
Range of Global Costs [€/m^2]:	448	502	492	550
Number of Building Variants:	144		144	



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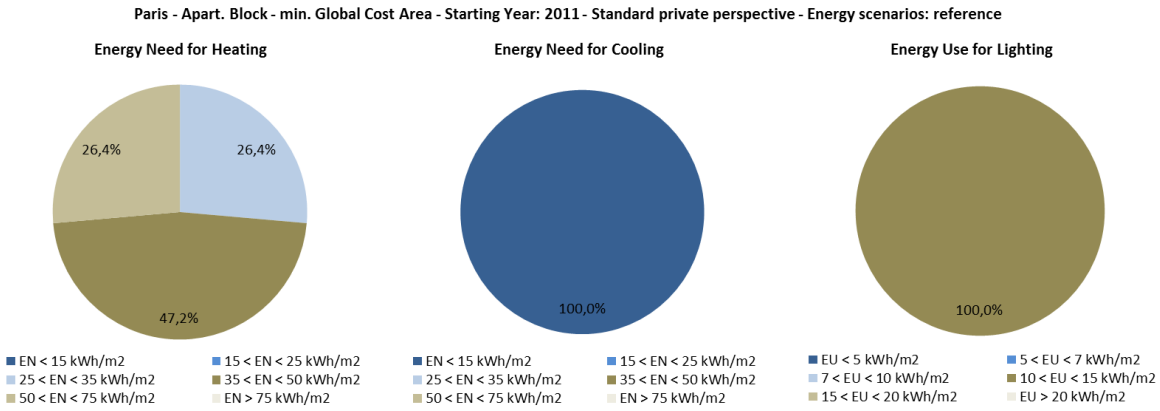

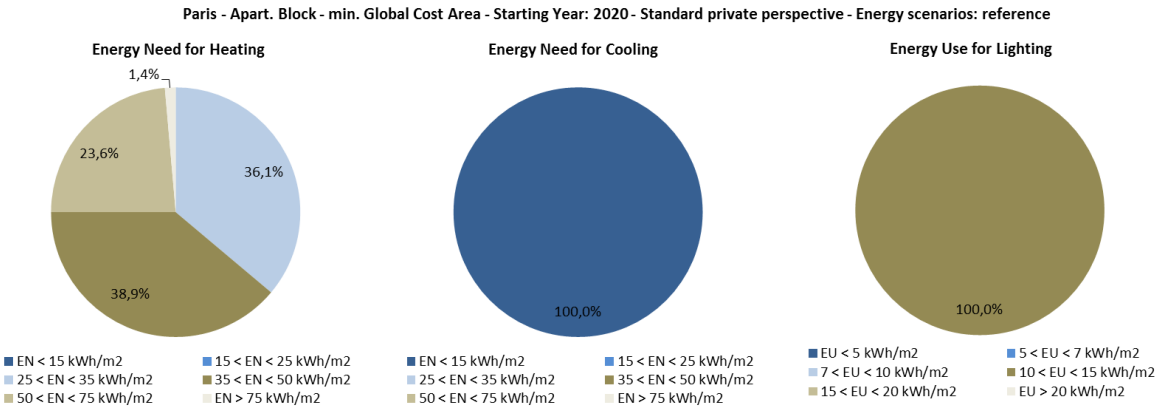

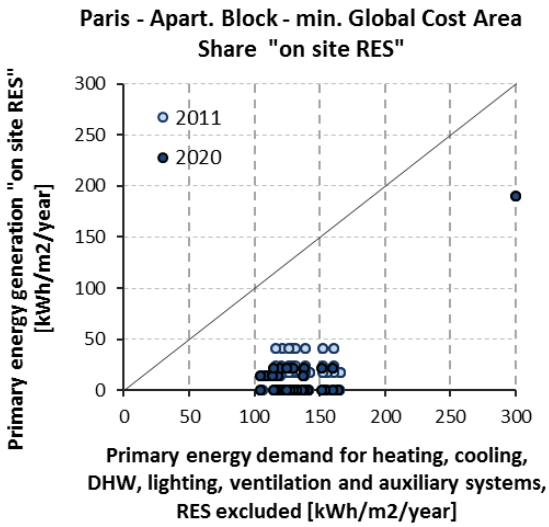

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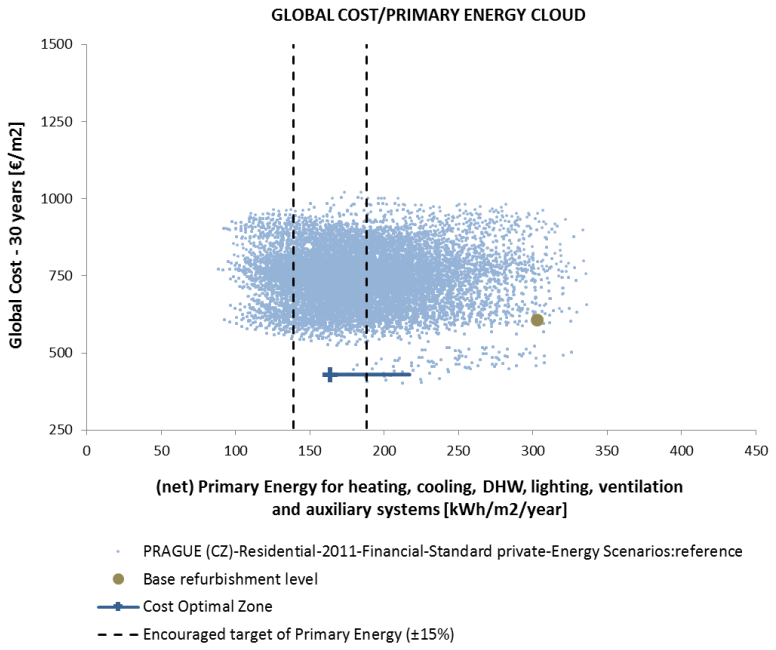
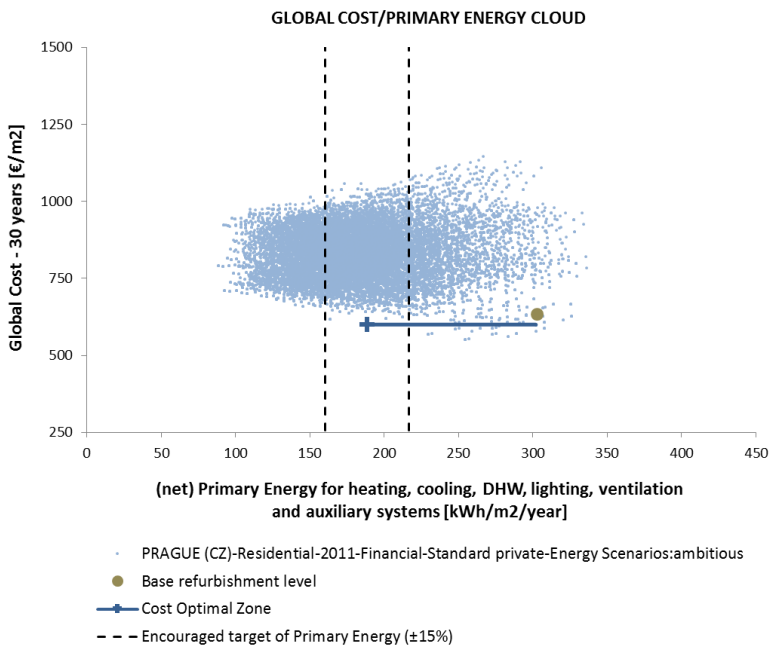
8.1.2.8 Prague





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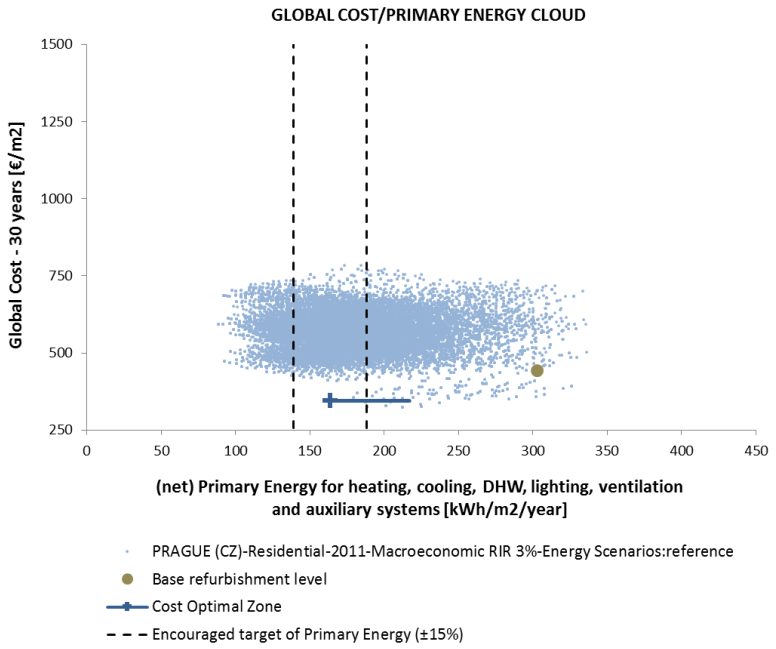

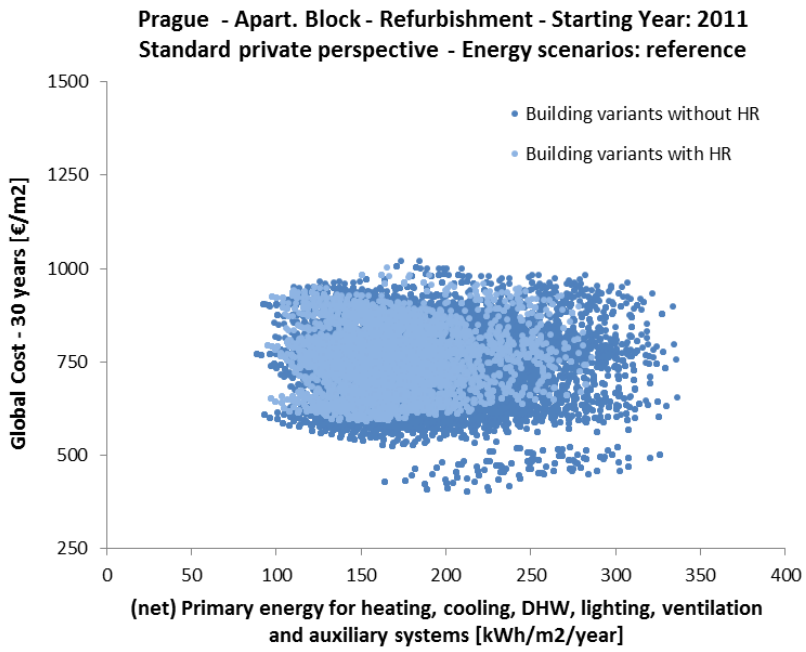

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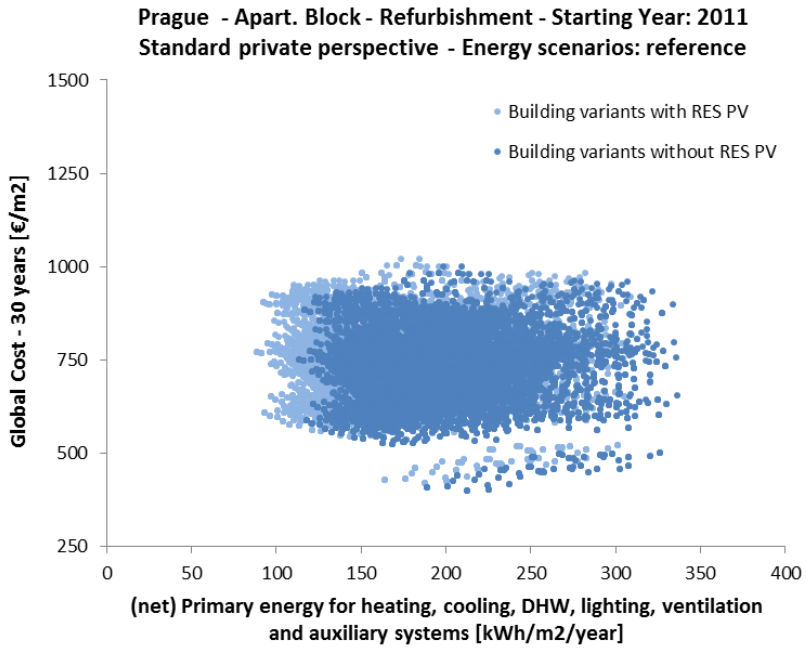

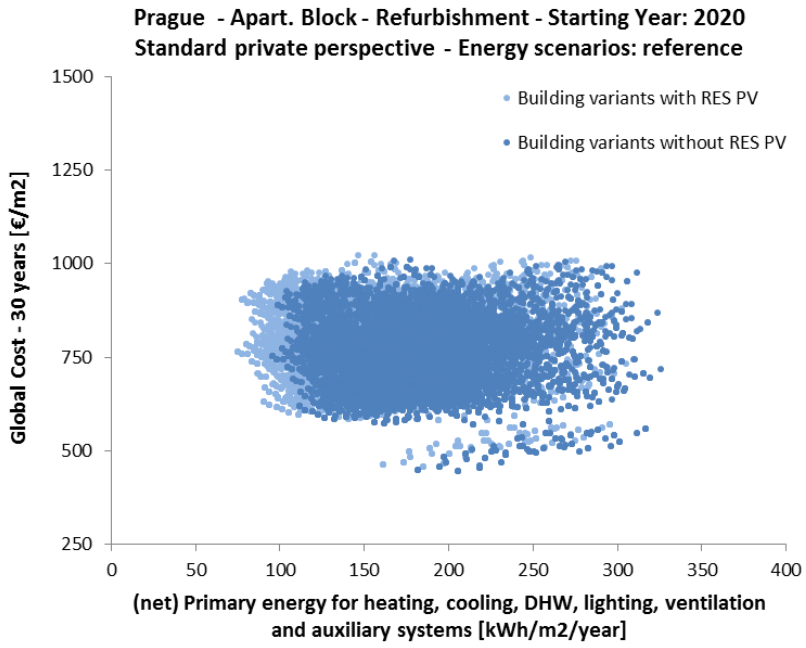

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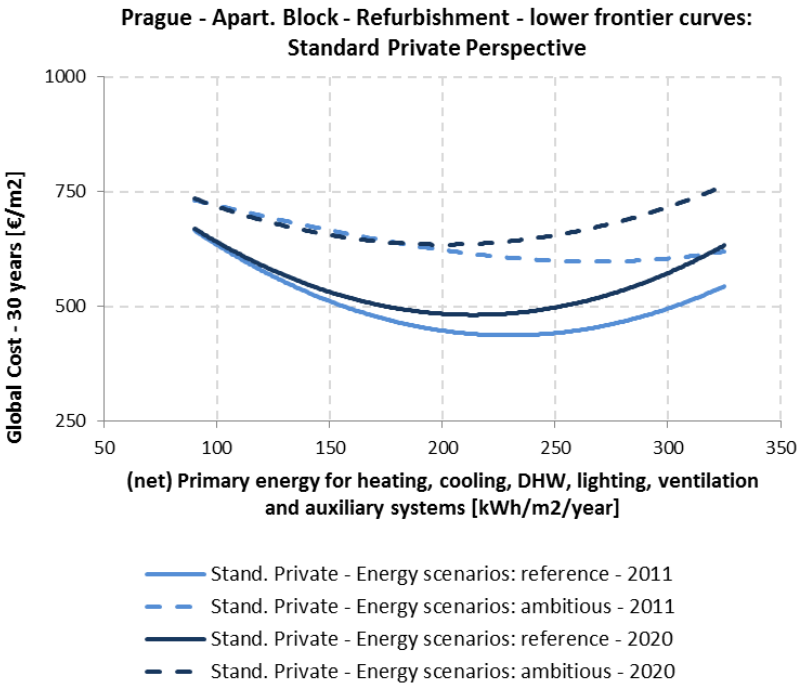

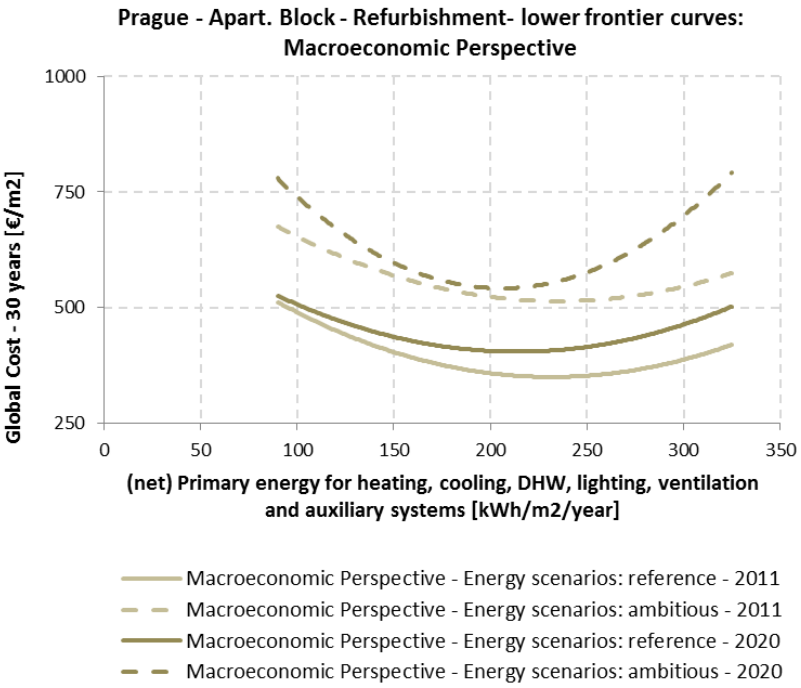

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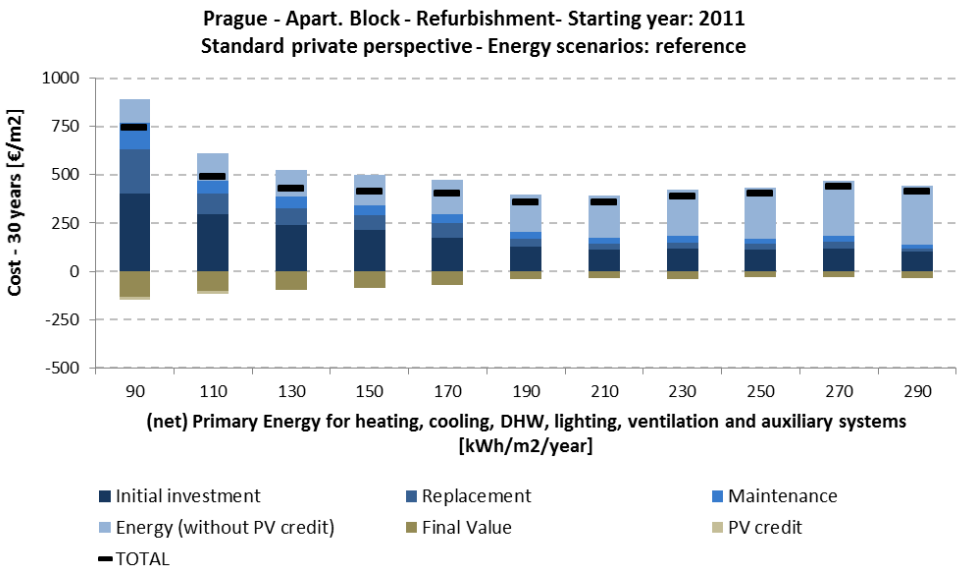

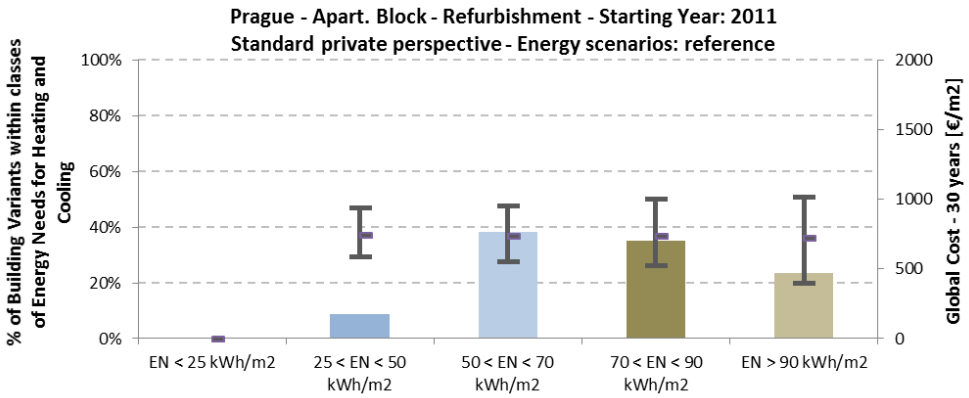

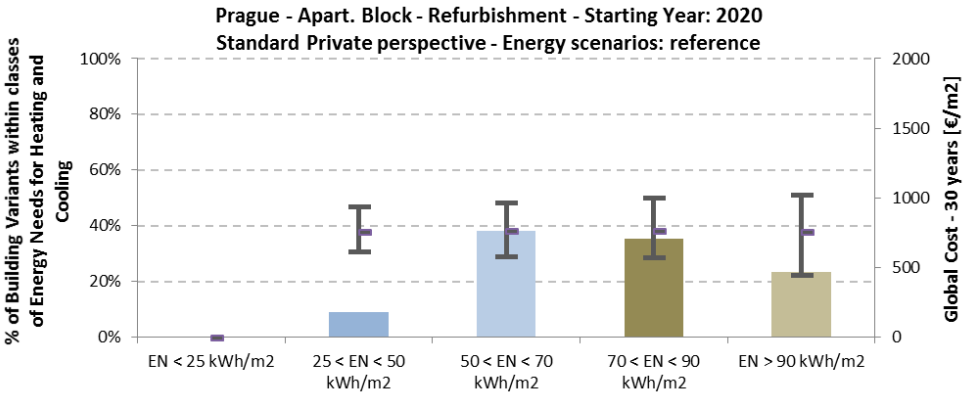

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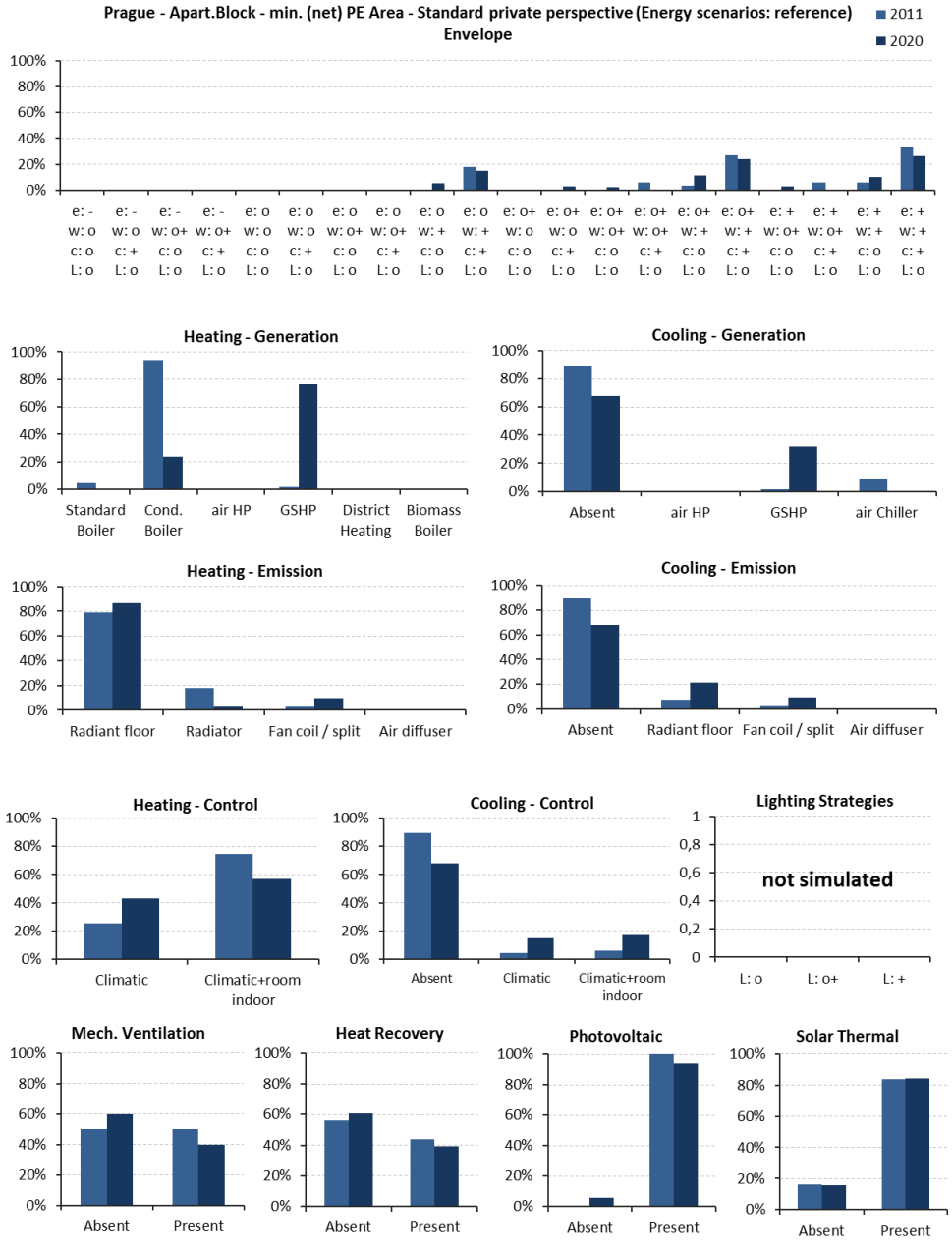
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	88	115	75	100
Range of Global Costs [€/m^2]:	576	691	610	759
Number of Building Variants:	134		135	



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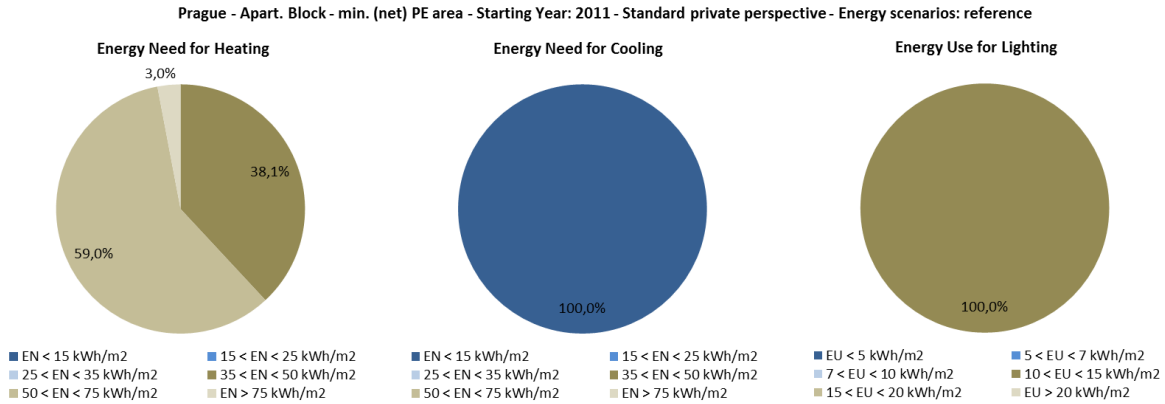

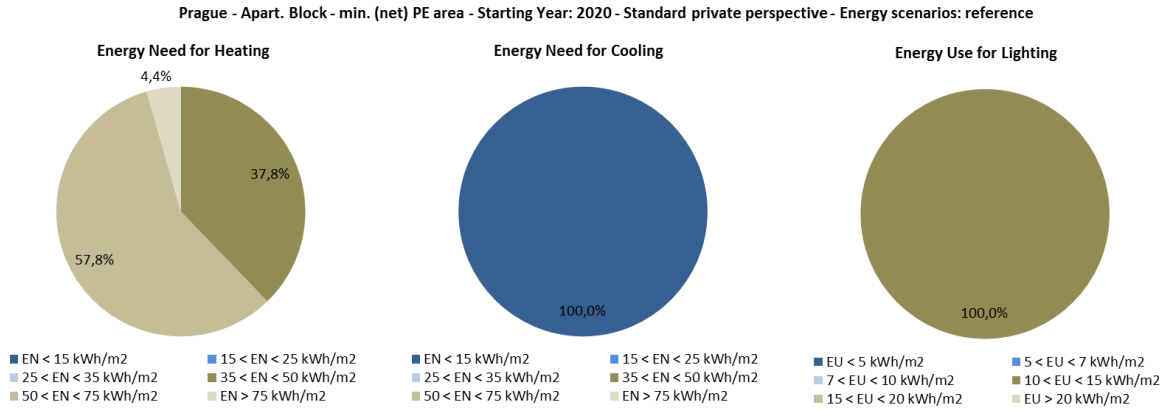

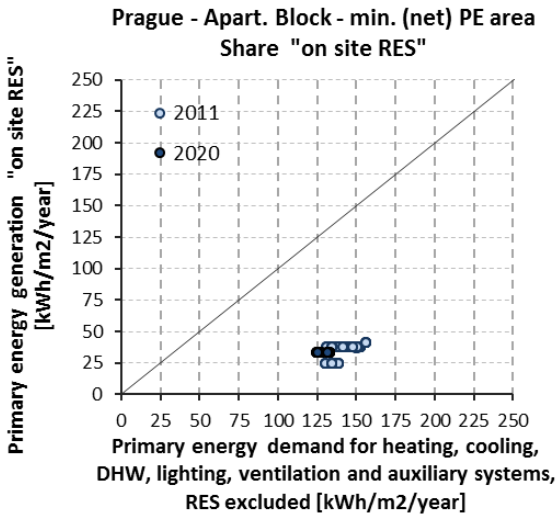

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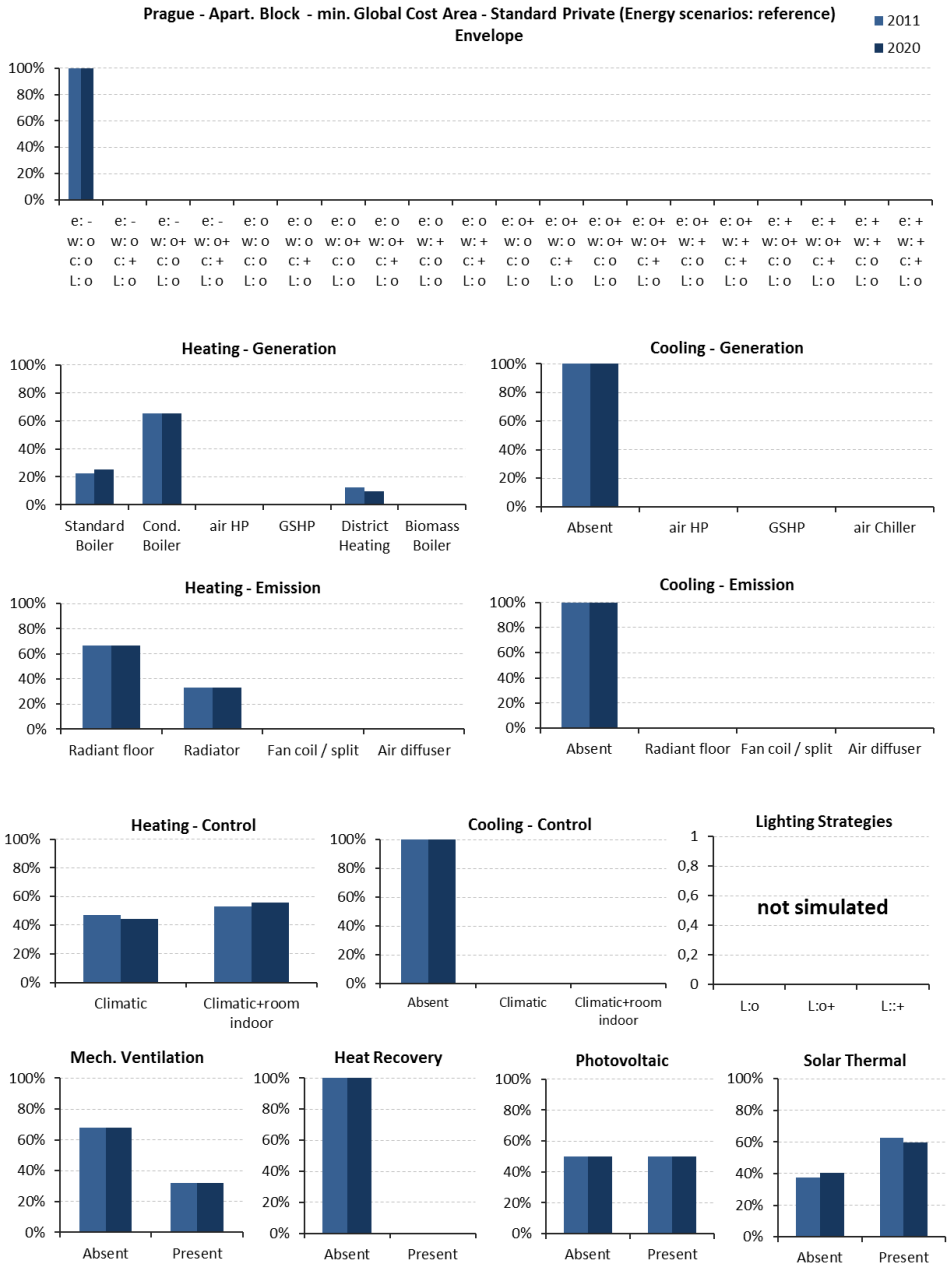
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	150	270	150	260
Range of Global Costs [€/m^2]:	401	482	445	526
Number of Building Variants:	144		144	



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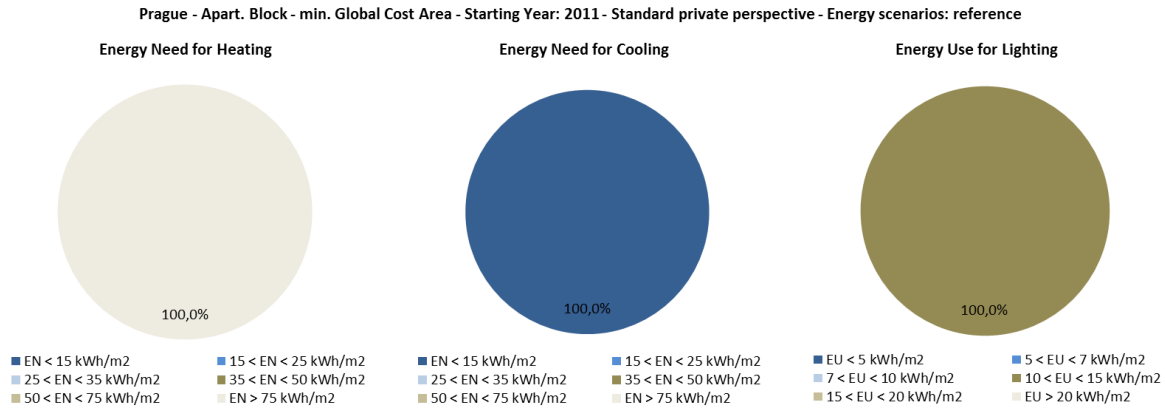

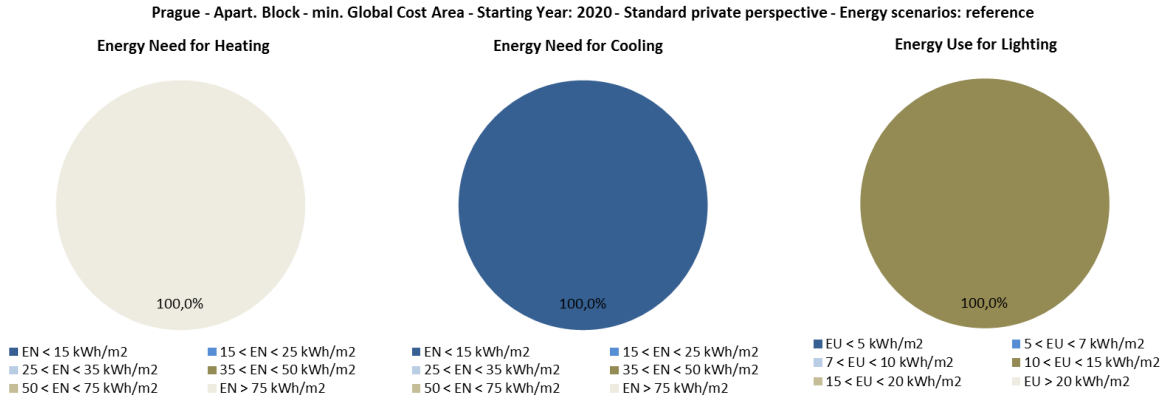

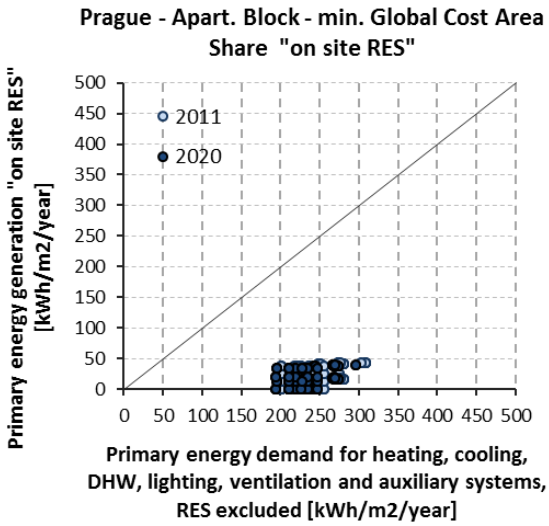

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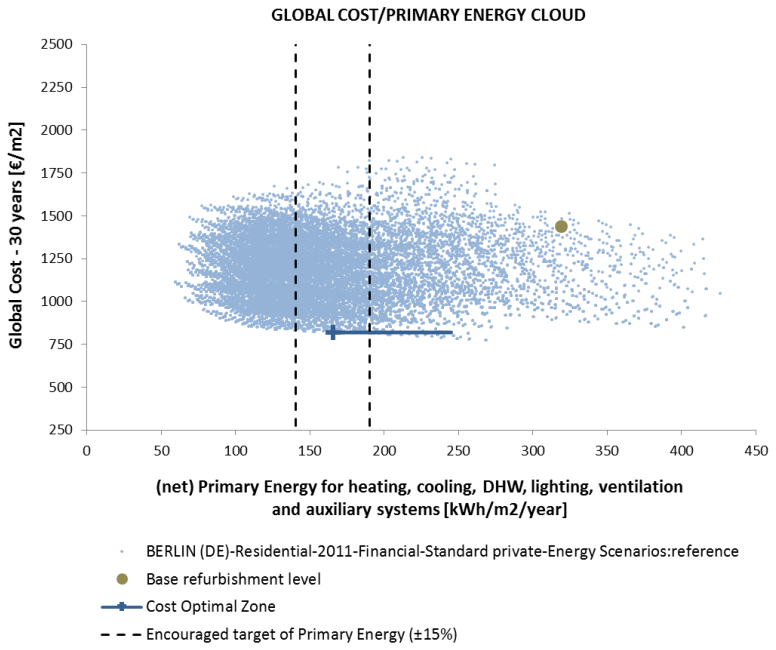
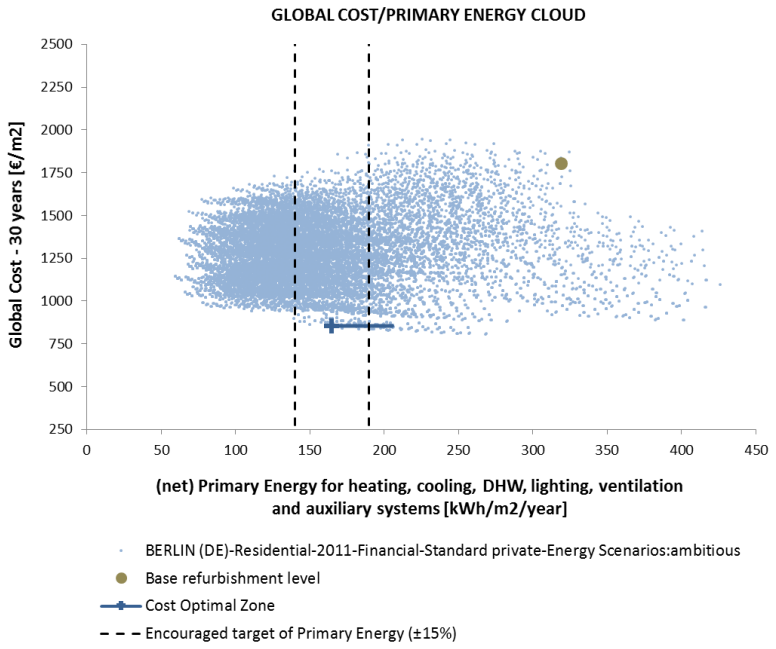
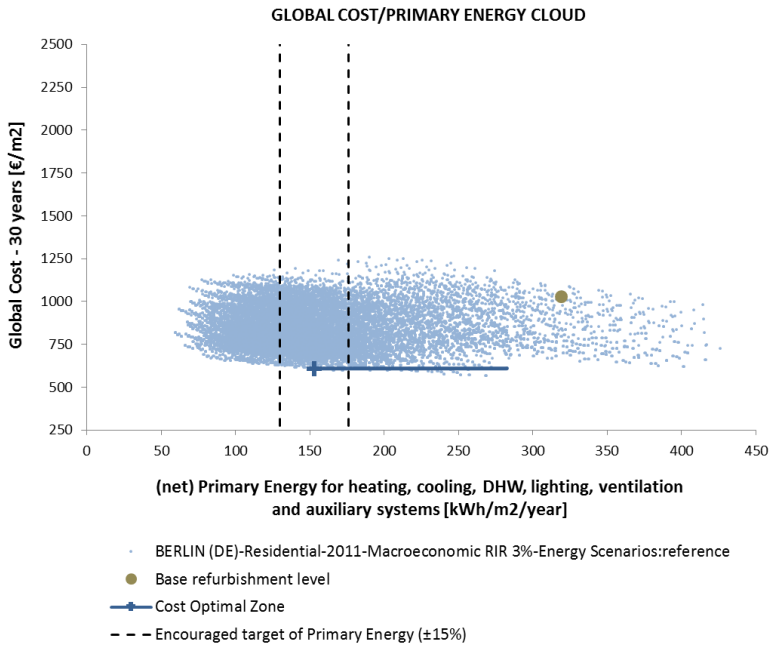
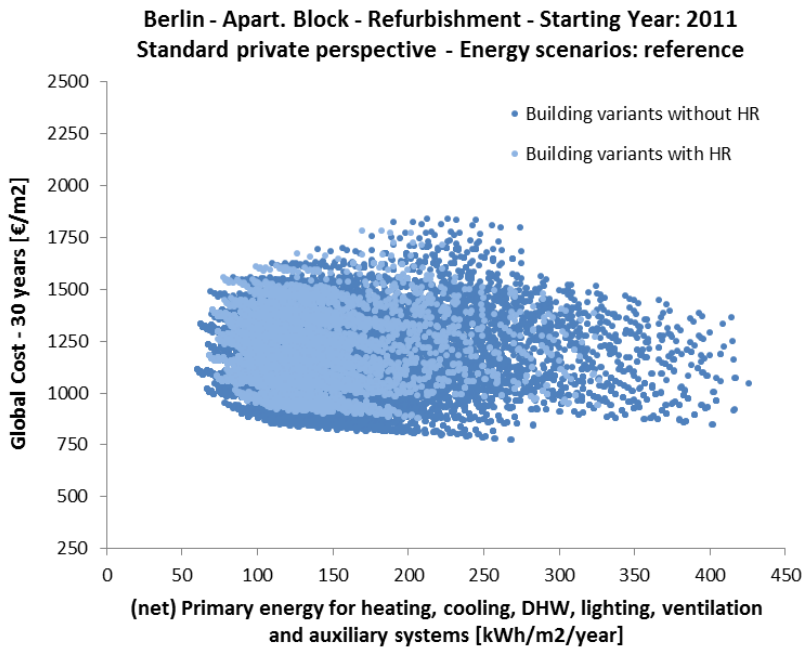
8.1.2.9 Berlin





Co-funded by the Intelligent Energy Europe Programme of the European Union





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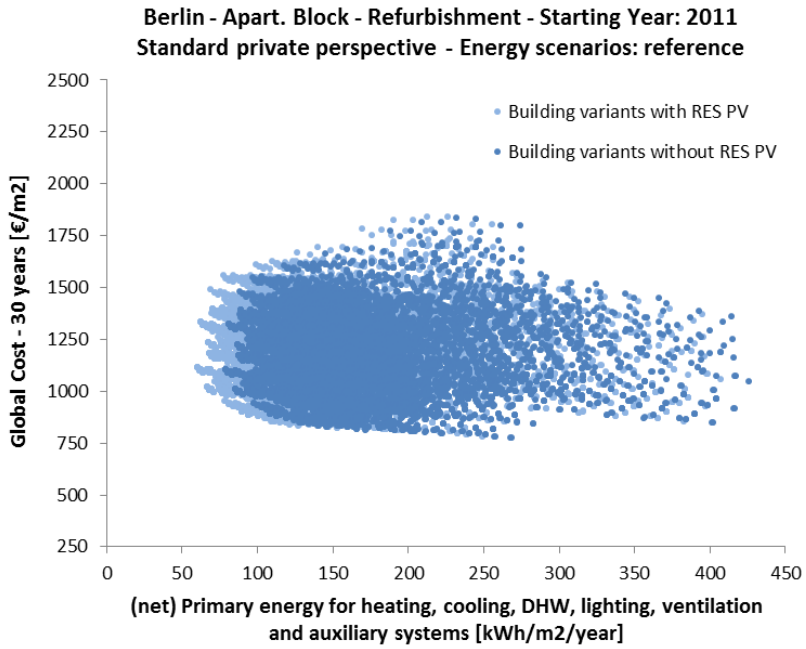

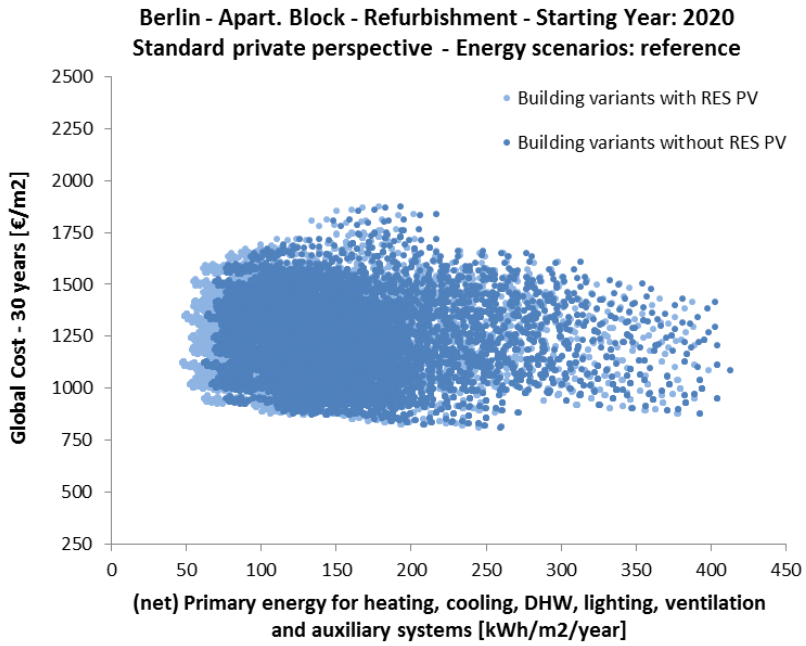

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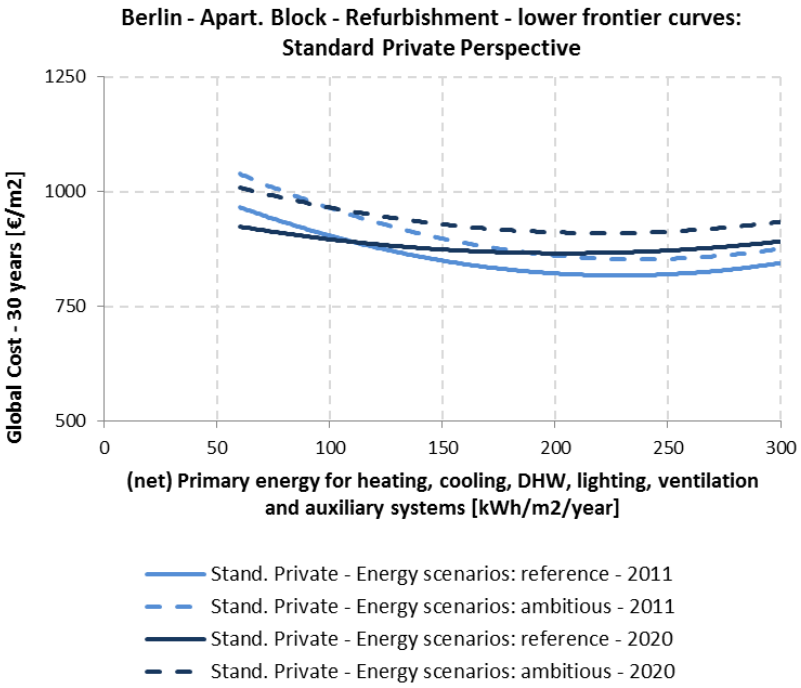

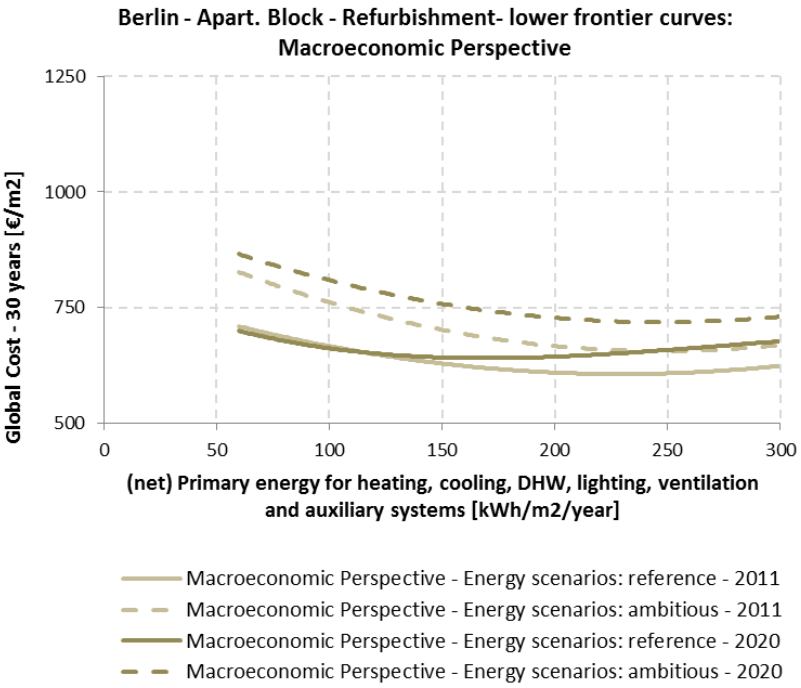

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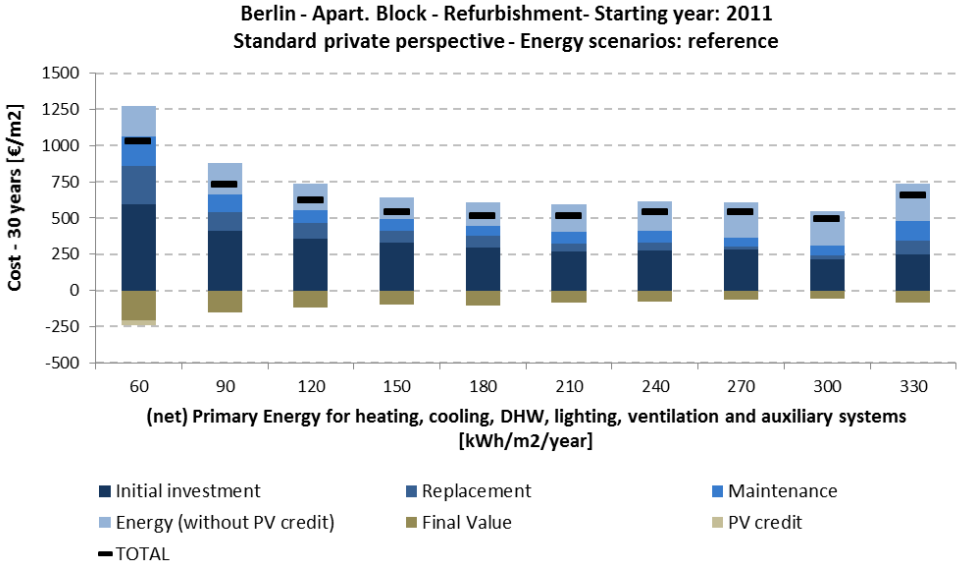

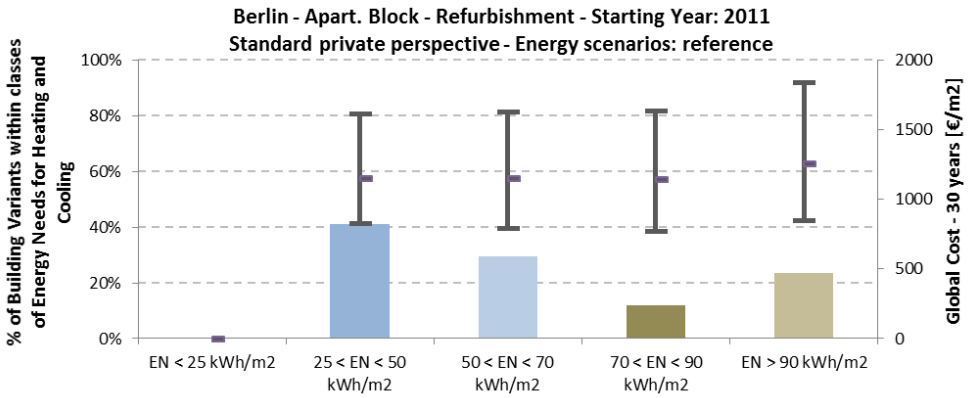

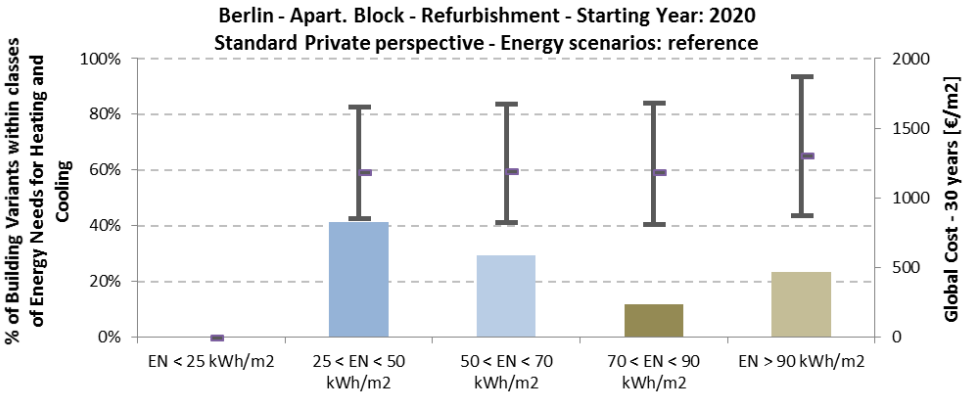

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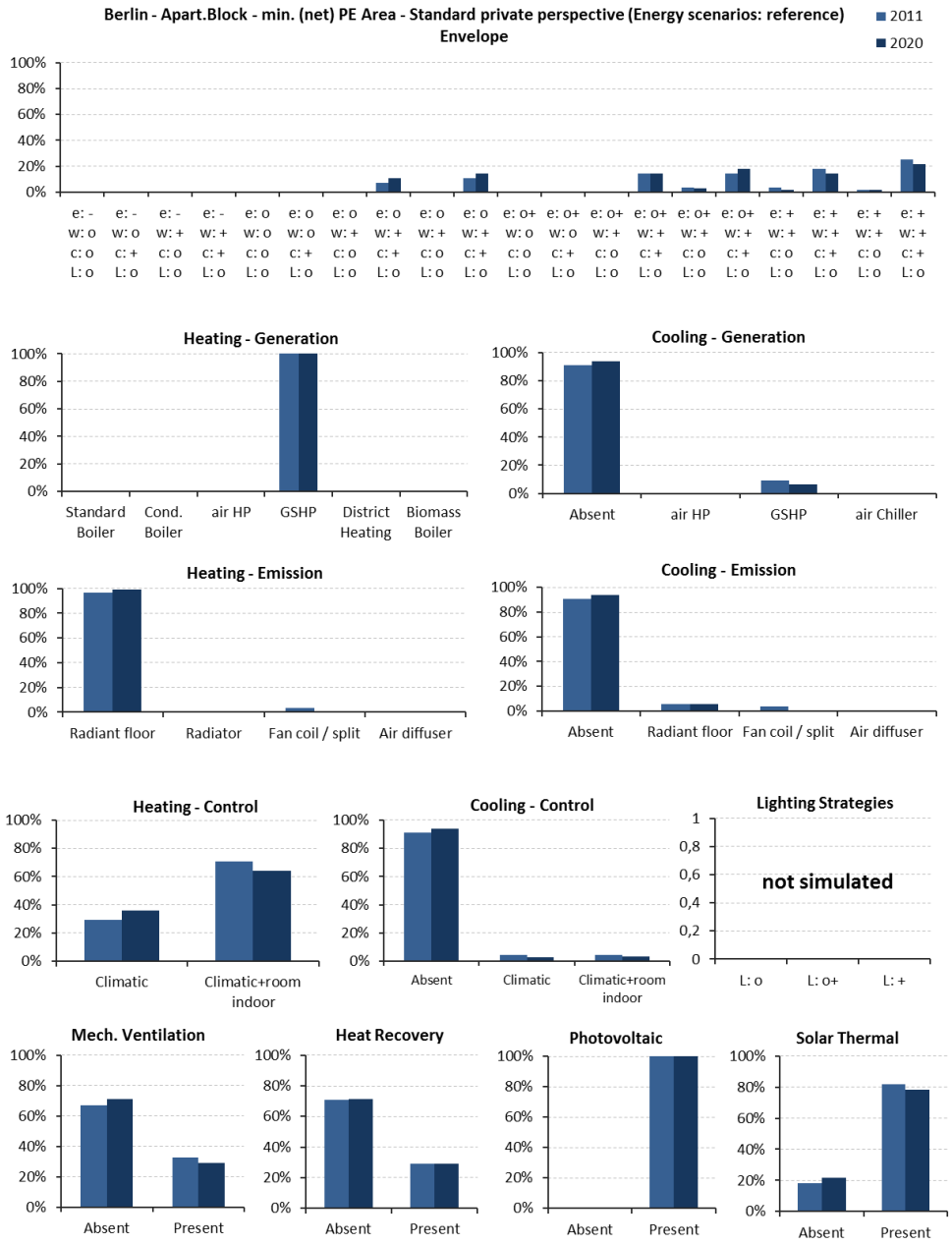
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	60	75	47	60
Range of Global Costs [€/m²]:	992	1191	951	1189
Number of Building Variants:	110		110	



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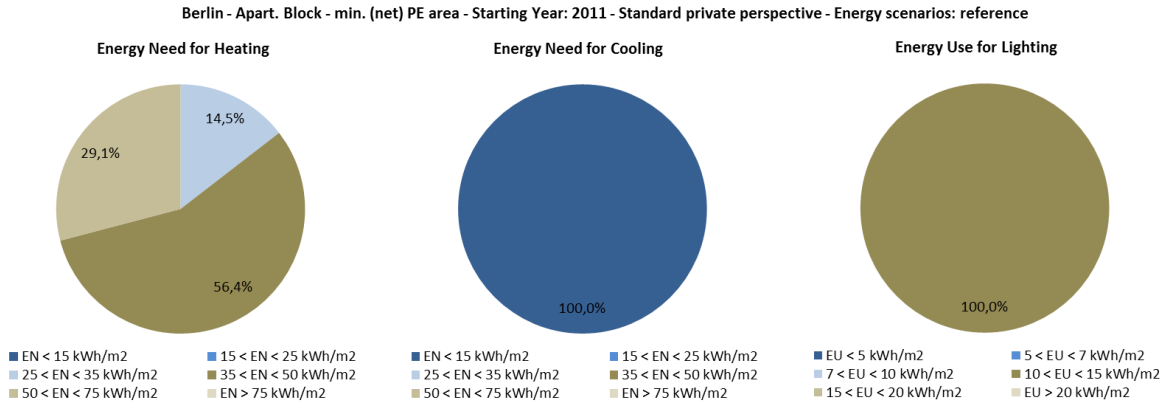

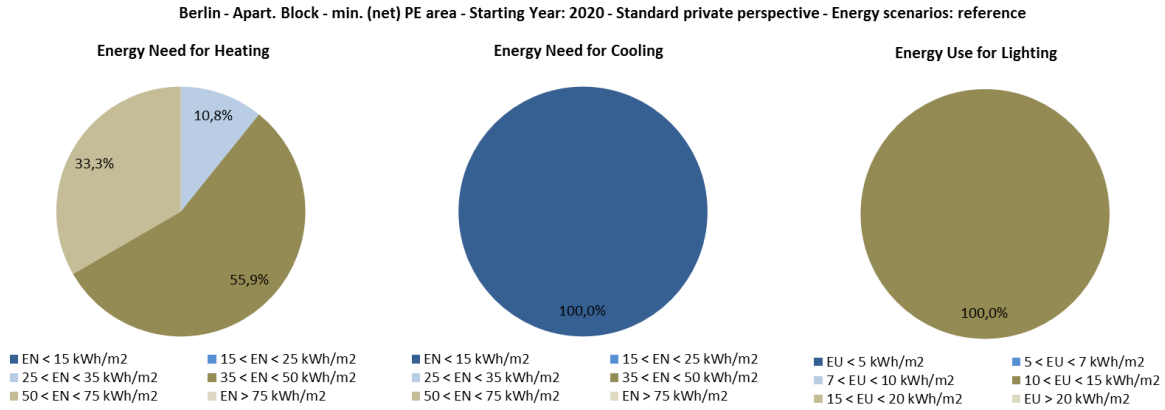

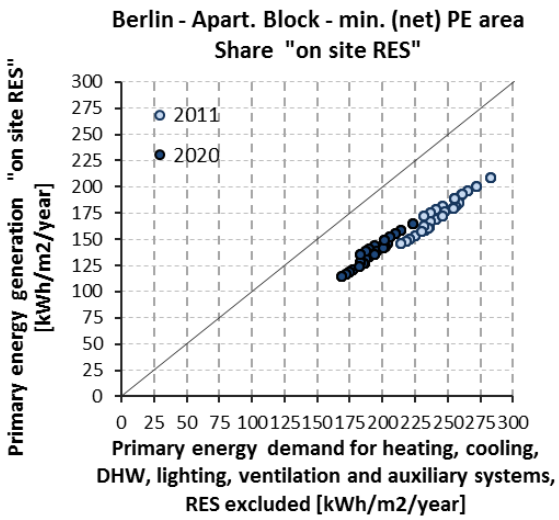

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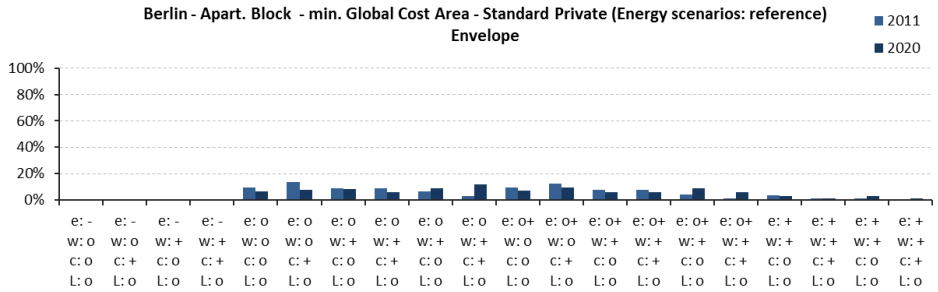
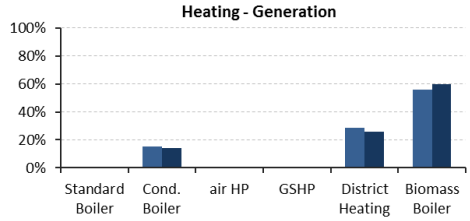
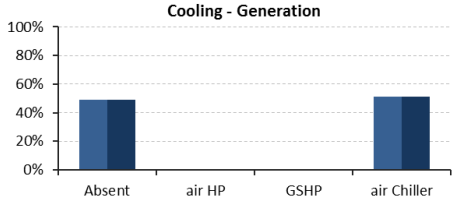
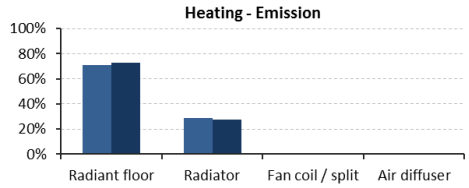
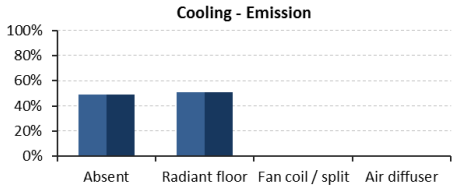
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	100	300	50	230
Range of Global Costs [€/m²]:	776	853	813	893
Number of Building Variants:	278		278	

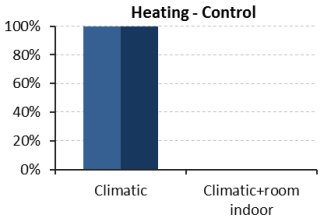


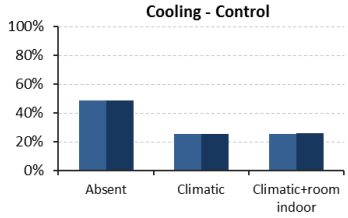


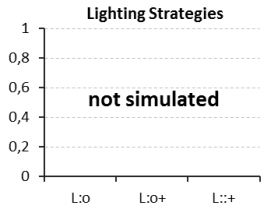


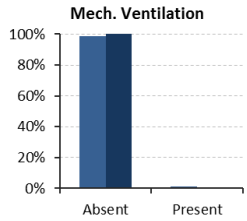


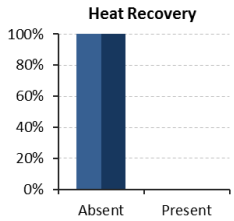


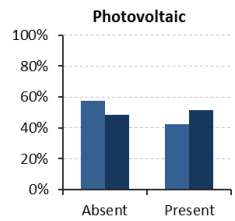


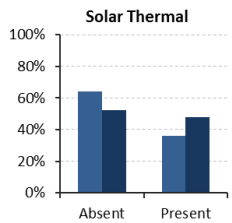












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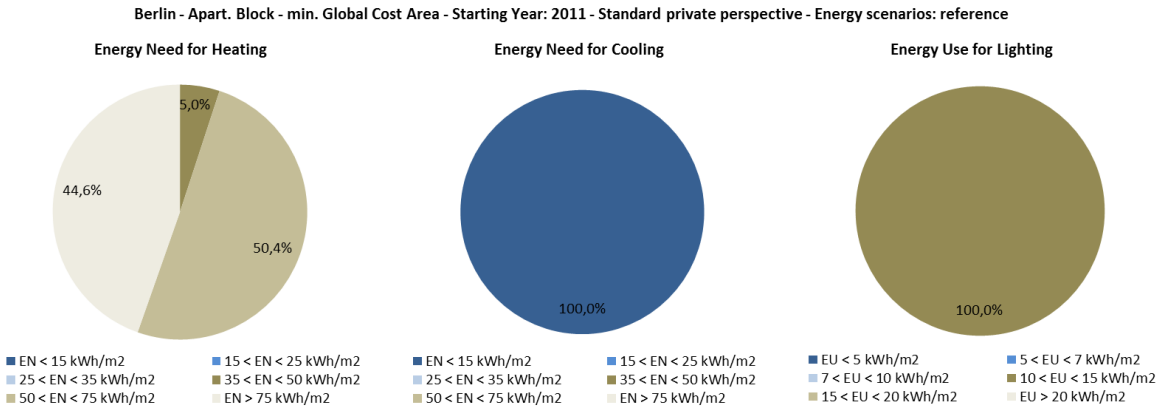

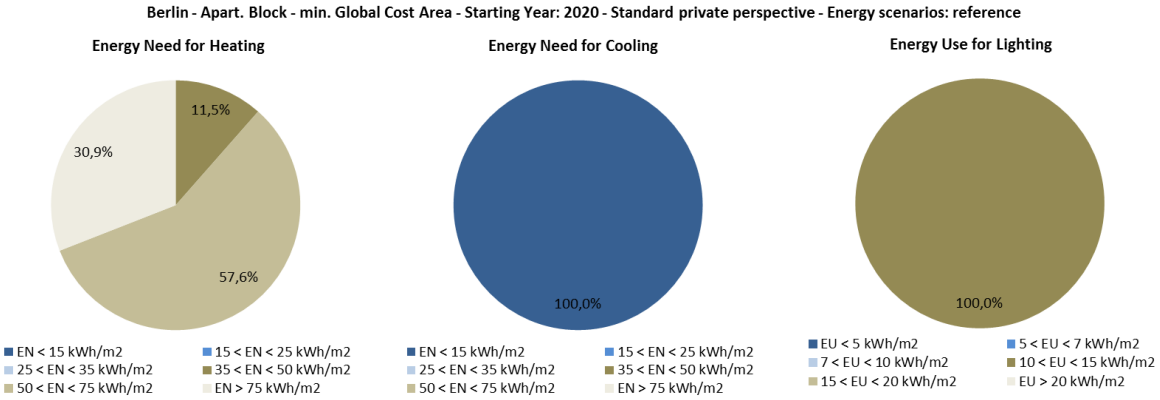

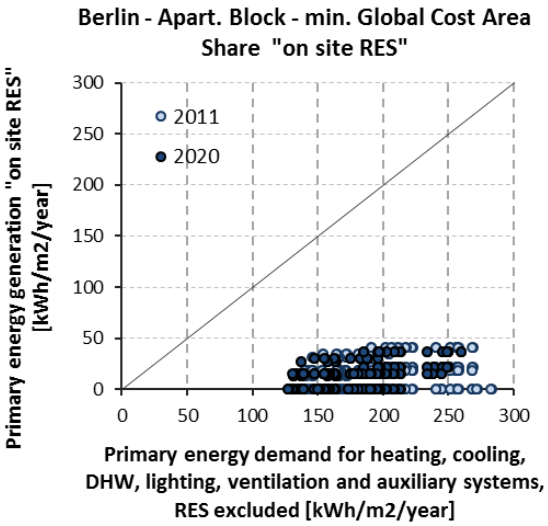

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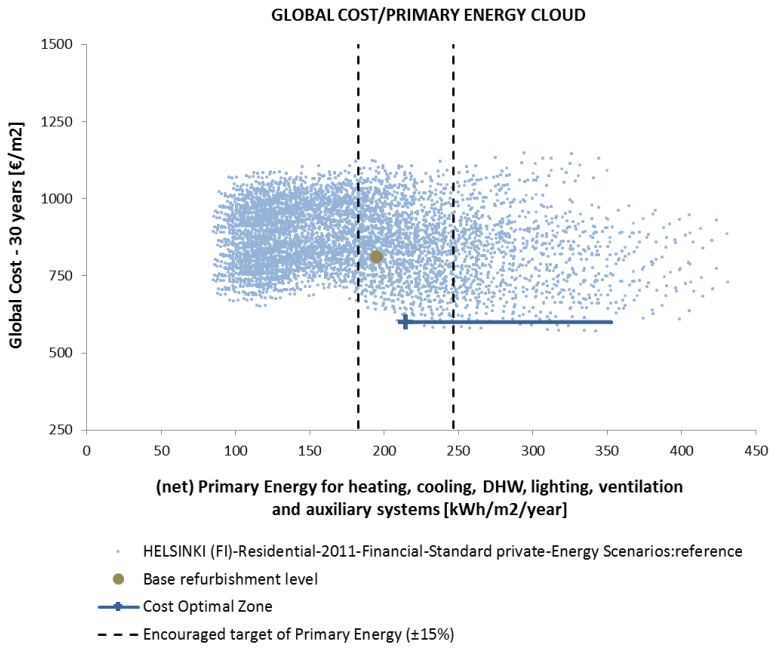
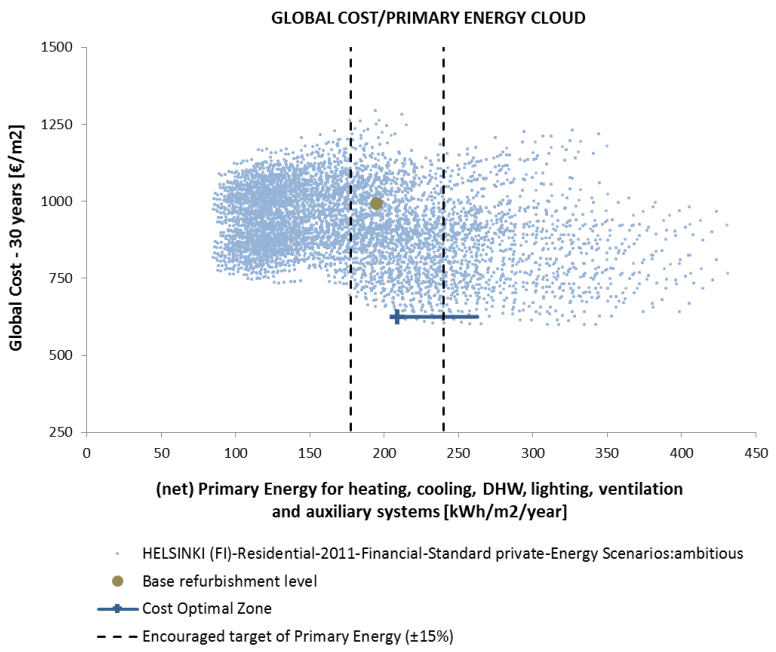
8.1.2.10 Helsinki





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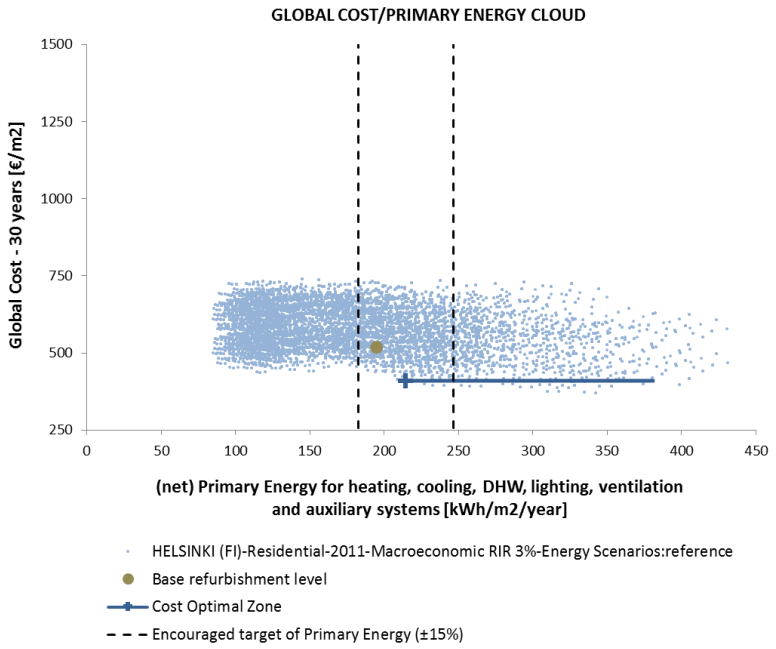

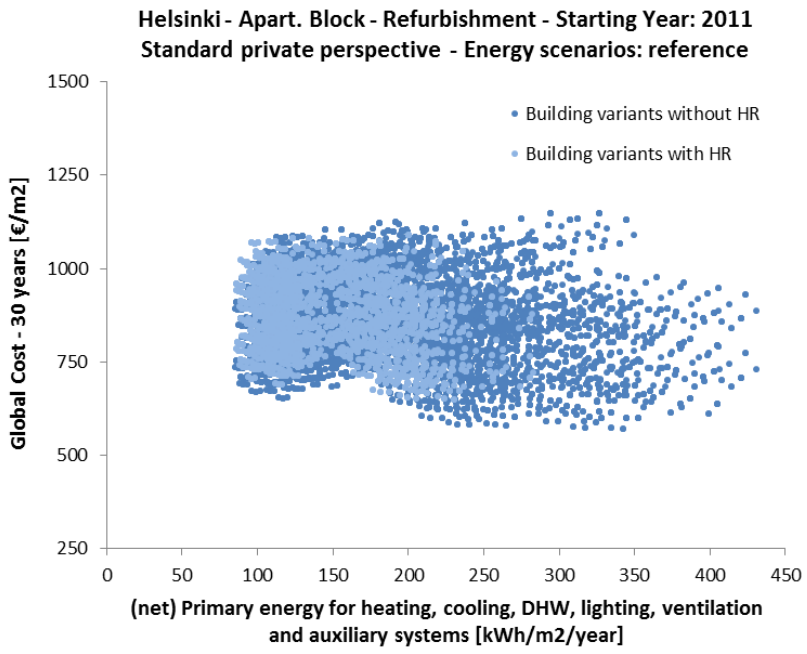

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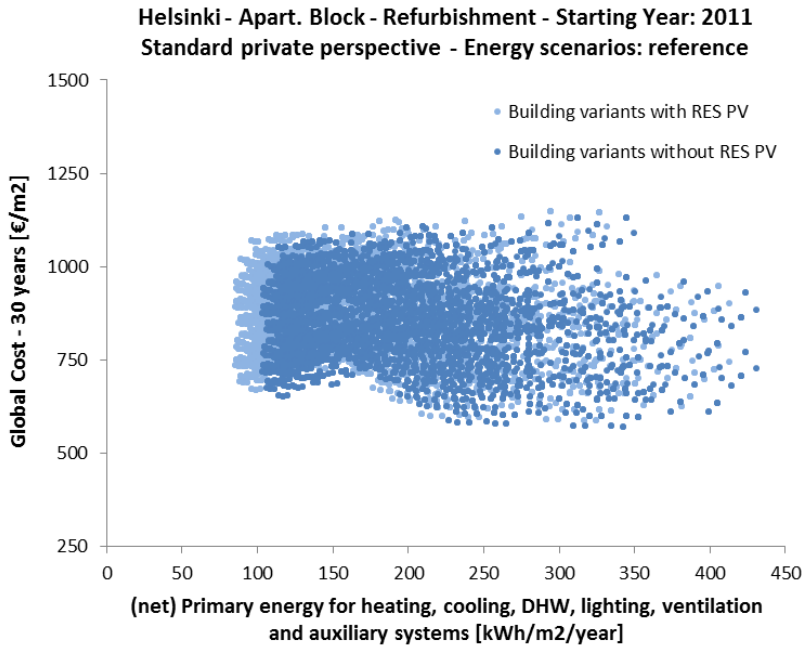

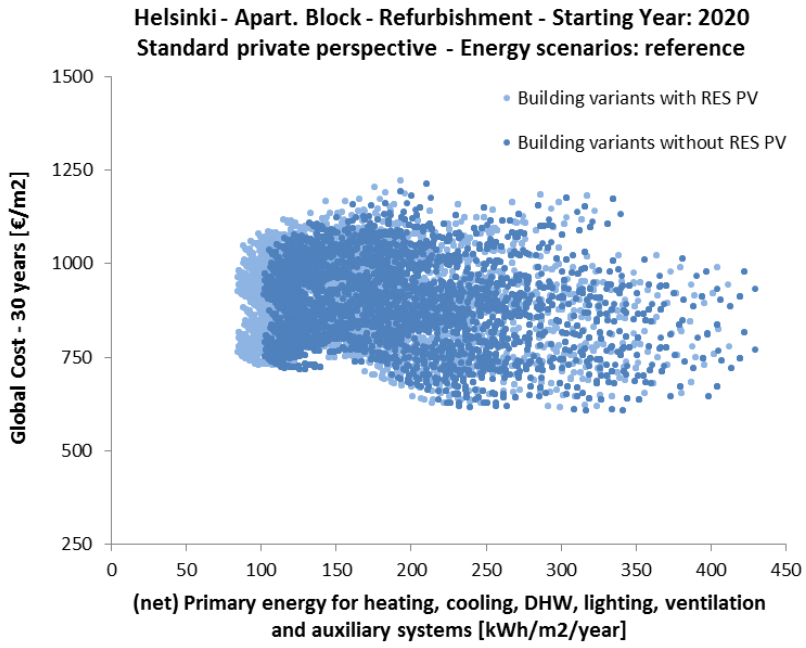

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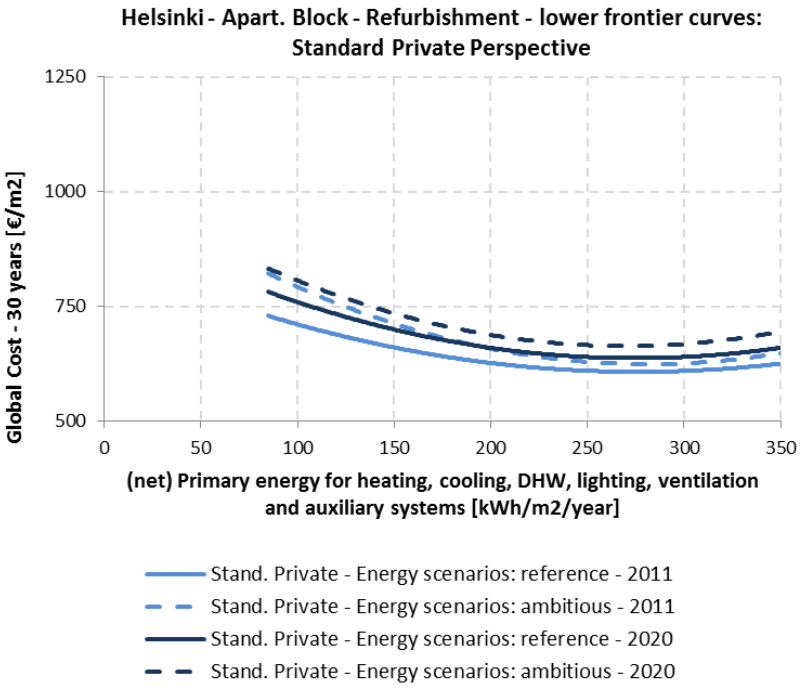

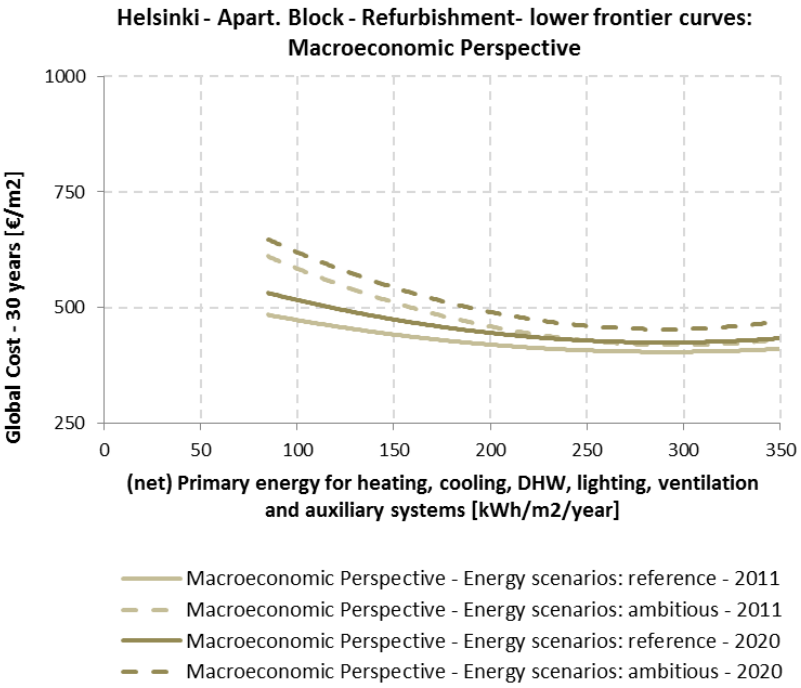

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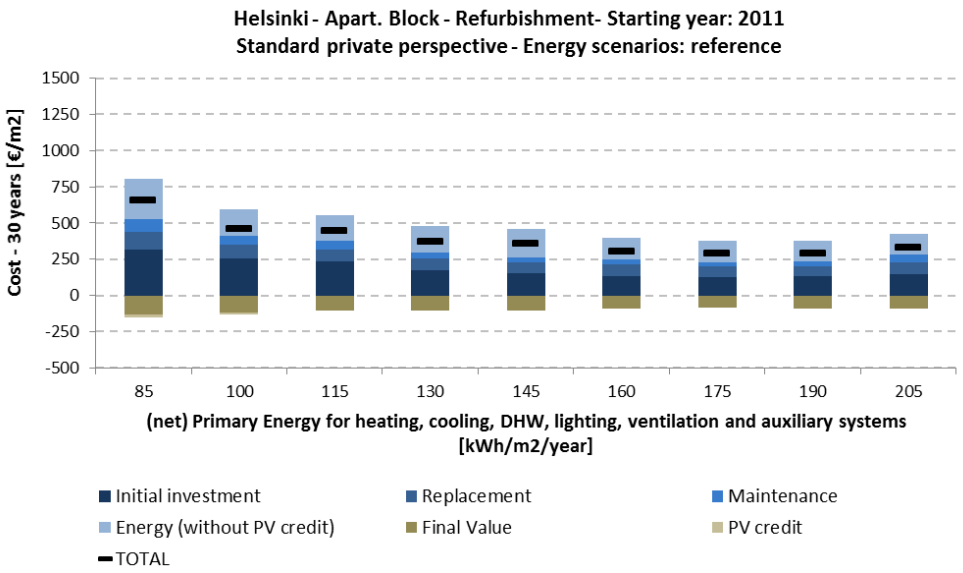

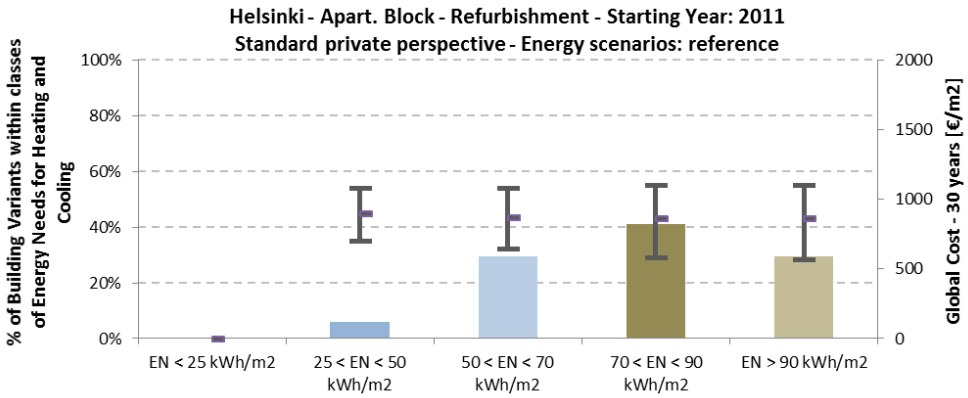

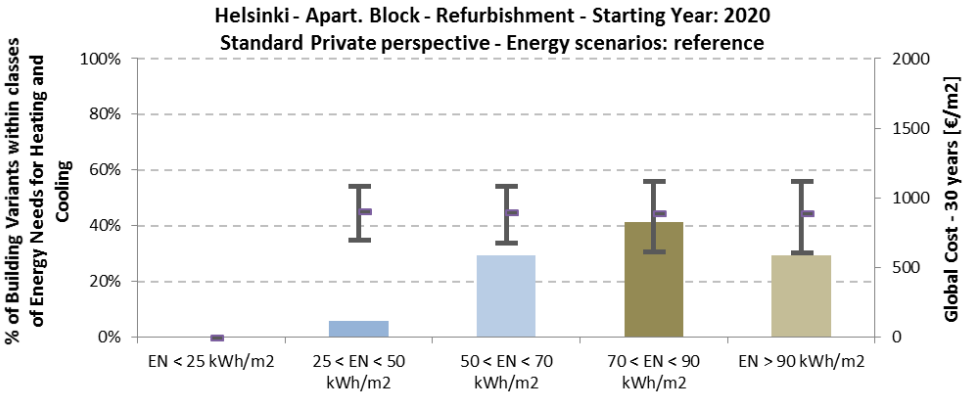

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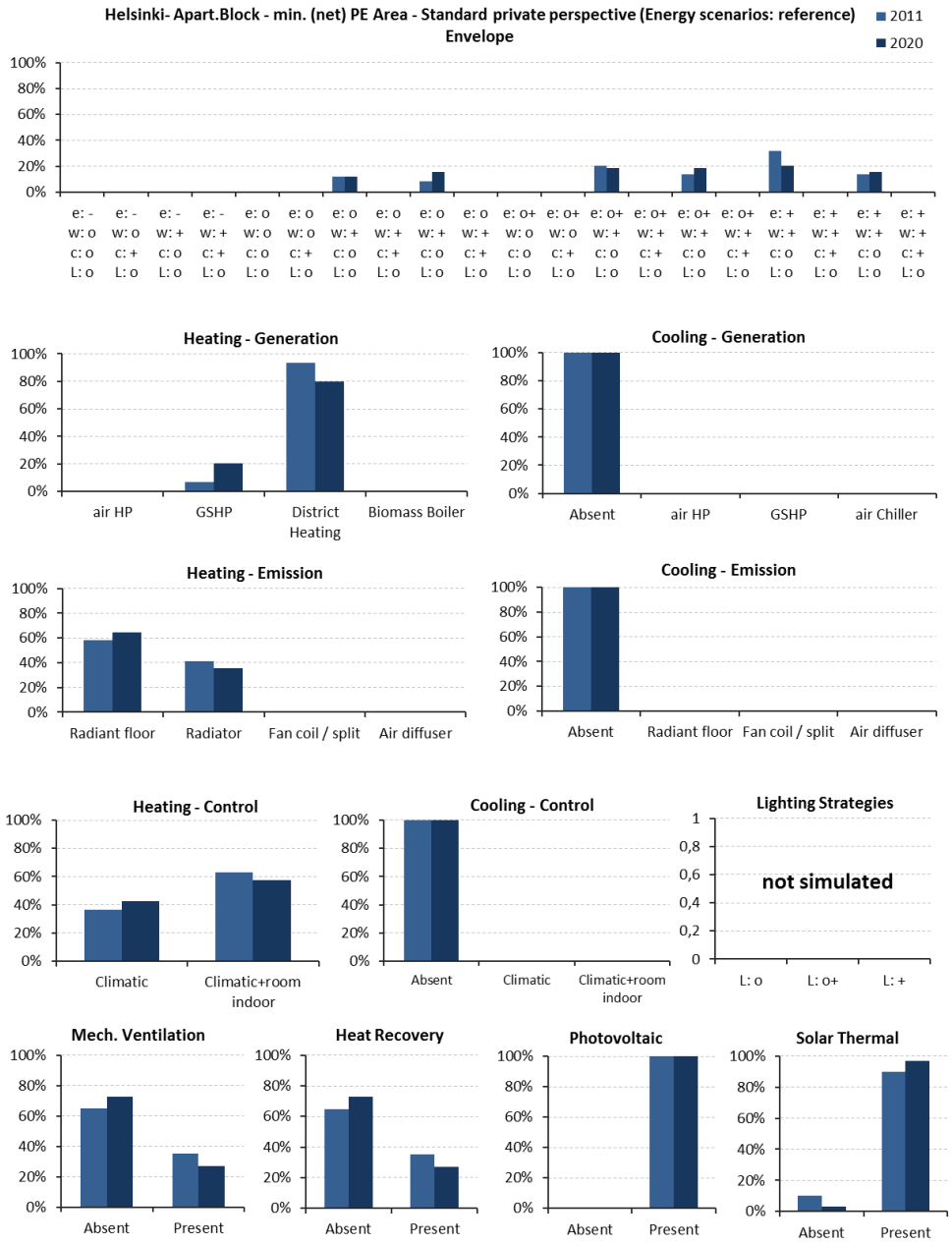
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	85	100	84	100
Range of Global Costs [€/m²]:	669	770	730	788
Number of Building Variants:	117		118	



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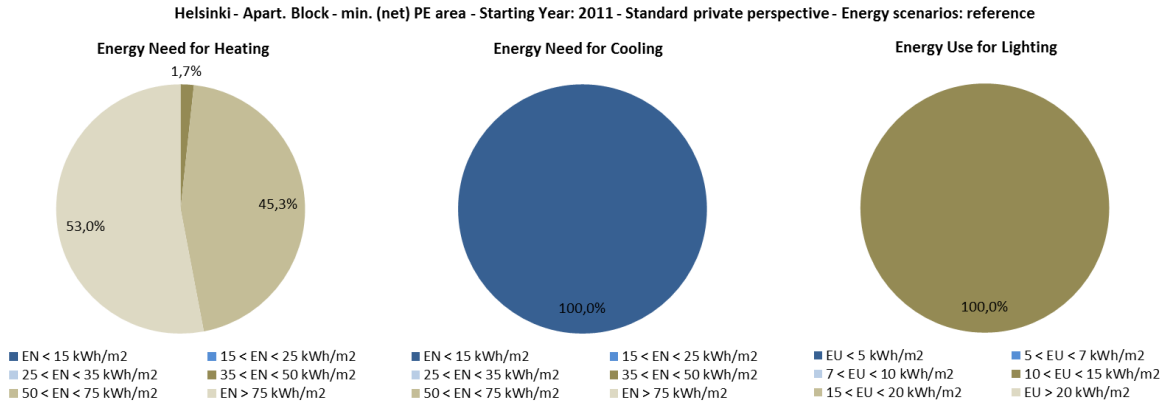

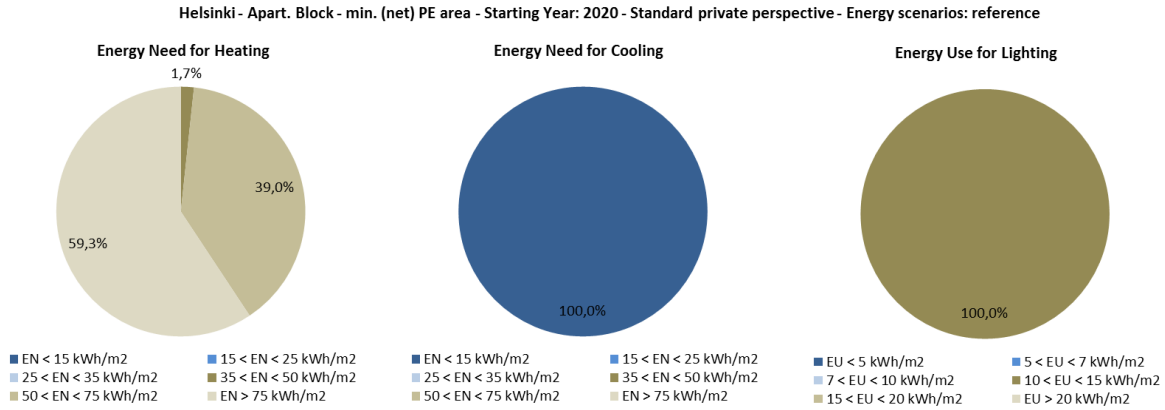

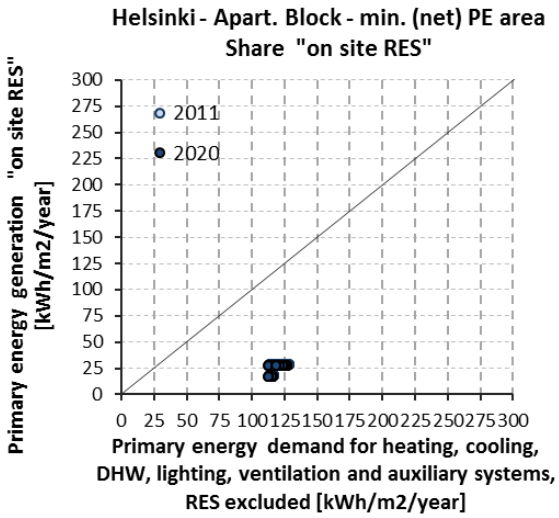

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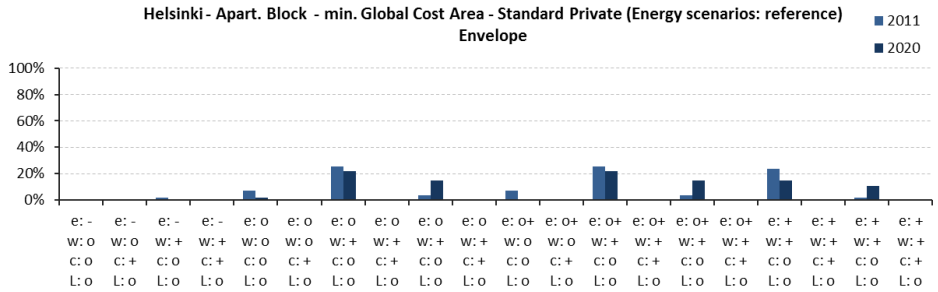
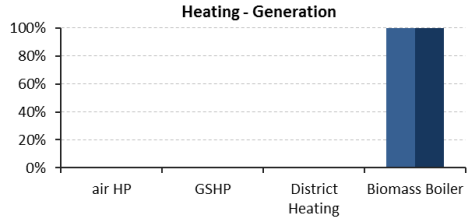
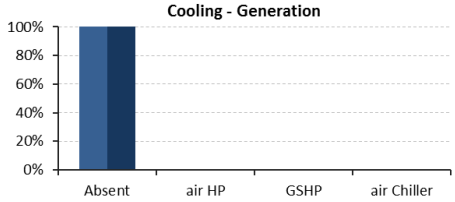
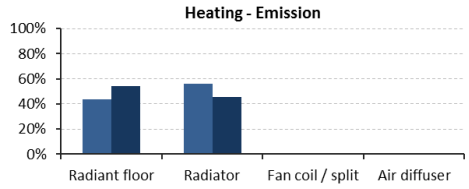
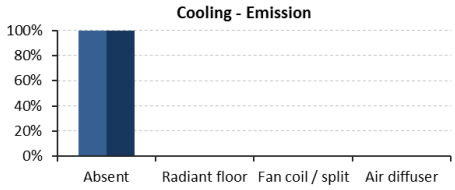
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	200	300	175	275
Range of Global Costs [€/m^2]:	572	629	608	660
Number of Building Variants:	110		110	

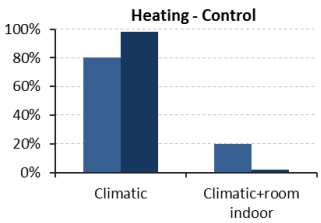


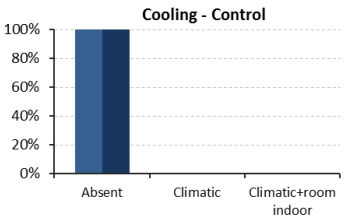


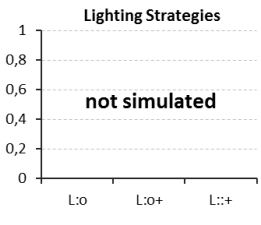


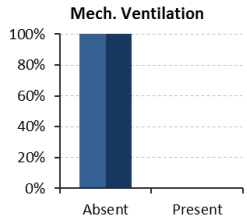


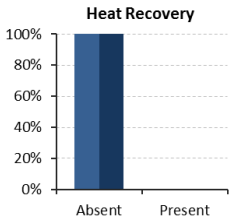


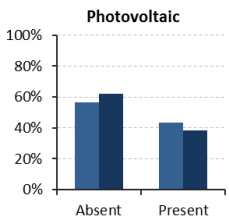


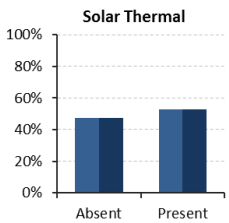












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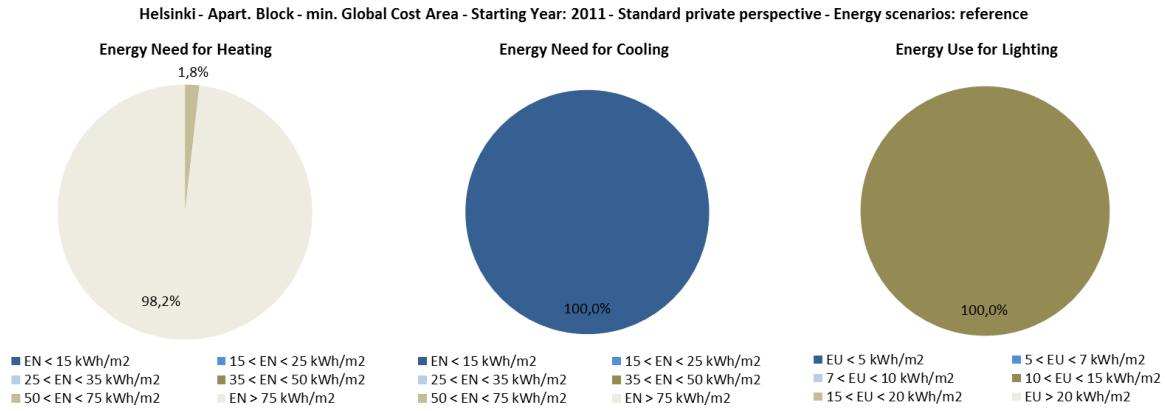

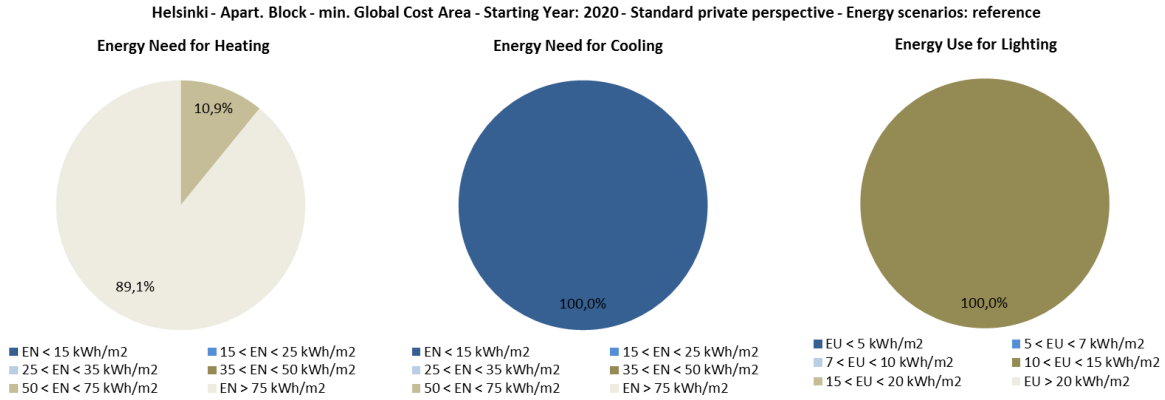

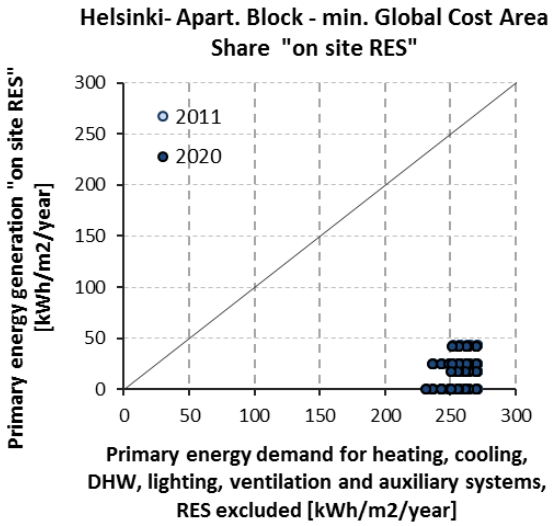

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8.1.3 Office

Results about single family houses are presented in the following chapters.

About “Envelope Section” divided in these fields

- Opaque envelope Insulation **(e)**
- Windows (frame and glazing) **(w)**
- Cooling Strategies **(c)**
- Lighting efficiency (as internal gain) **(L)**

variants are expressed using this code with “-, o-, o, o+, +”, see table below

Tabella 5: variants codes for opaque envelope, windows, cooling strategies and lighting efficiency in Office.

cod.	Opaque Envelope Insulation			Windows	Cooling strategies			
	Additional insulation compared to base case (in thickness of insulation "x" [cm])			number of glass + type of glass + "Air permeability Classification EN12207"	solar shading + control systems - natural night ventilation	lighting load + control system		
	Wall	Roof	Basement			cod	efficiency of ligthing	control
-	0	0	0	single glass standard glass Class 0	solar shading ABSENT natural night ventilation ABSENT	o o+ +	low medium high	manual manual automatised
o-	5 ÷ 10	5 ÷ 10	5	***	solar shading PRESENT + MANUAL Control Automatised natural ventilation ABSENT	o o+ +	low medium high	manual manual automatised
o	10 ÷ 15	15 ÷ 20	10 ÷ 15	double glass standard glass Class 2	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation ABSENT	o o+ +	low medium high	manual manual automatised
o+	20 ÷ 25	20 ÷ 25	10 ÷ 15	double glass low-e glass Class 3	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT medium performance	o o+ +	low medium high	manual manual automatised
+	30	30	15	triple glass low-e glass Class 4	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT high performance	o o+ +	low medium high	manual manual automatised

*** There aren’t variant that can be assigned to this code

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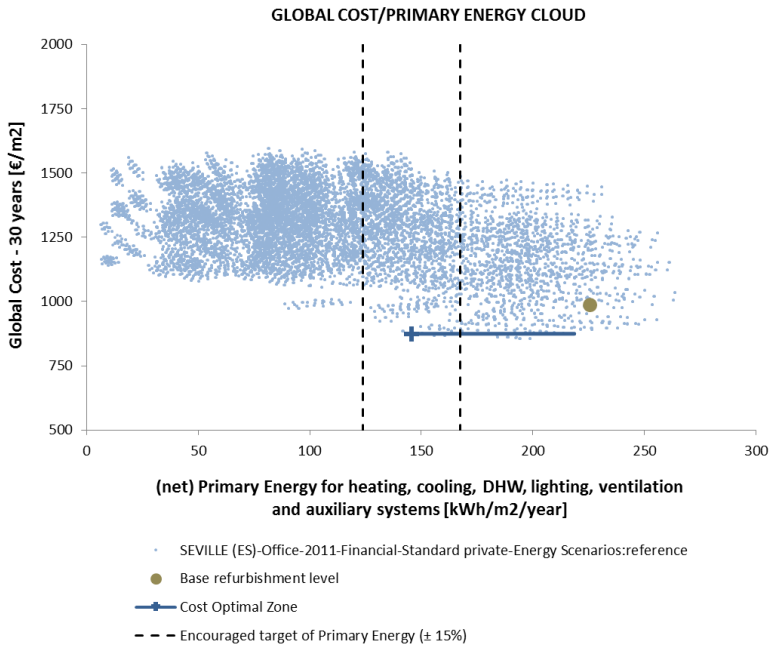
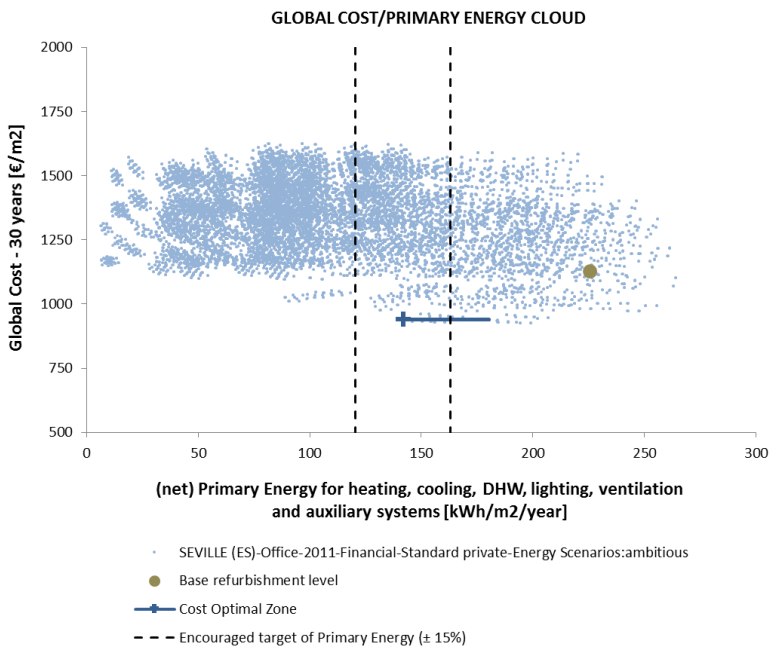
8.1.3.1 Seville





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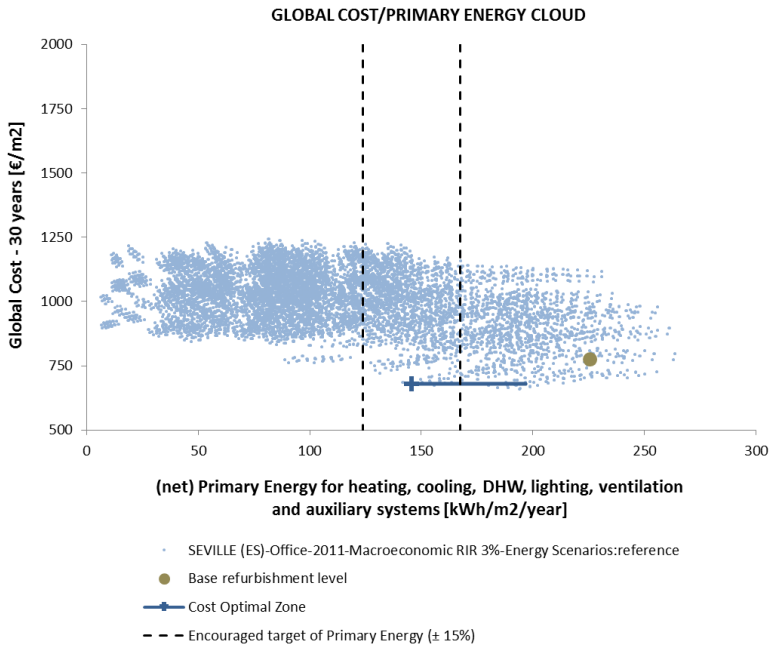

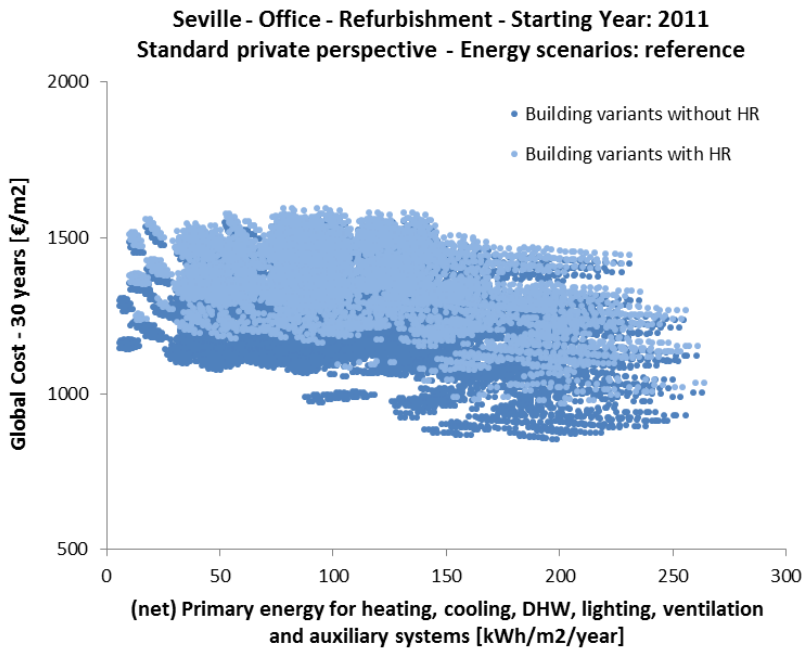

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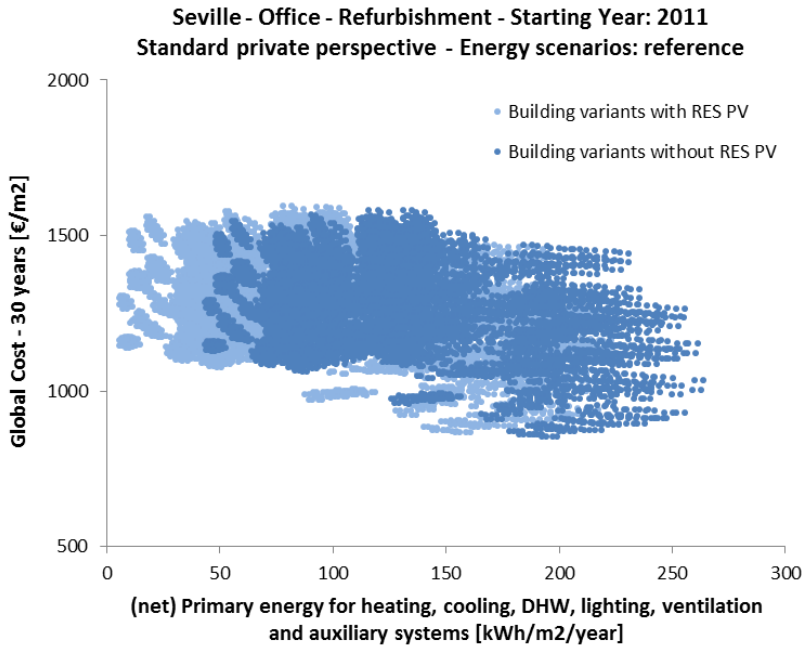

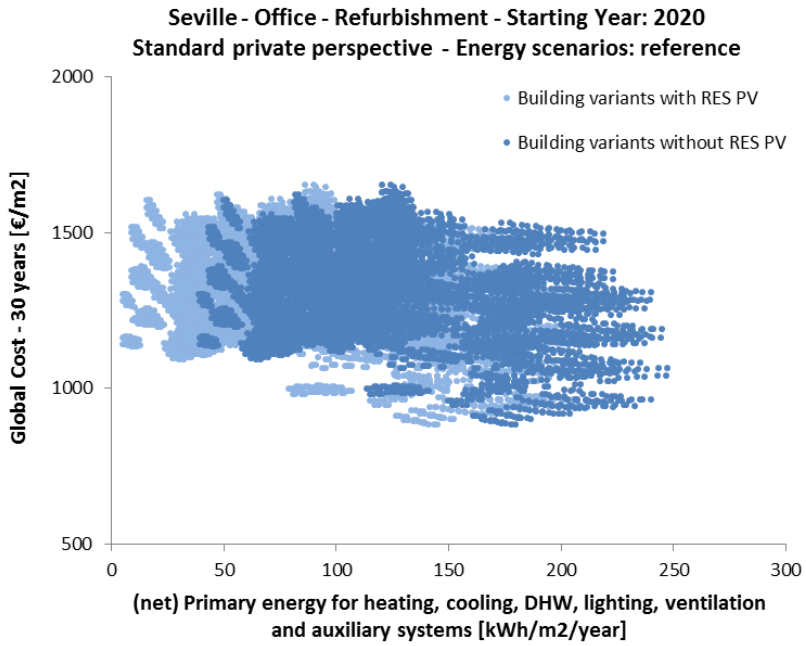

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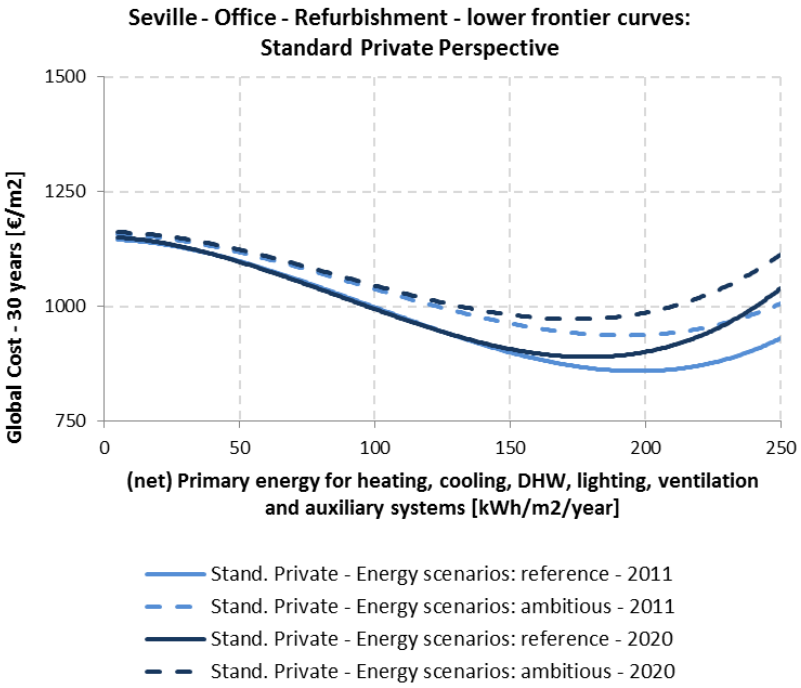

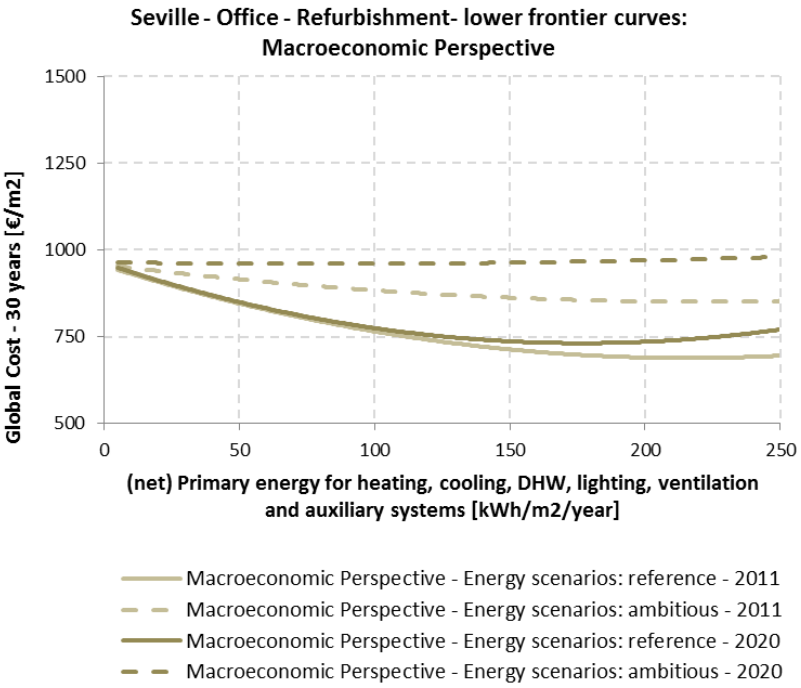

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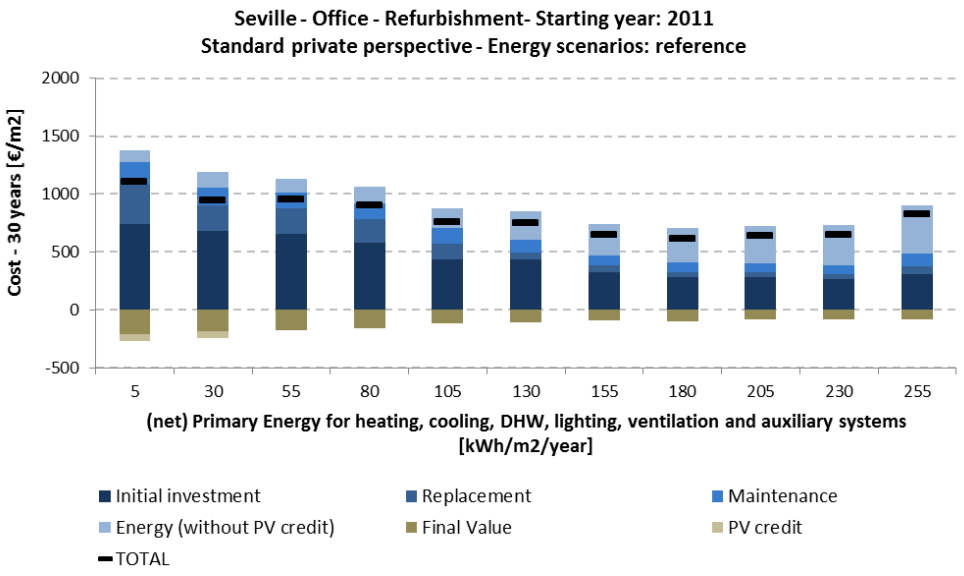

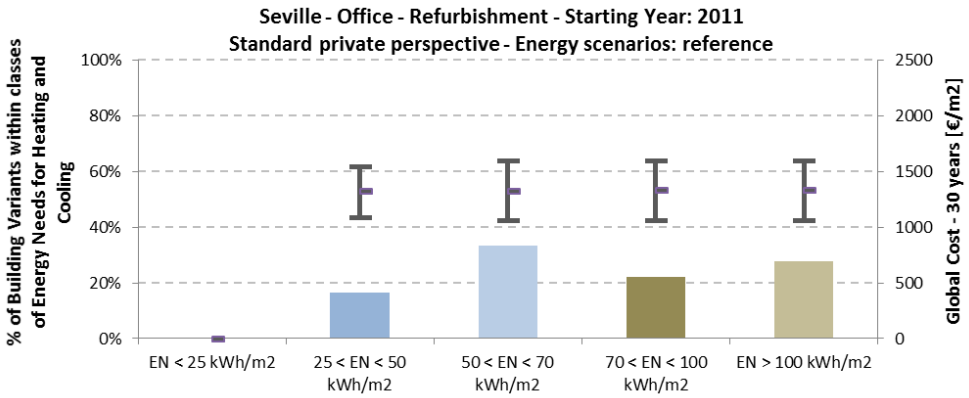

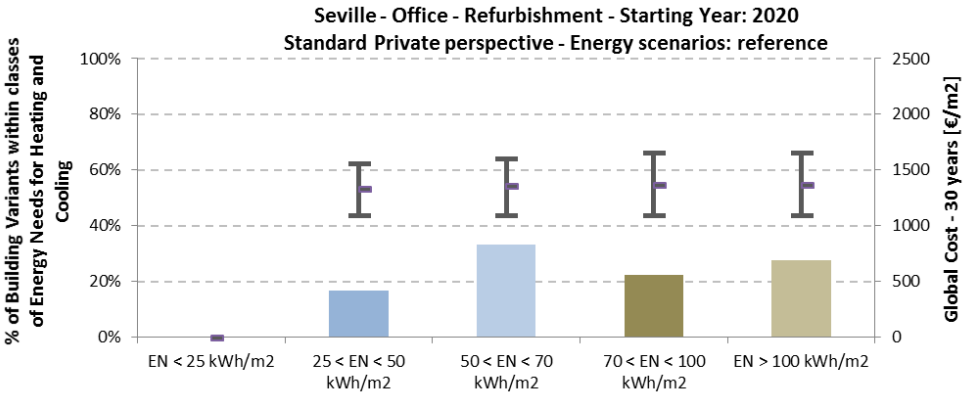

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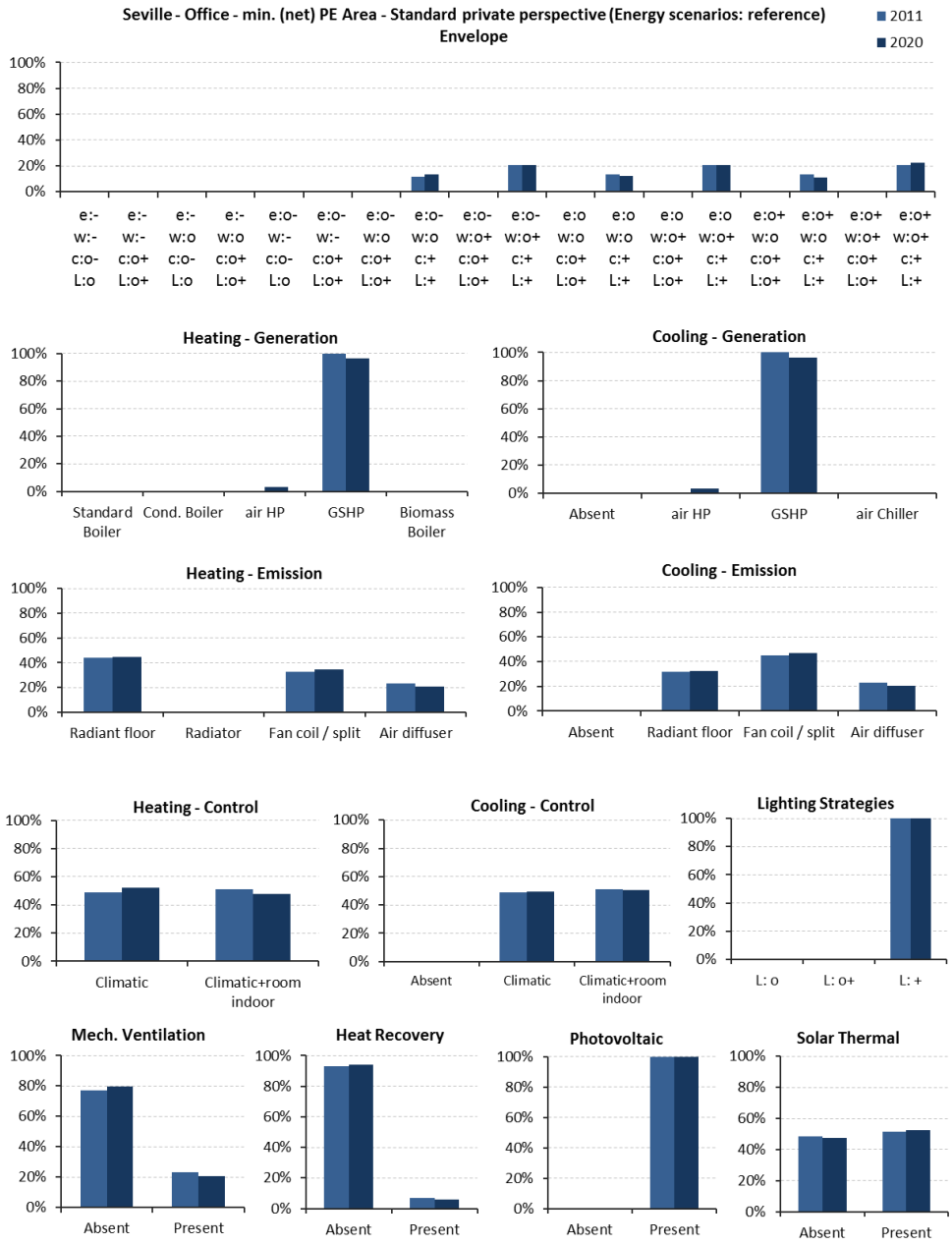
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	6	25	5	25
Range of Global Costs [€/m^2]:	1124	1293	1097	1285
Number of Building Variants:	147		147	



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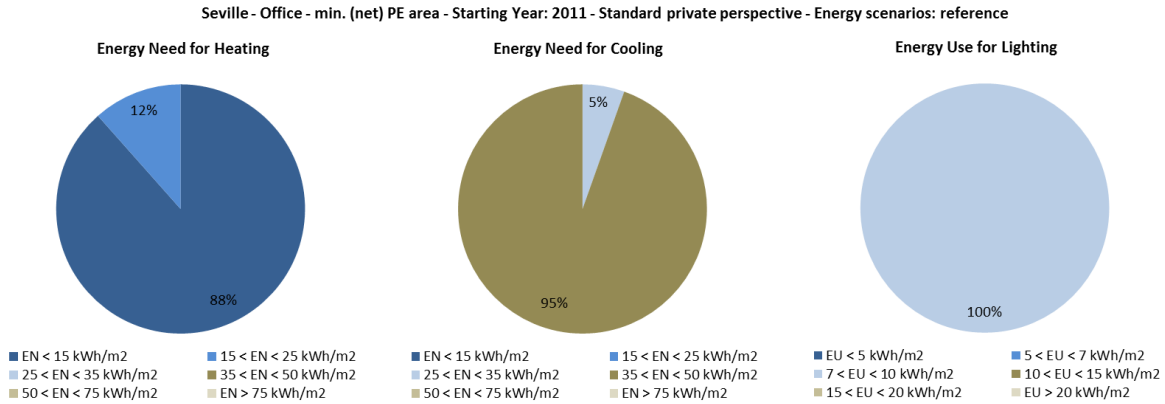

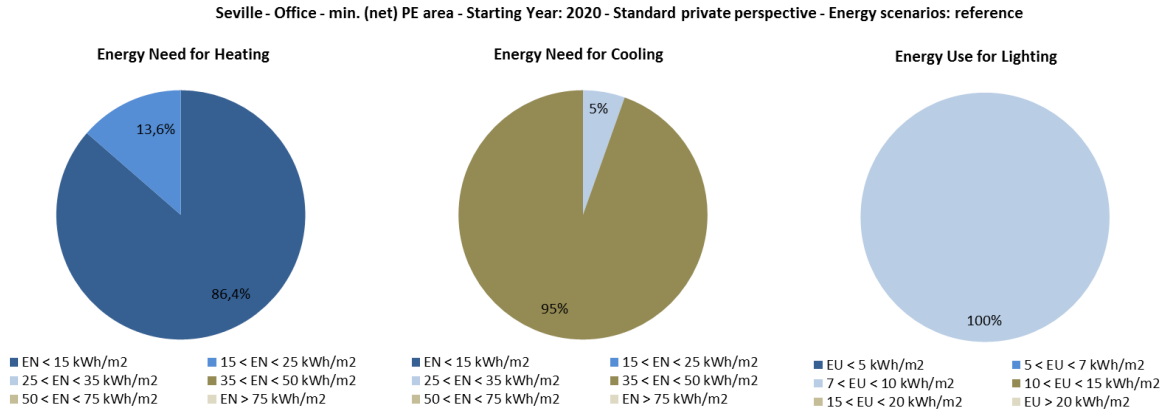

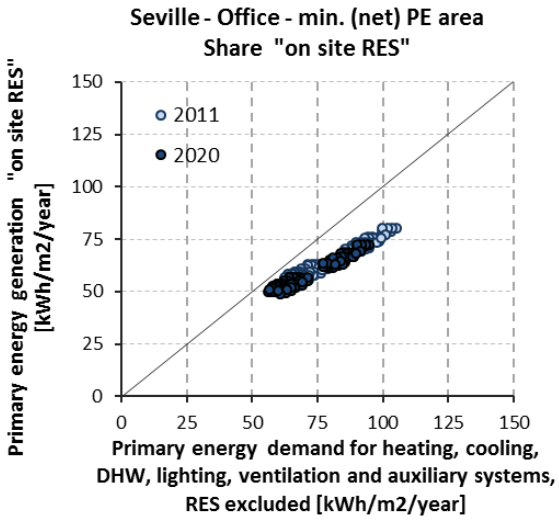

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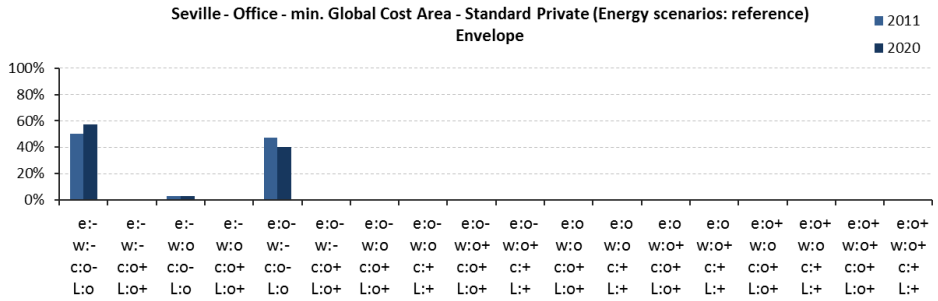
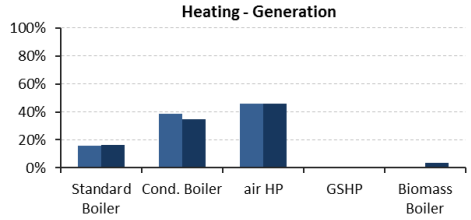
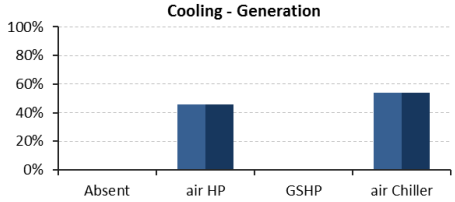
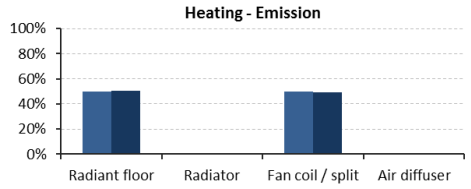
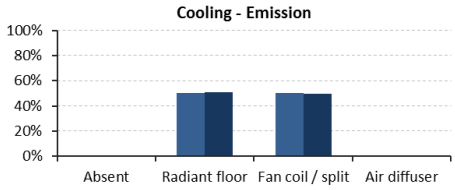
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	125	225	125	225
Range of Global Costs [€/m^2]:	855	915	885	948
Number of Building Variants:	148		148	

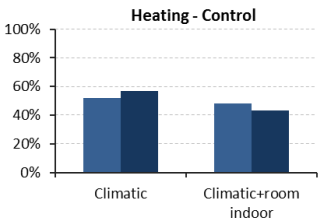


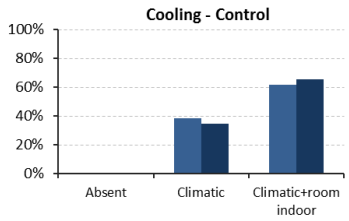


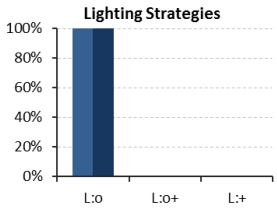


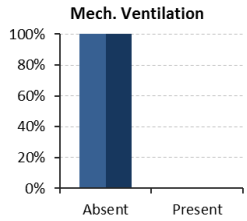


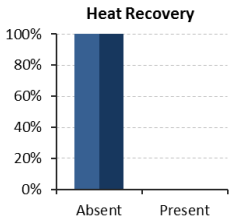


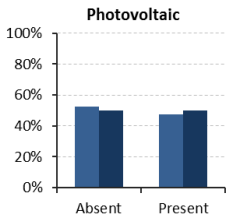


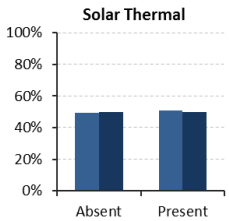












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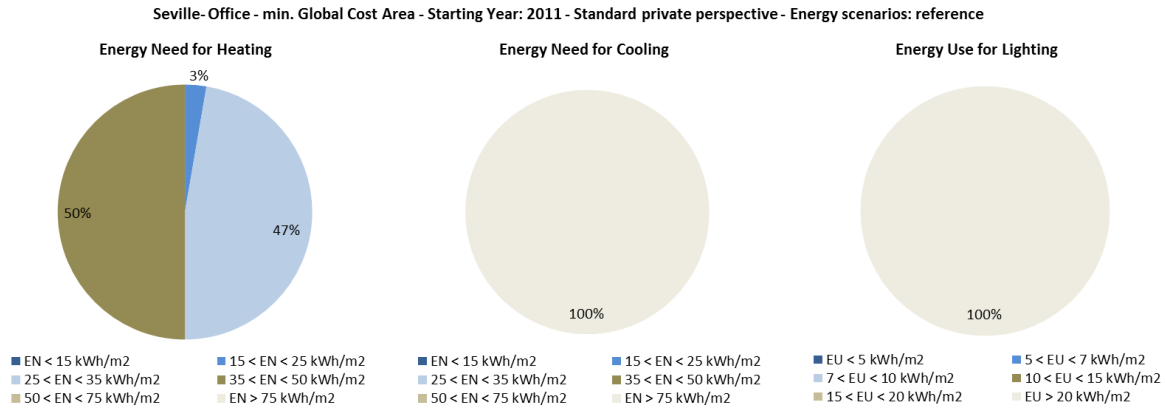
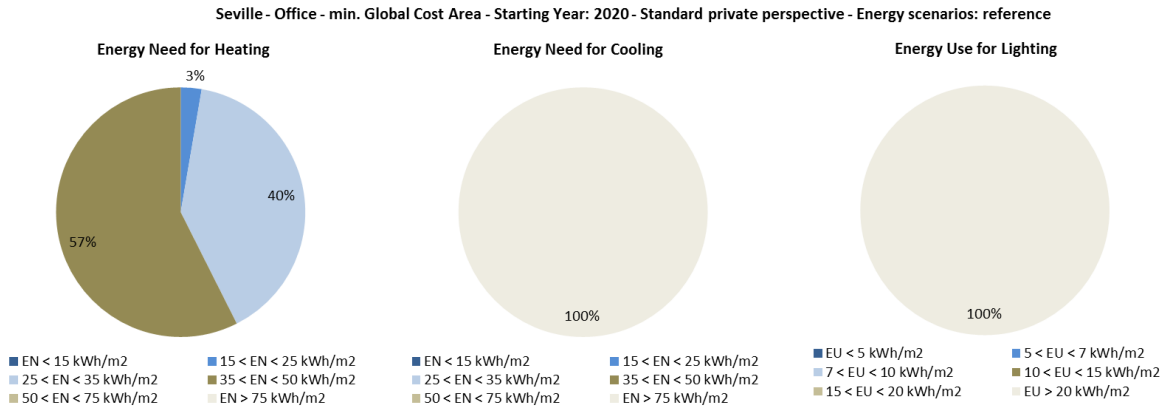
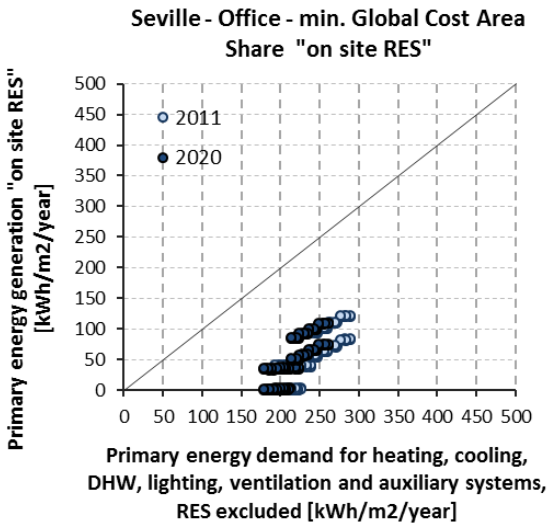
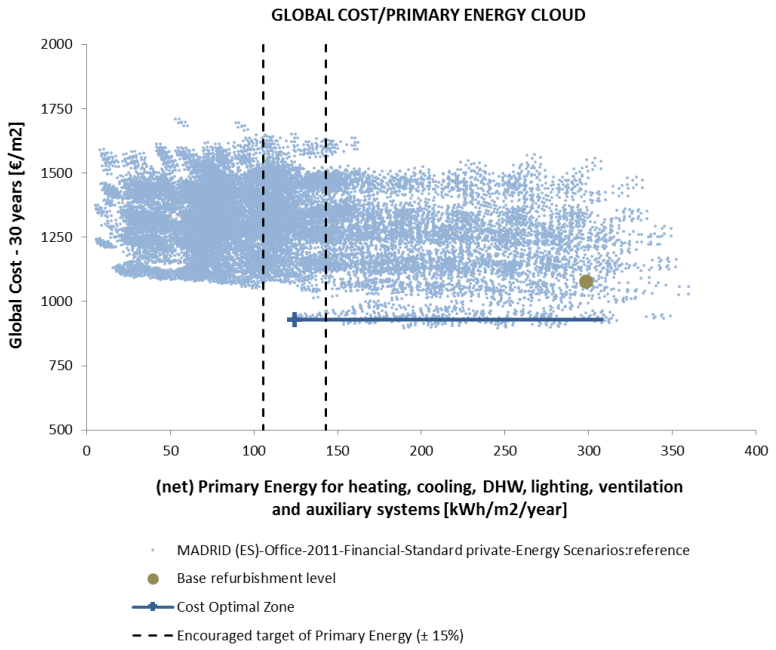
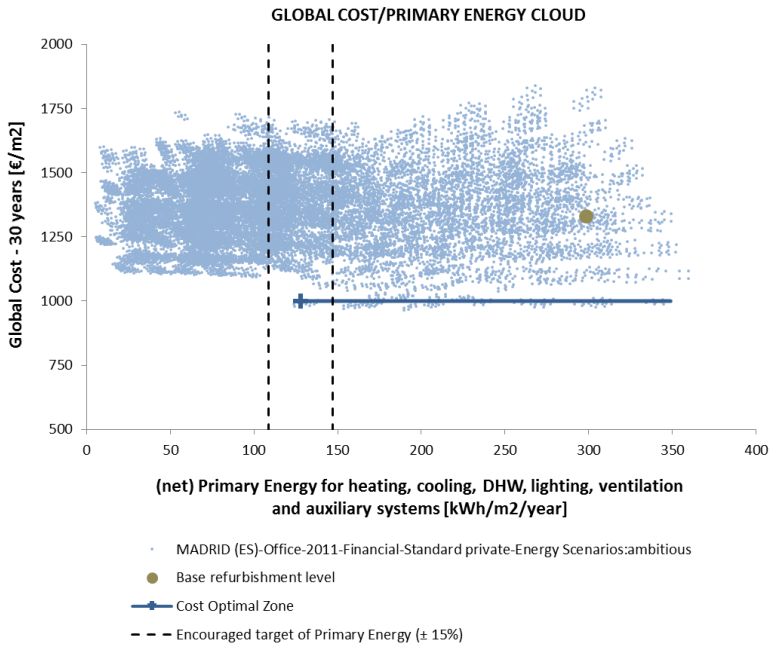

Seville- Office - min. Global Cost Area - Starting Year: 2011 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
3%
50%
47%
Energy Need for Cooling
100%
Energy Use for Lighting
100%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2


Seville - Office - min. Global Cost Area - Starting Year: 2020 - Standard private perspective - Energy scenarios: reference
Energy Need for Heating
3%
40%
57%
Energy Need for Cooling
100%
Energy Use for Lighting
100%
EN < 15 kWh/m2
15 < EN < 25 kWh/m2
25 < EN < 35 kWh/m2
35 < EN < 50 kWh/m2
50 < EN < 75 kWh/m2
EN > 75 kWh/m2
EU < 5 kWh/m2
5 < EU < 7 kWh/m2
7 < EU < 10 kWh/m2
10 < EU < 15 kWh/m2
15 < EU < 20 kWh/m2
EU > 20 kWh/m2


Seville - Office - min. Global Cost Area
Share "on site RES"
Primary energy generation "on site RES" [kWh/m2/year]
500
450
400
350
300
250
200
150
100
50
0
2011
2020
0 50 100 150 200 250 300 350 400 450 500
Primary energy demand for heating, cooling, DHW, lighting, ventilation and auxiliary systems, RES excluded [kWh/m2/year]

8.1.3.2 Madrid





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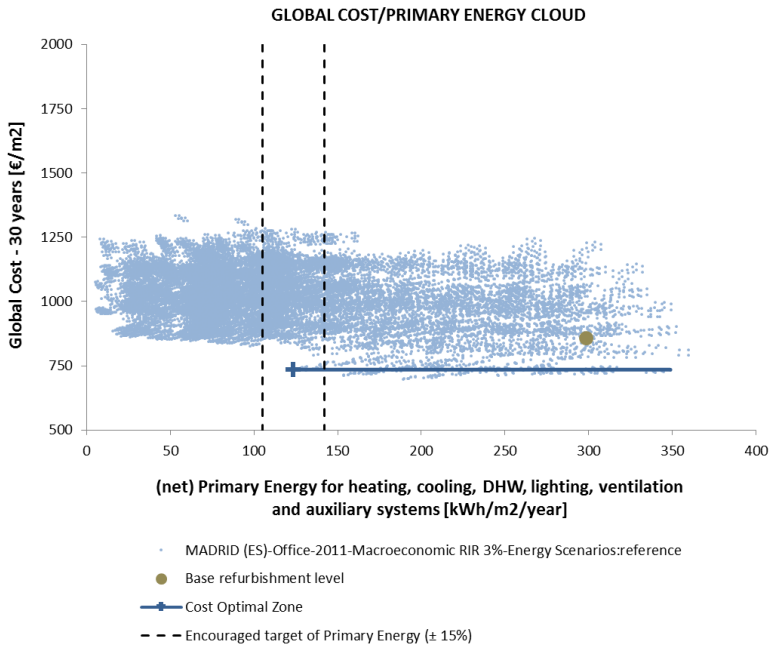

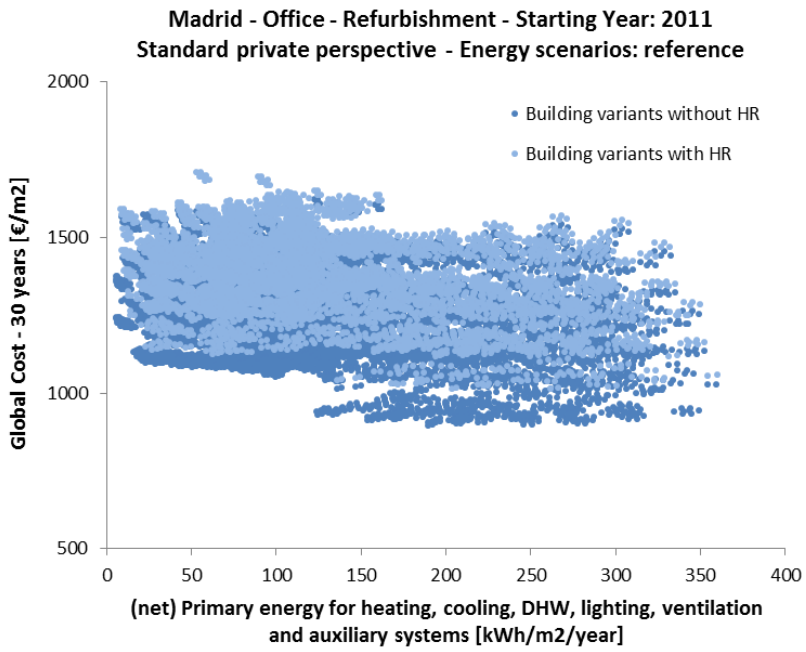

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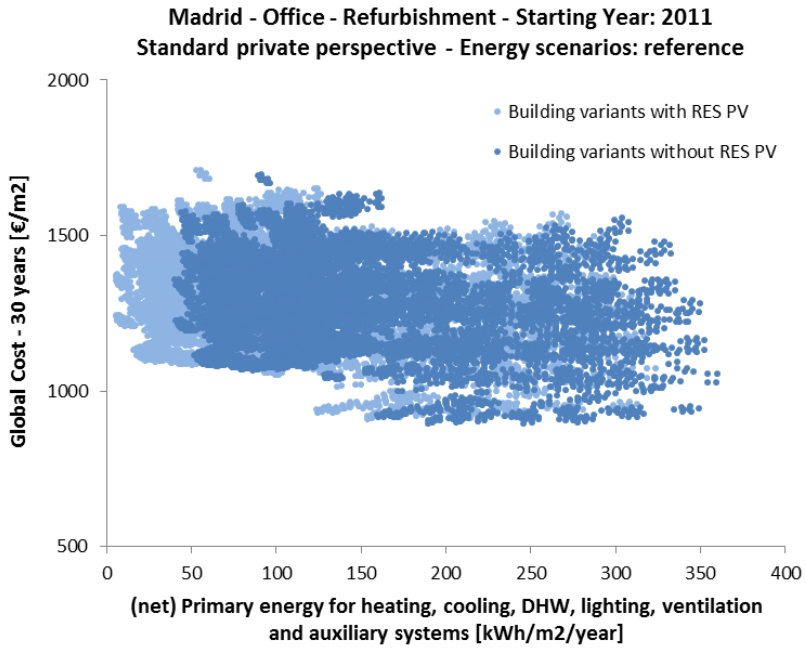

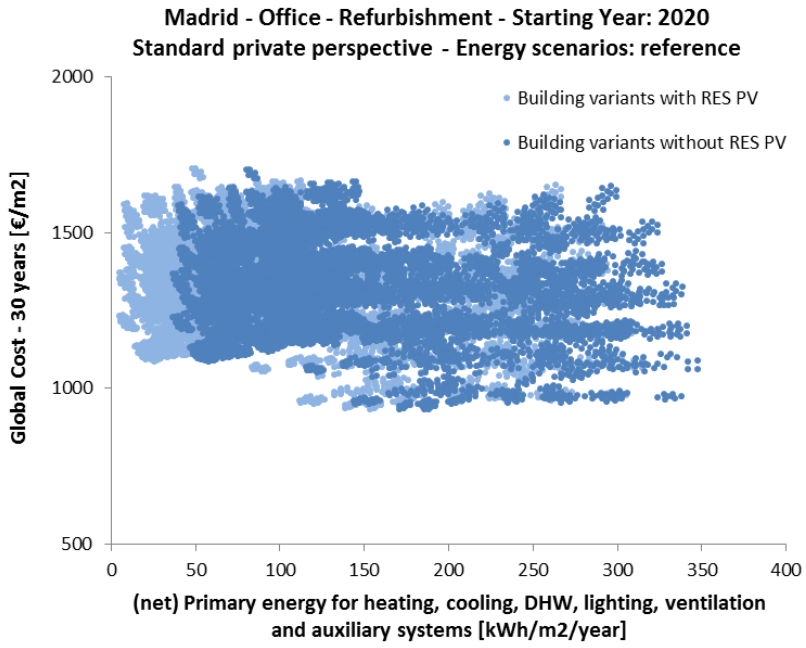

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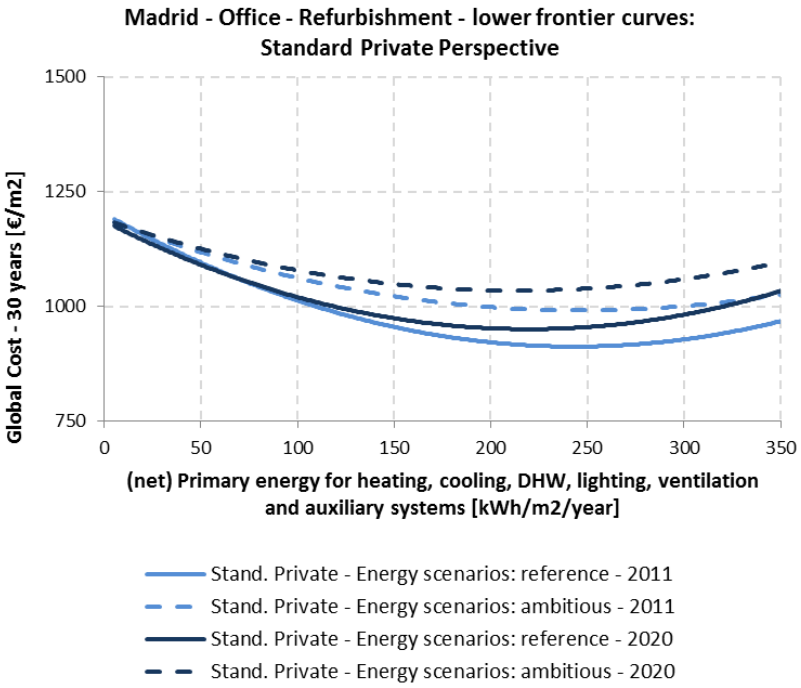

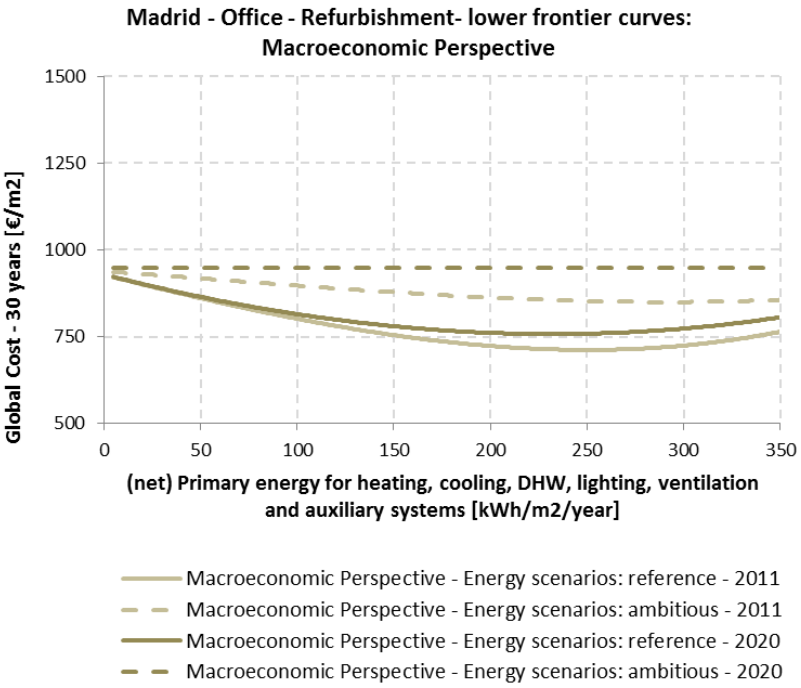

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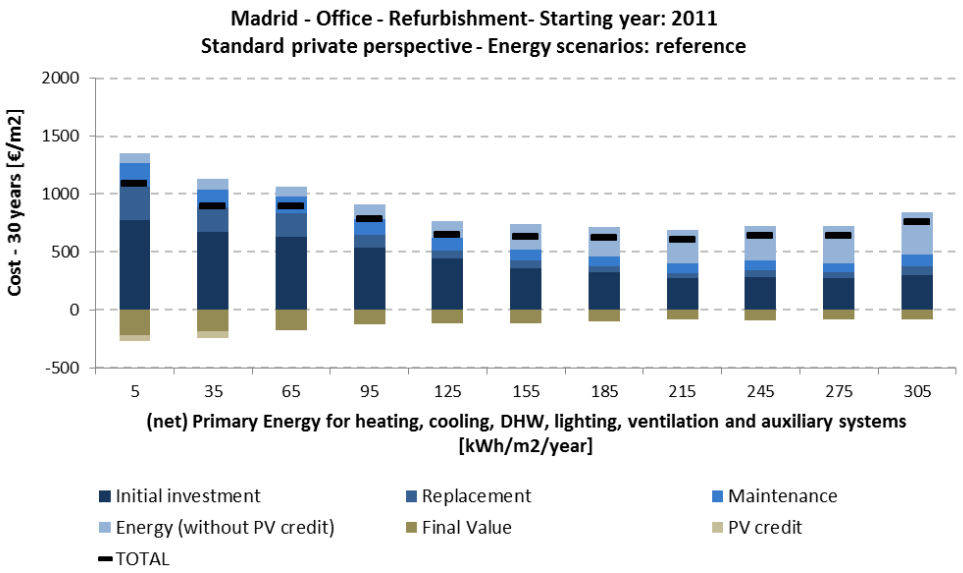

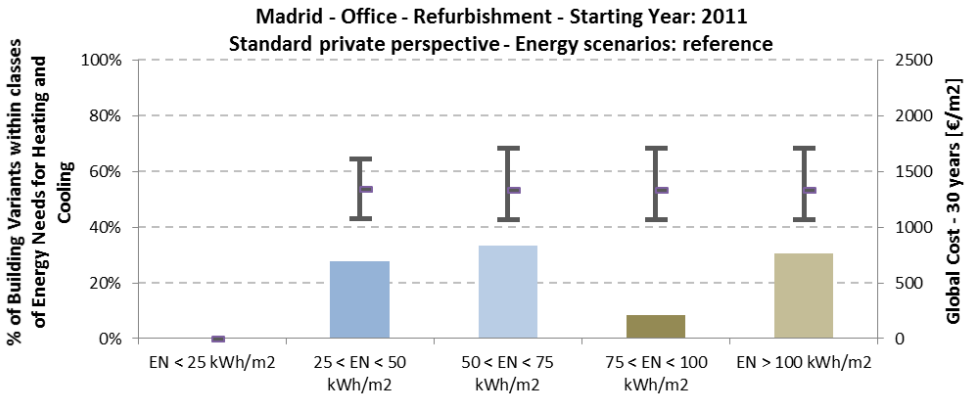

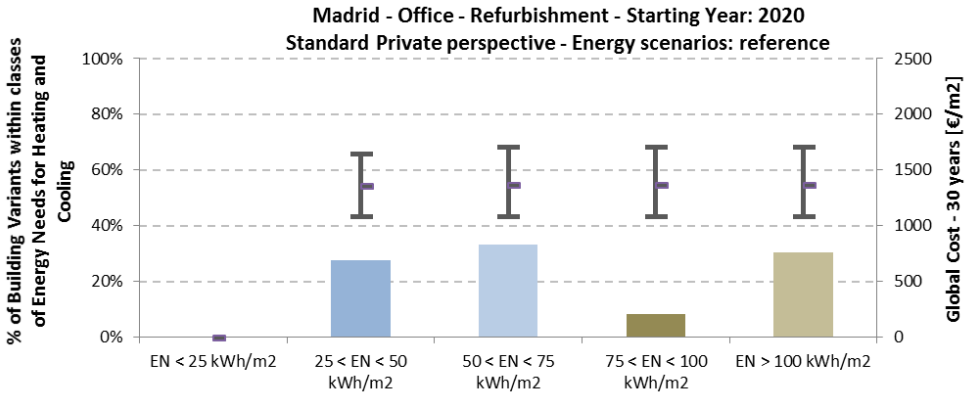

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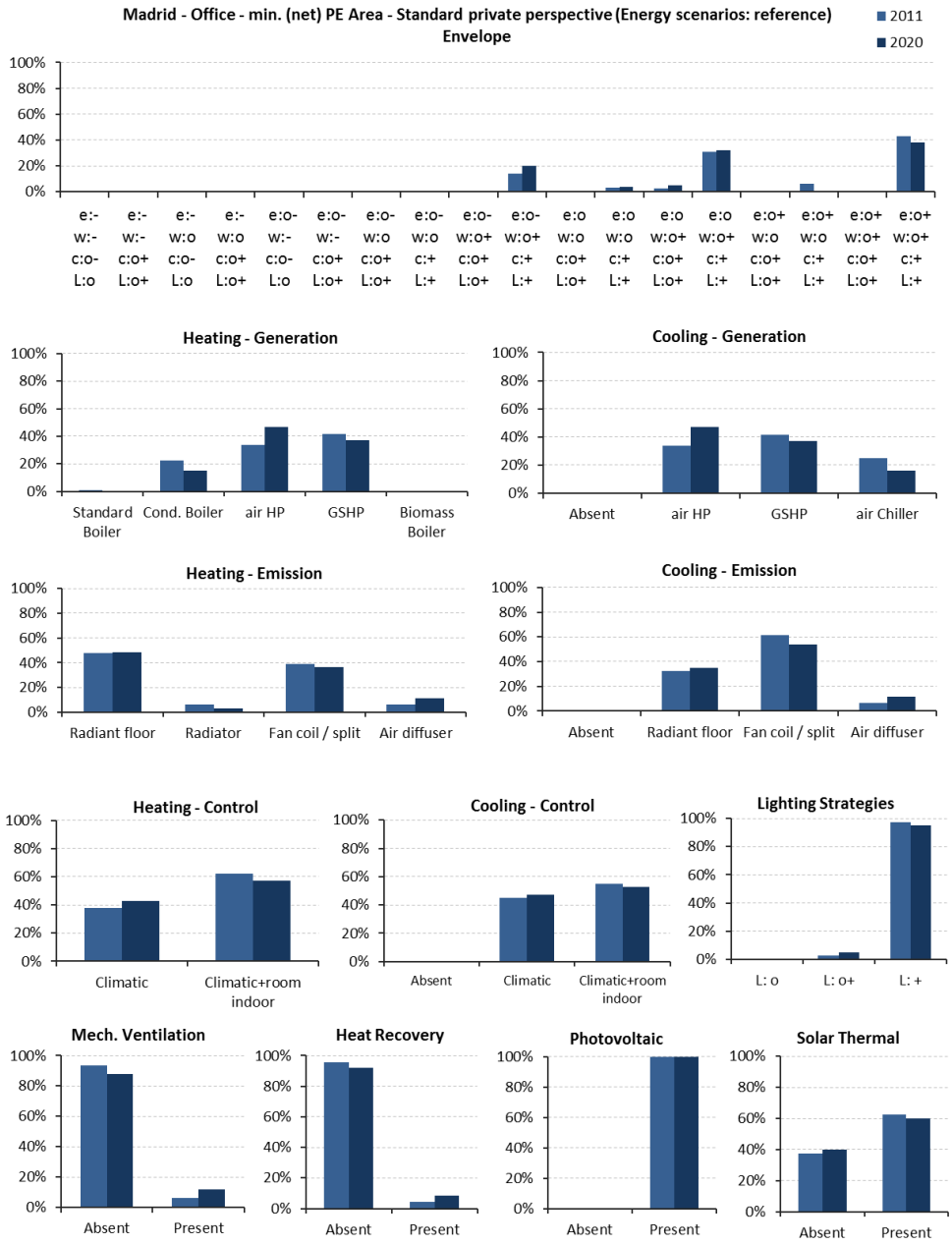
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	5	25	5	25
Range of Global Costs [€/m^2]:	1099	1263	1088	1260
Number of Building Variants:	158		158	



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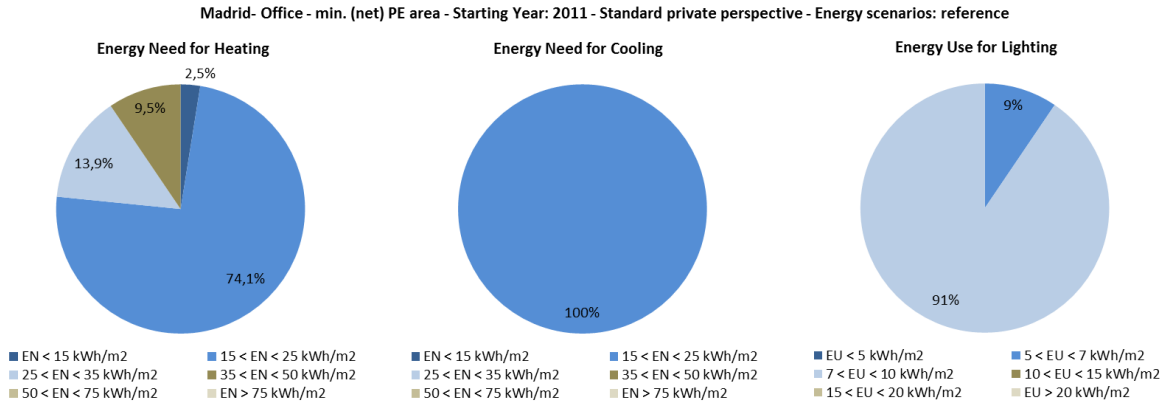

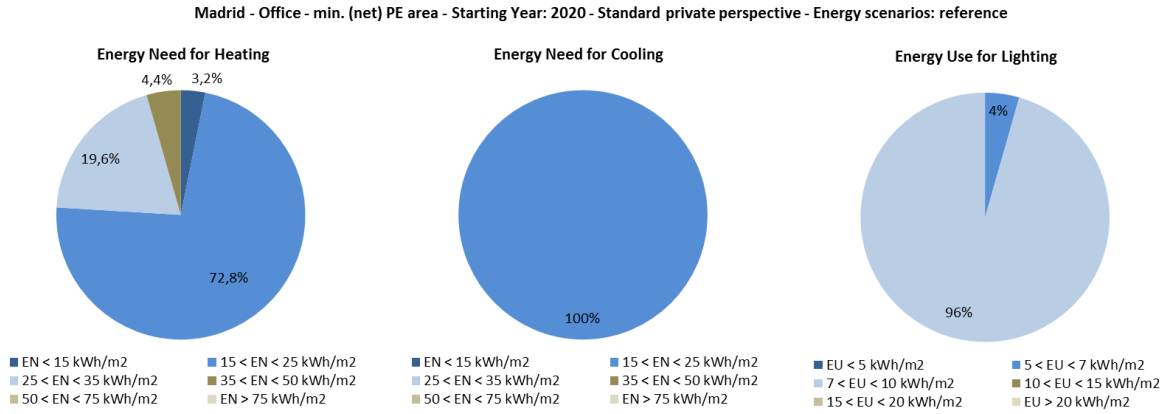

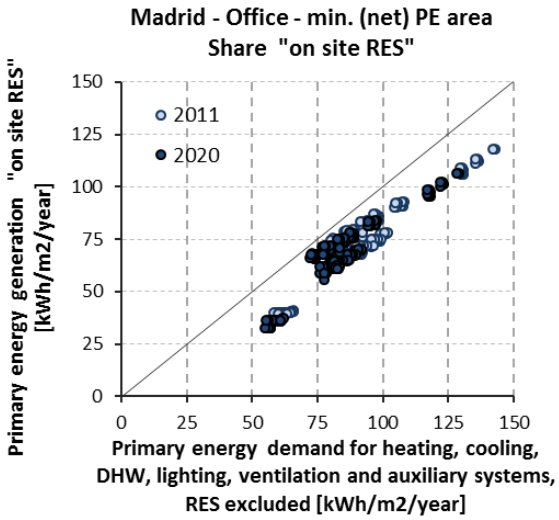

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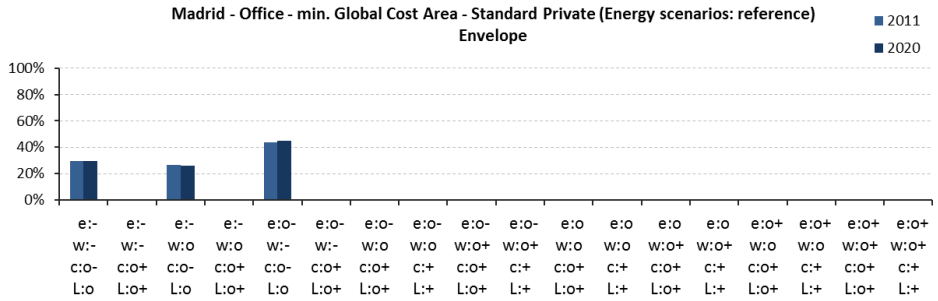
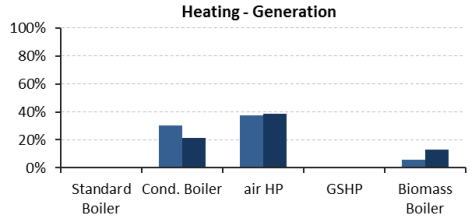
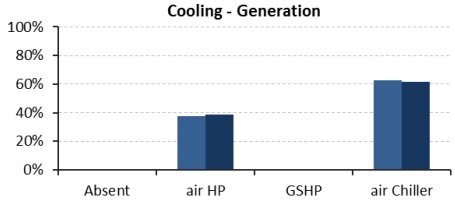
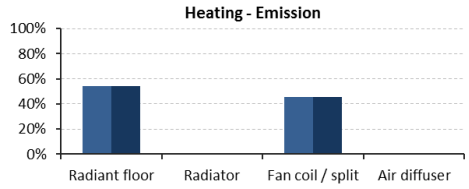
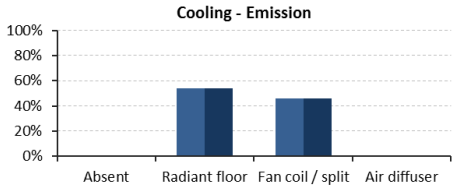
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	100	280	90	280
Range of Global Costs [€/m^2]:	896	950	931	989
Number of Building Variants:	249		249	

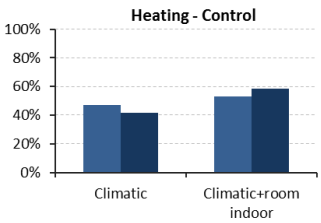


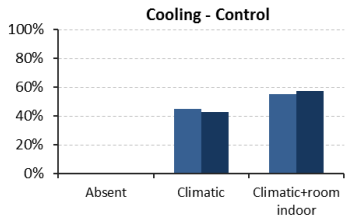


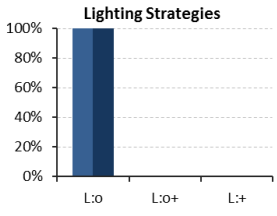


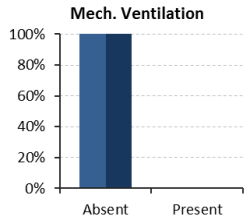


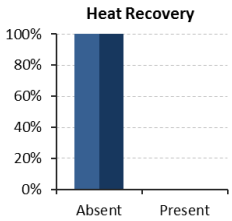


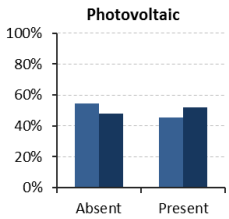


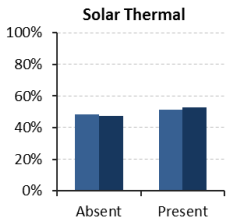












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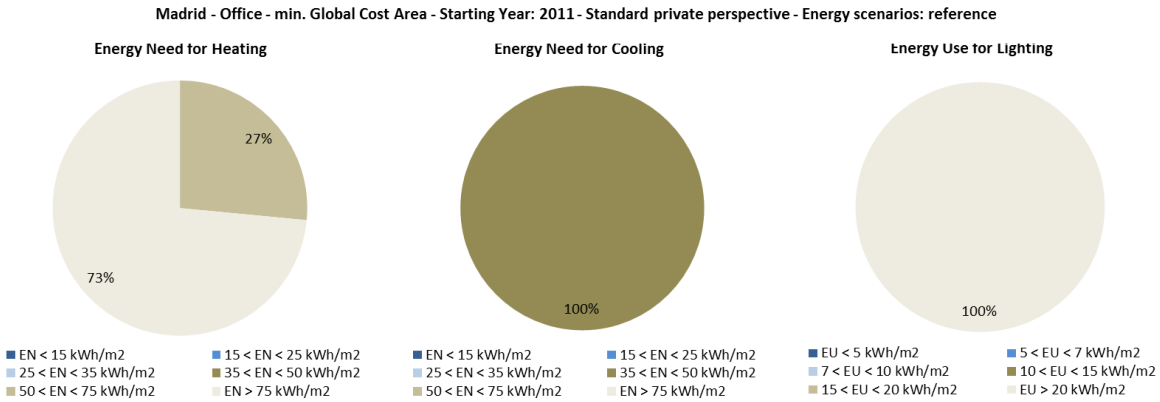

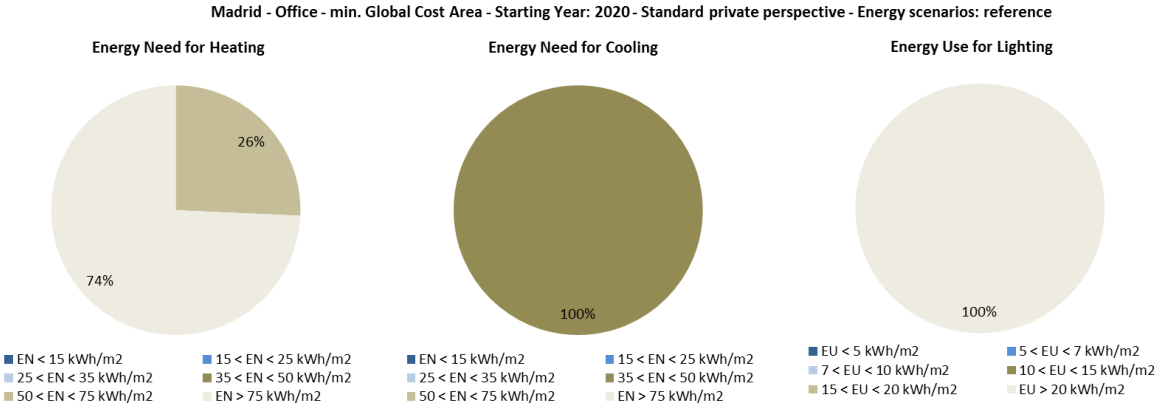

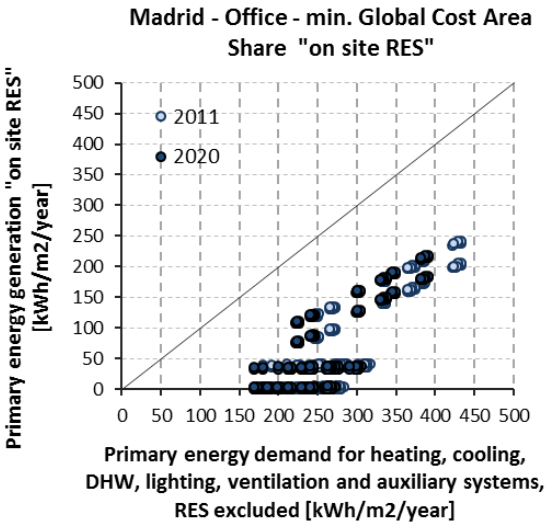

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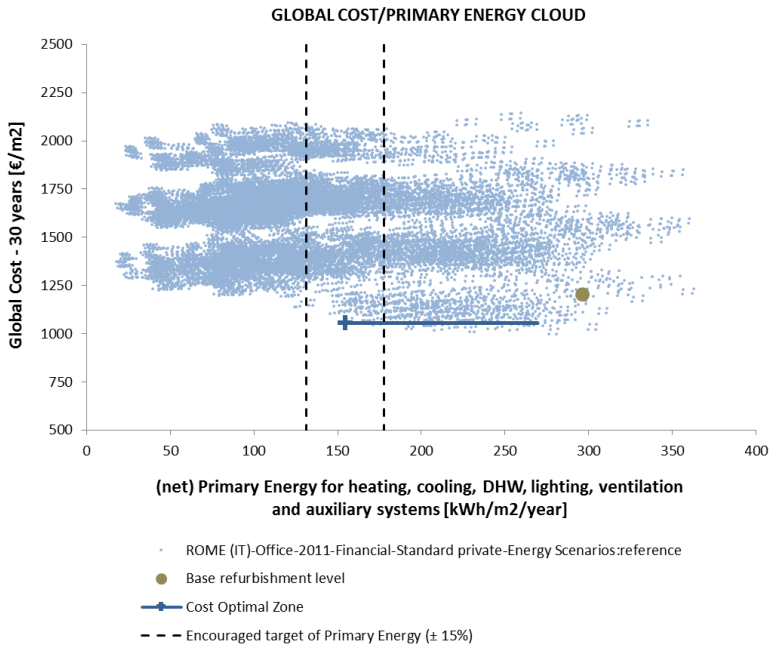
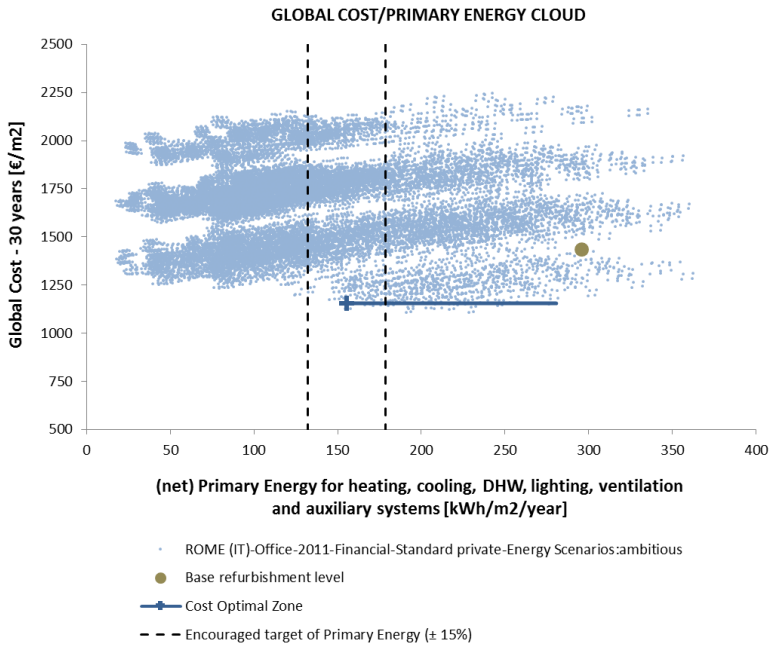
8.1.3.3 Rome





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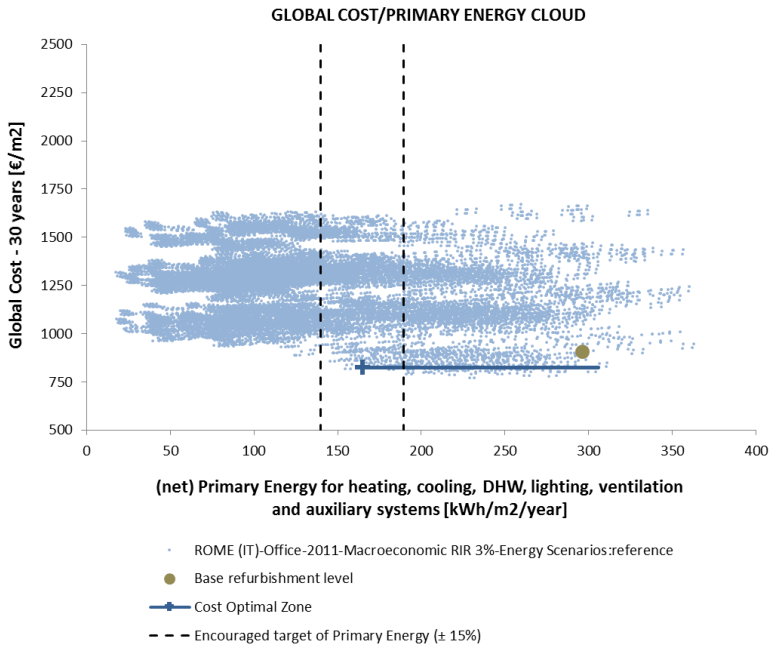

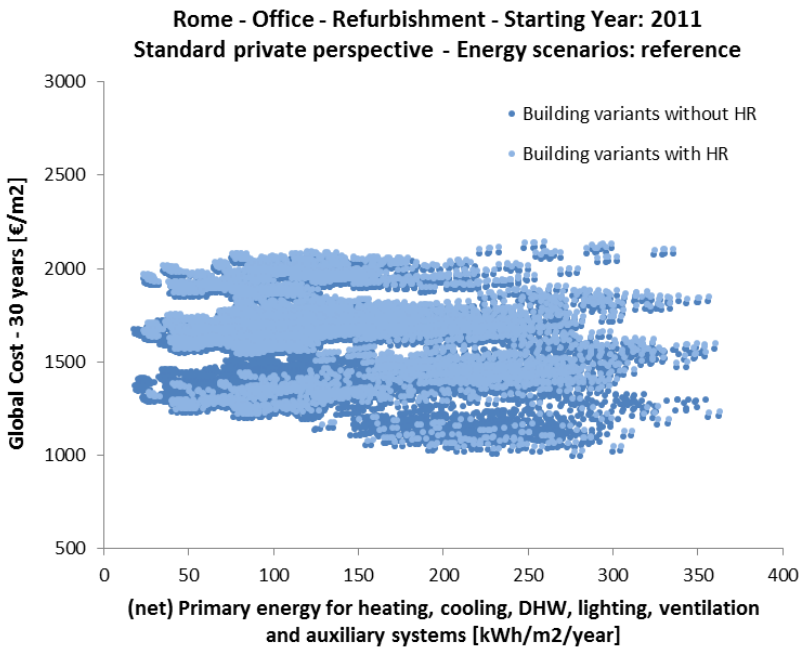

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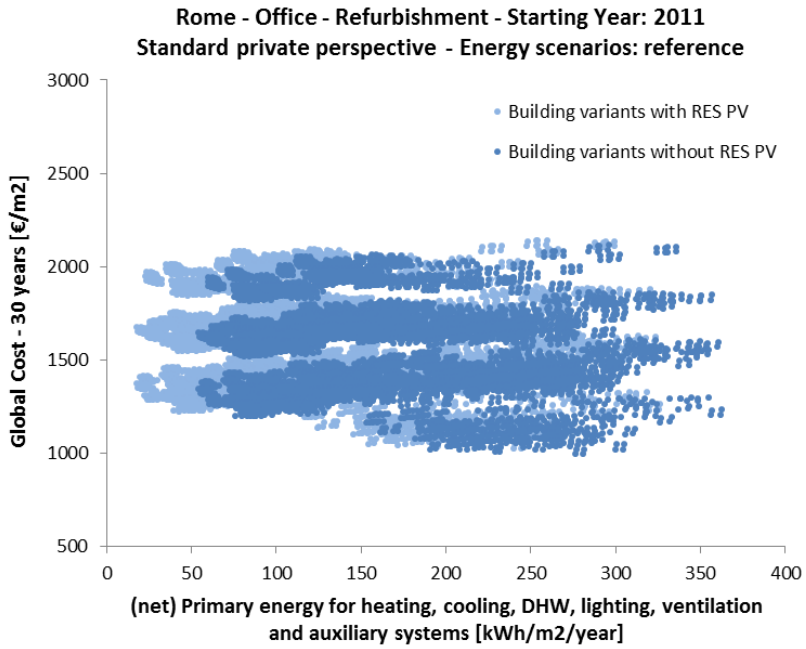

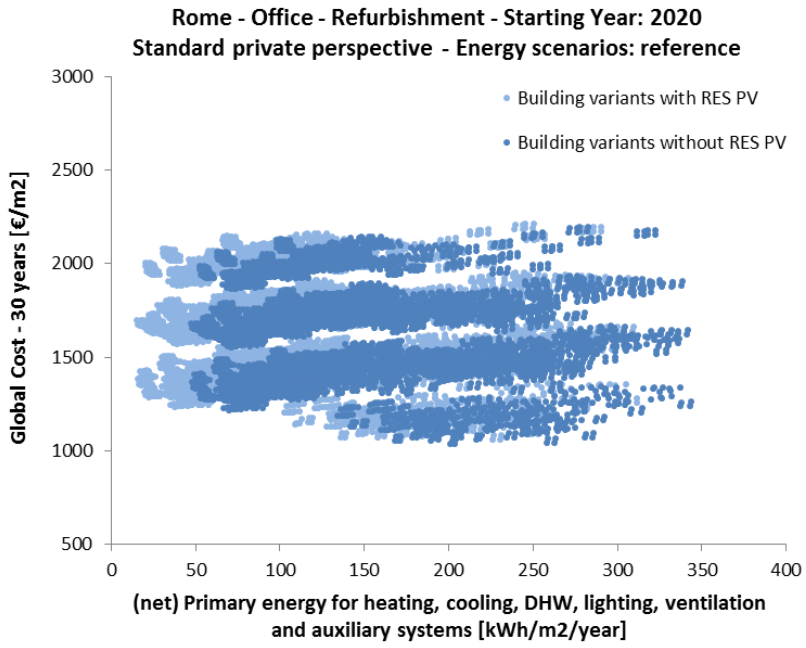

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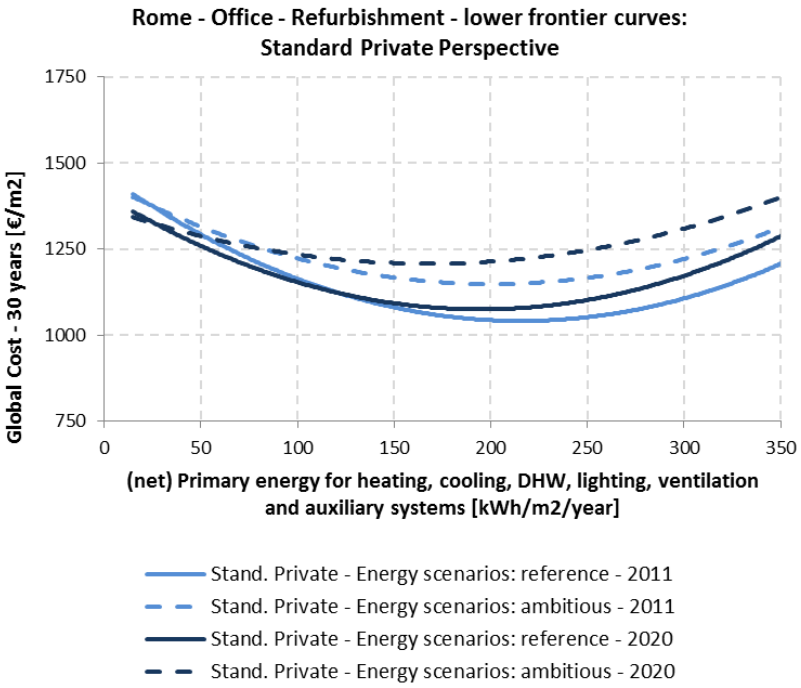

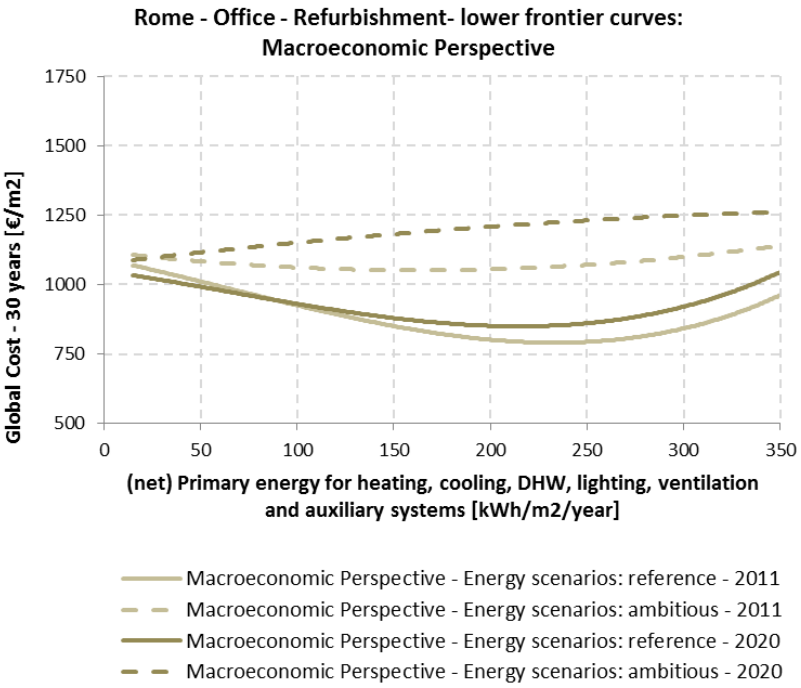

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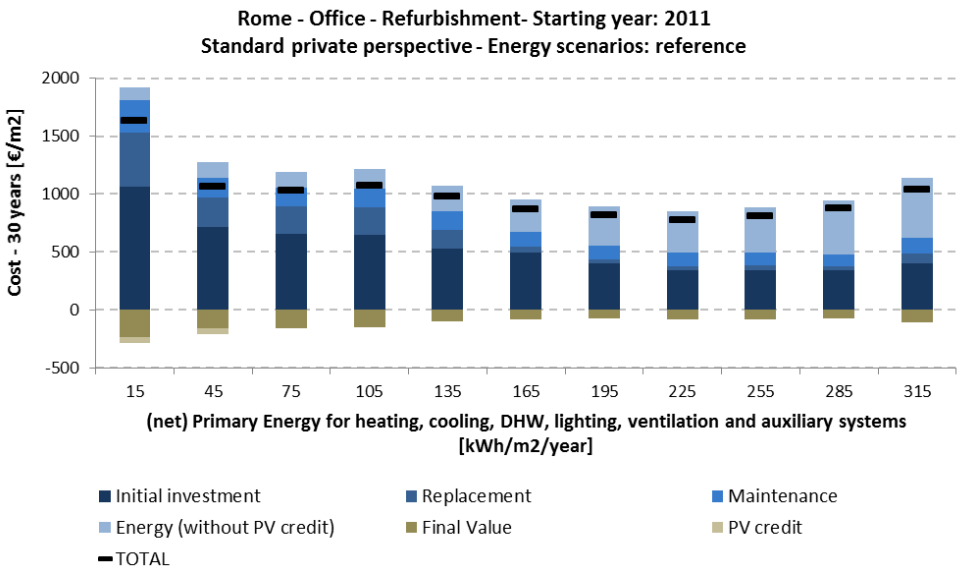

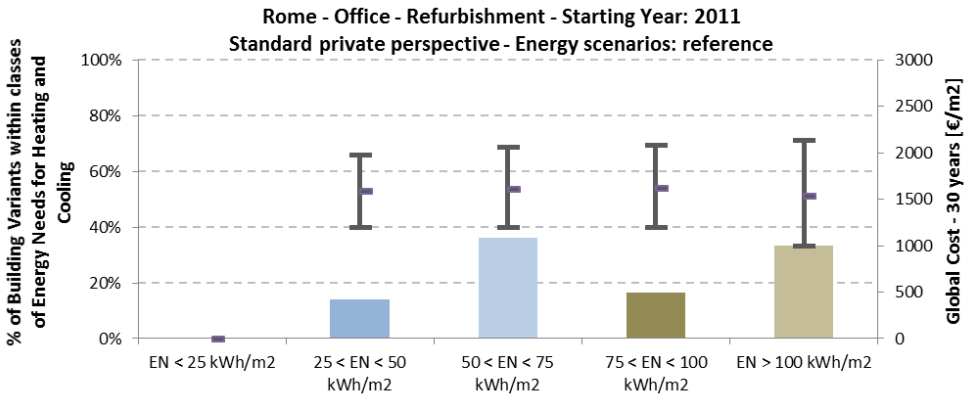

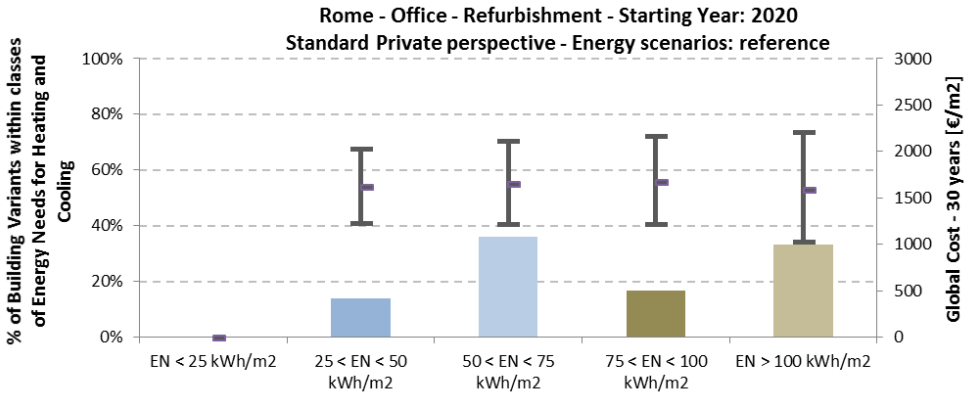

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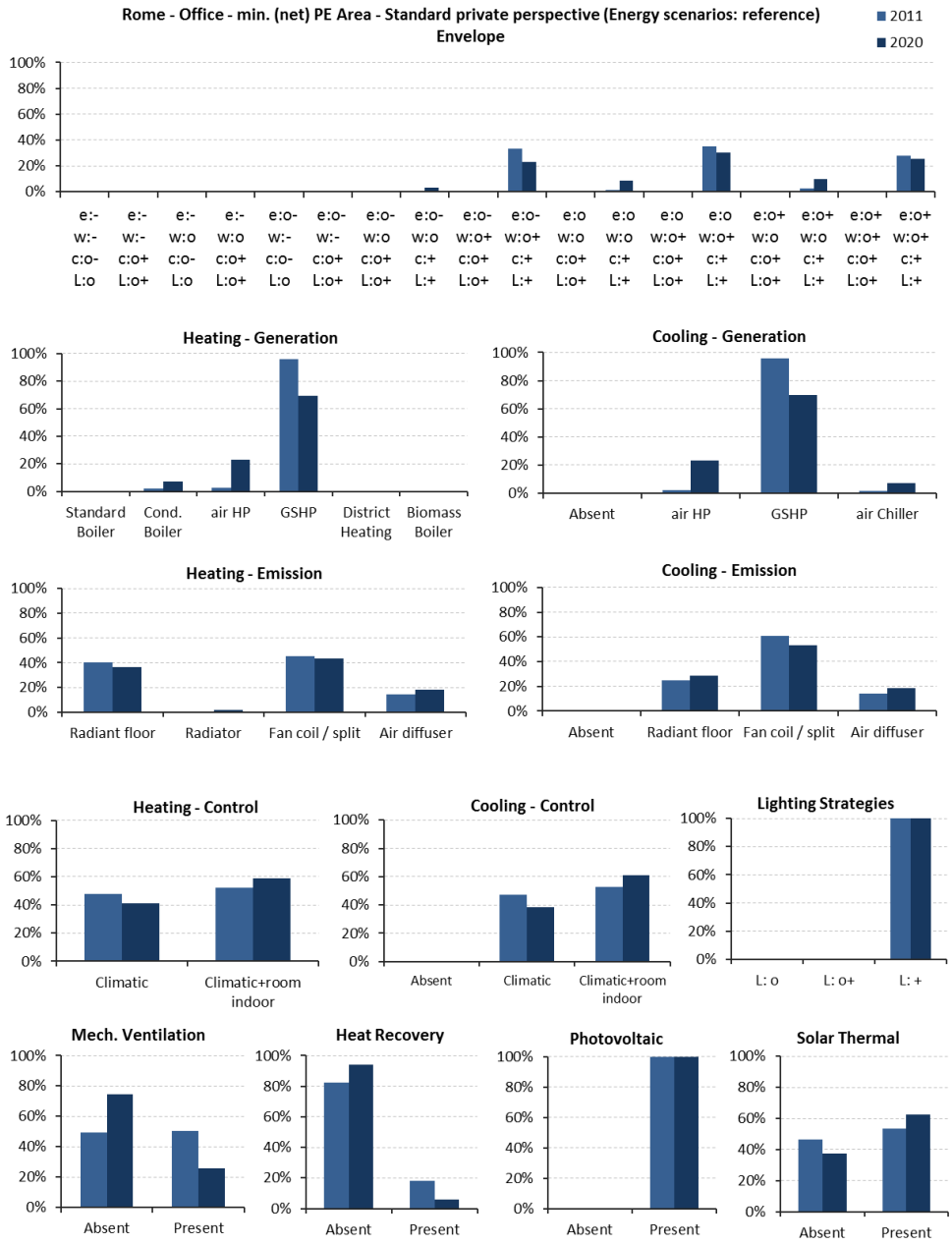
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	17	35	15	35
Range of Global Costs [€/m^2]:	1286	1672	1243	1640
Number of Building Variants:	168		168	



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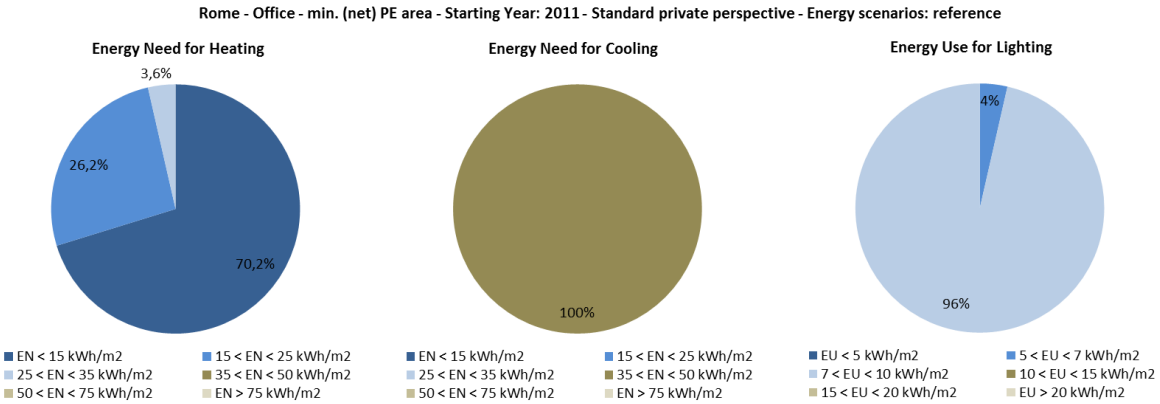

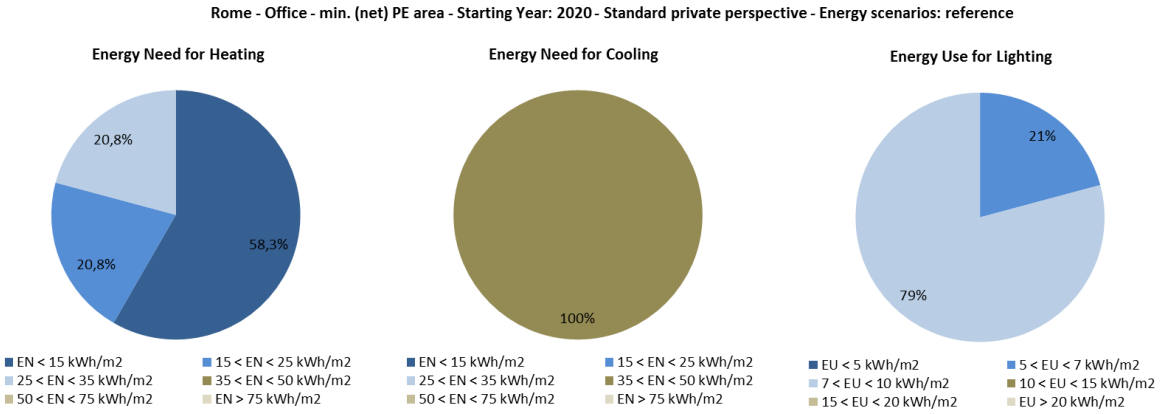

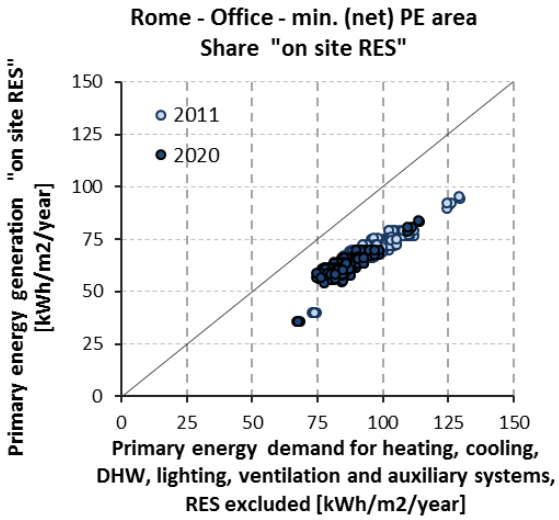

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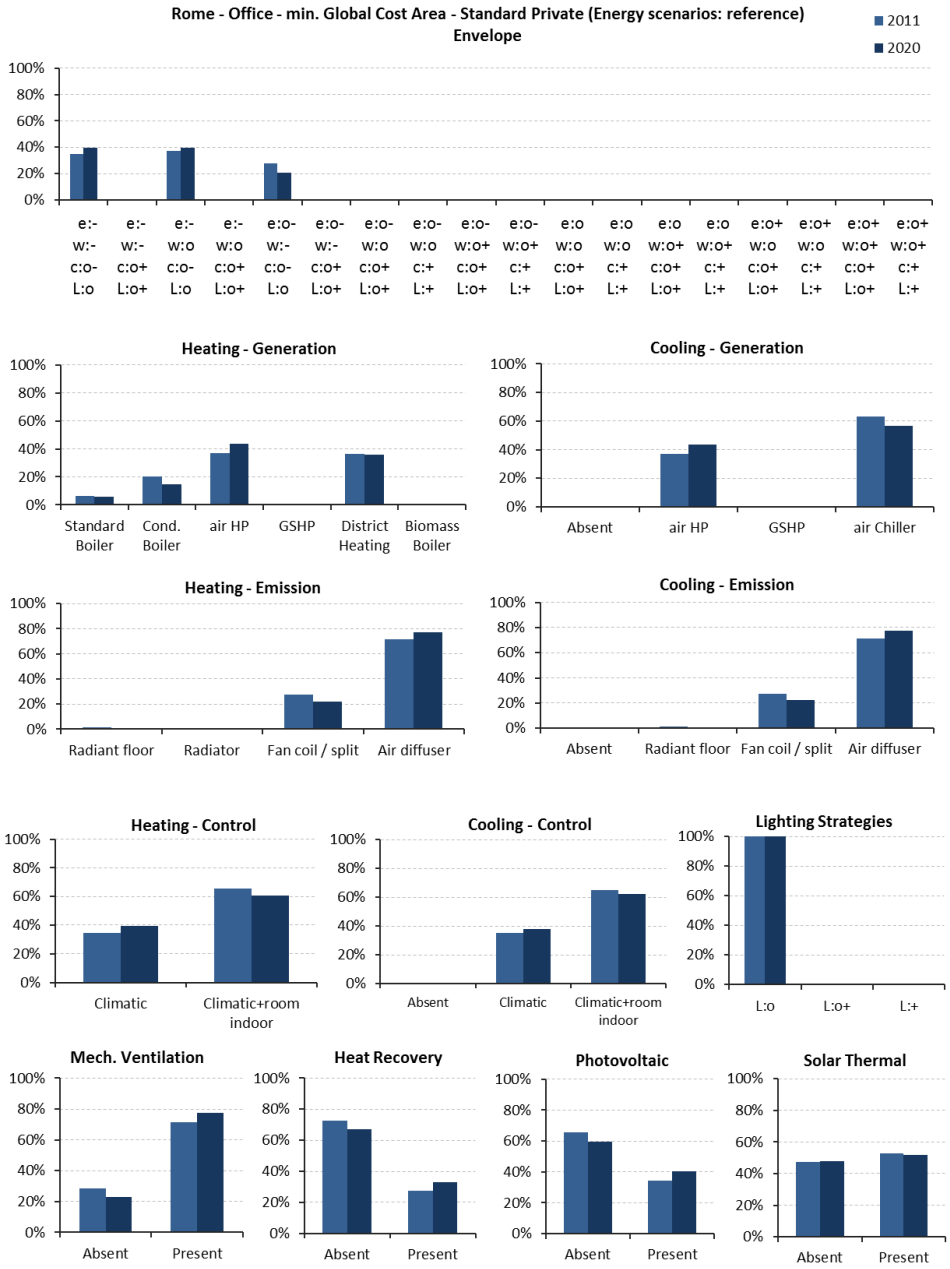
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	135	275	130	270
Range of Global Costs [€/m^2]:	997	1086	1034	1121
Number of Building Variants:	154		154	



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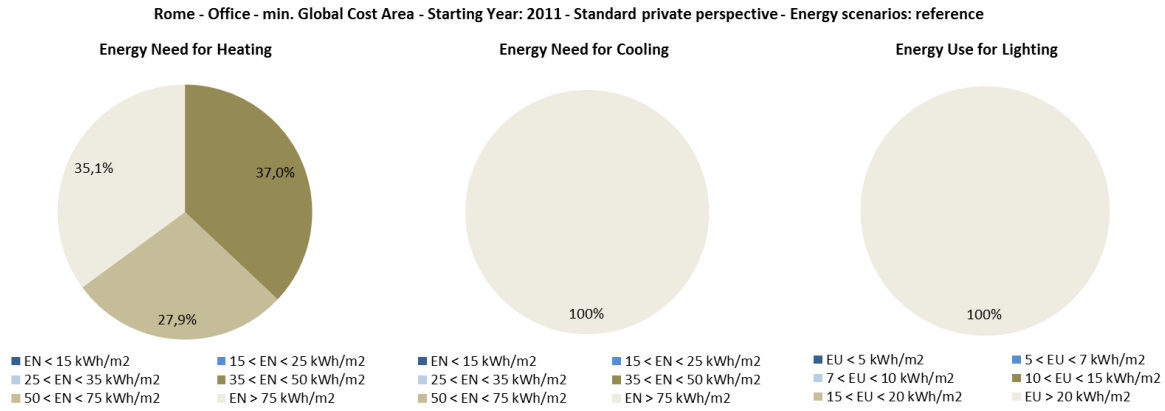

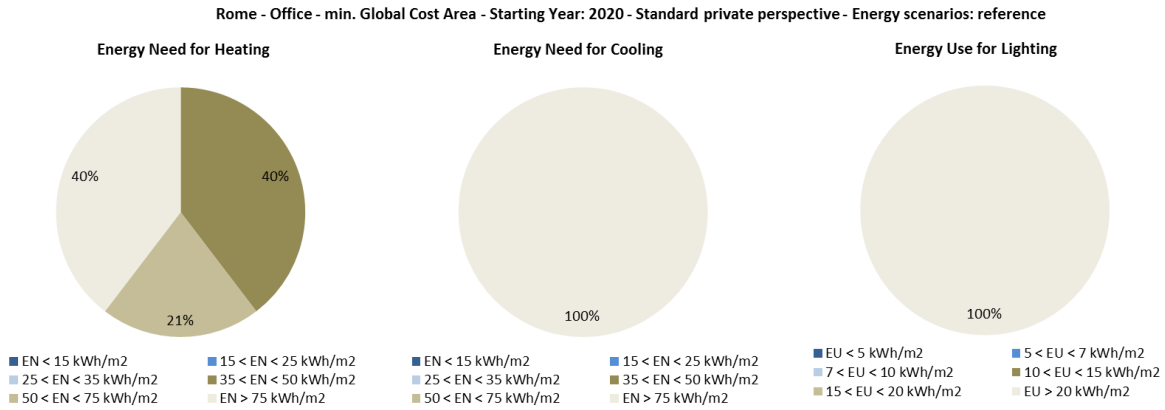

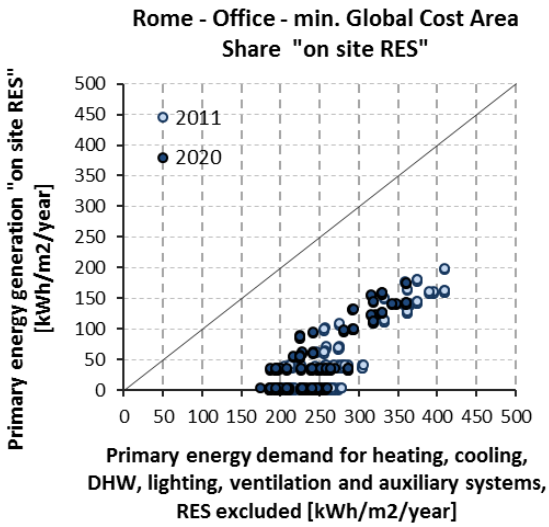

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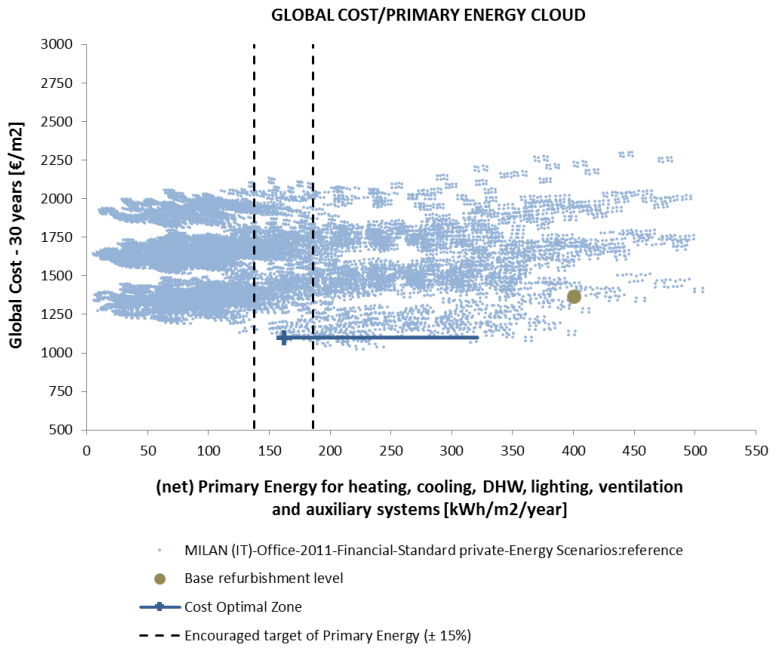
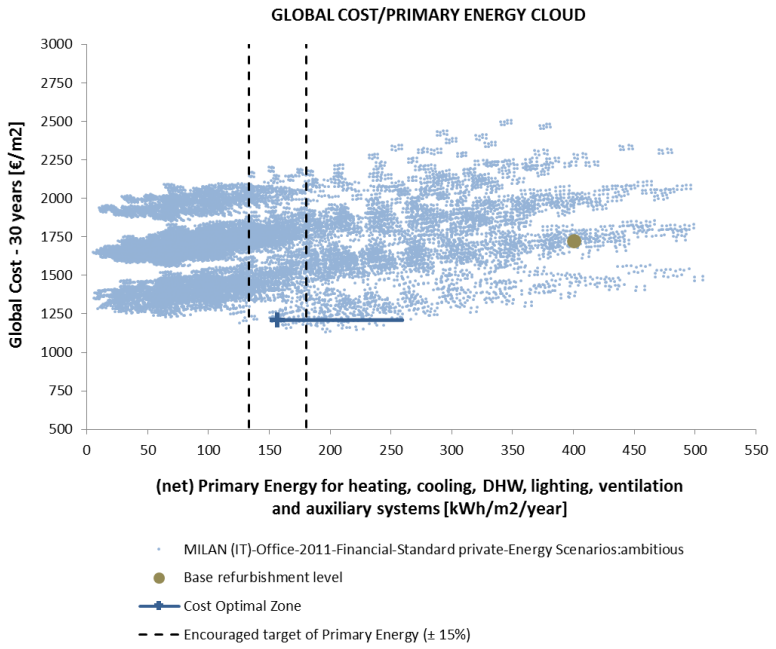
8.1.3.4 Milan





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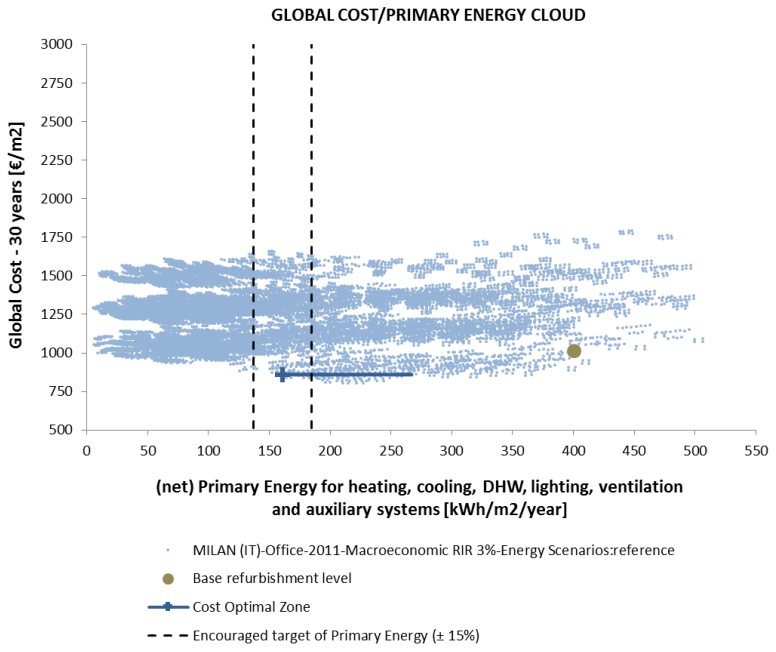

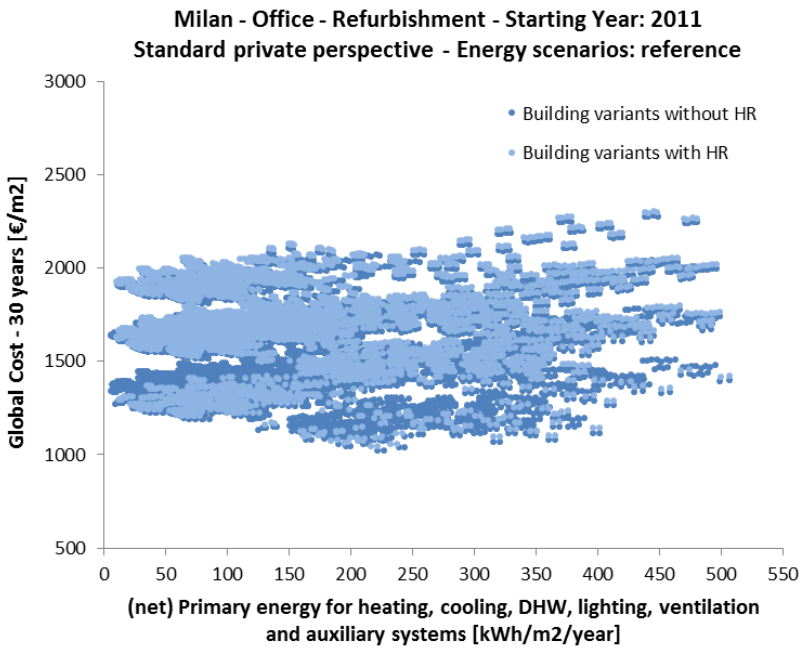

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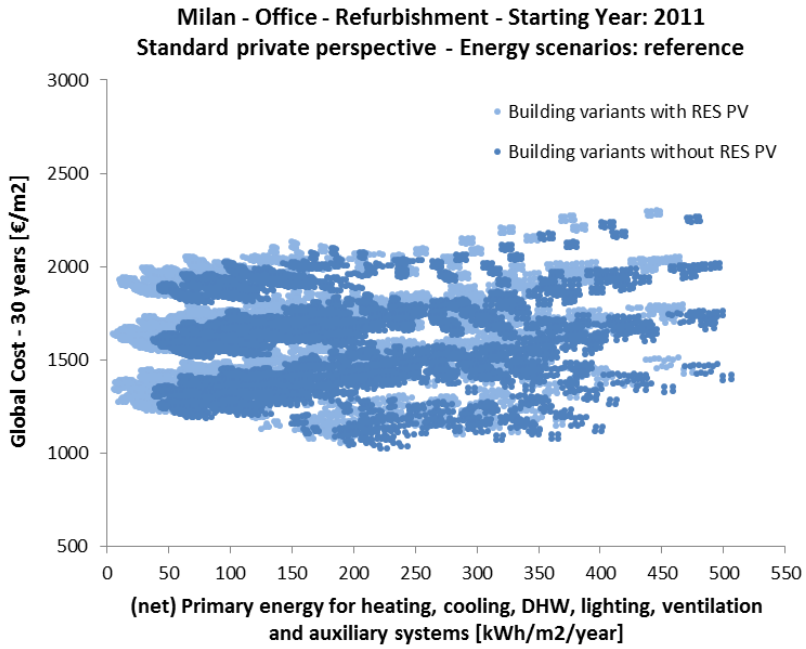

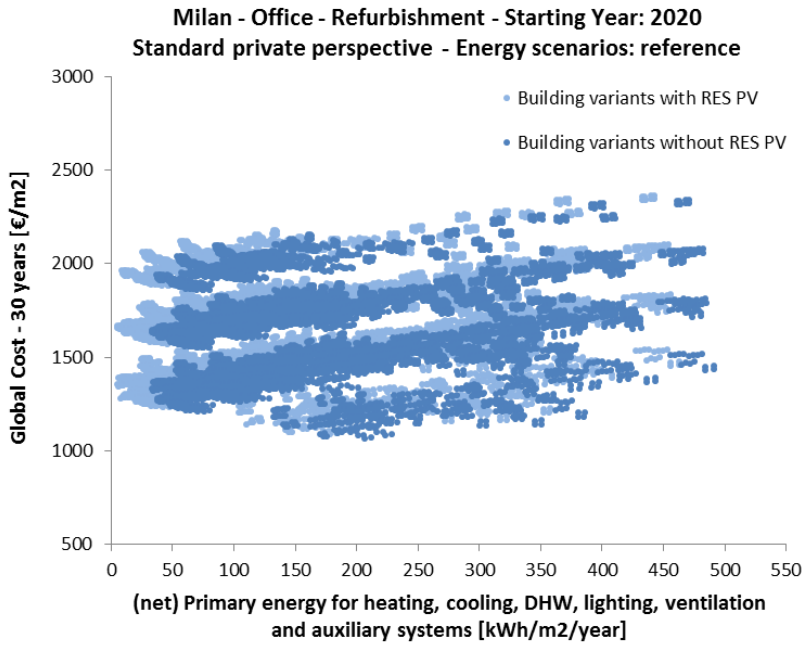

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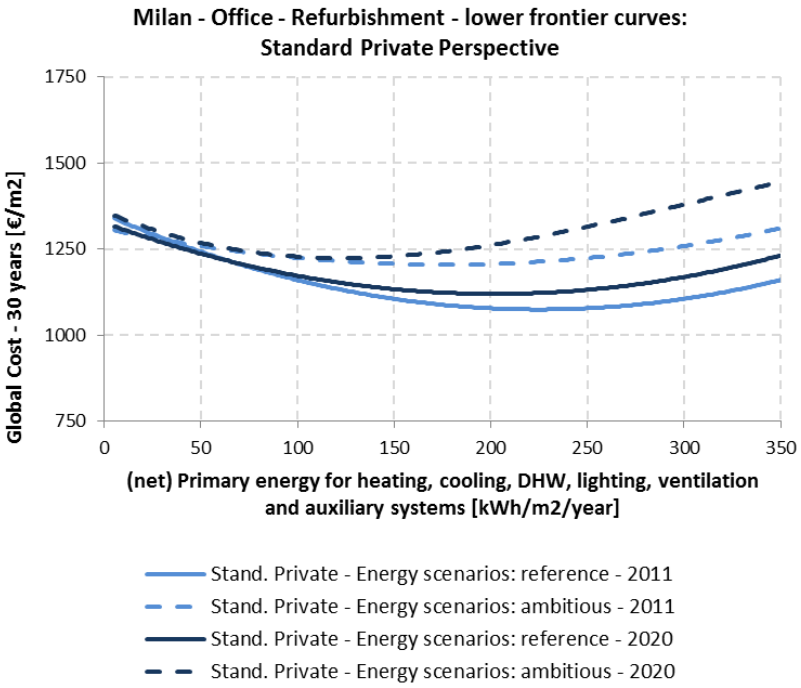

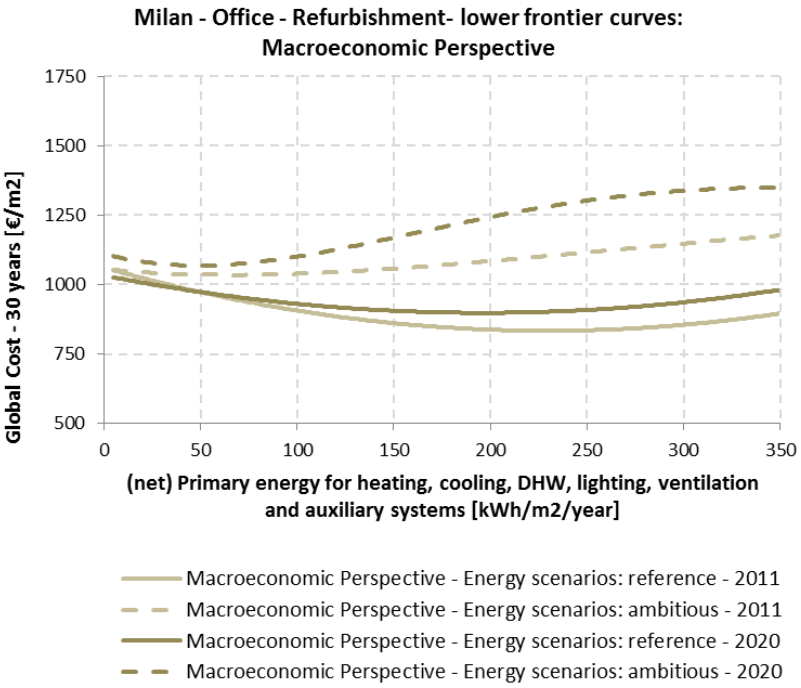

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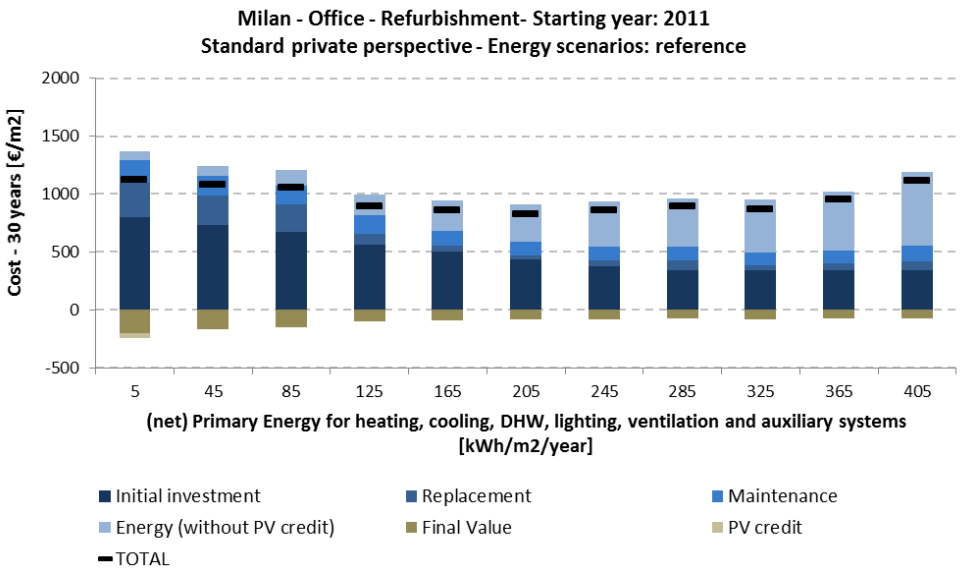

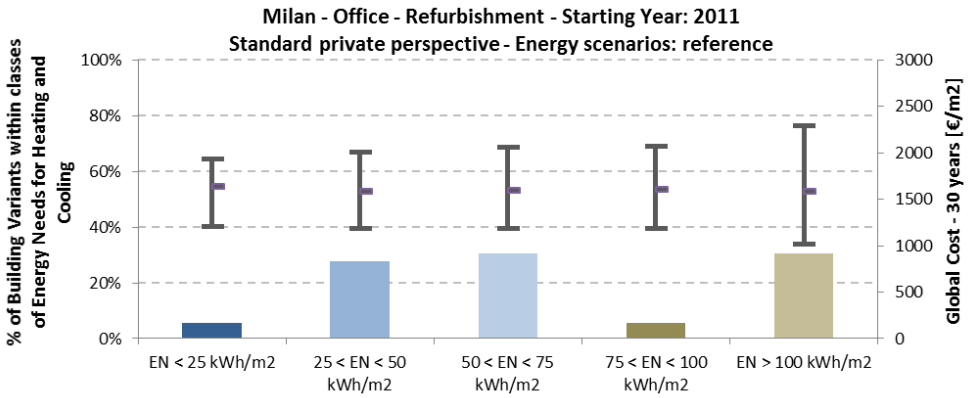

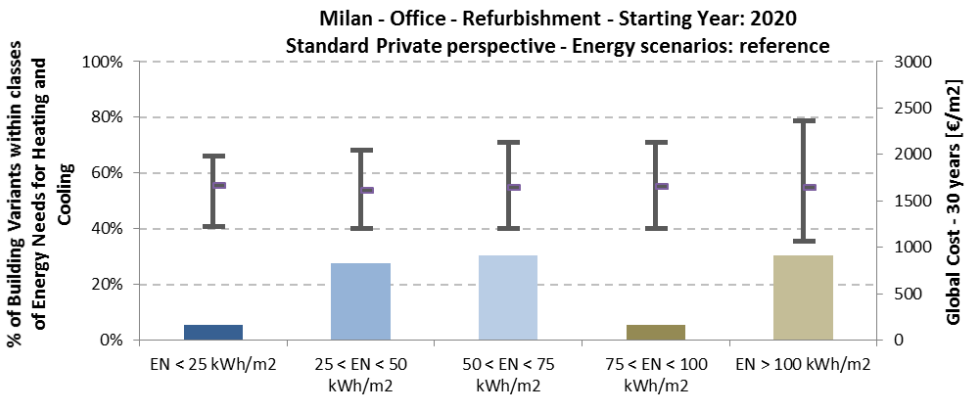

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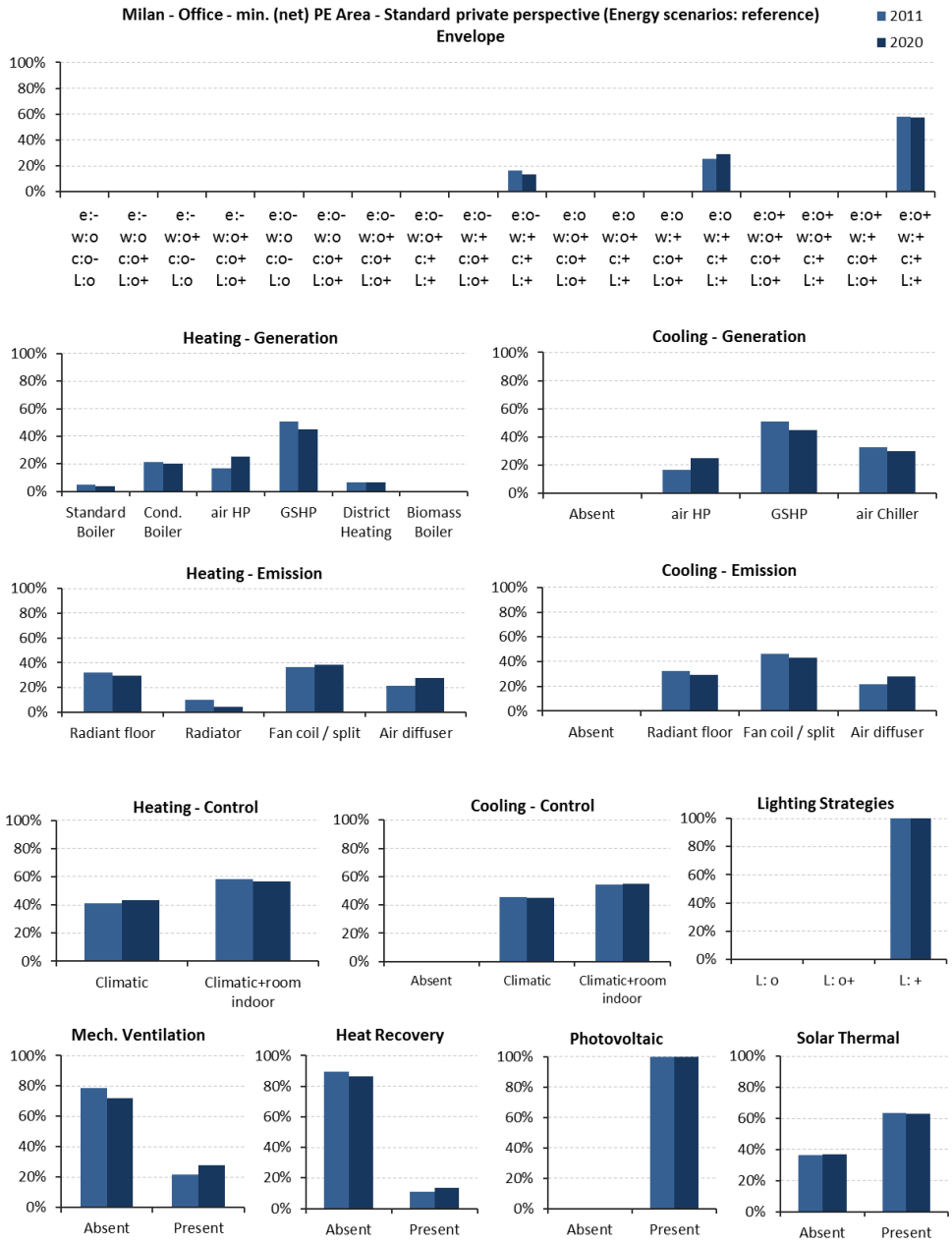
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	5	25	5	25
Range of Global Costs [€/m^2]:	1248	1497	1253	1393
Number of Building Variants:	140		140	



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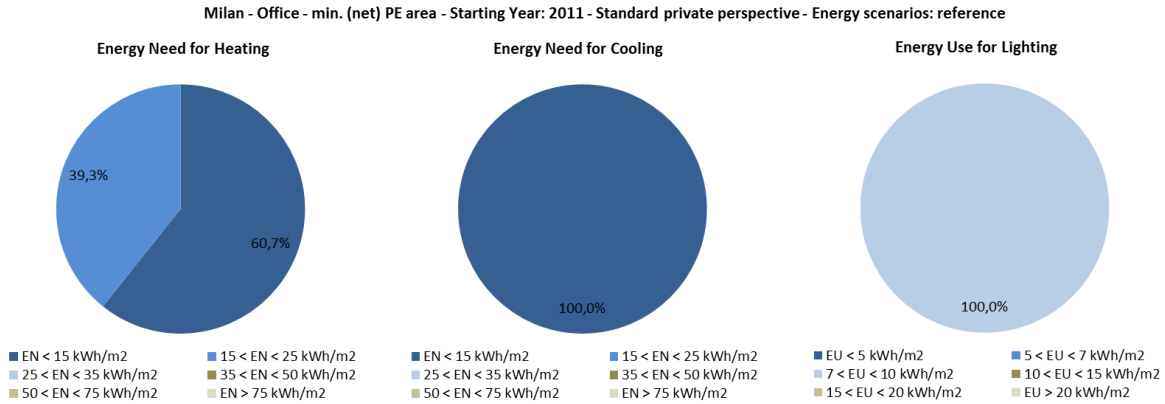

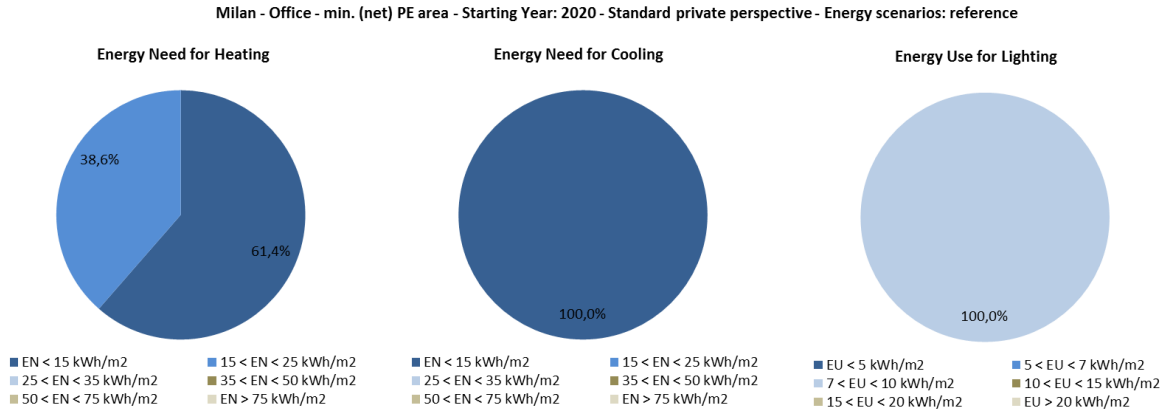

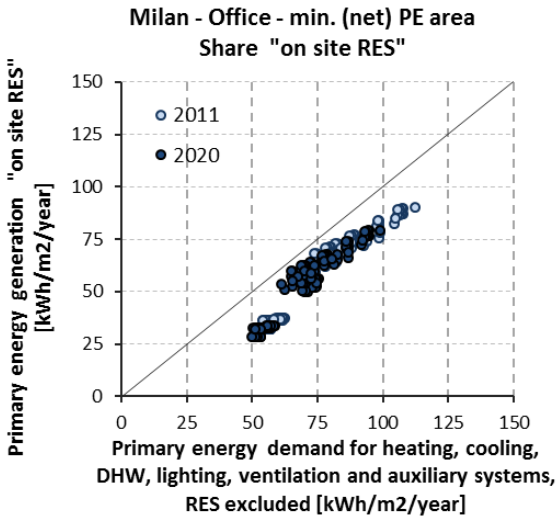

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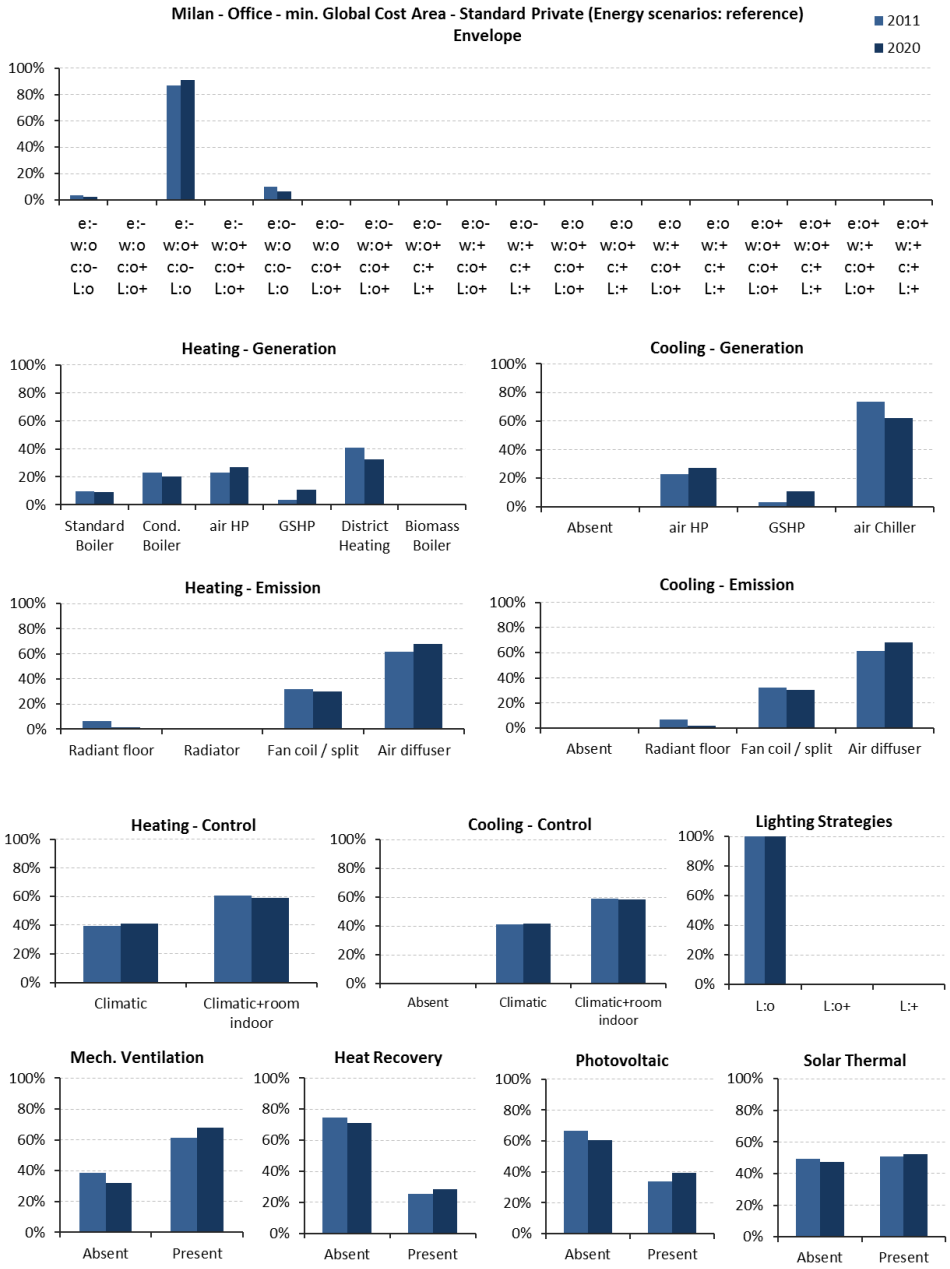
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	100	340	90	320
Range of Global Costs [€/m^2]:	1025	1127	1067	1162
Number of Building Variants:	122		122	



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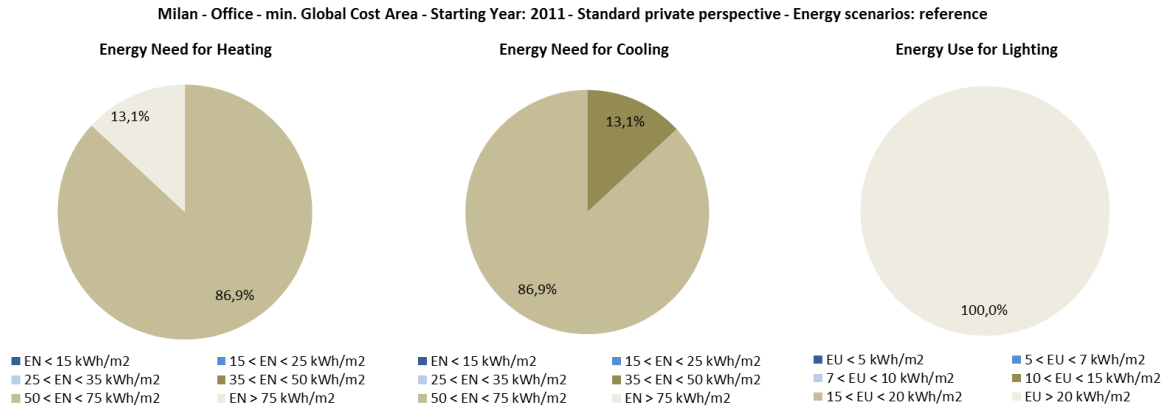

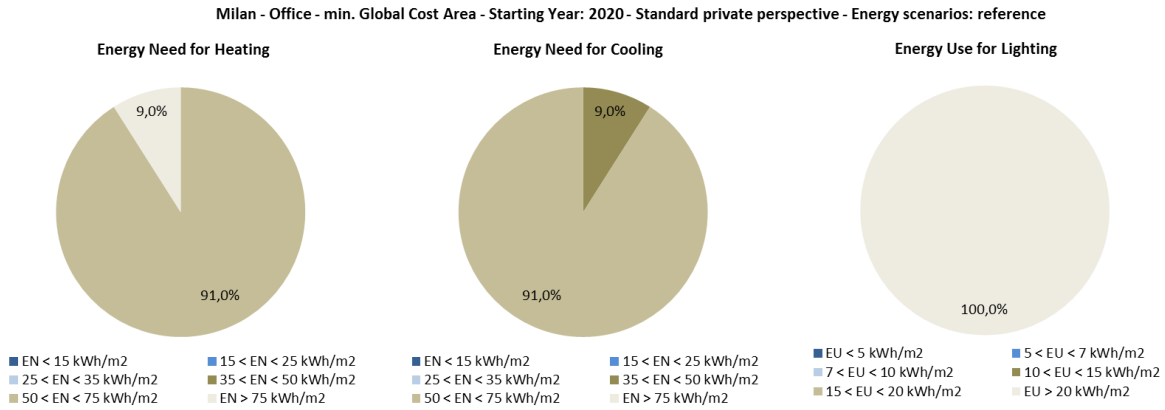

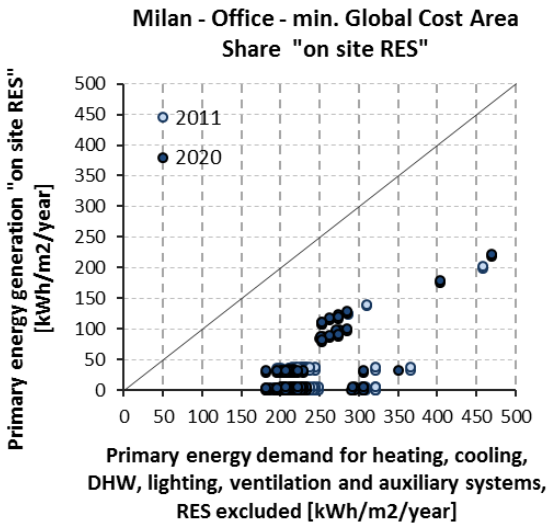

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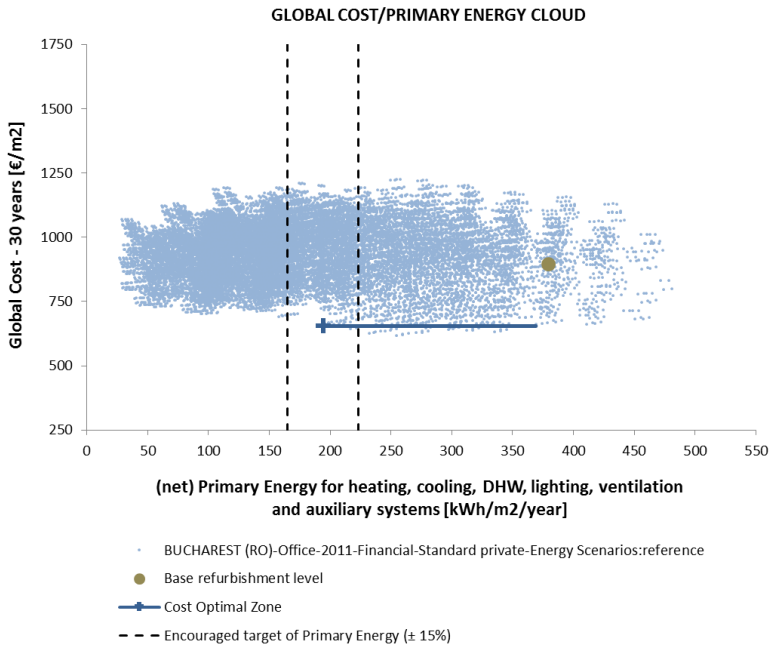
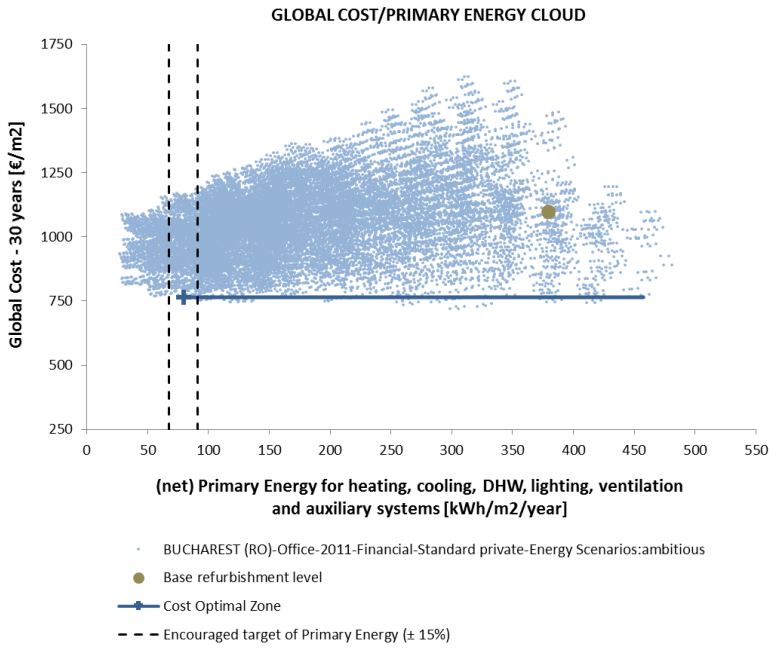
8.1.3.5 Bucharest





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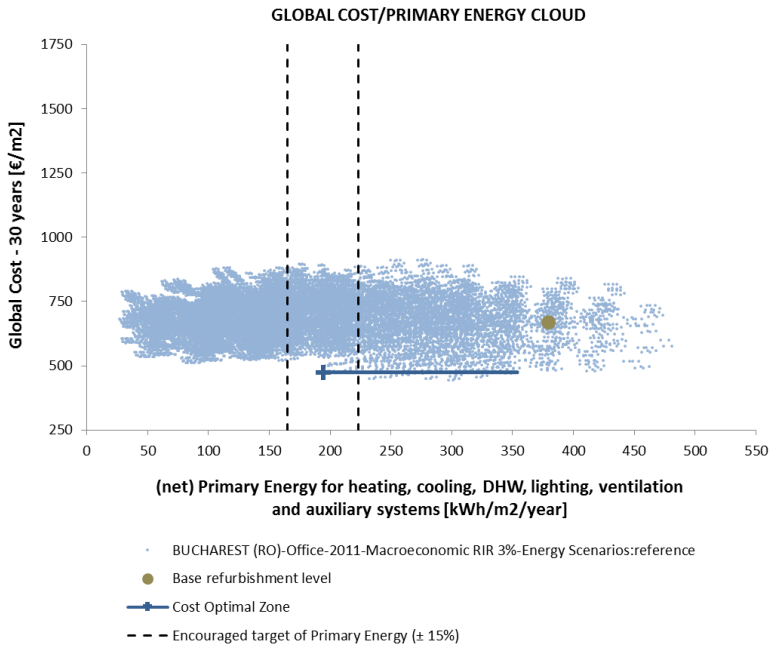

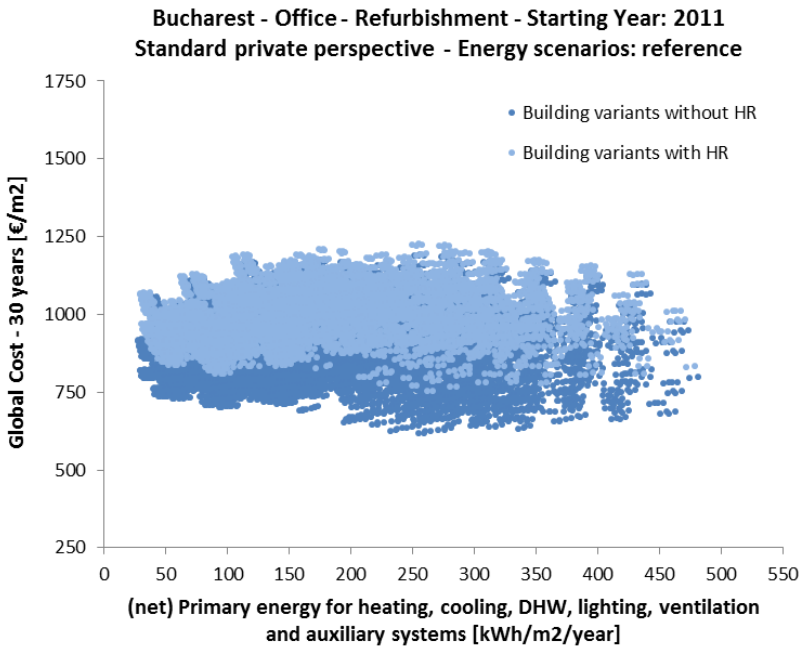

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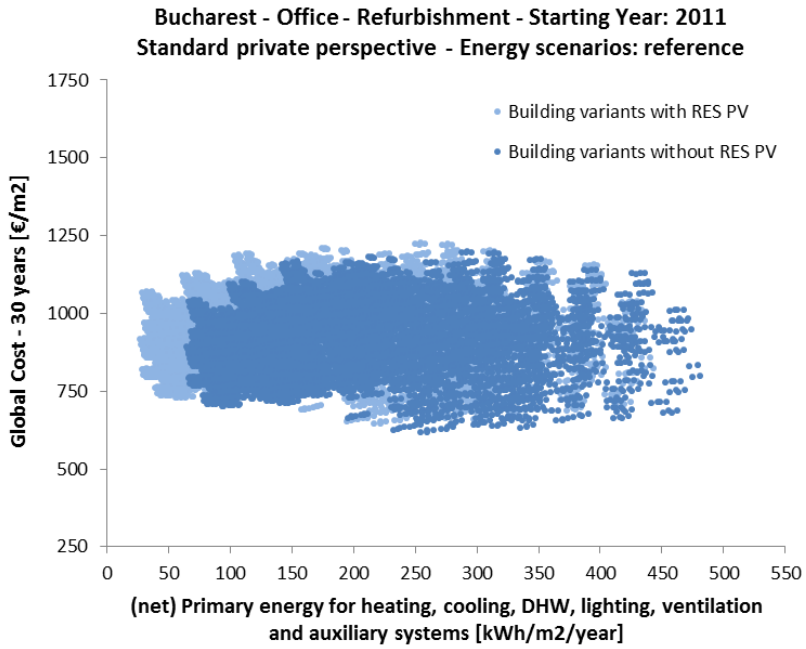

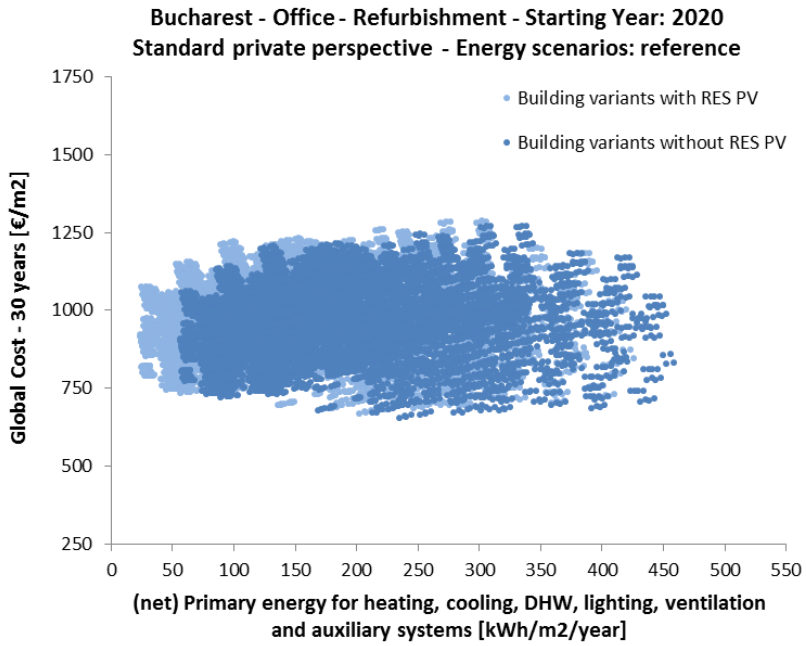

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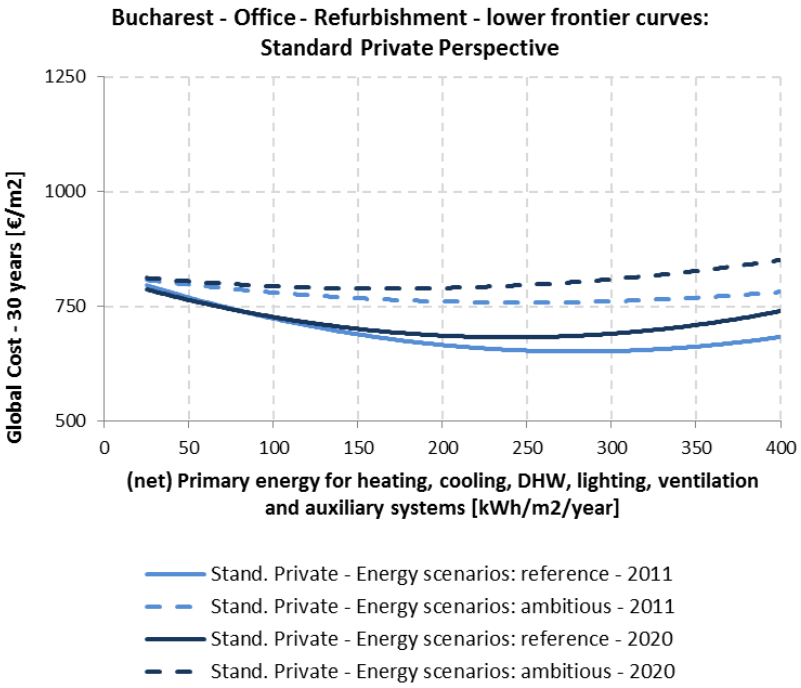

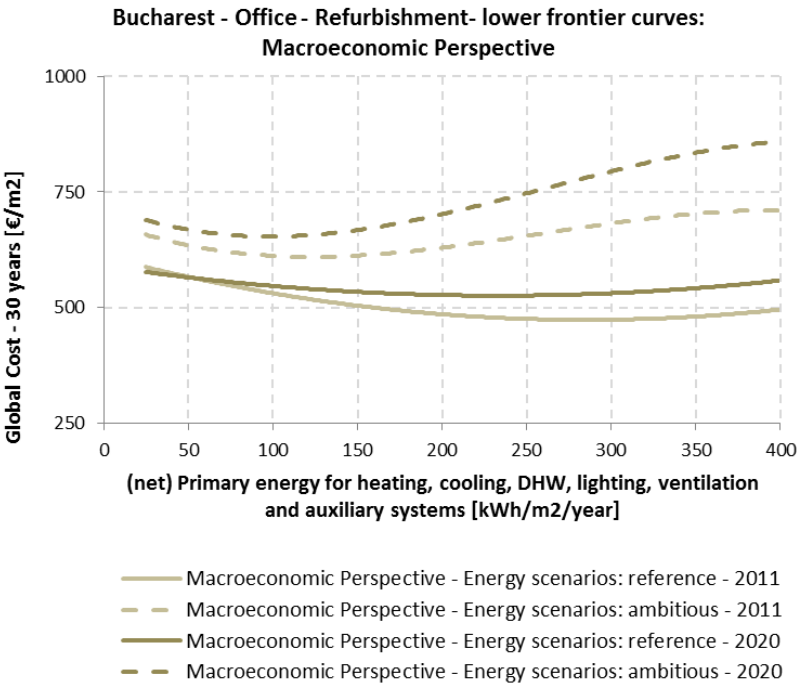

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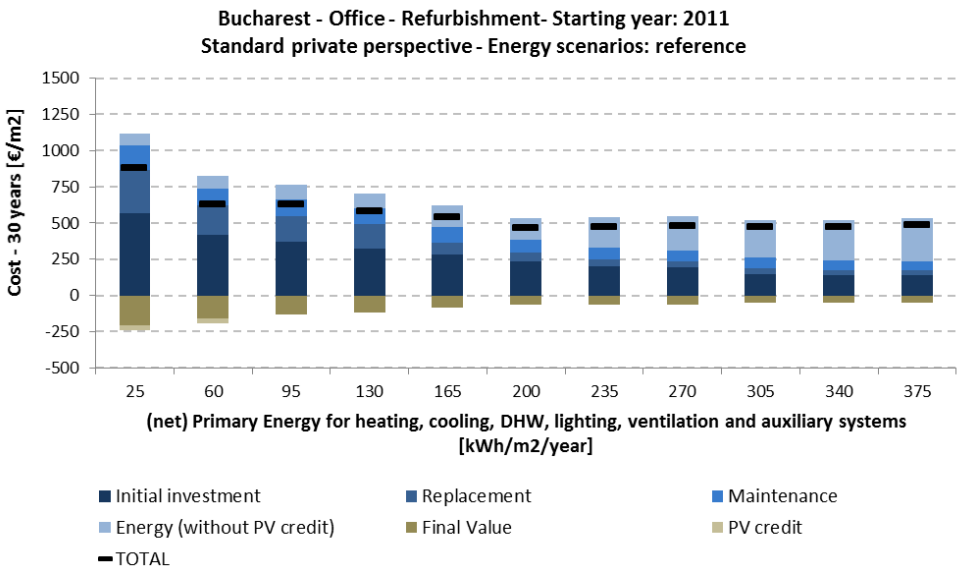

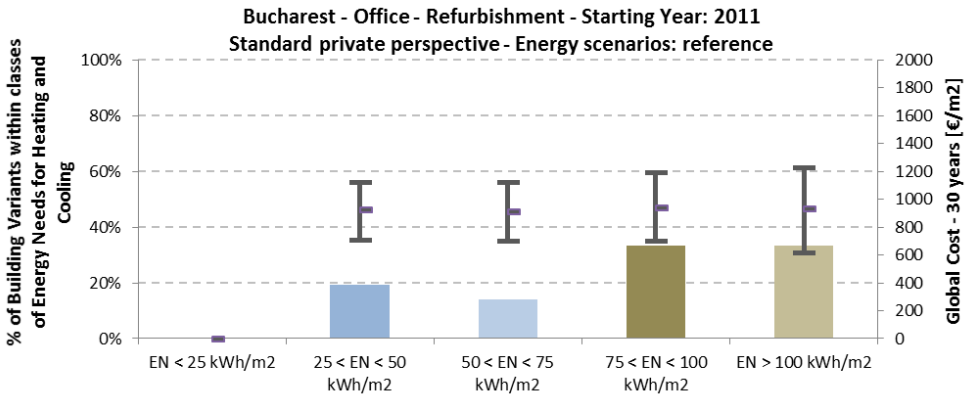

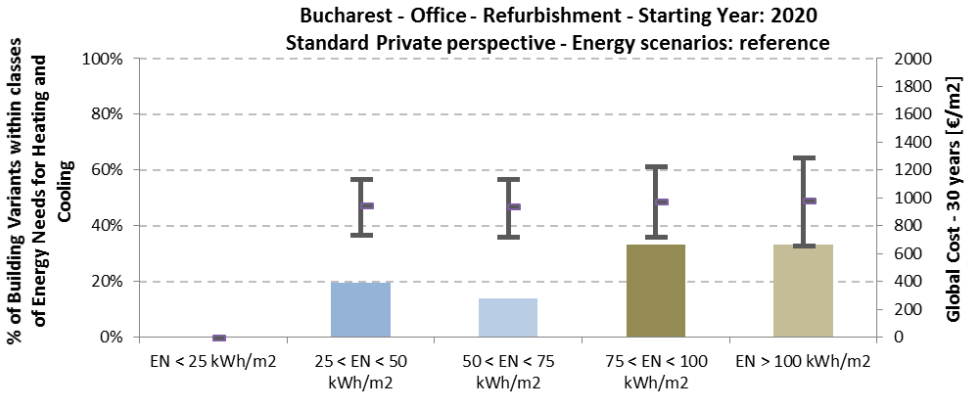

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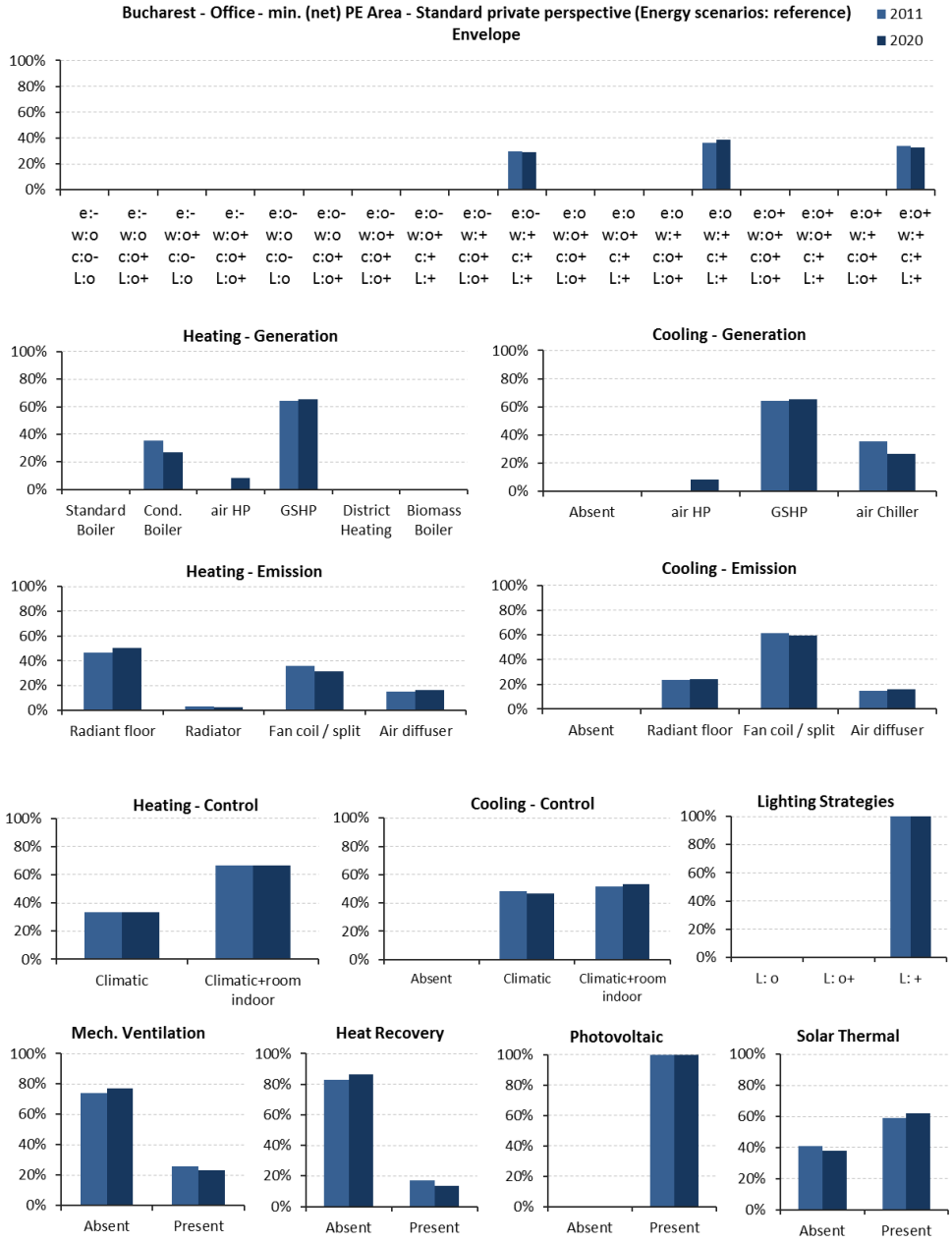
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	27	45	23	45
Range of Global Costs [€/m^2]:	735	919	747	924
Number of Building Variants:	135		135	



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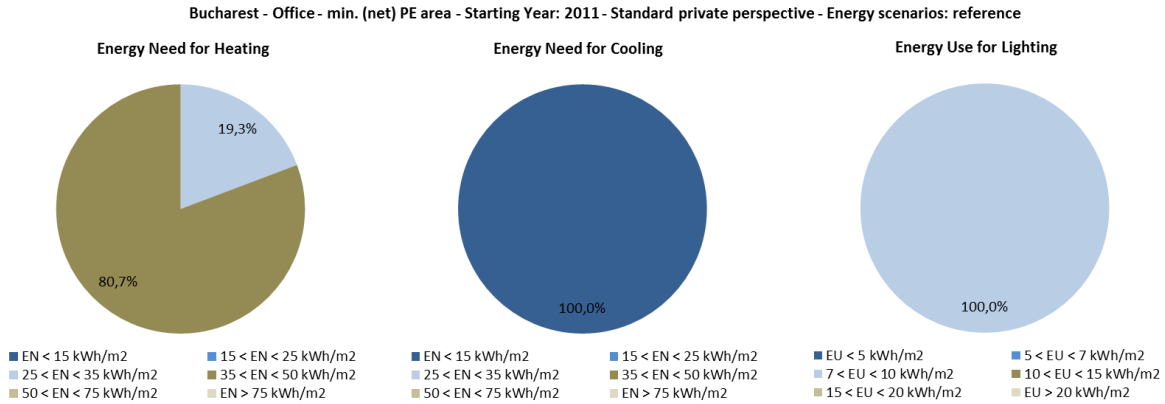

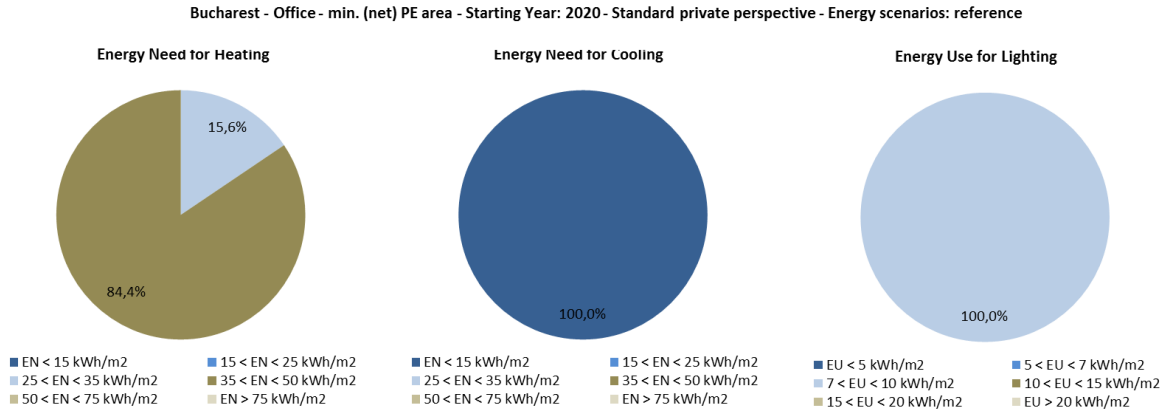

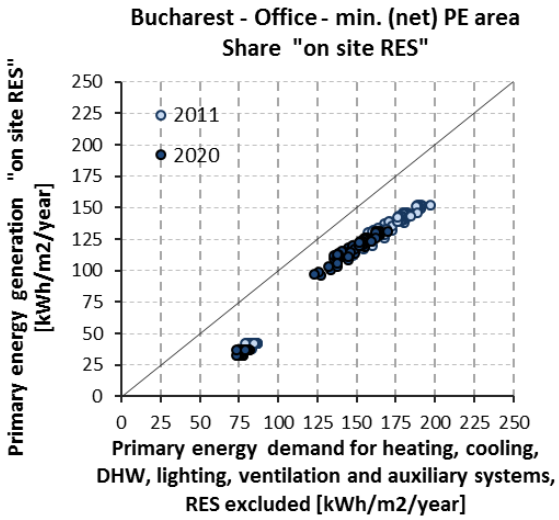

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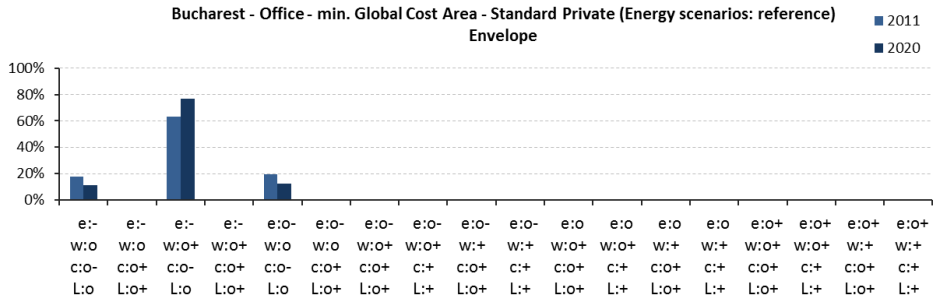
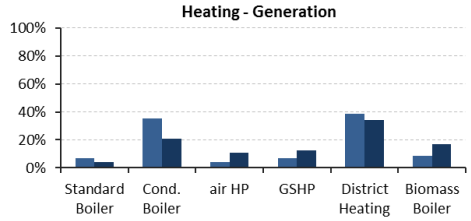
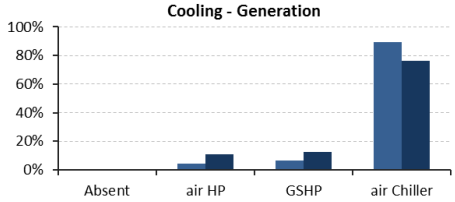
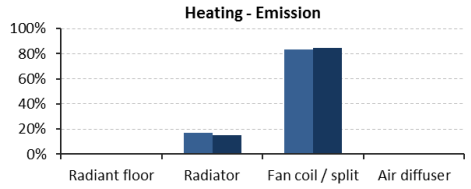
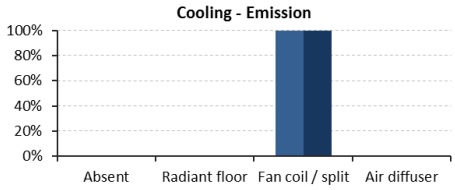
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	170	340	160	310
Range of Global Costs [€/m^2]:	618	680	655	720
Number of Building Variants:	119		119	

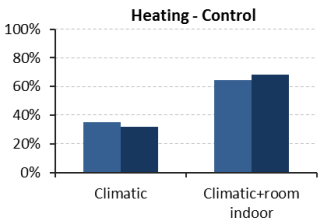


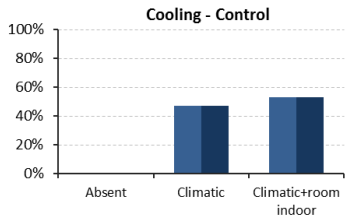


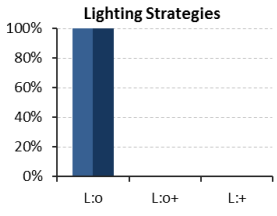


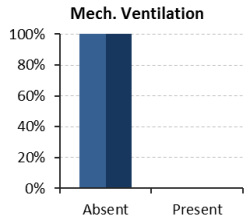


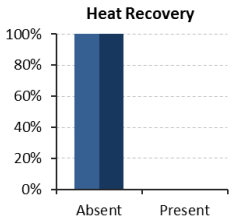


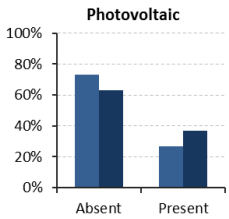


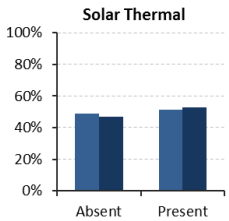












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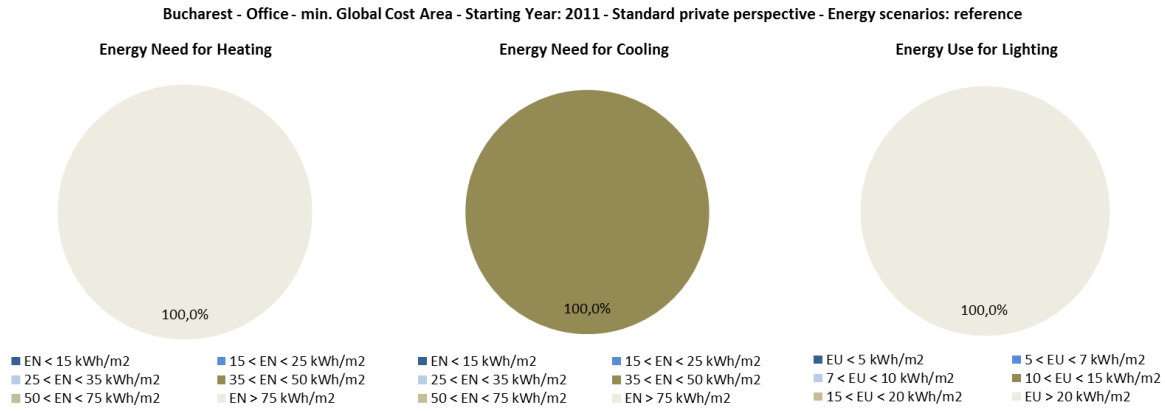

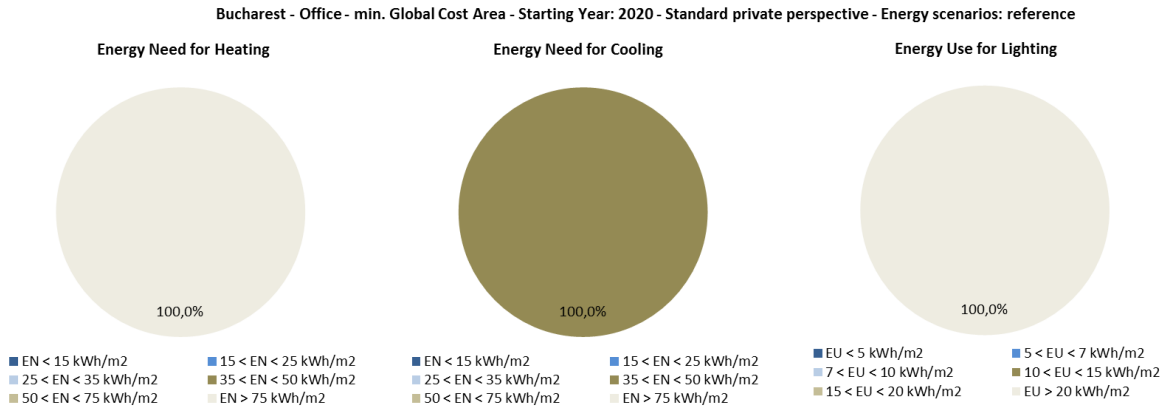

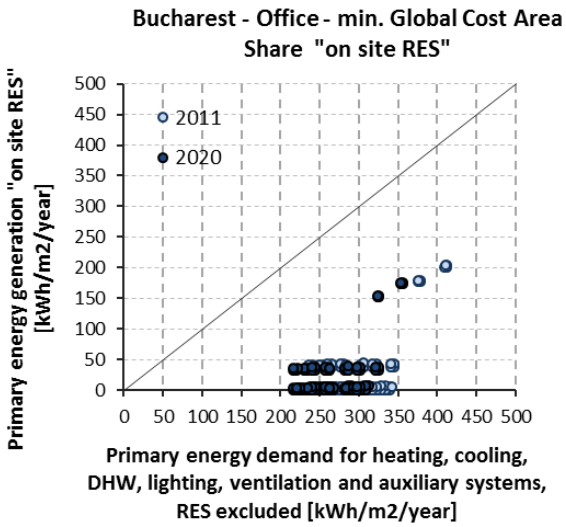

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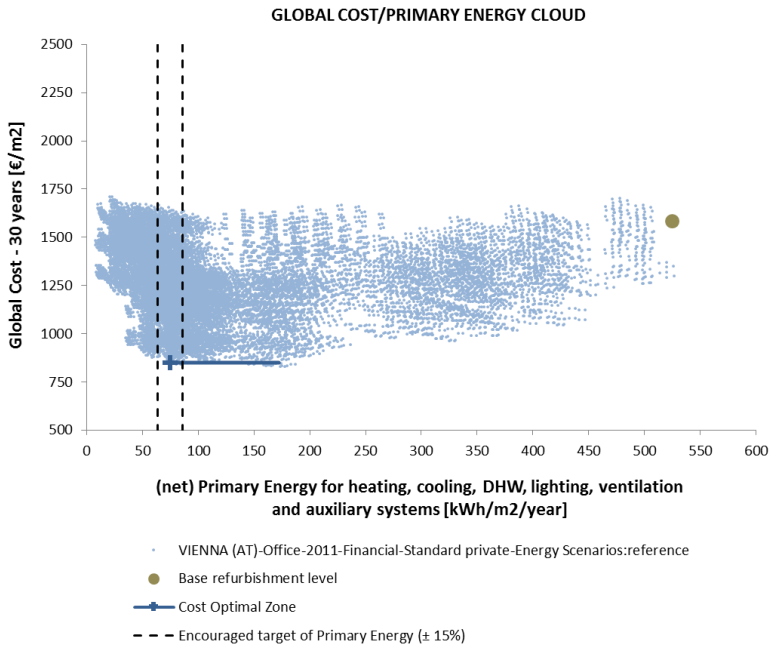
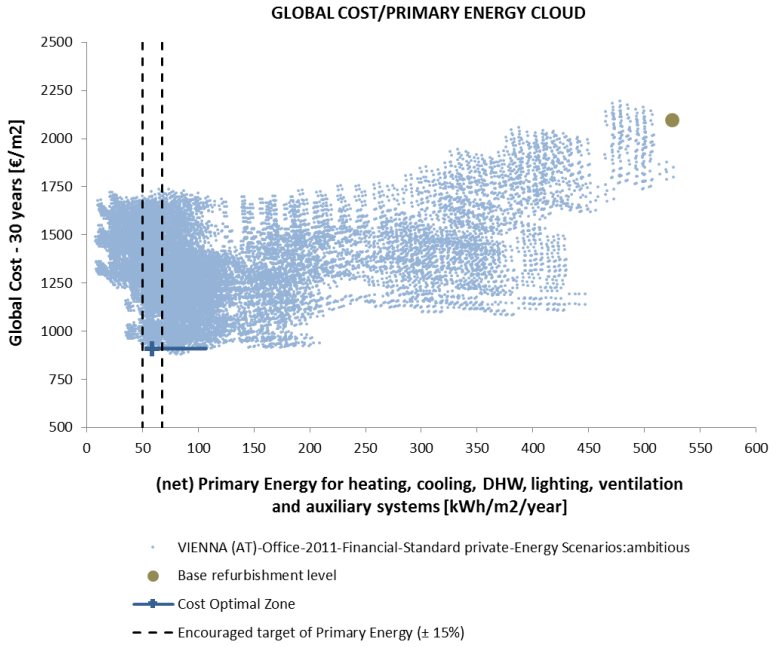
8.1.3.6 Vienna





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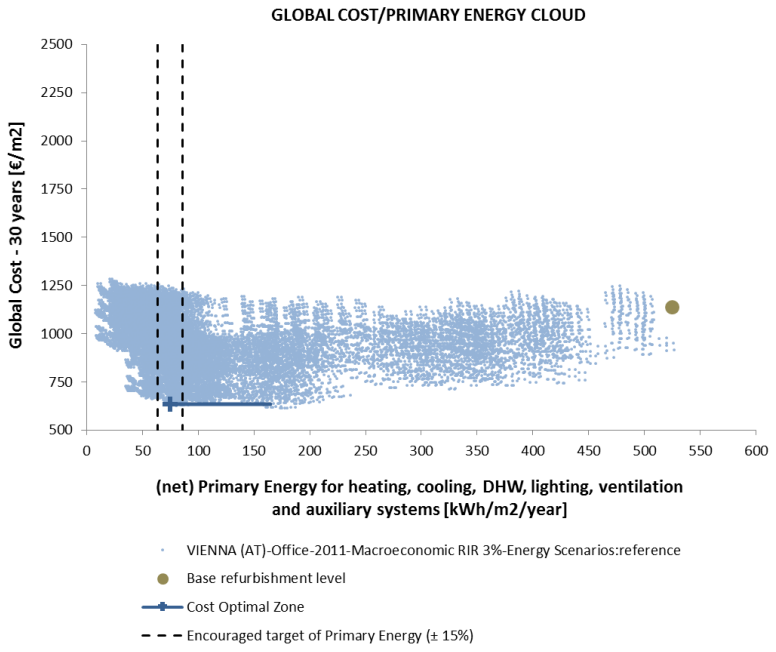

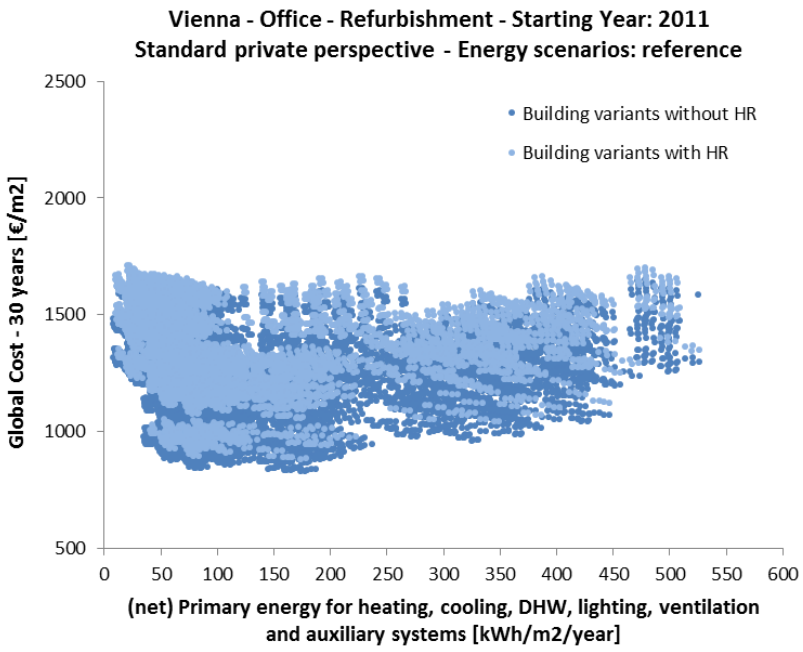

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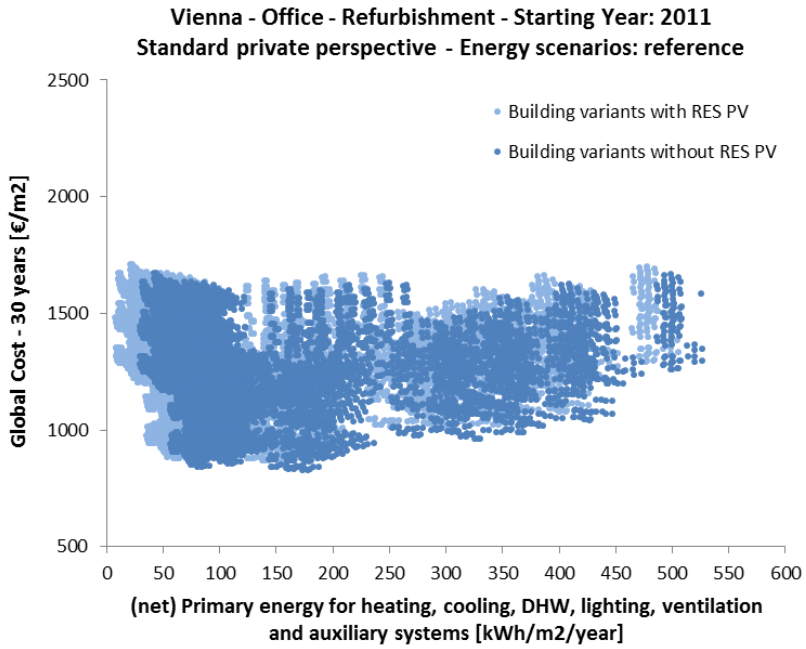

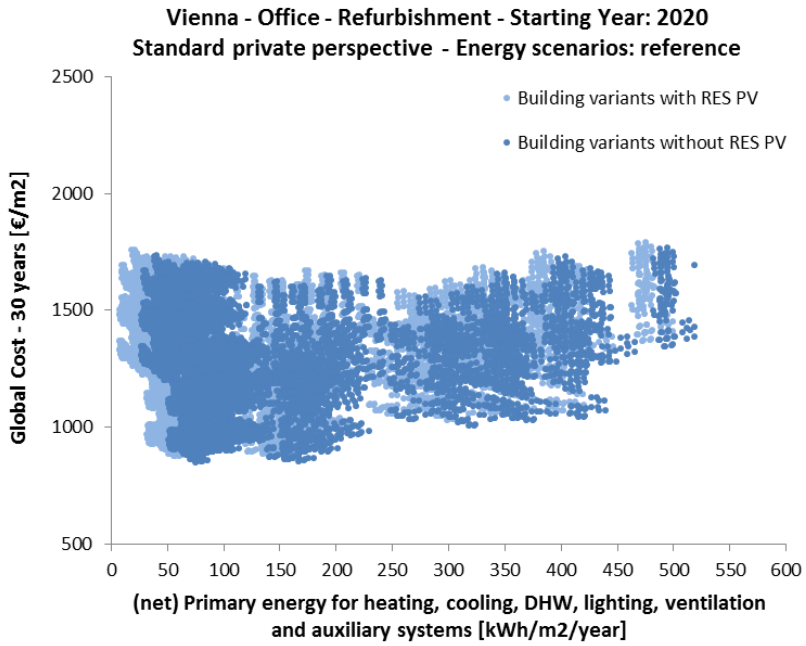

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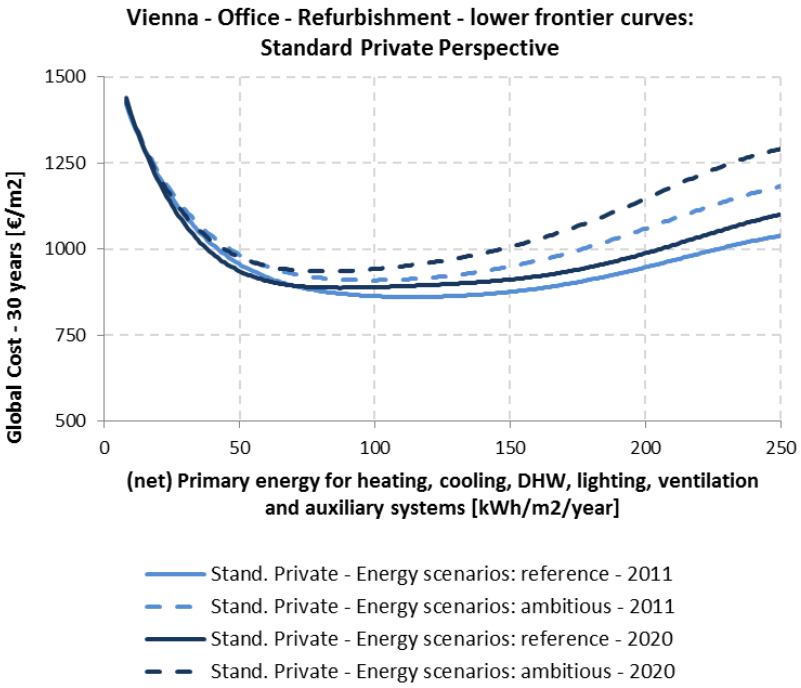

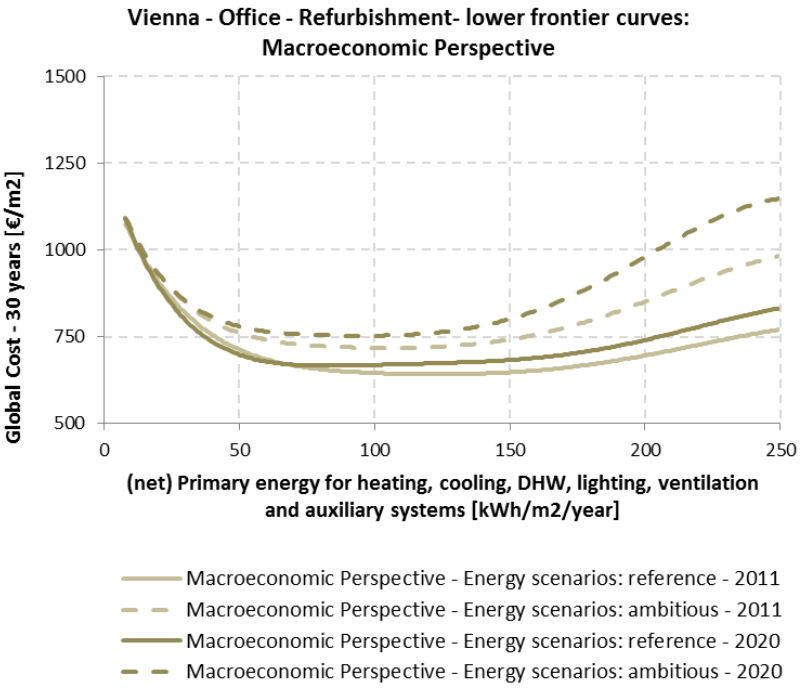

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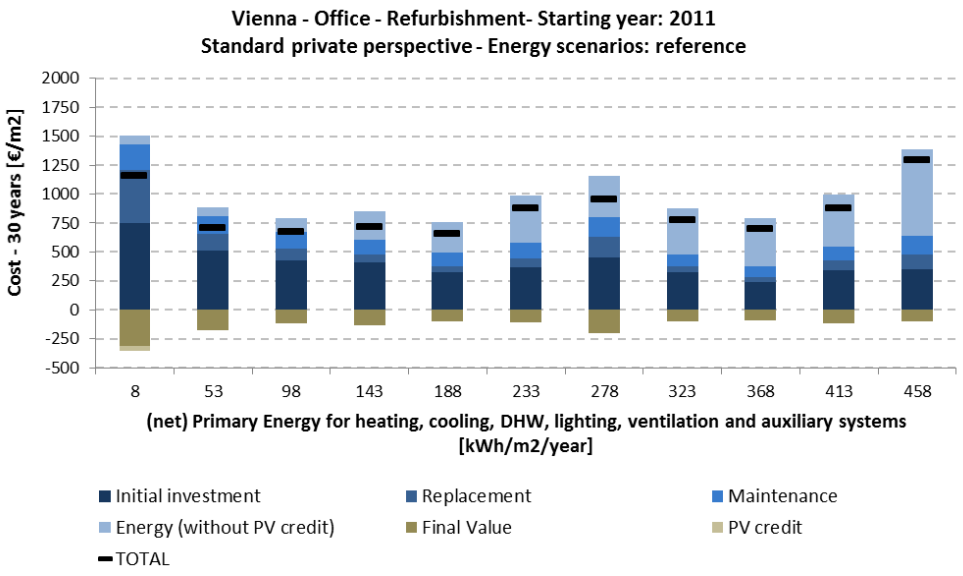

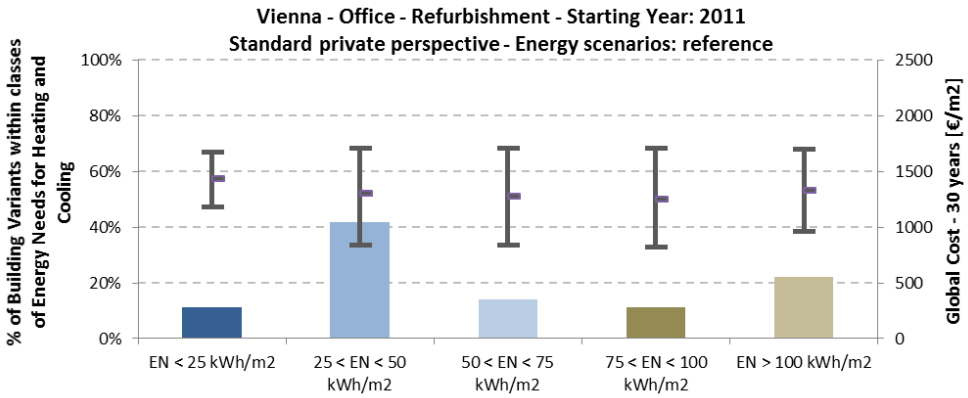

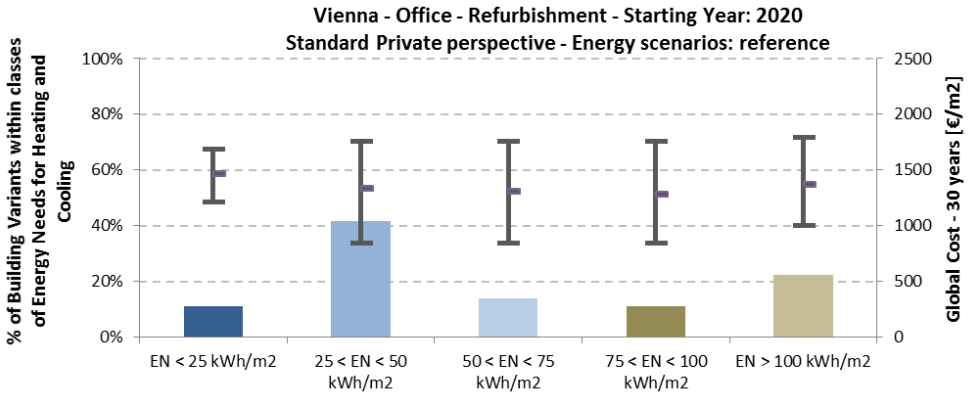

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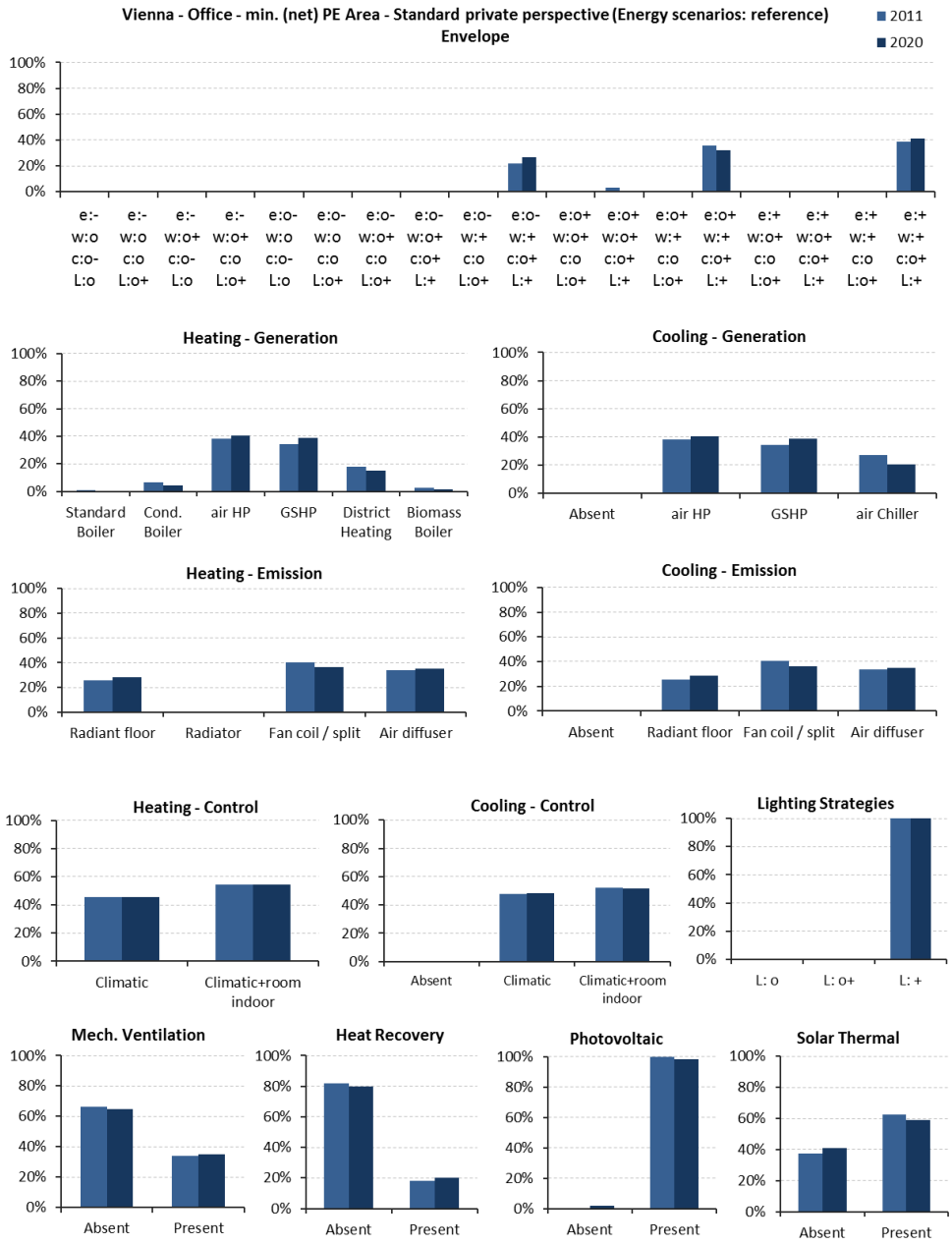
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	8	28	7	27
Range of Global Costs [€/m²]:	1207	1328	1268	1351
Number of Building Variants:	165		165	



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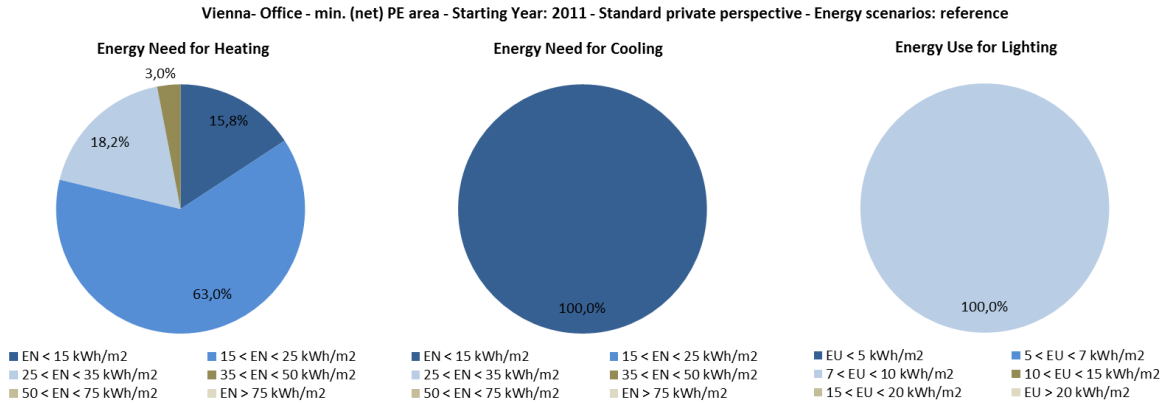

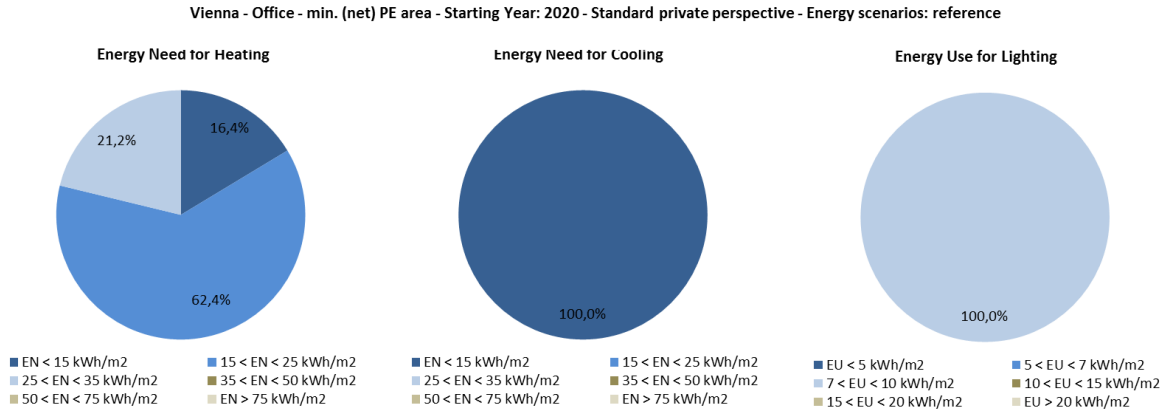

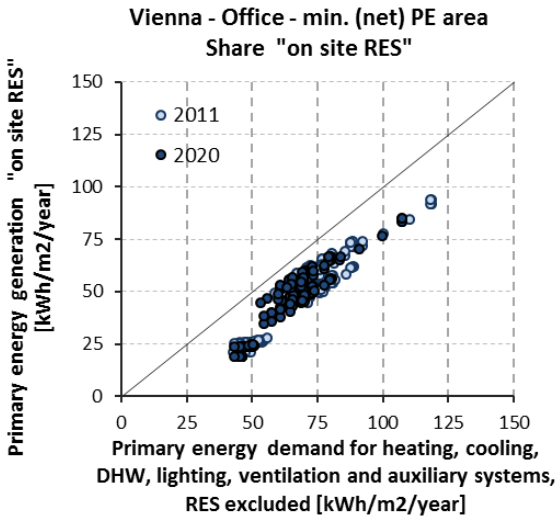

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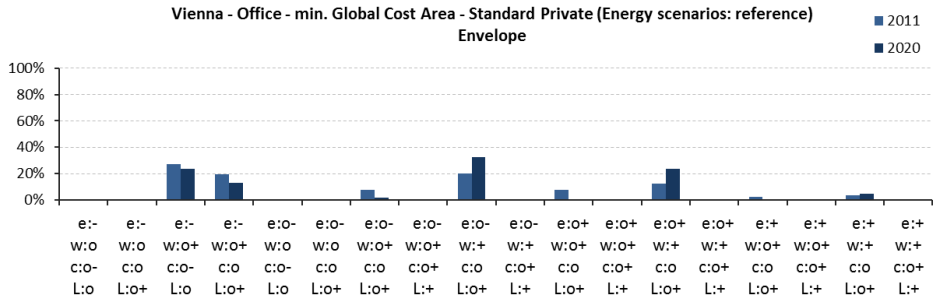
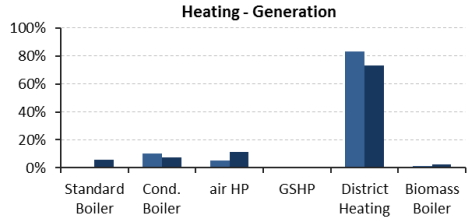
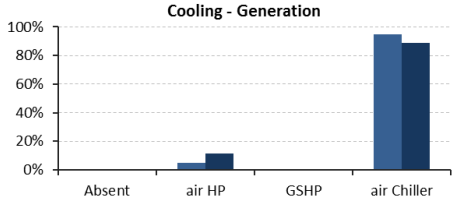
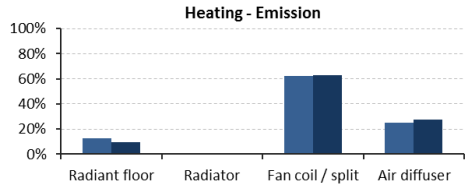
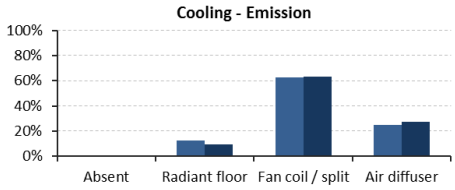
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	23	200	25	200
Range of Global Costs [€/m^2]:	829	887	852	904
Number of Building Variants:	160		160	

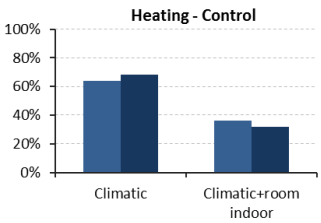


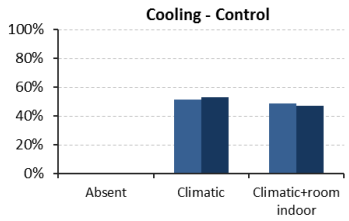


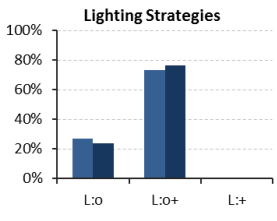


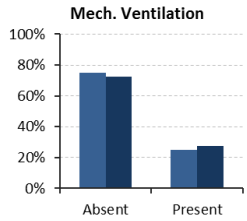


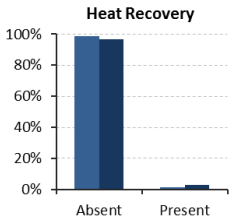


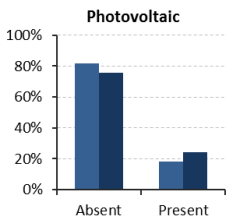


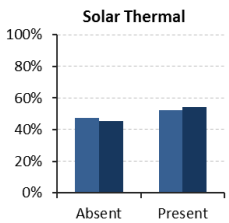












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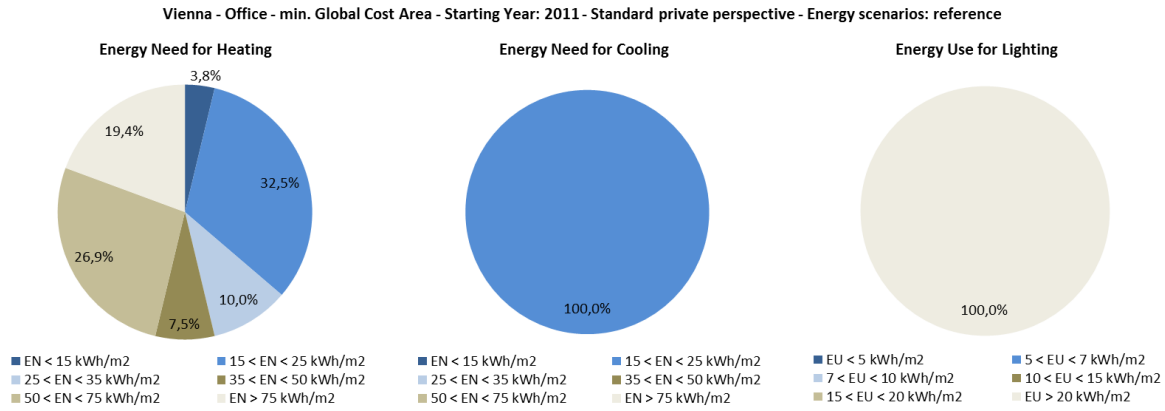

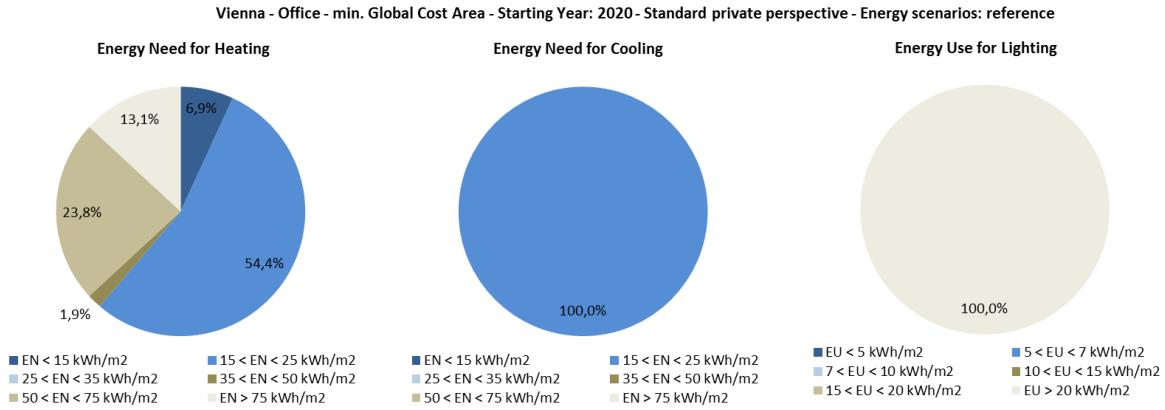

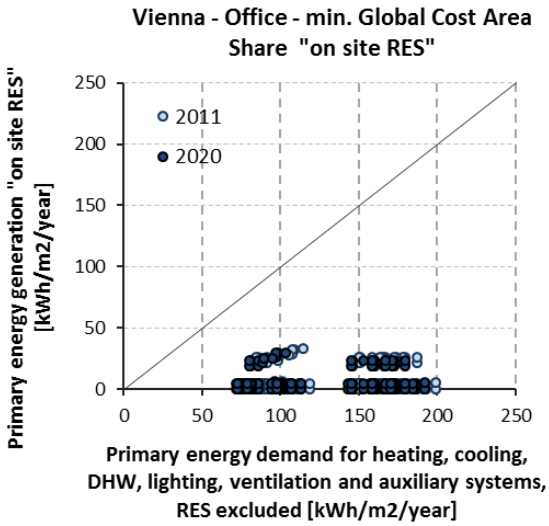

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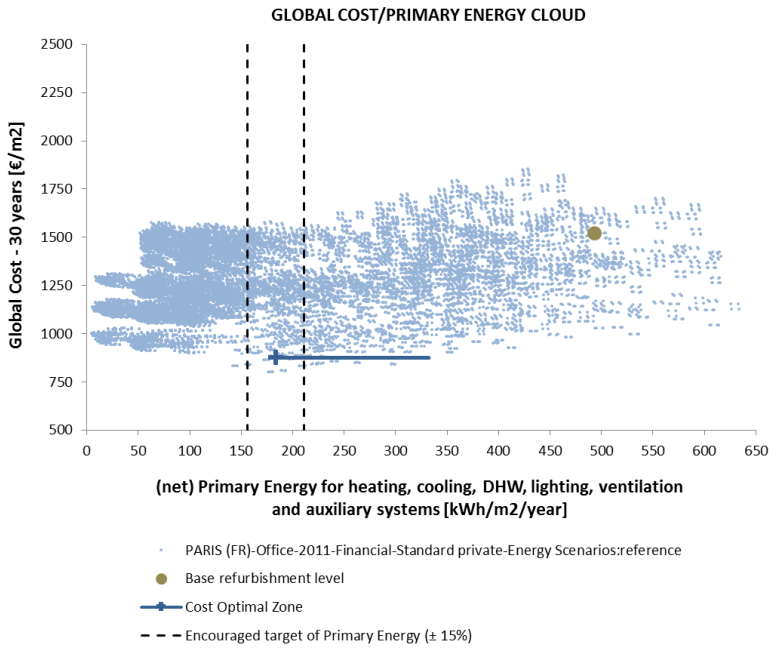
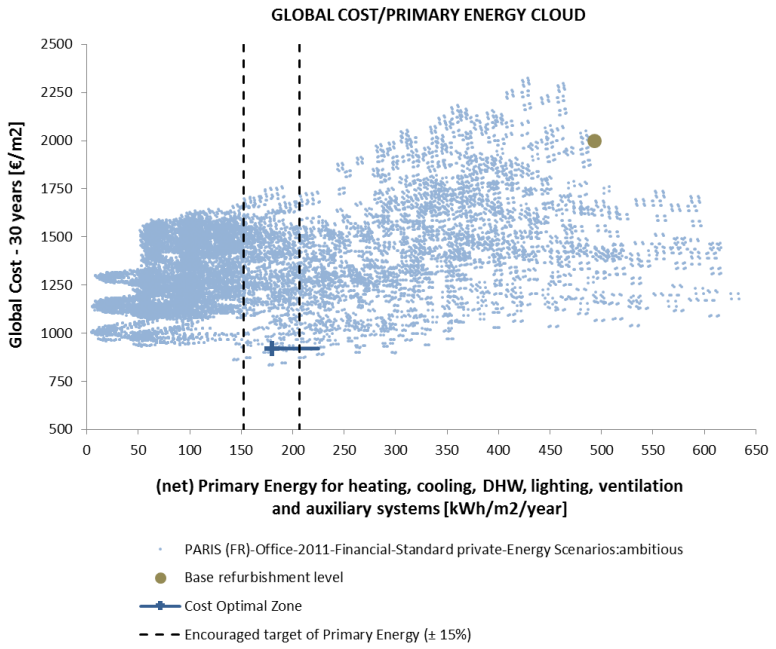
8.1.3.7 Paris





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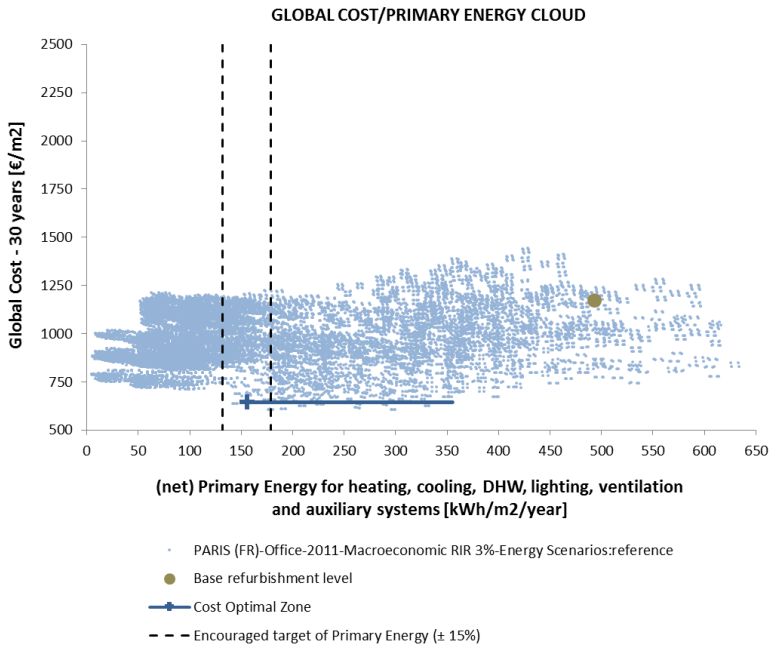

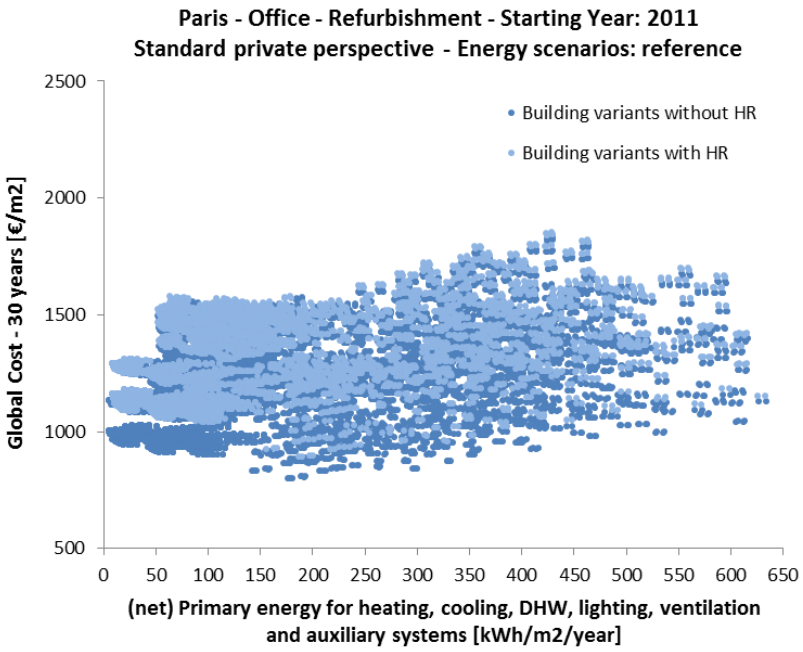

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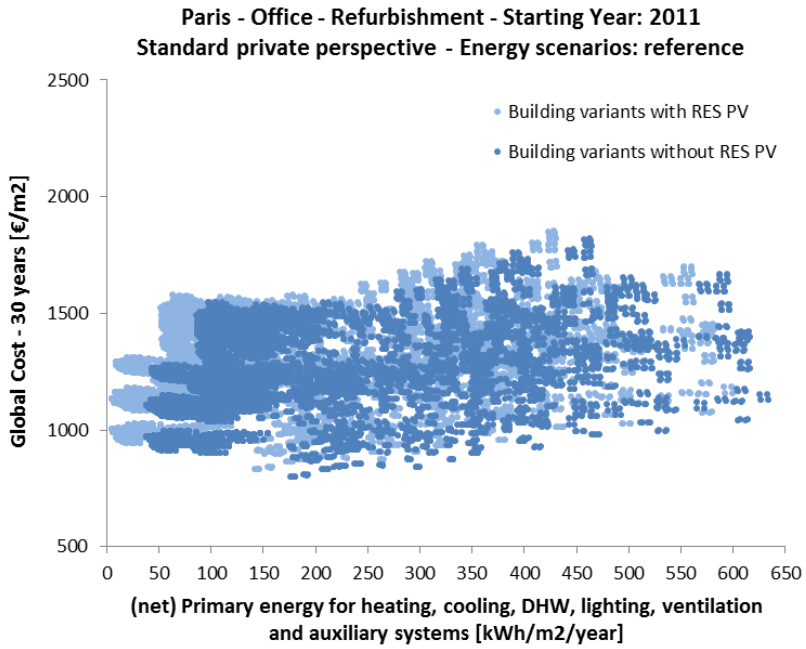

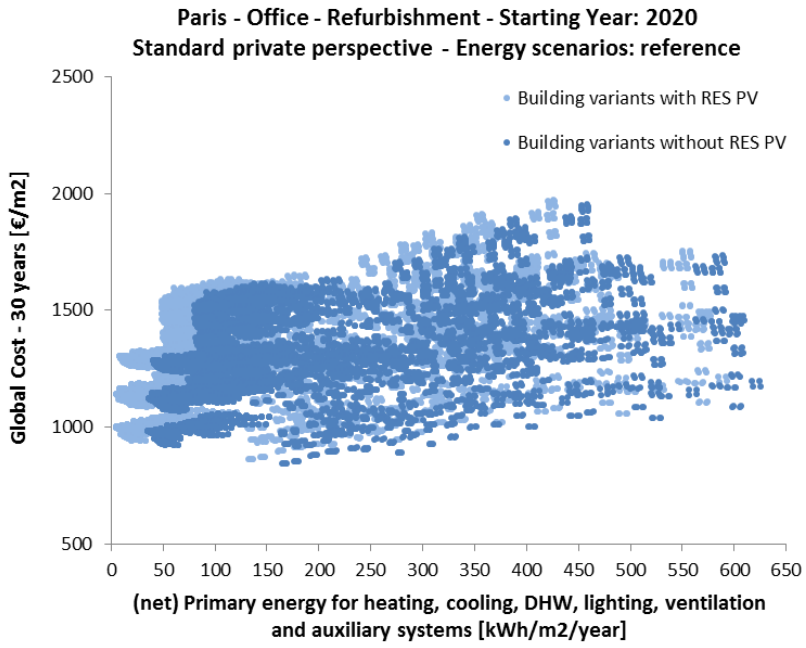

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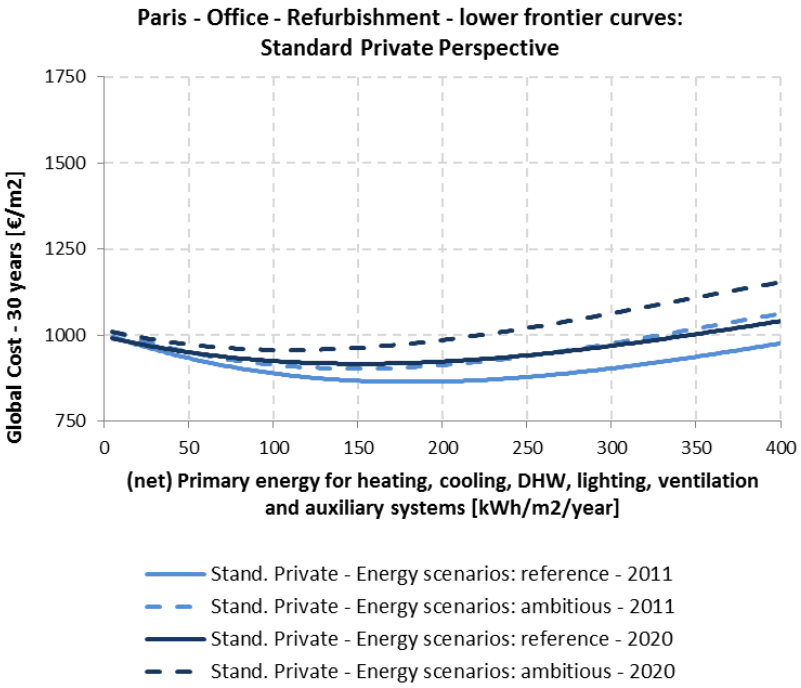

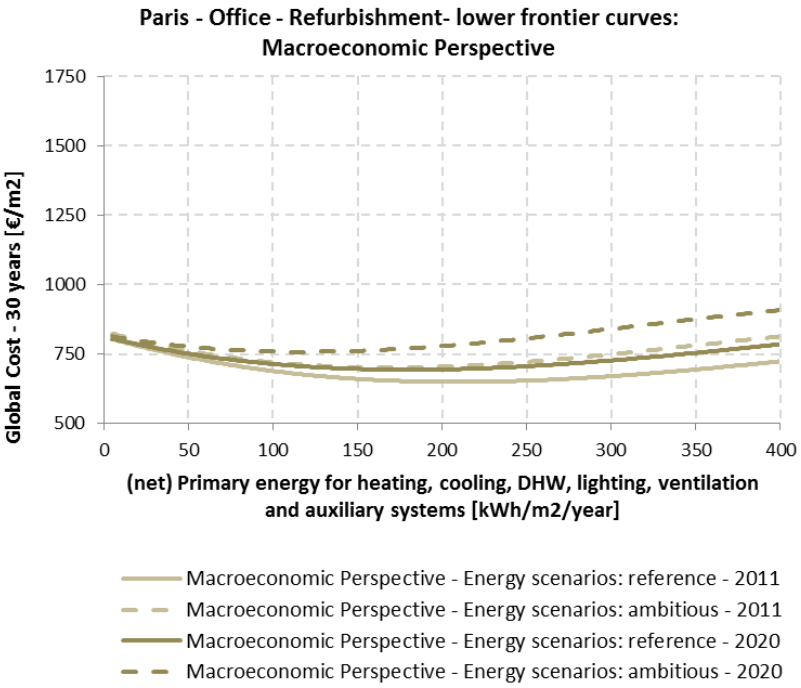

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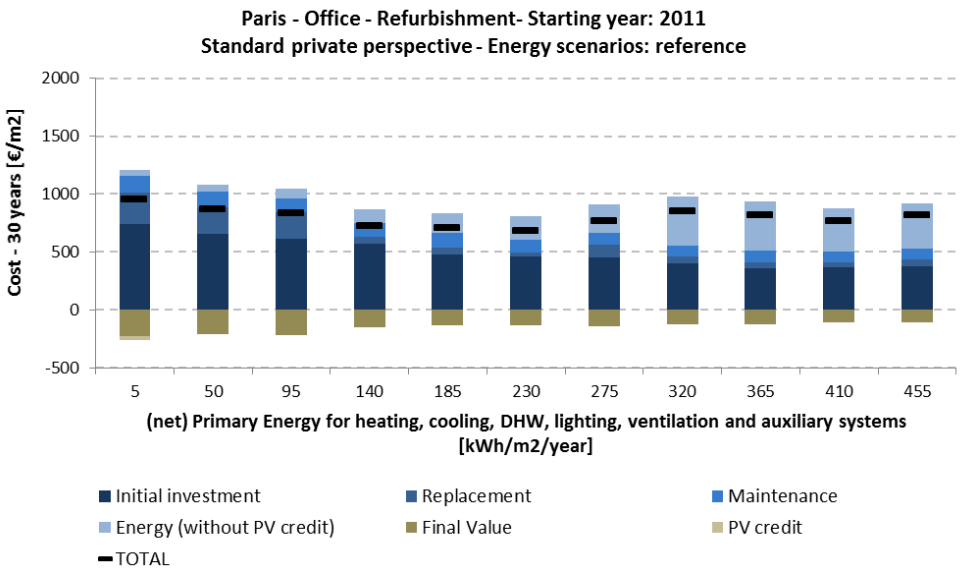

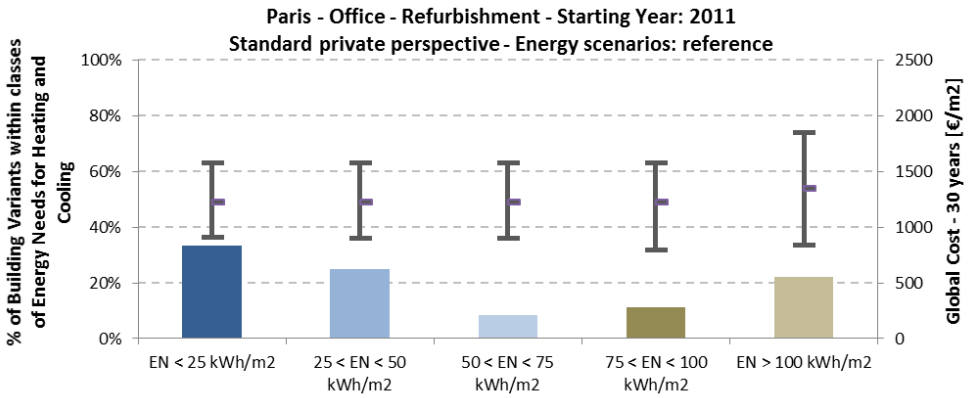

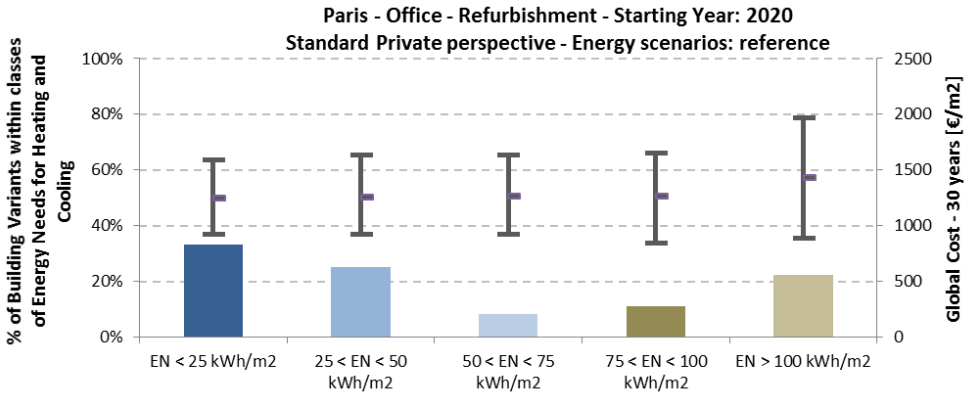

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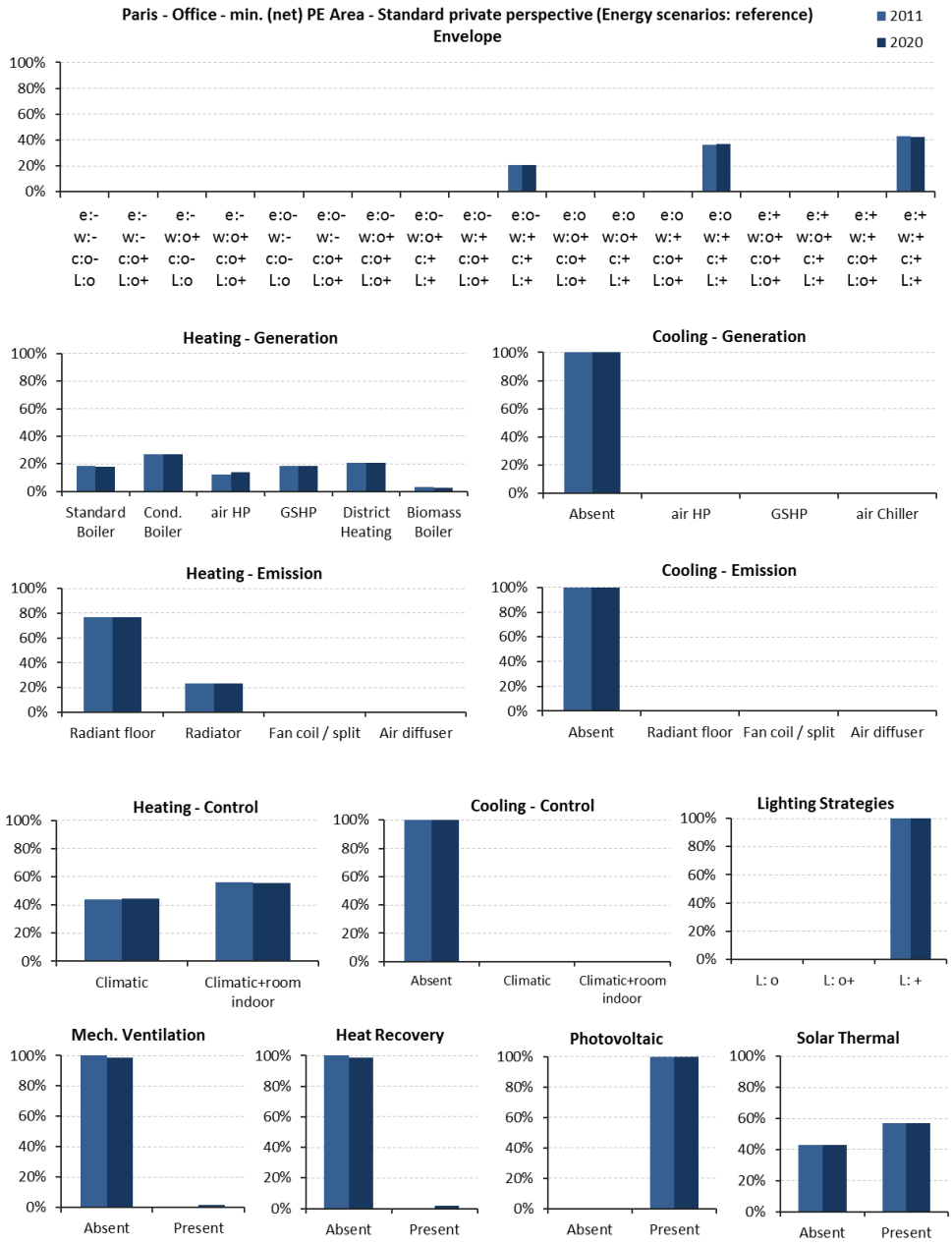
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	5	25	5	25
Range of Global Costs [€/m²]:	943	1038	946	1097
Number of Building Variants:	260		260	



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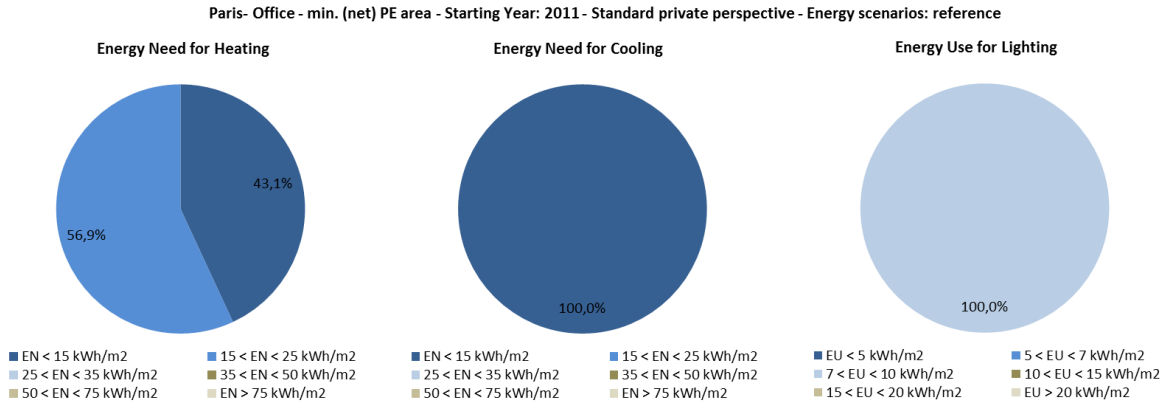

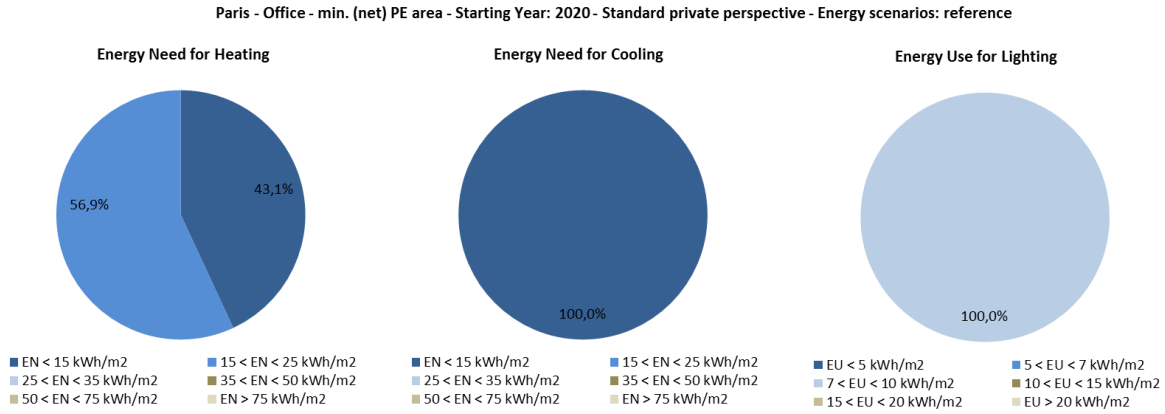

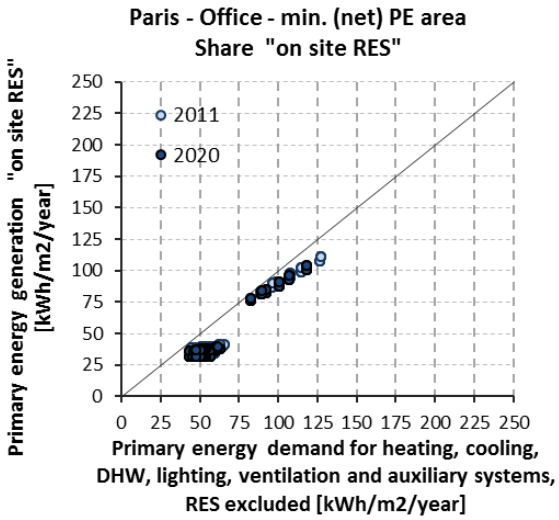

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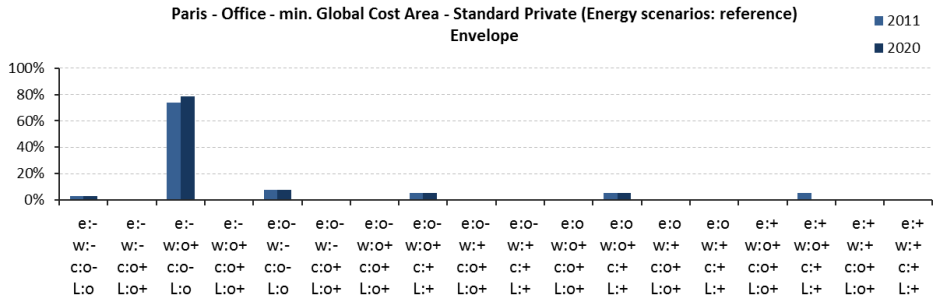
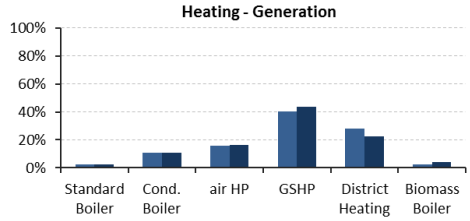
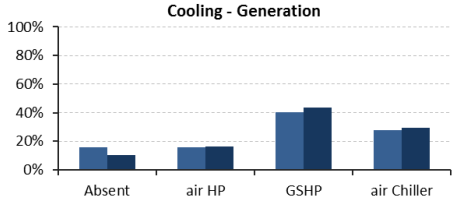
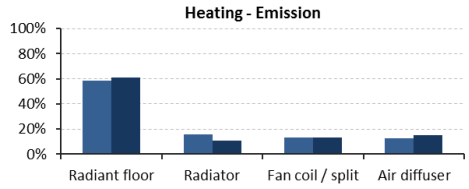
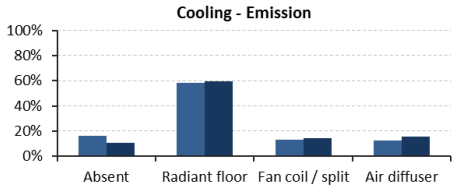
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	80	280	80	260
Range of Global Costs [€/m^2]:	801	921	845	975
Number of Building Variants:	151		151	

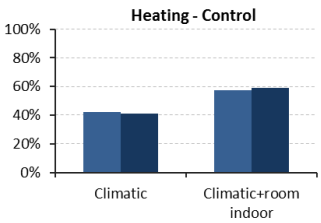


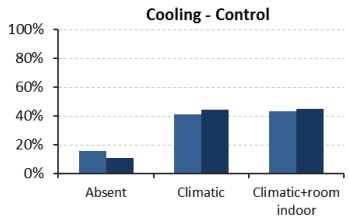


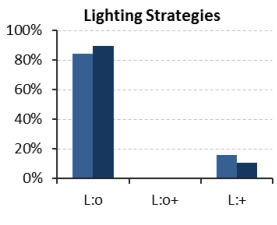


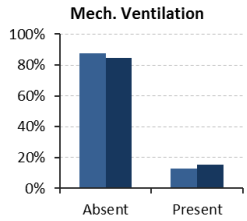


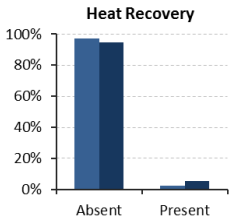


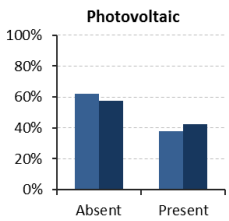


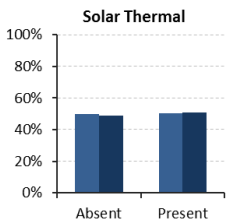


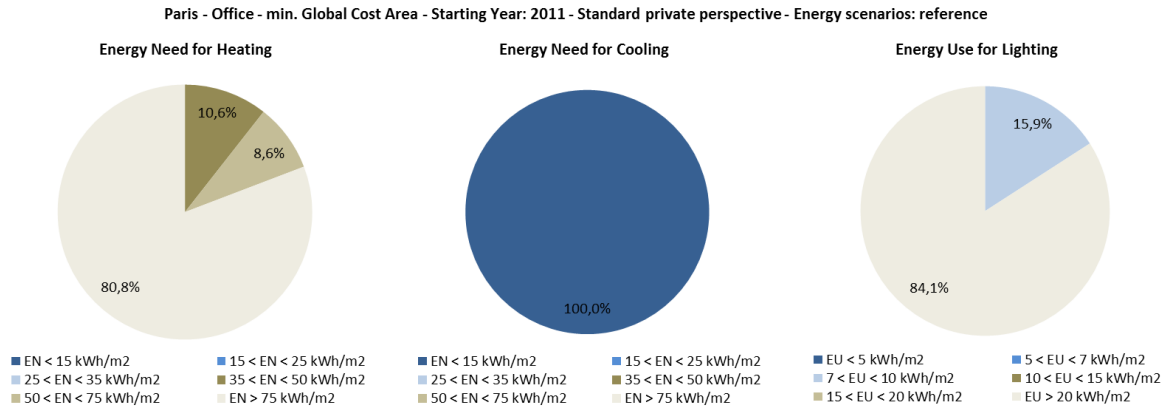


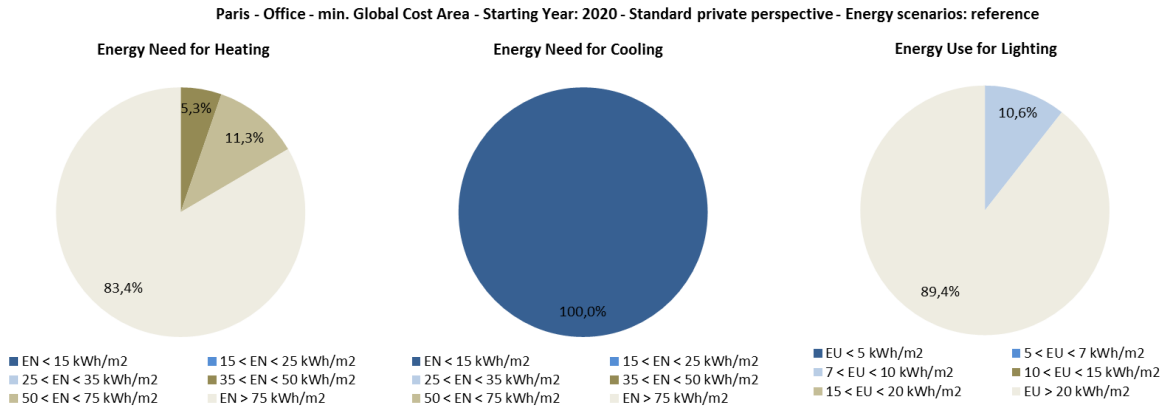


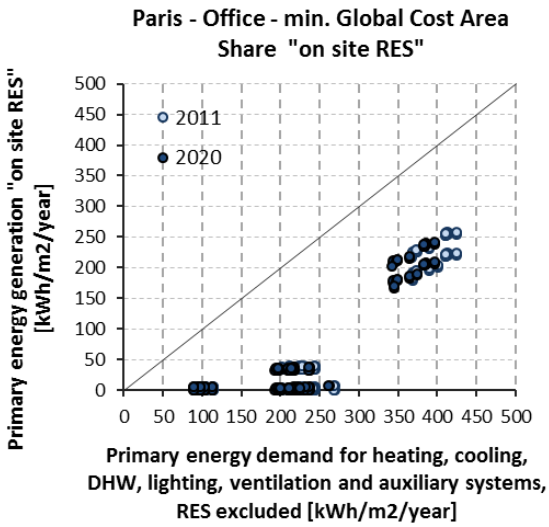












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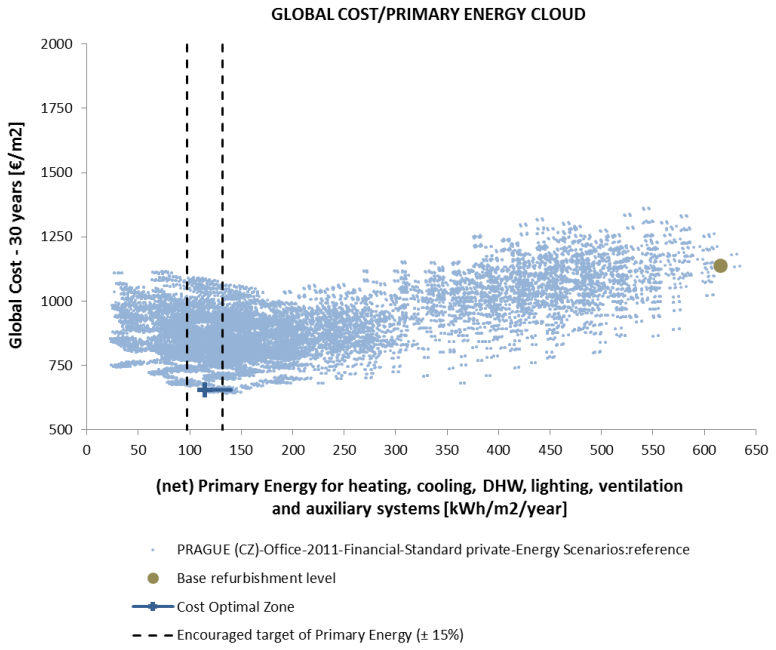
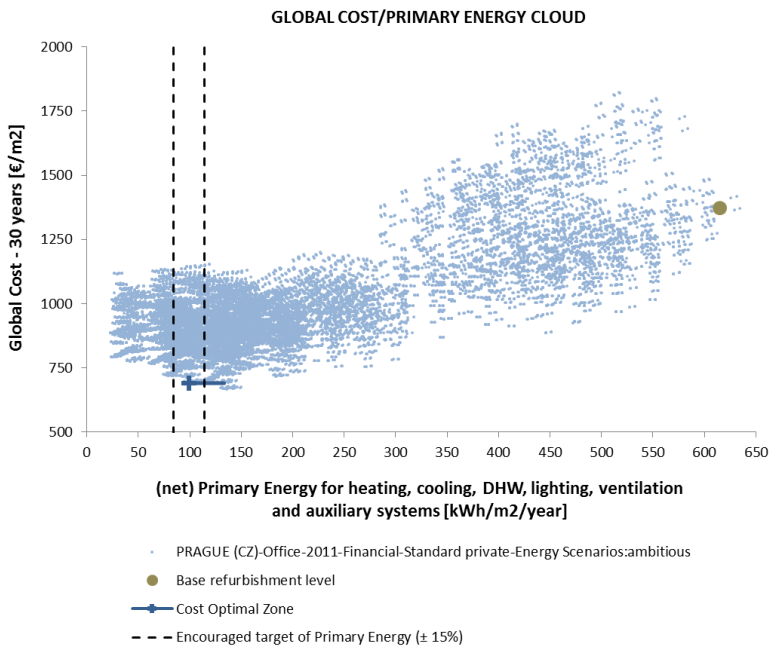
8.1.3.8 Prague





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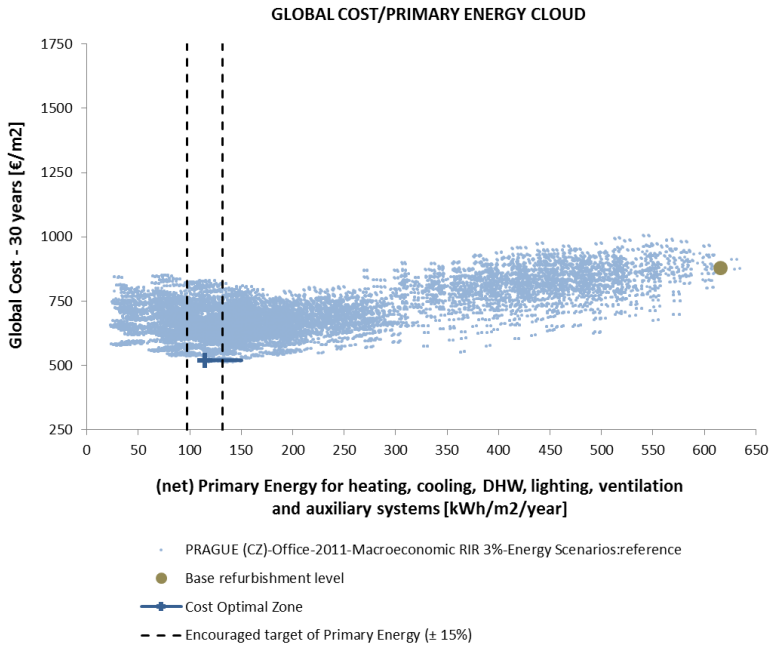

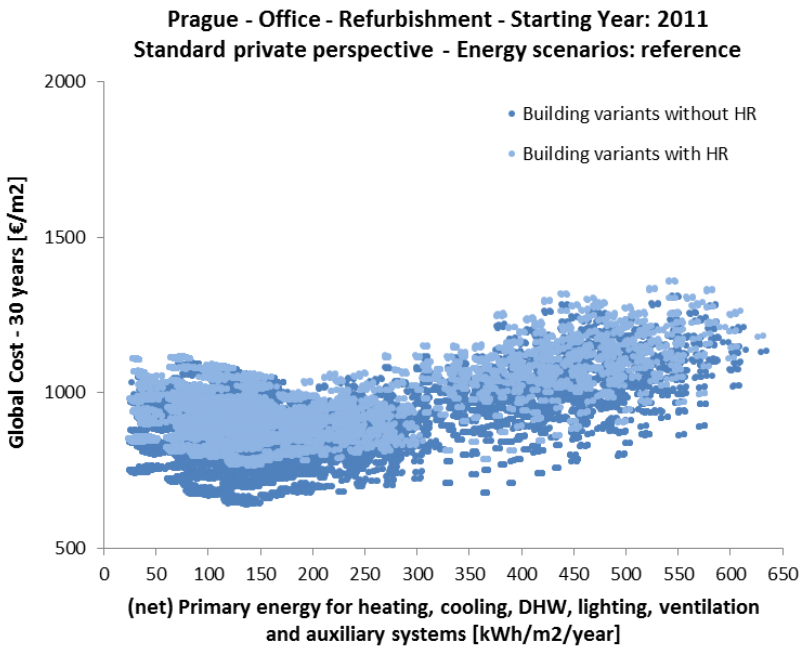

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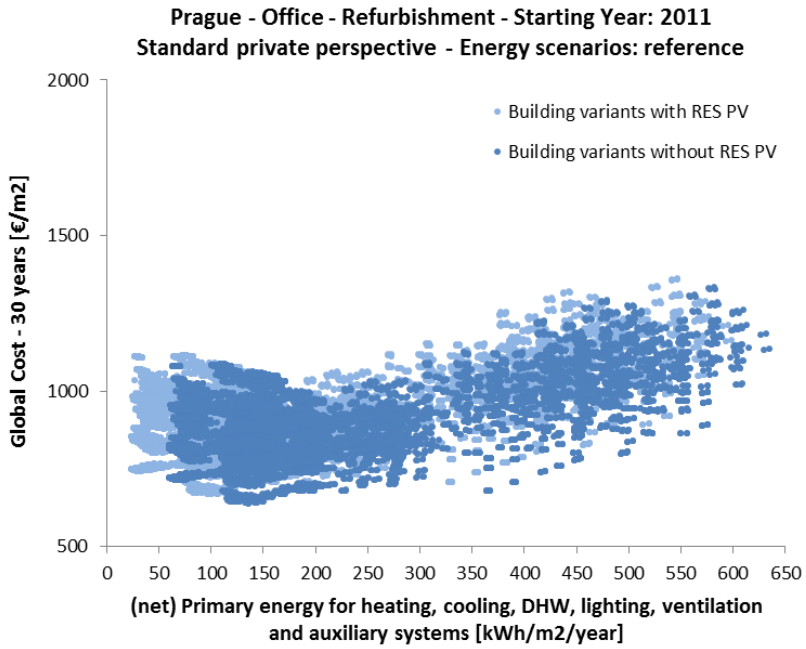

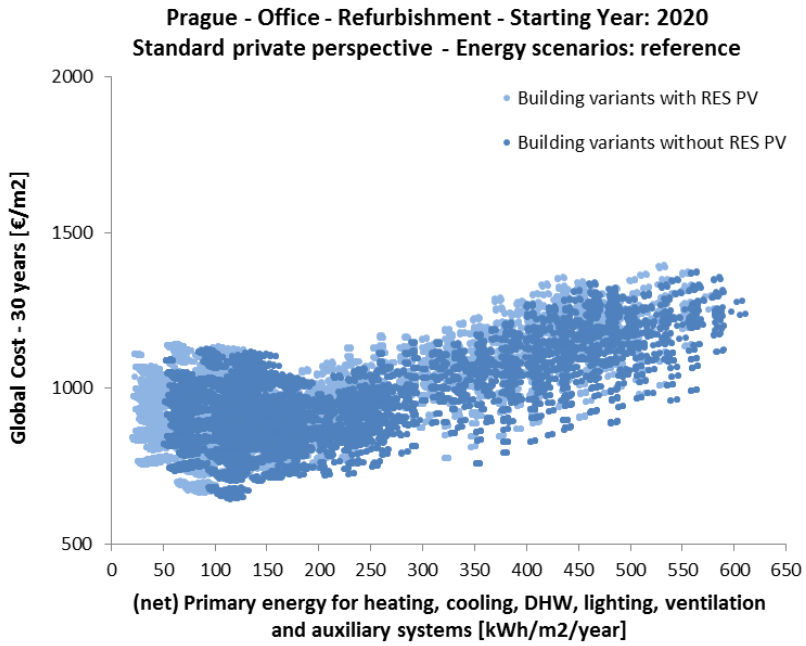

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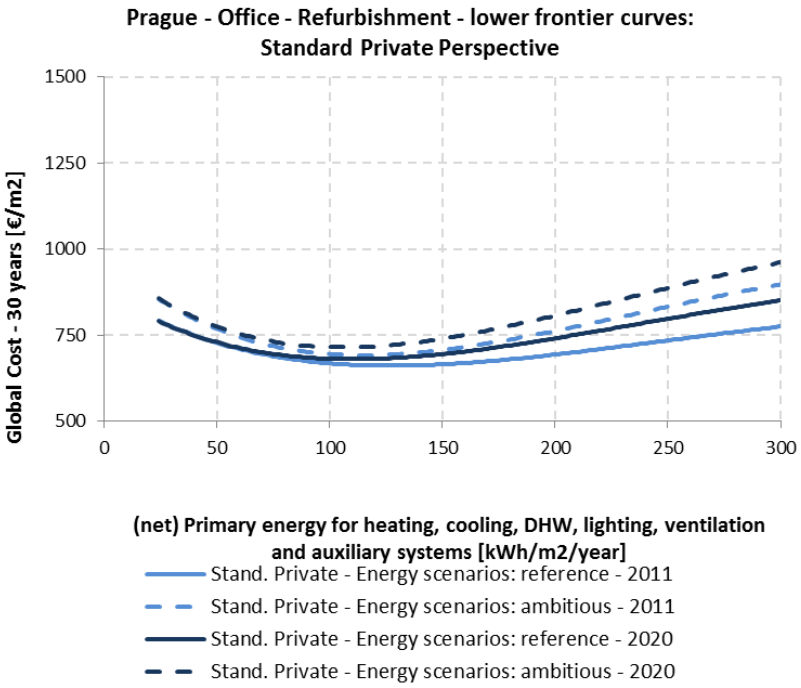

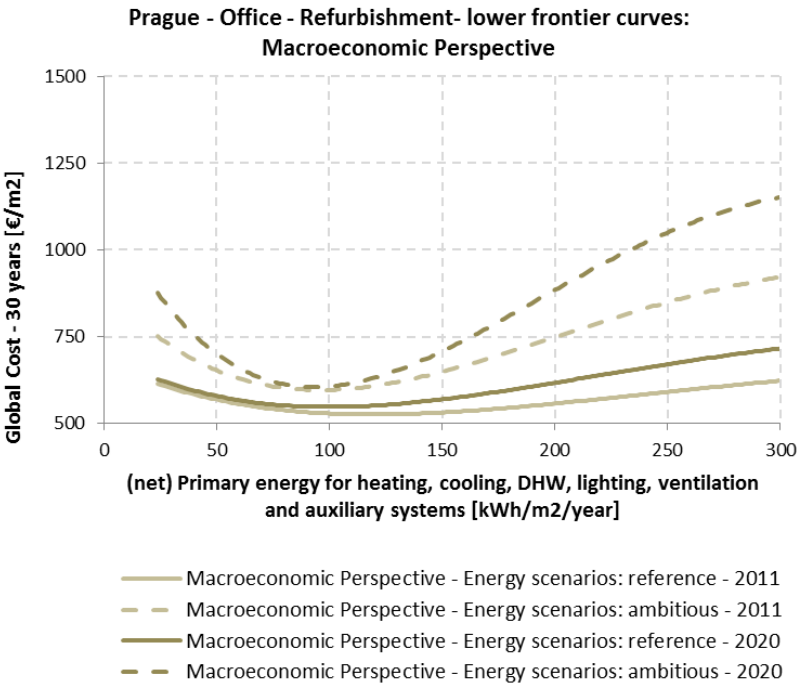

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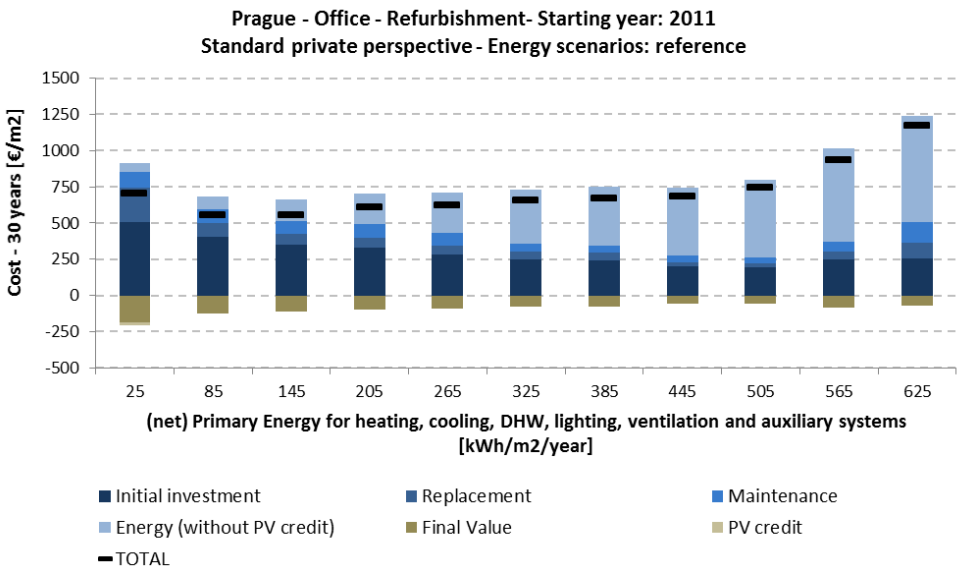

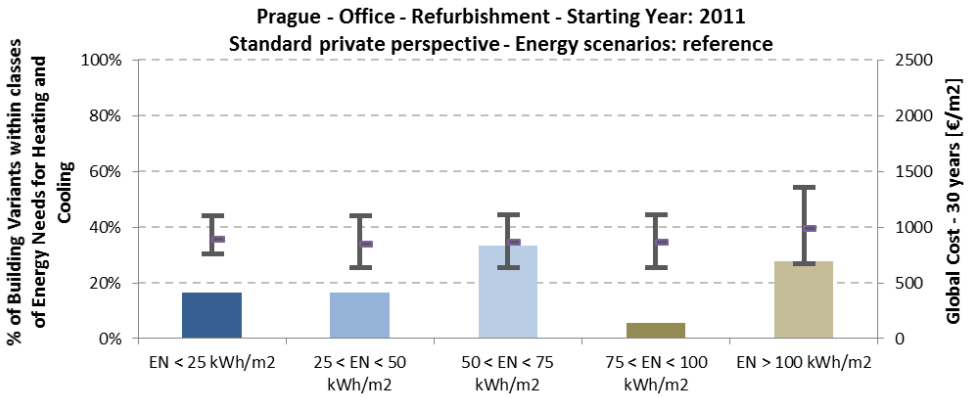

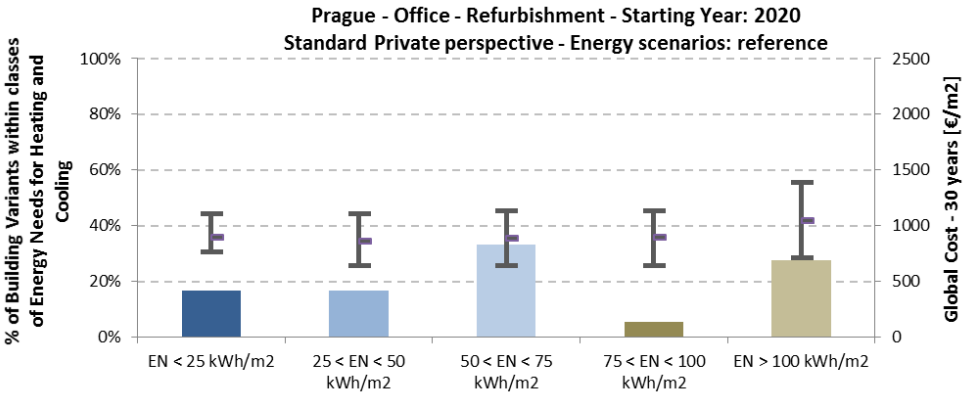

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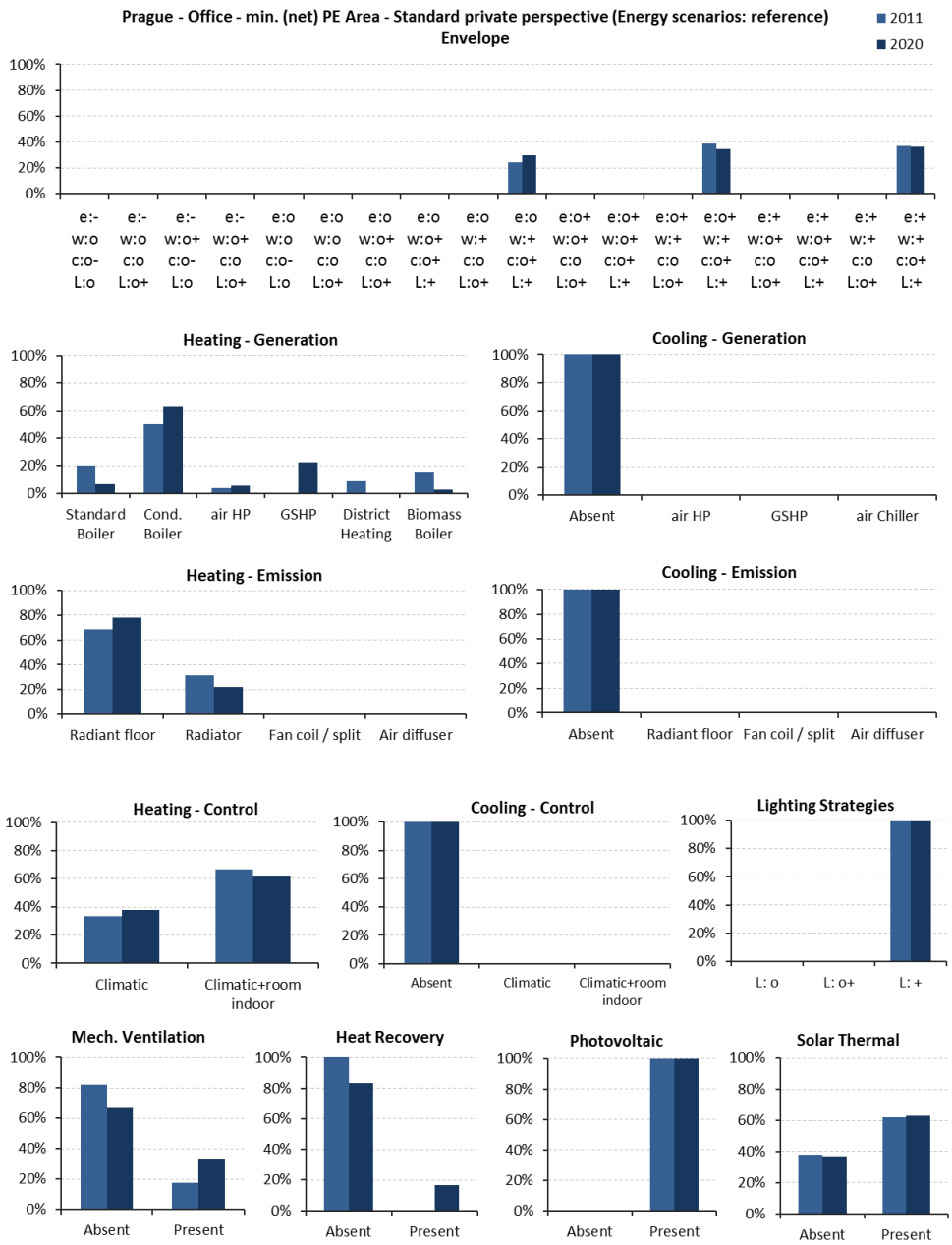
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	23	45	20	40
Range of Global Costs [€/m^2]:	751	826	759	854
Number of Building Variants:	216		216	



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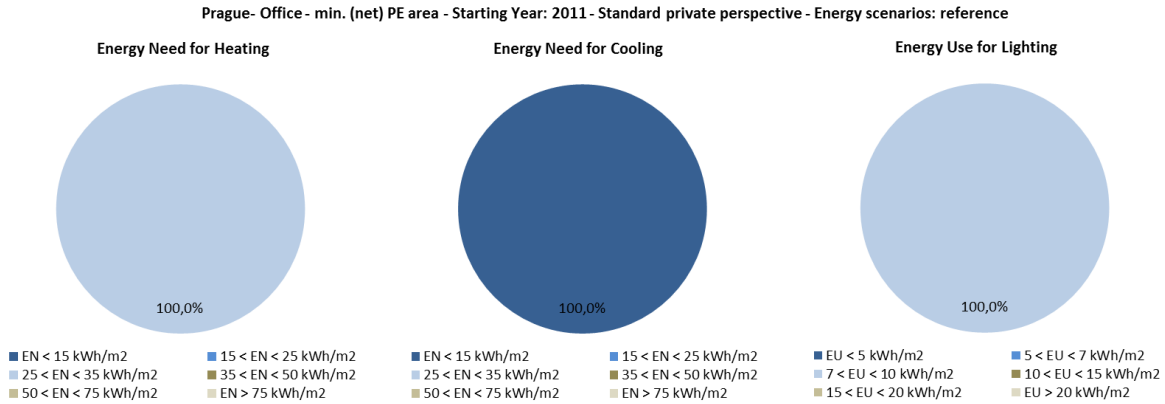

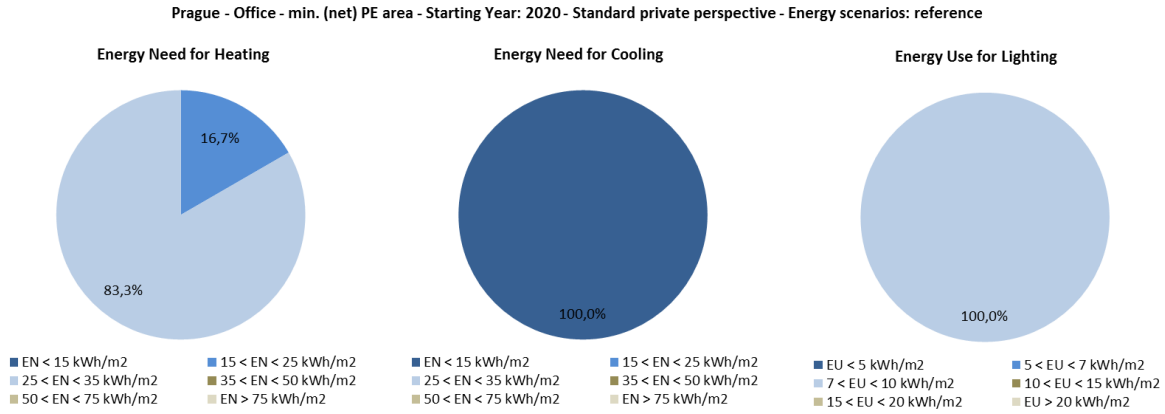

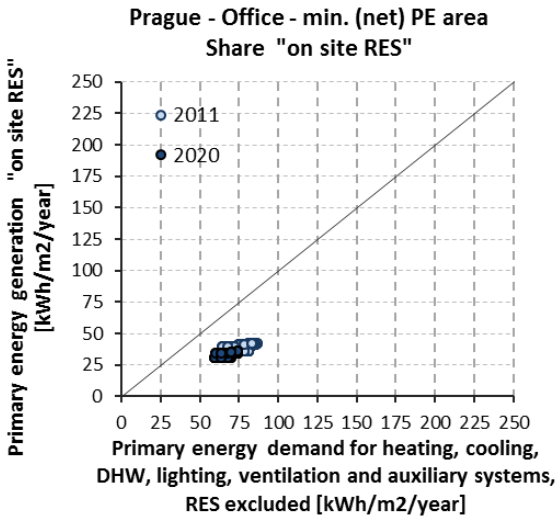

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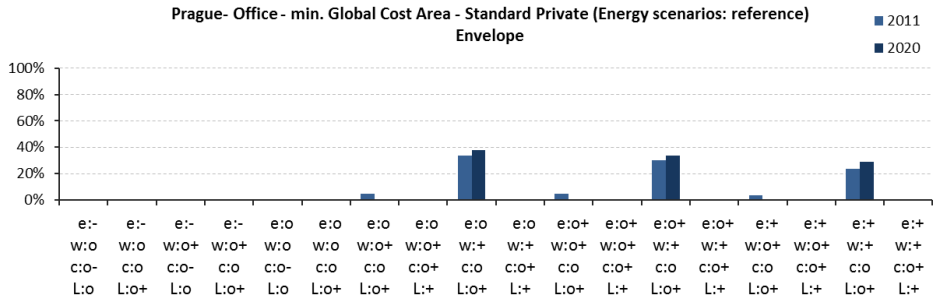
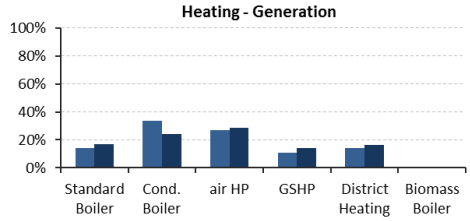
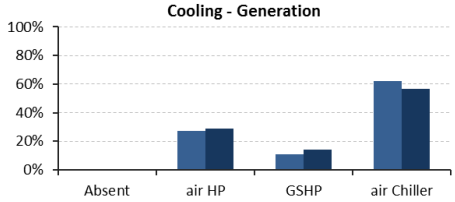
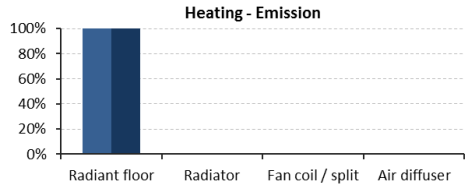
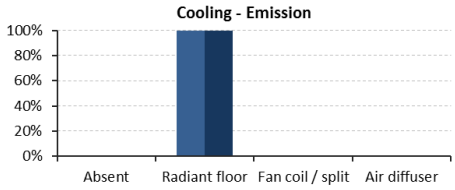
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	70	200	50	180
Range of Global Costs [€/m^2]:	641	679	645	685
Number of Building Variants:	167		167	

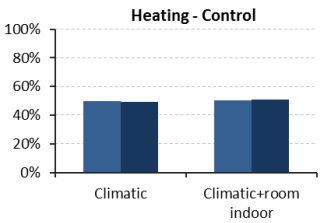


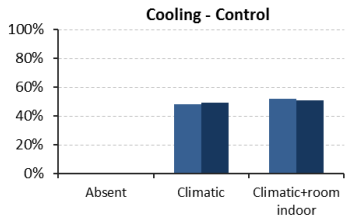


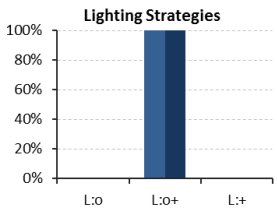


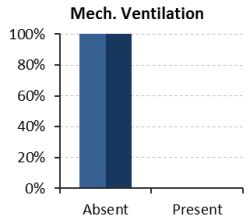


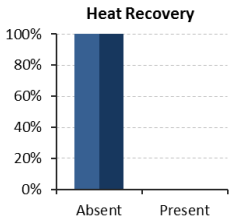


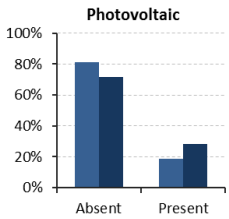


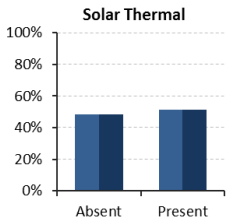












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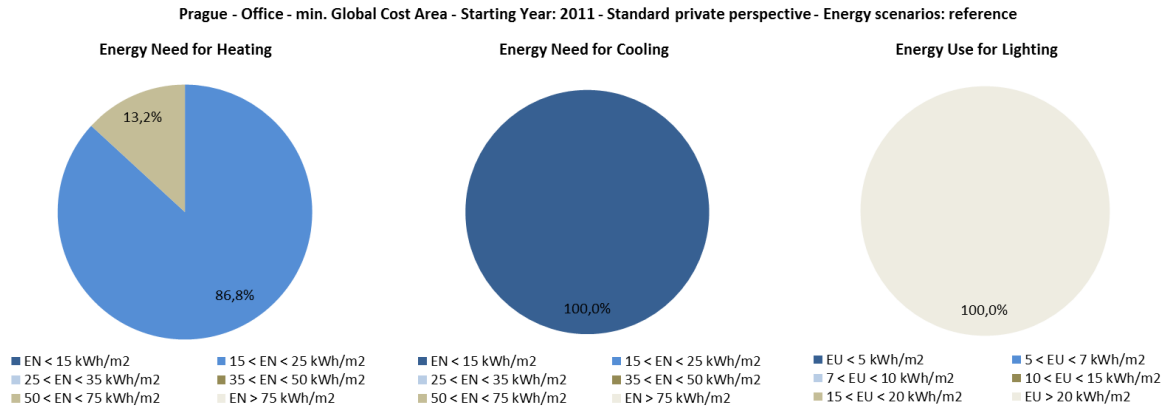

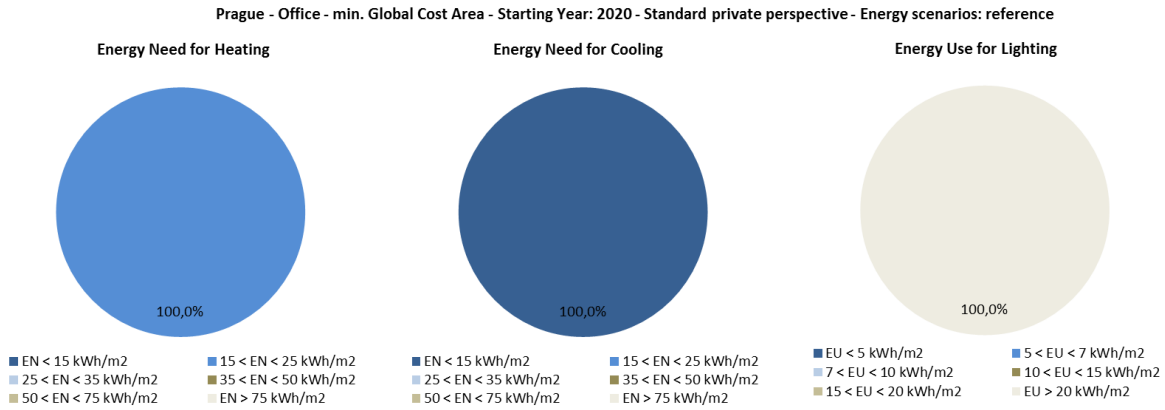

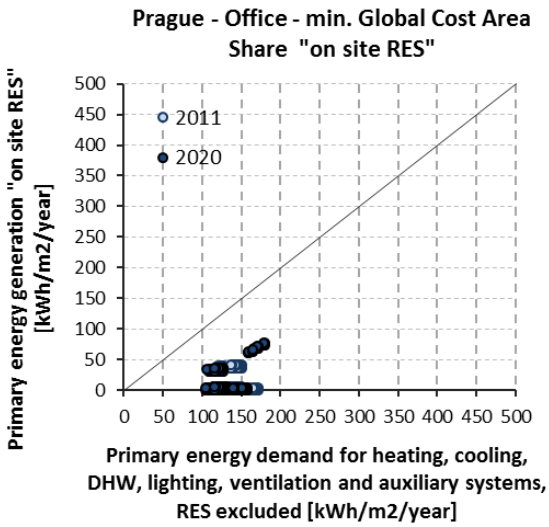

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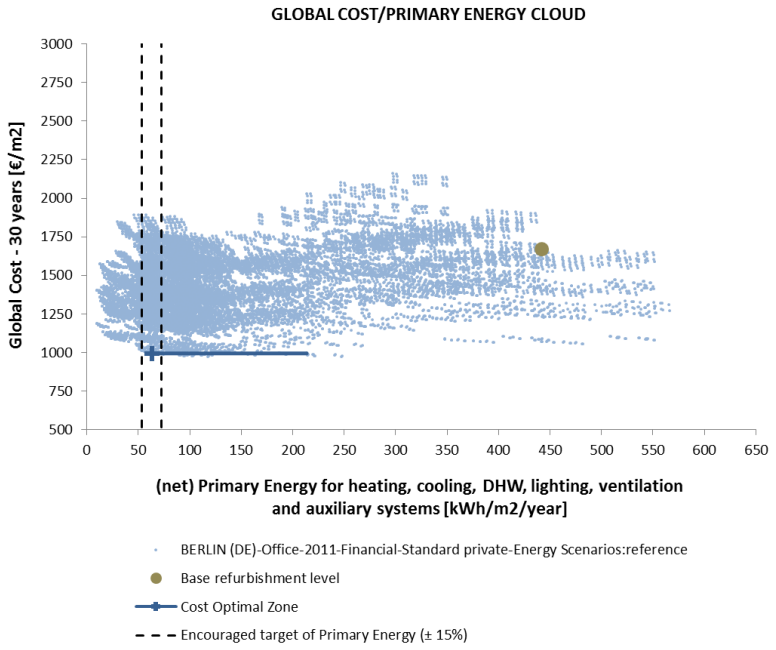
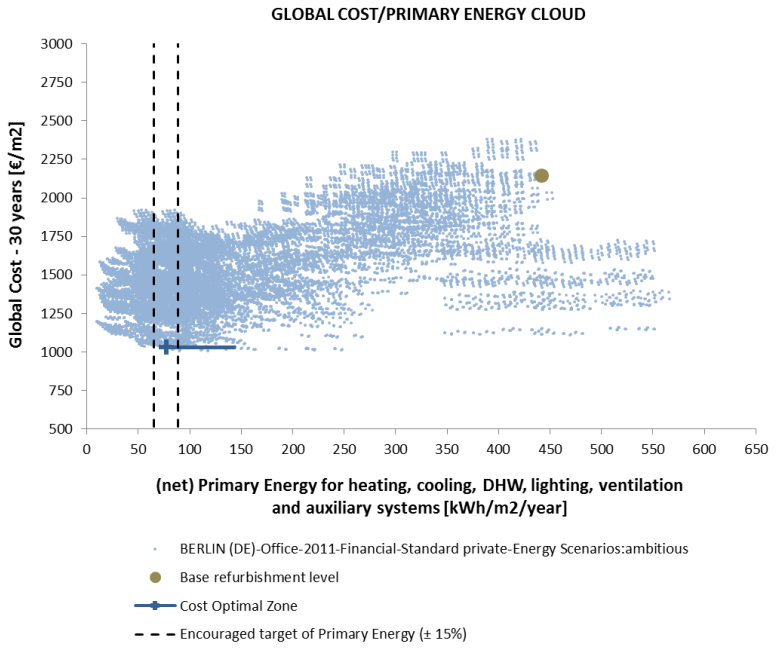
8.1.3.9 Berlin





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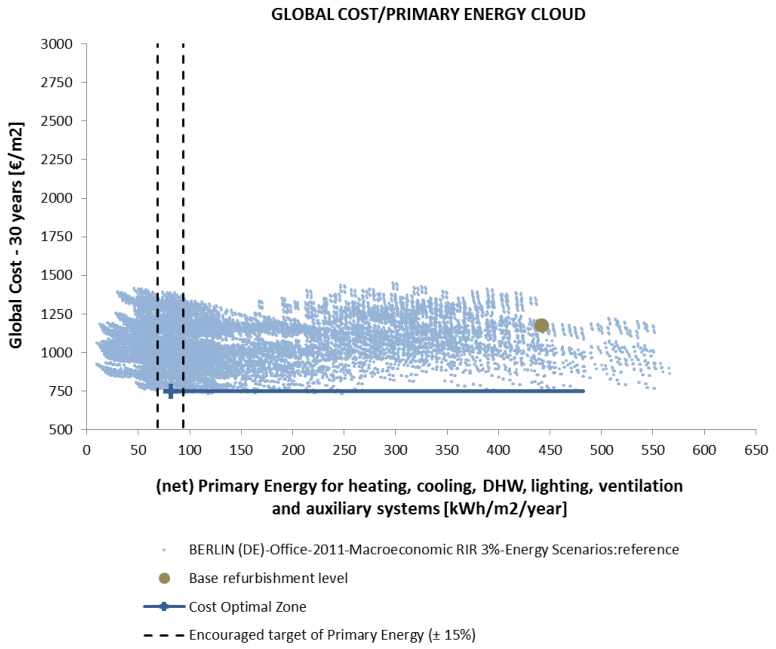

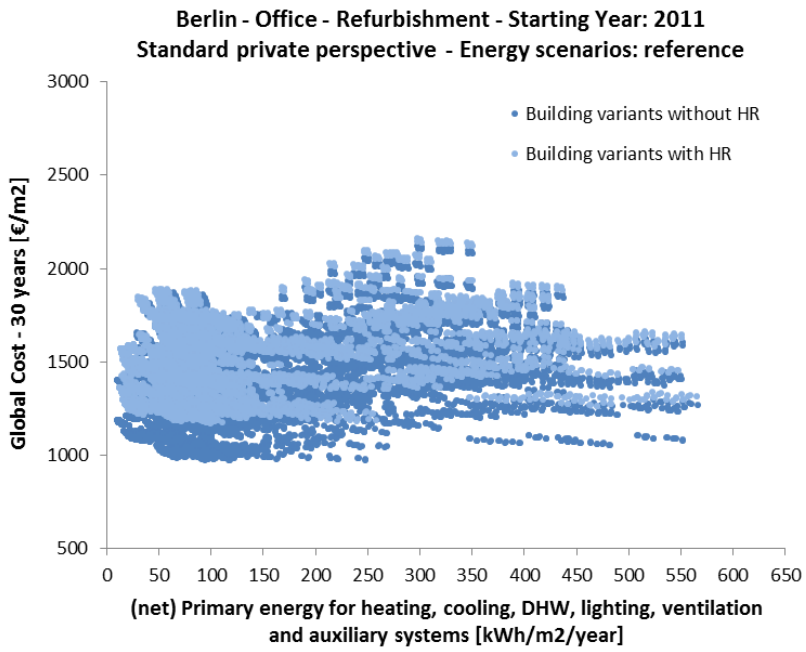

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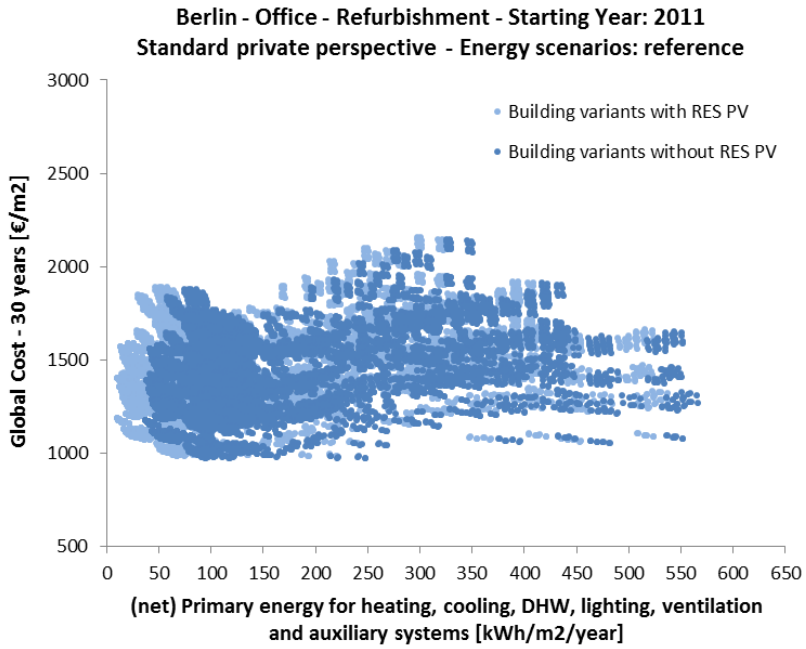

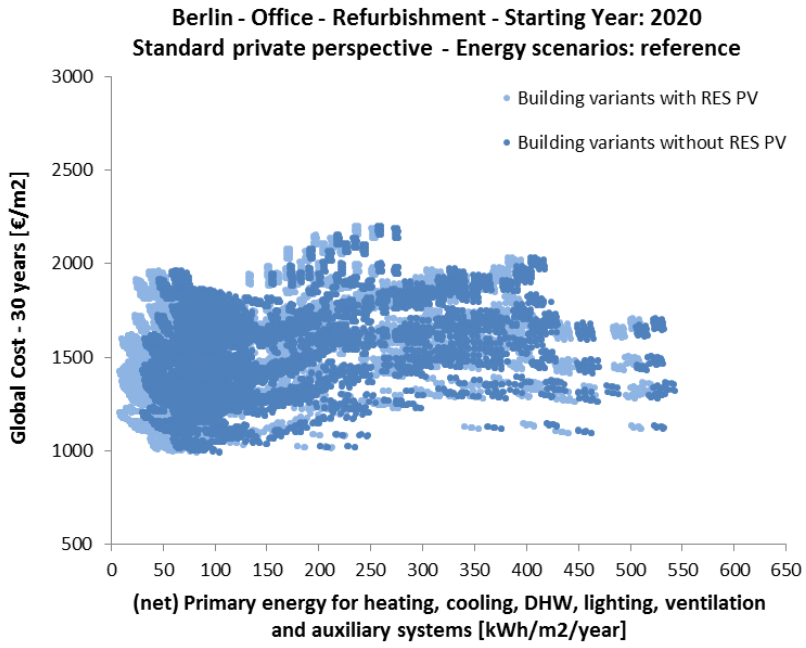

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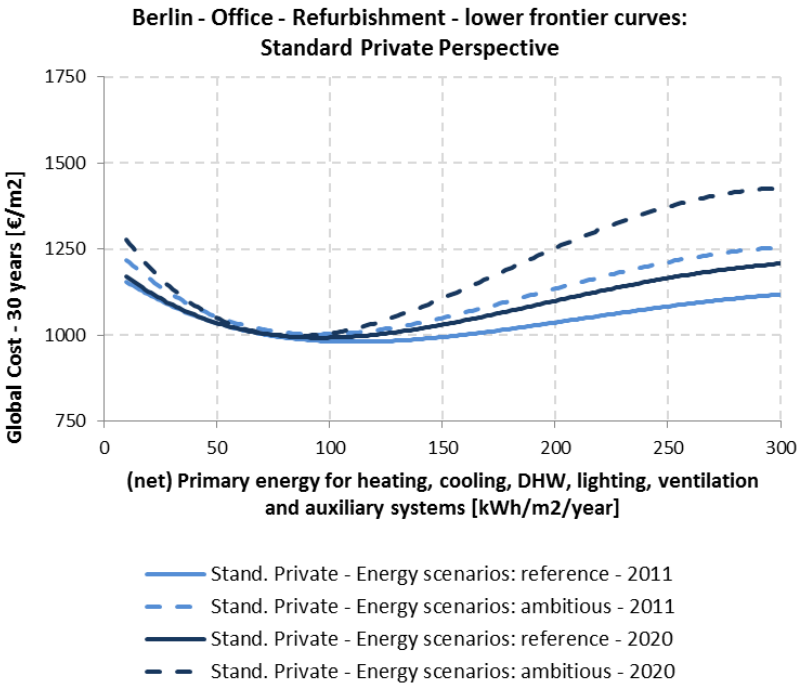

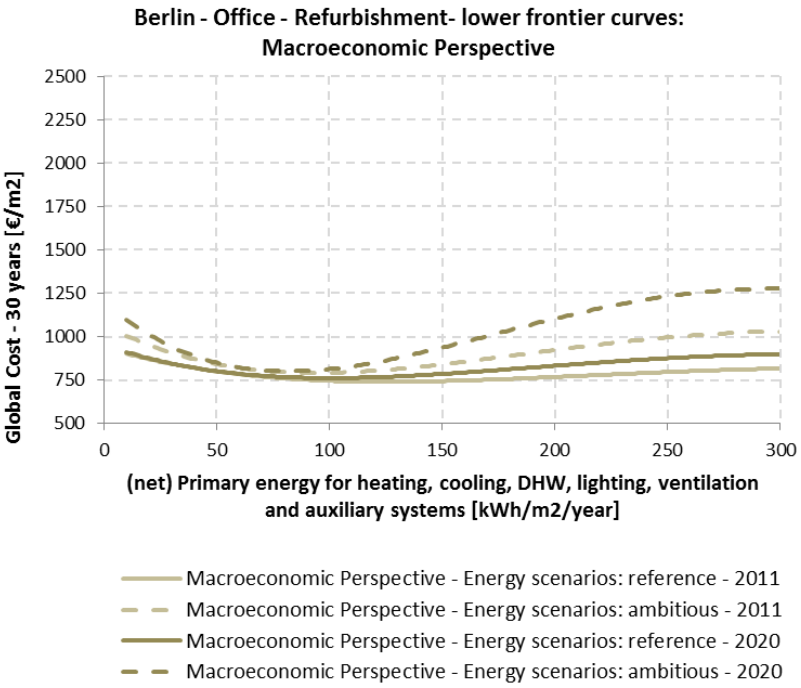

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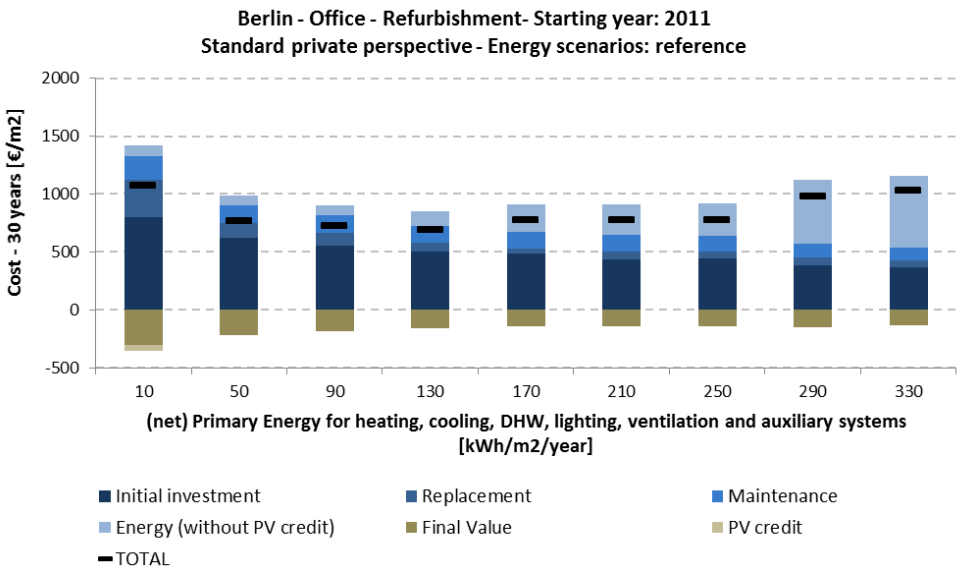

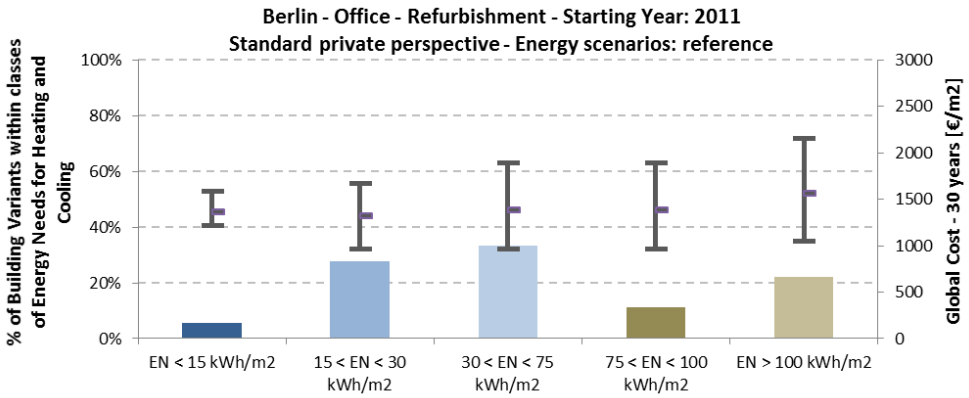

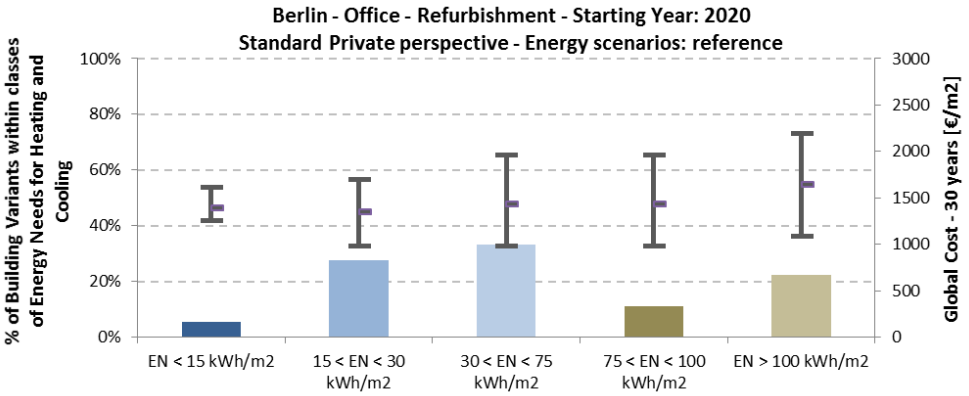

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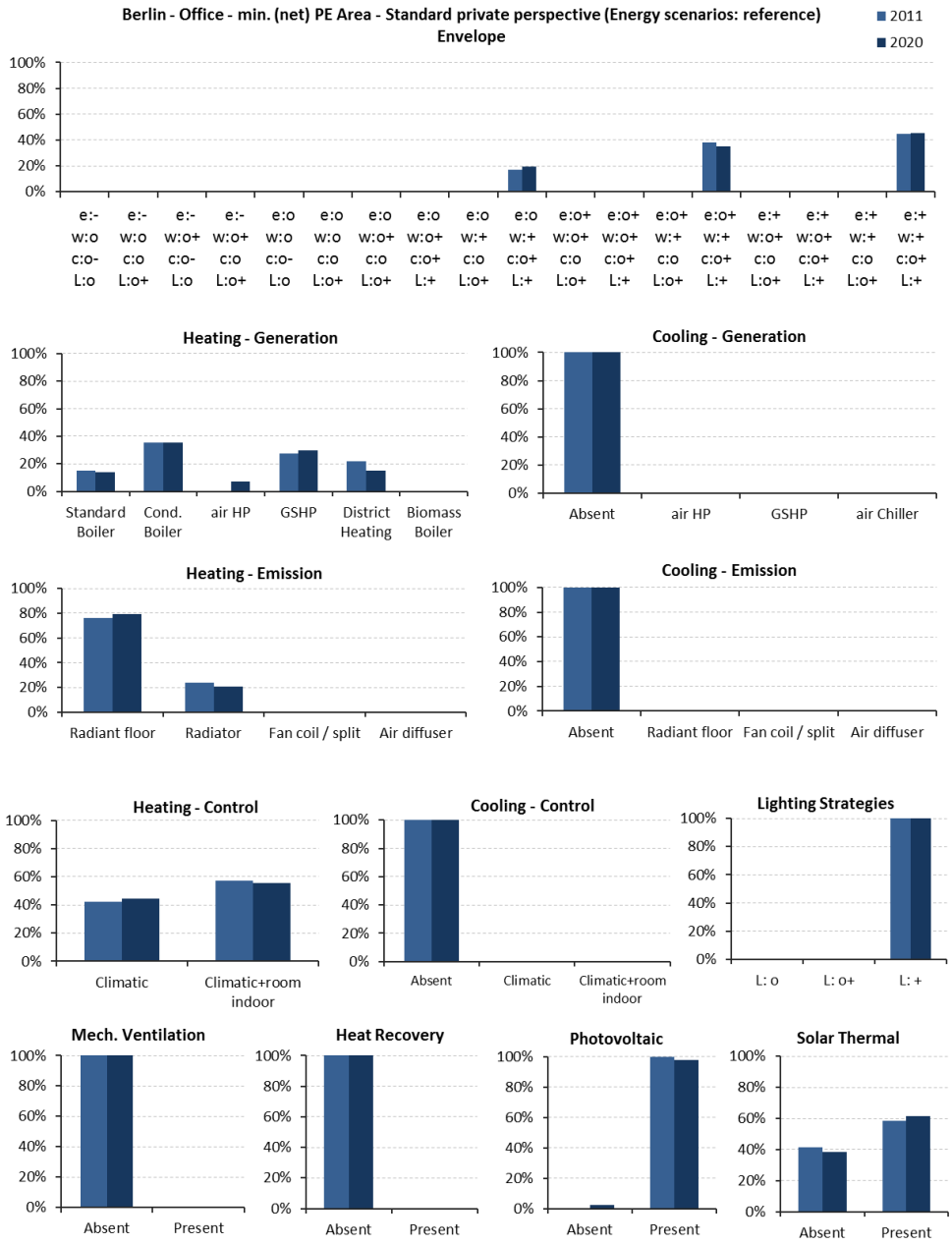
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	10	30	8	30
Range of Global Costs [€/m²]:	1084	1192	1104	1209
Number of Building Variants:	176		176	



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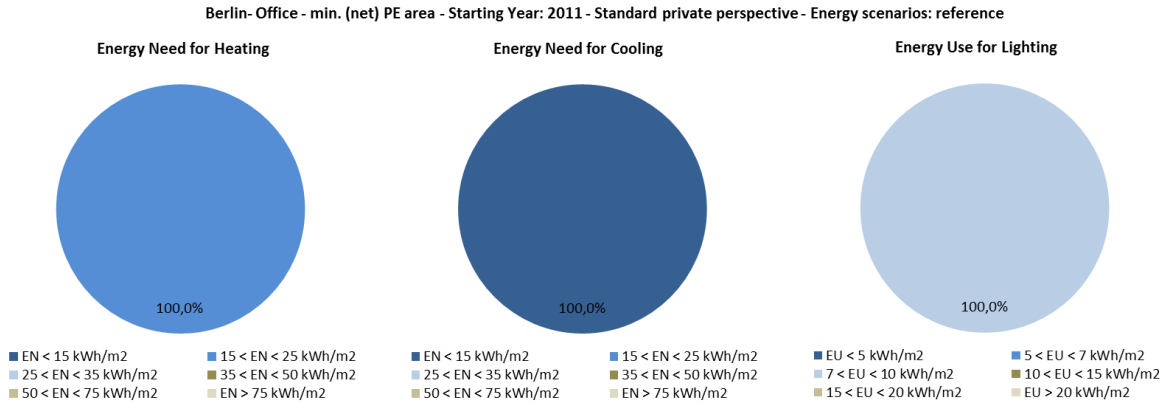

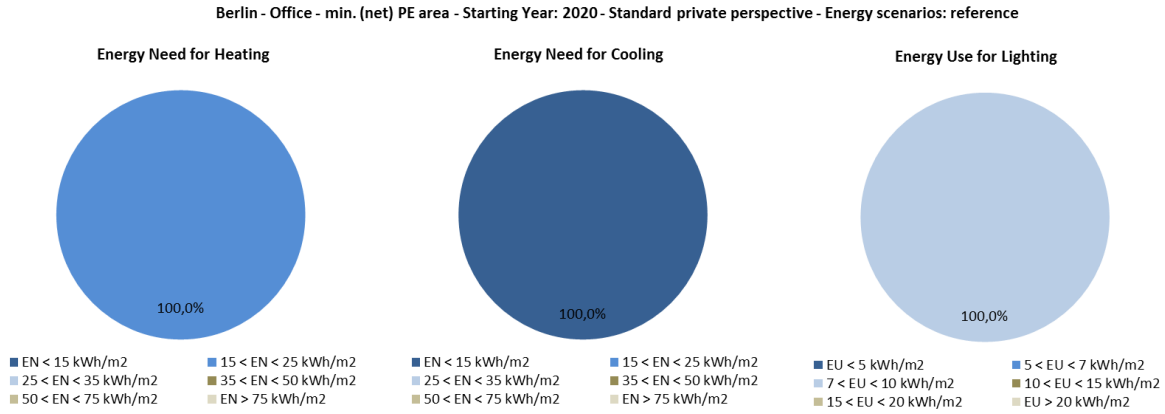

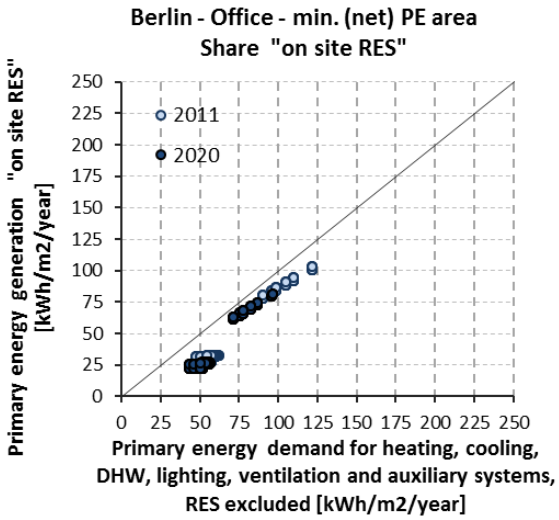

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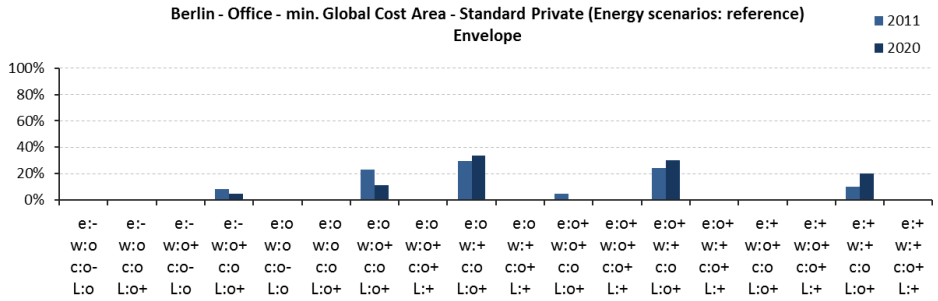
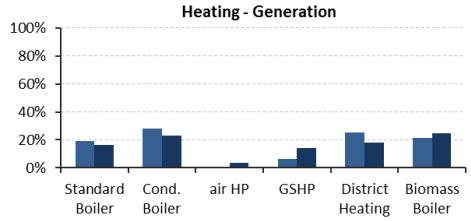
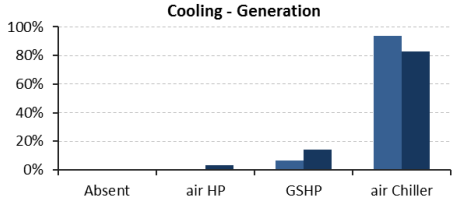
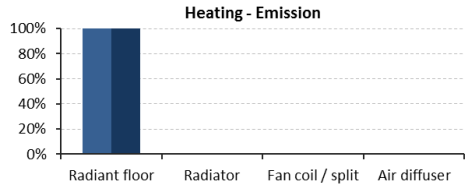
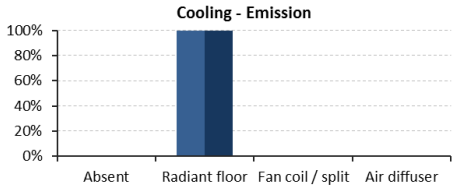
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	20	210	20	210
Range of Global Costs [€/m^2]:	974	1023	991	1052
Number of Building Variants:	266		266	

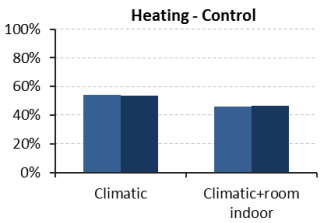


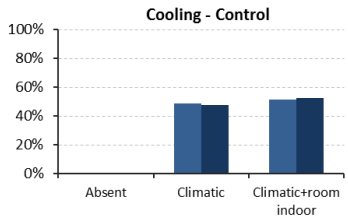


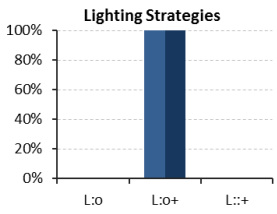


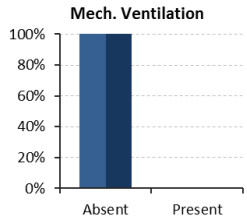


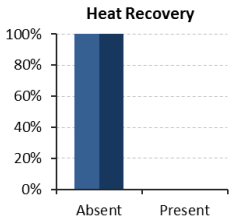


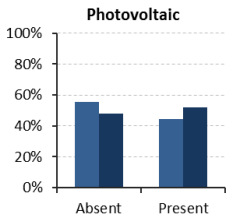


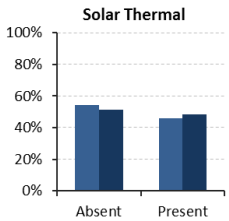


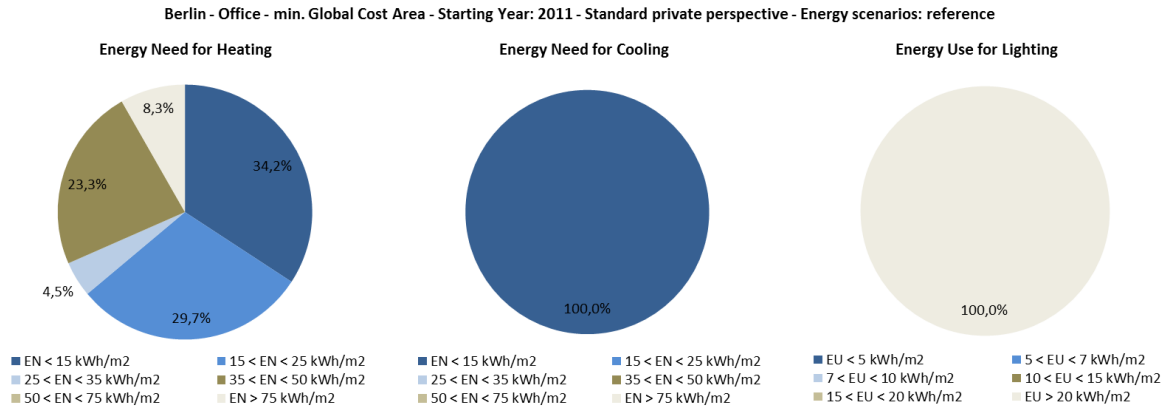


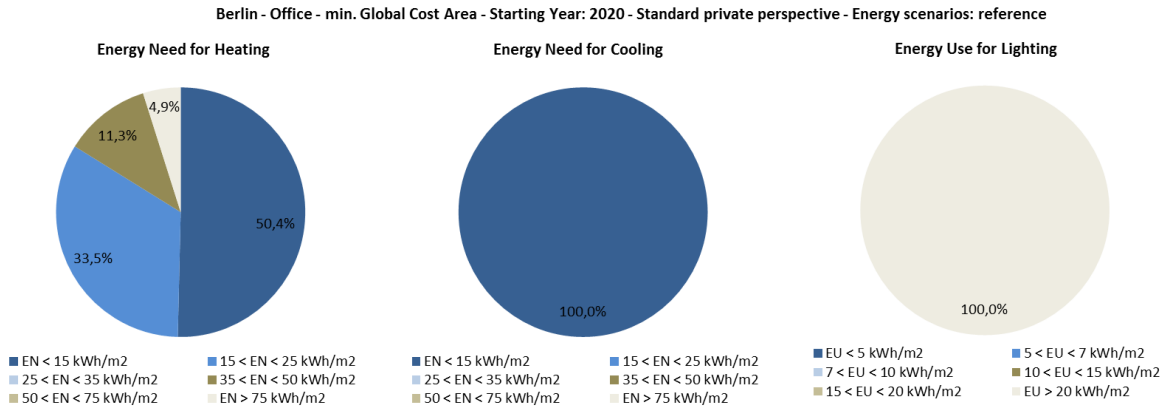


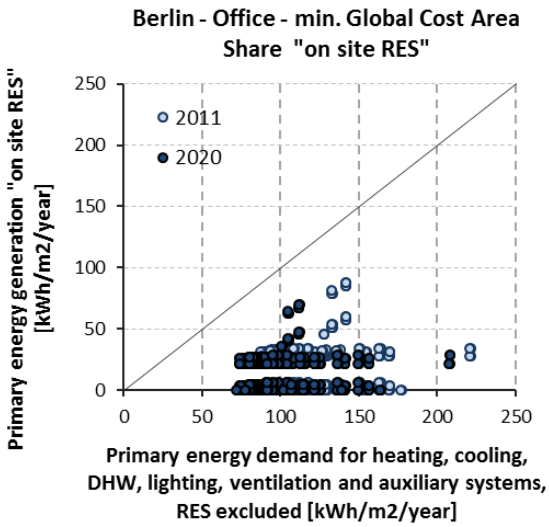












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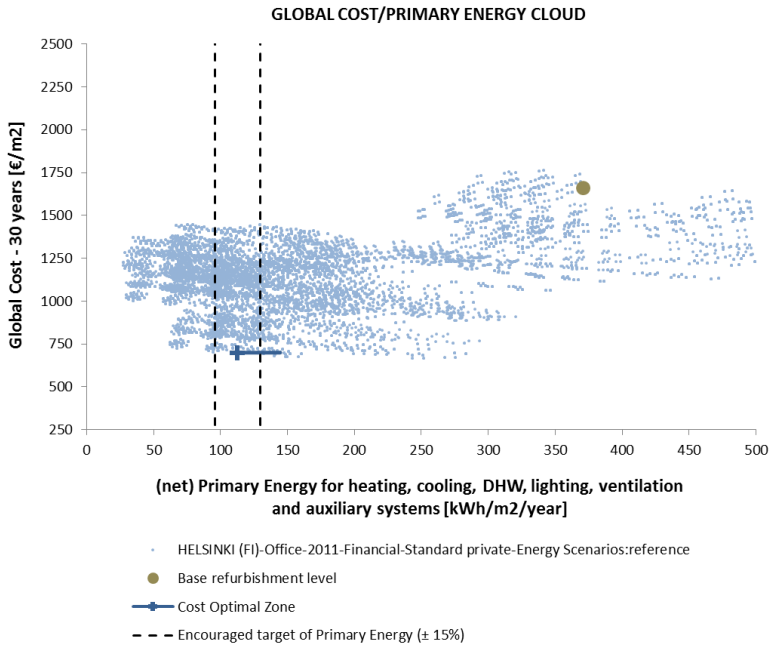
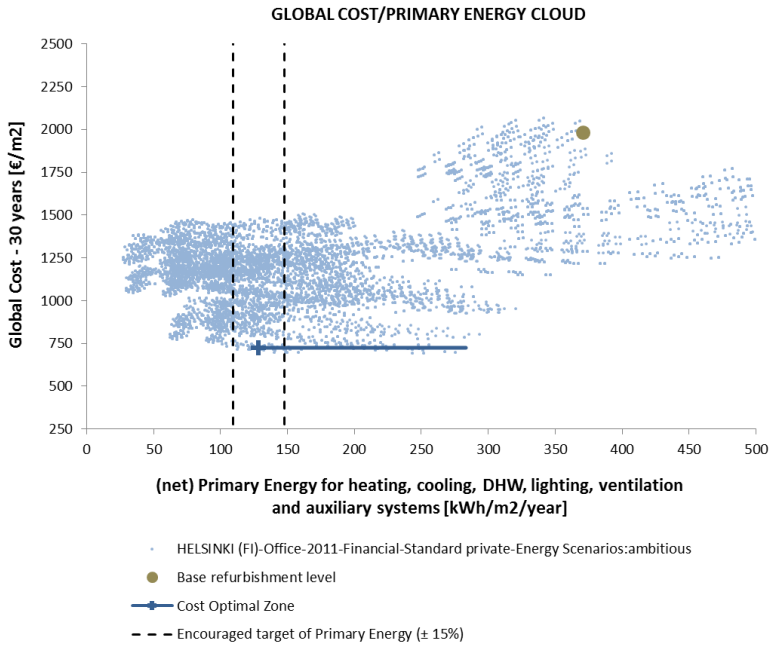
8.1.3.10 Helsinki





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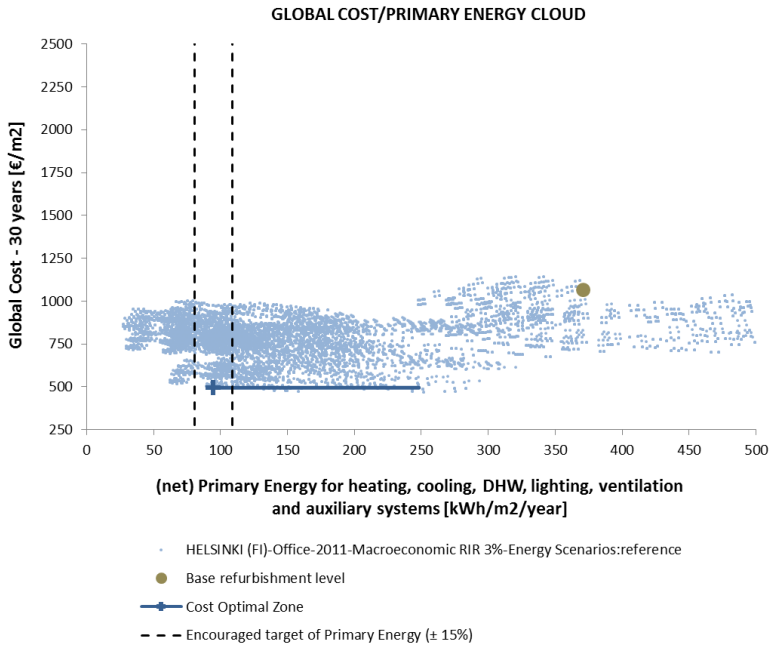

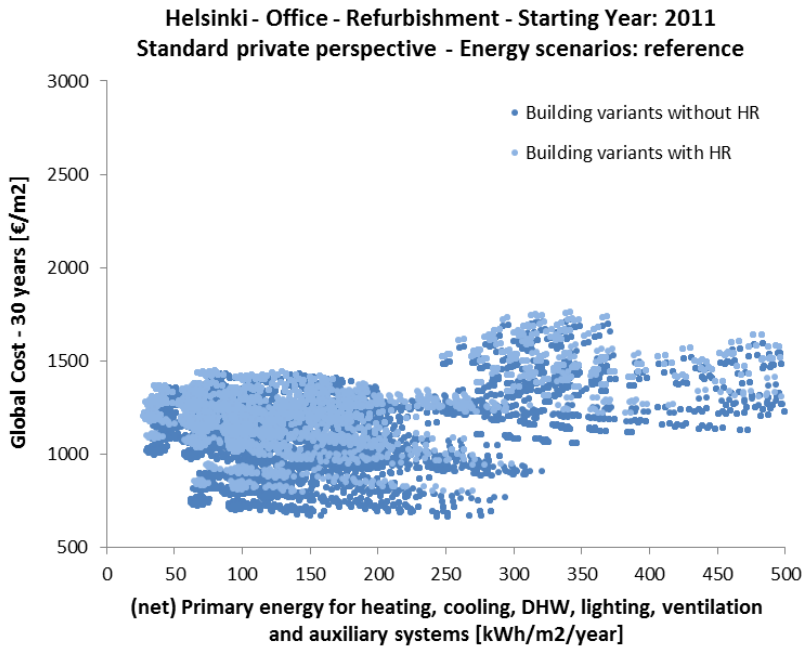

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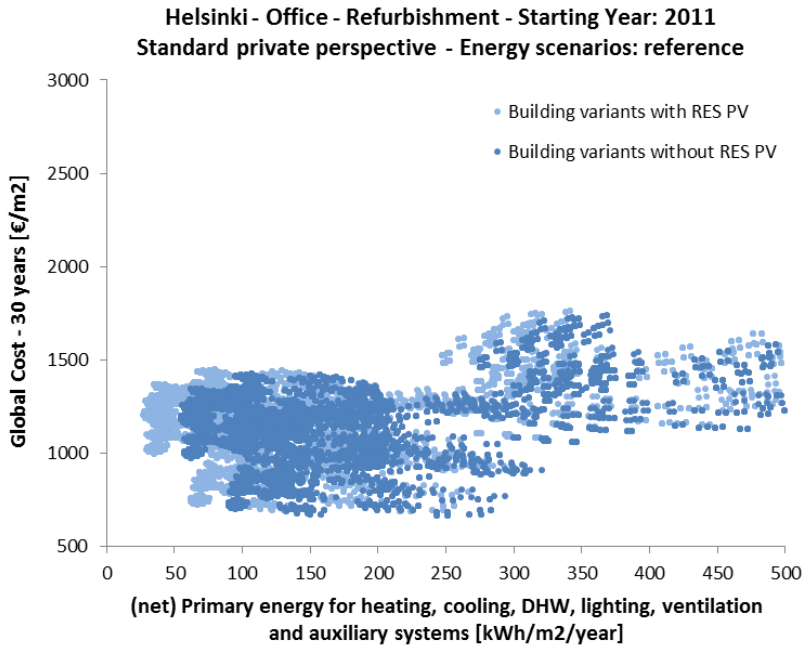

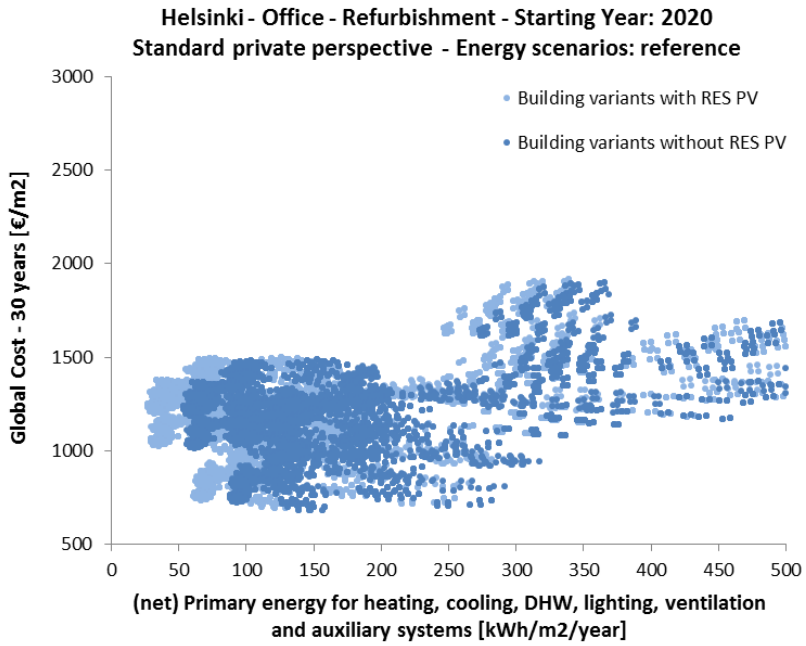

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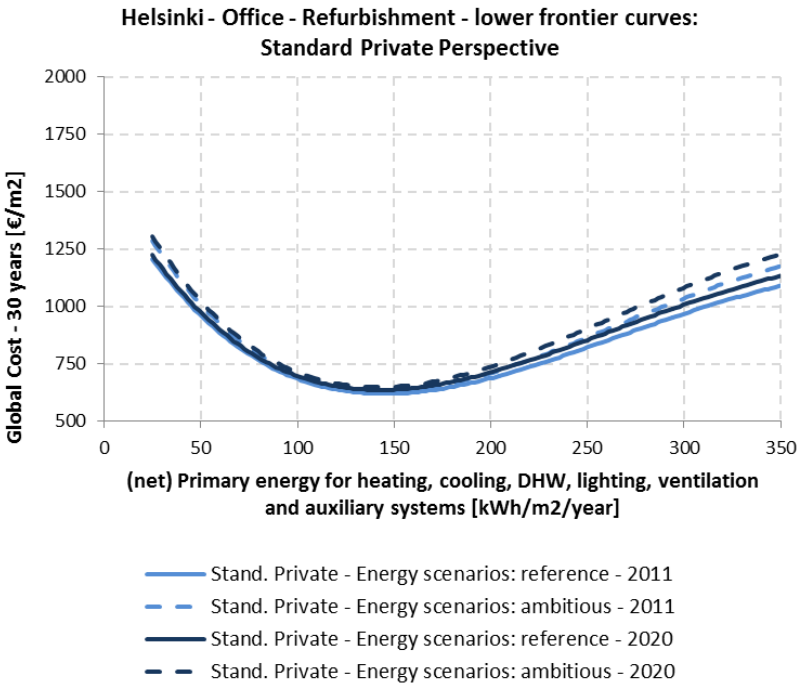

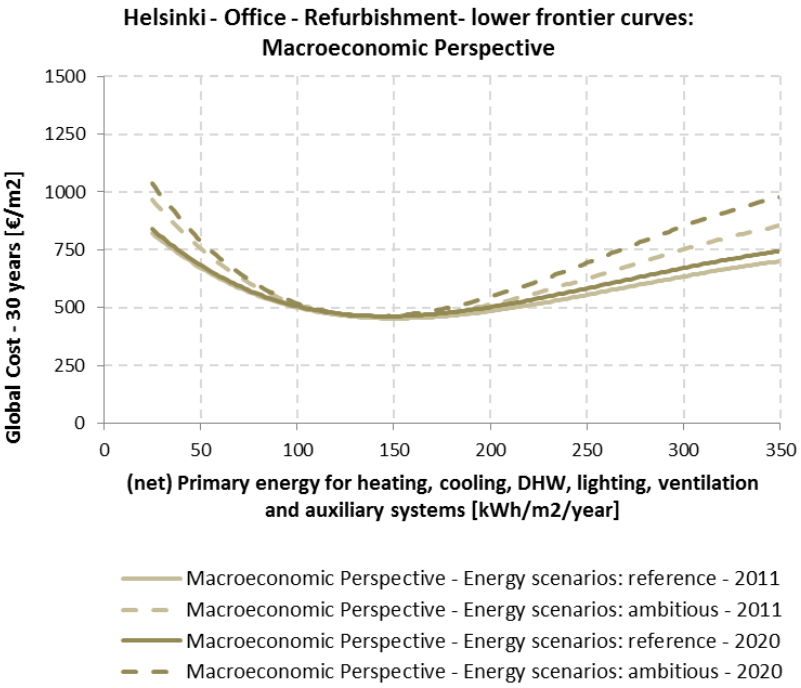

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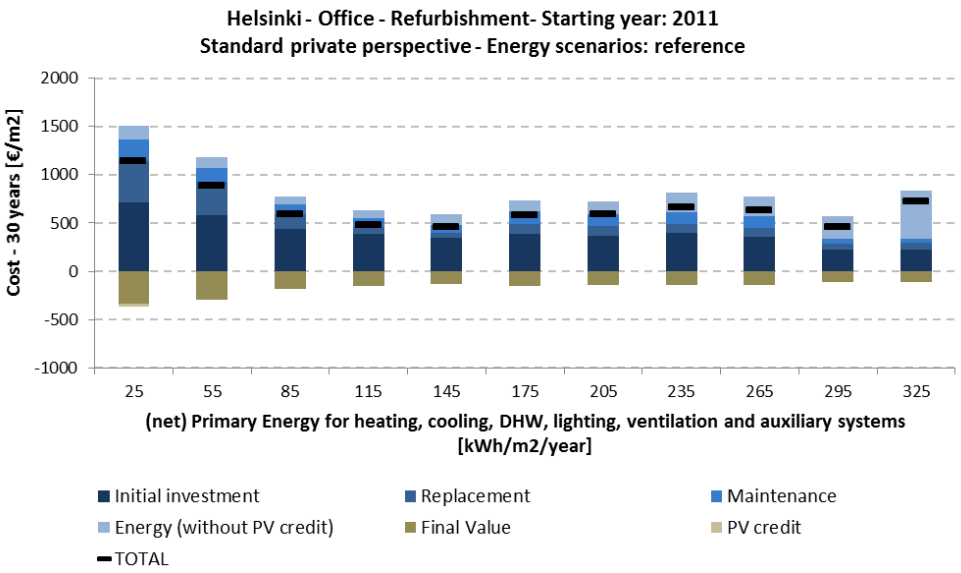

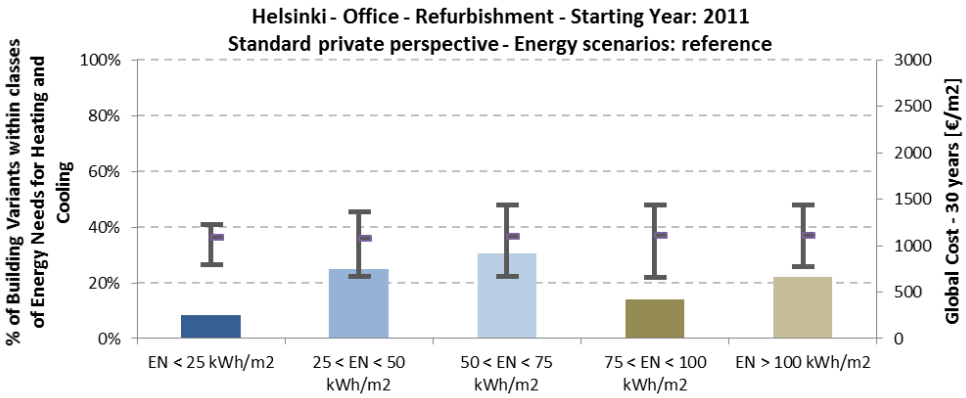

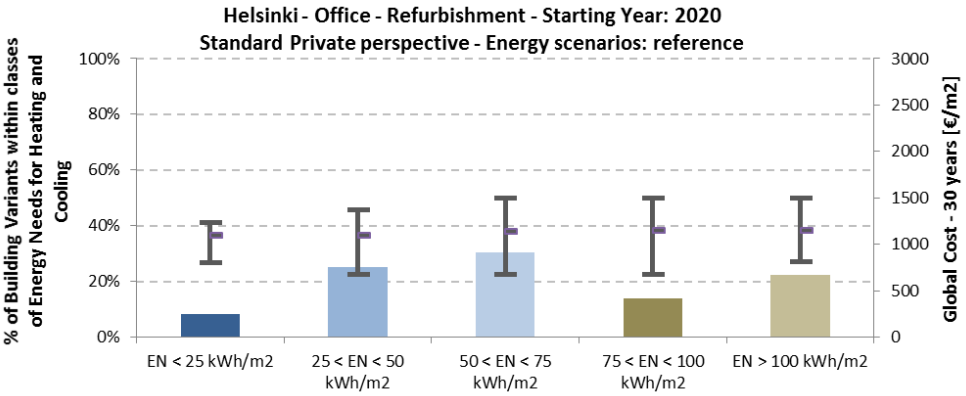

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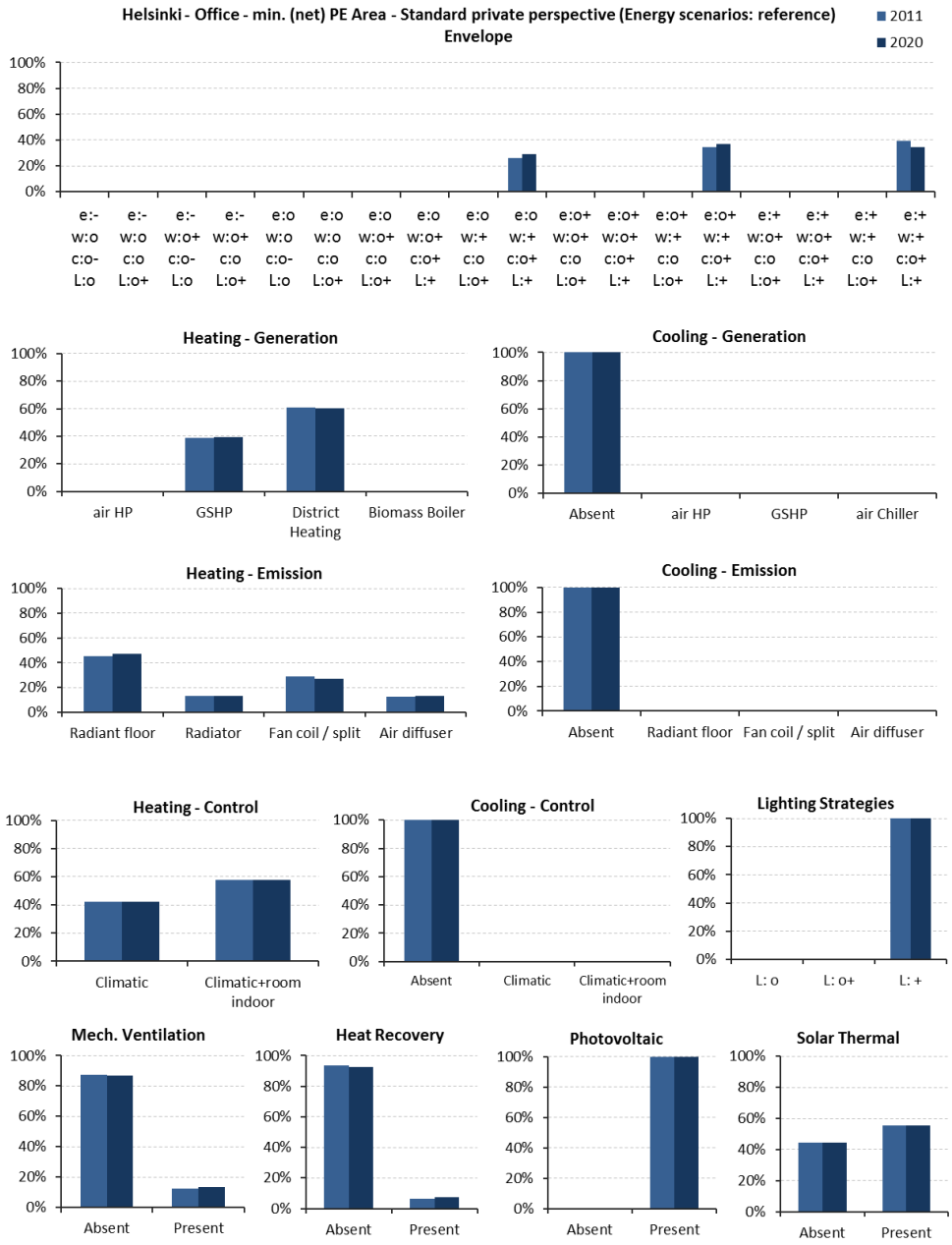
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	27	45	27	45
Range of Global Costs [€/m^2]:	1020	1173	1047	1166
Number of Building Variants:	185		185	



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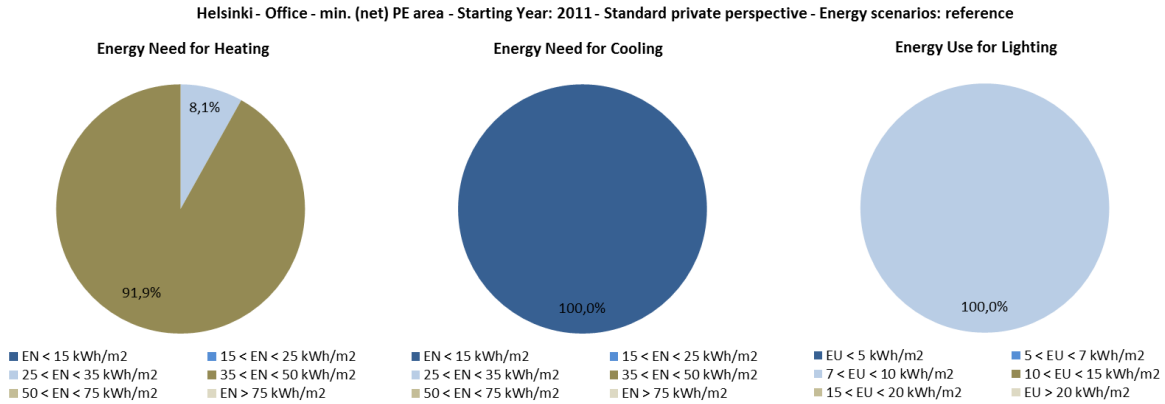

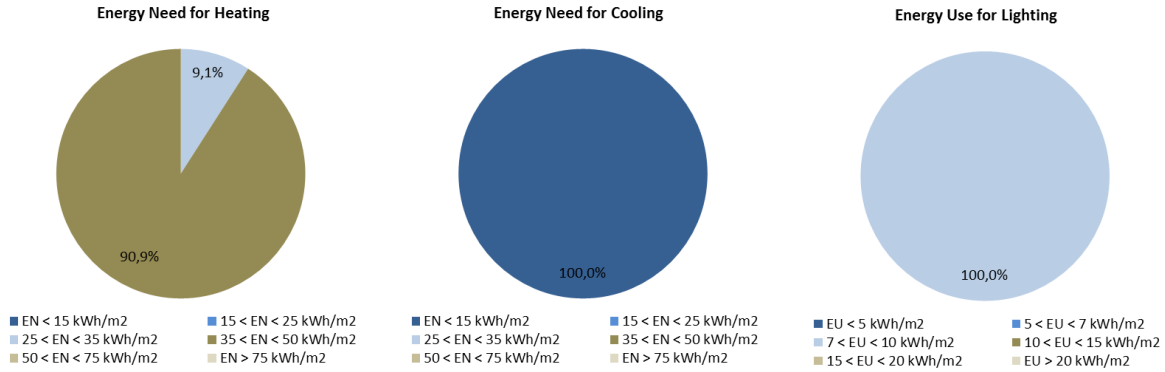

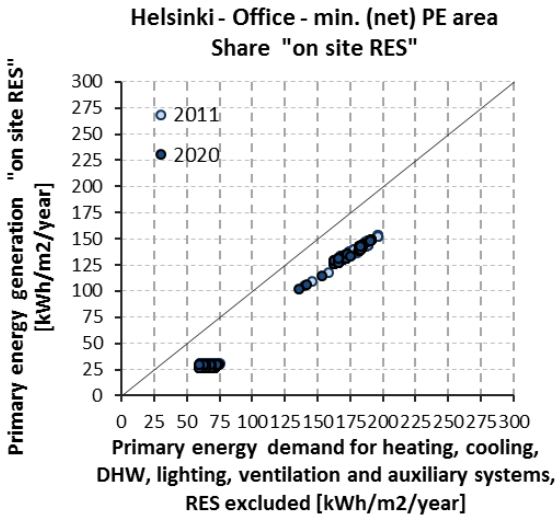

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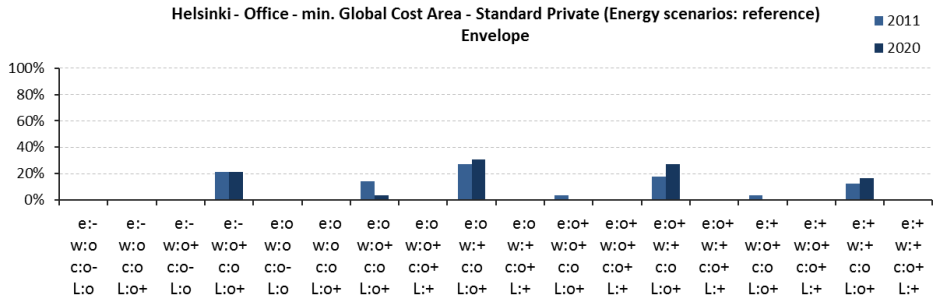
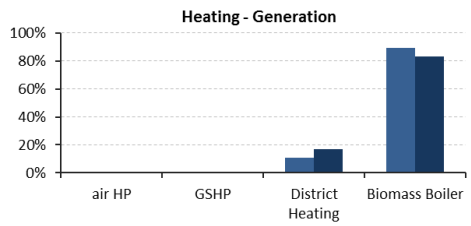
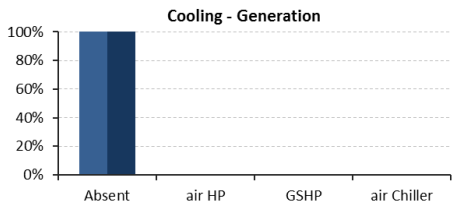
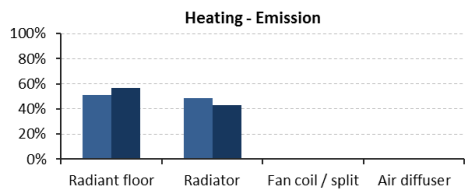
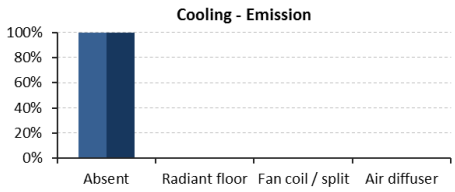
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	50	300	50	300
Range of Global Costs [€/m^2]:	666	726	681	749
Number of Building Variants:	226		226	

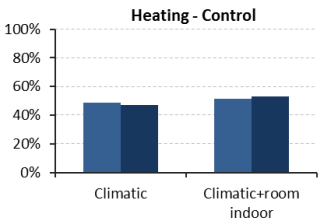


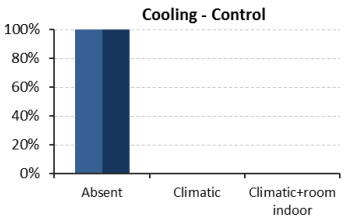


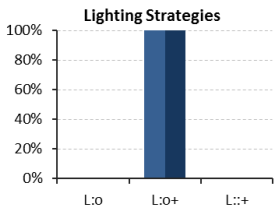


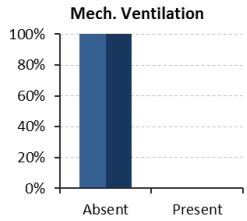


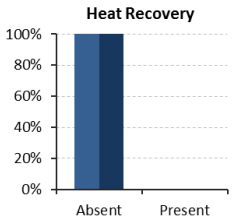


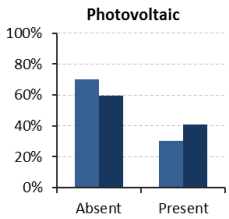


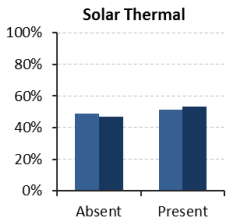












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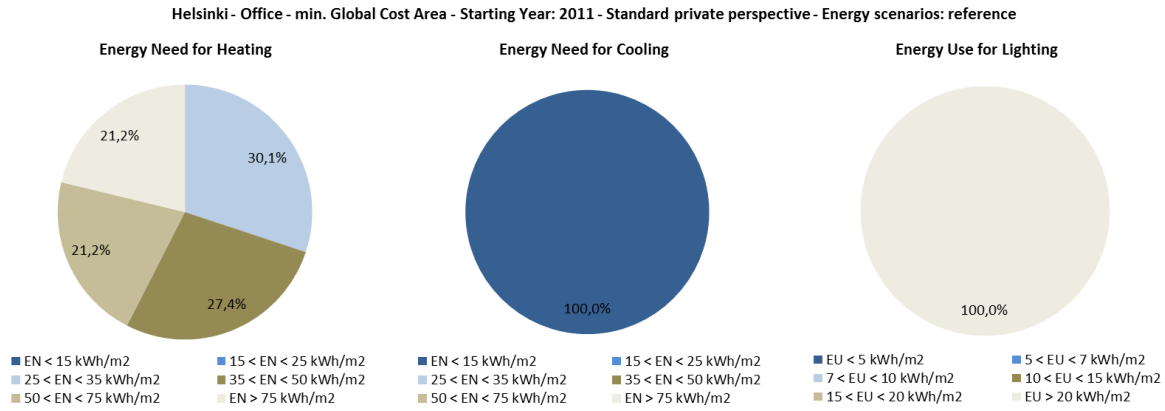

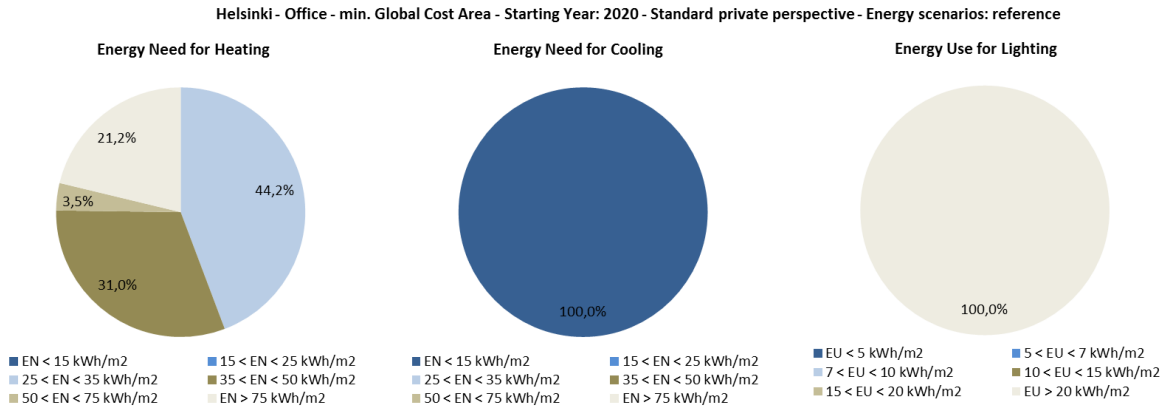

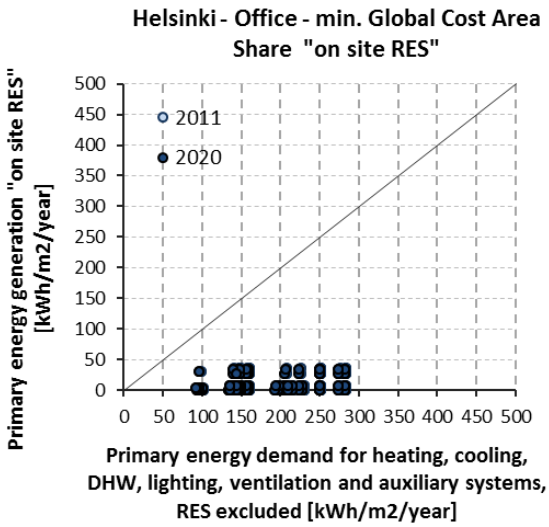

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8.1.4 School

Results about single family houses are presented in the following chapters.

About “Envelope Section” divided in these fields

- Opaque envelope Insulation **(e)**
- Windows (frame and glazing) **(w)**
- Cooling Strategies **(c)**
- Lighting efficiency (as internal gain) **(L)**

variants are expressed using this code with “-, o-, o, o+, +”, see table below

Tabella 6: variants codes for opaque envelope, windows, cooling strategies and lighting efficiency in School.

cod.	Opaque Envelope Insulation			Windows	Cooling strategies			
	Additional insulation compared to base case (in thickness of insulation "x" [cm])			number of glass + type of glass + "Air permeability Classification EN12207"	solar shading + control systems - natural night ventilation	lighting load + control system		
	Wall	Roof	Basement			cod	efficiency of lig-thing	control
-	0	0	0	single glass standard glass Class 0	solar shading ABSENT natural night ventilation ABSENT	o o+ +	low medium high	manual manual automatised
o-	5 ÷ 10	5 ÷ 10	5	***	solar shading PRESENT + MANUAL Control Automatised natural ventilation ABSENT	o o+ +	low medium high	manual manual automatised
o	10 ÷ 15	15 ÷ 20	10 ÷ 15	double glass standard glass Class 2	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation ABSENT	o o+ +	low medium high	manual manual automatised
o+	20 ÷ 25	20 ÷ 25	10 ÷ 15	double glass low-e glass Class 3	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT medium performance	o o+ +	low medium high	manual manual automatised
+	30	30	15	triple glass low-e glass Class 4	solar shading PRESENT + AUTOMATISED control automatised natural night ventilation PRESENT high performance	o o+ +	low medium high	manual manual automatised

*** There aren’t variant that can be assigned to this code

Additional notes:

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For Prague calculations, the variant number 2 and 3 of opaque envelope strategies have thickness of insulation not so different for determine a clear identification in two different class of packages. Both are classified with the code “o”.

For more deep analysis of results in the bar plot graph "Envelope" the columns n. 5-6-7-8-9-10 correspond at the variant n. 2 with and the column 11-12-13-14 at the variant n. 3 with additional insulation of wall between 10 ÷ 15 cm, additional insulation of roof between 15 ÷ 20 cm and additional insulation of basement between 10 ÷ 12 cm.

Some exceptions:

For Bucharest calculations o+: thickness of roof insulation is 30 cm.

For Paris calculations o+: thickness of roof insulation is 30 cm.

For Prague calculations o+ : thickness of roof insulation is 30 cm.

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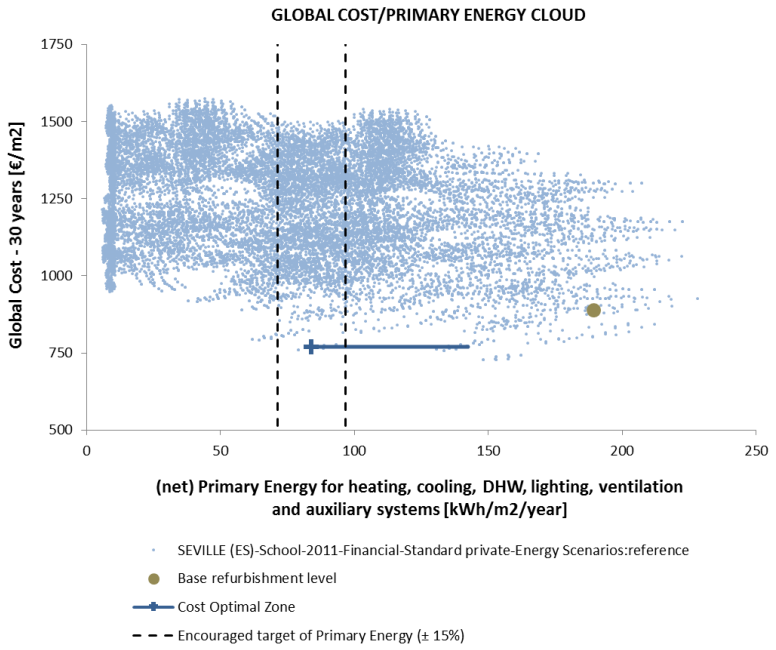
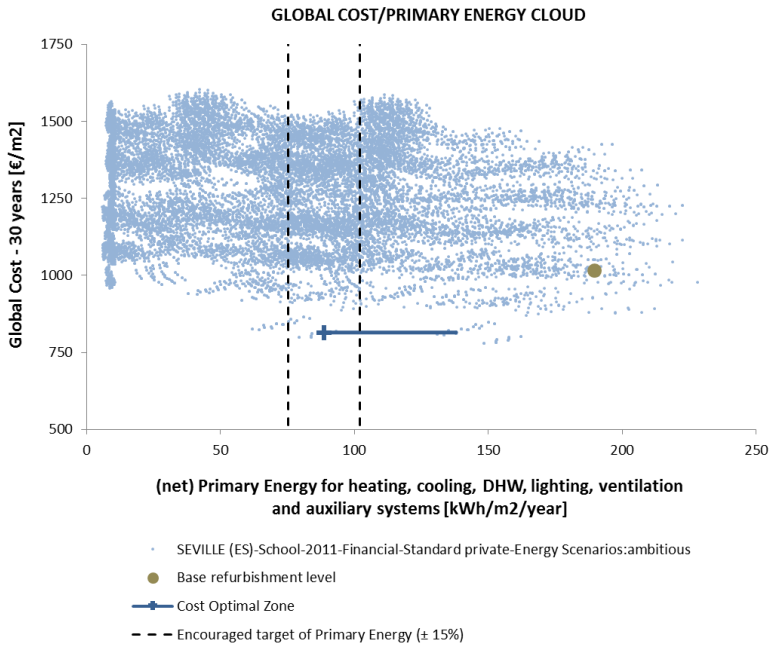
8.1.4.1 Seville





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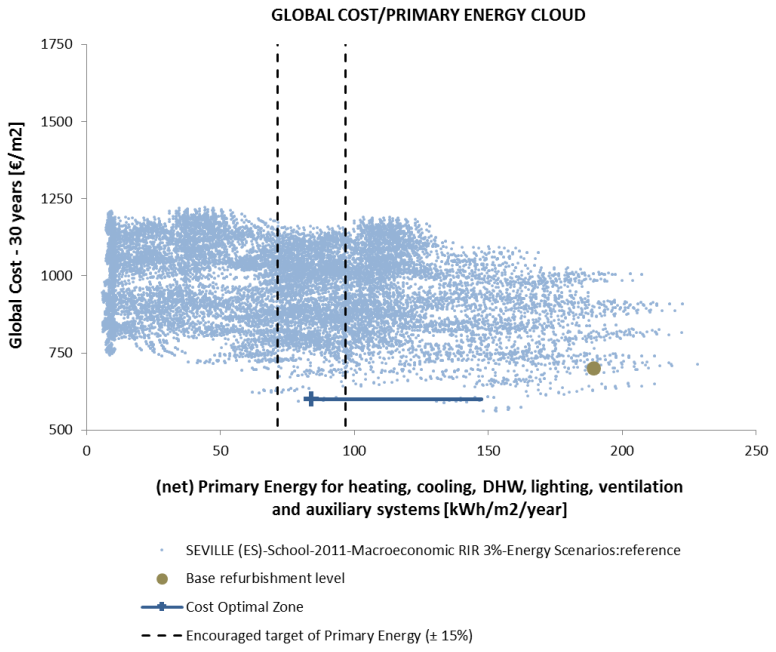

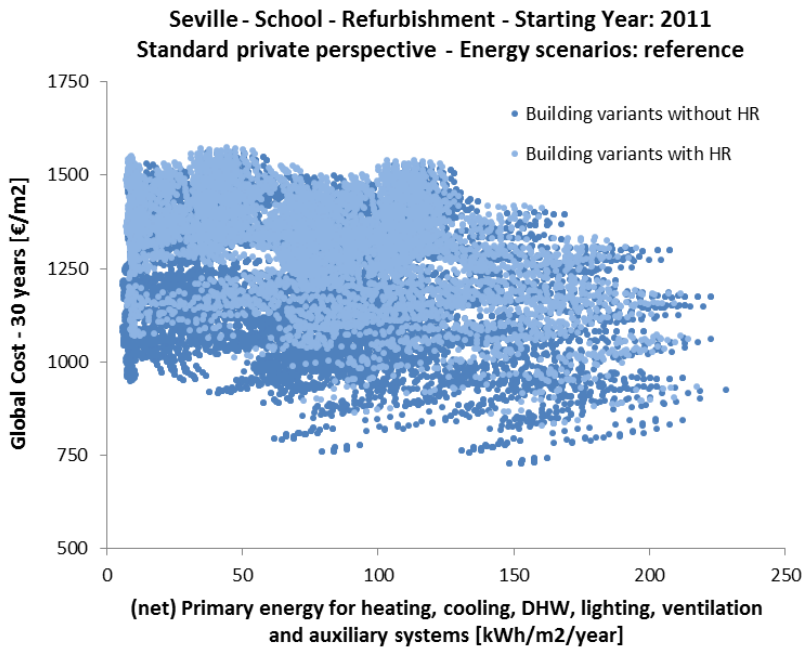

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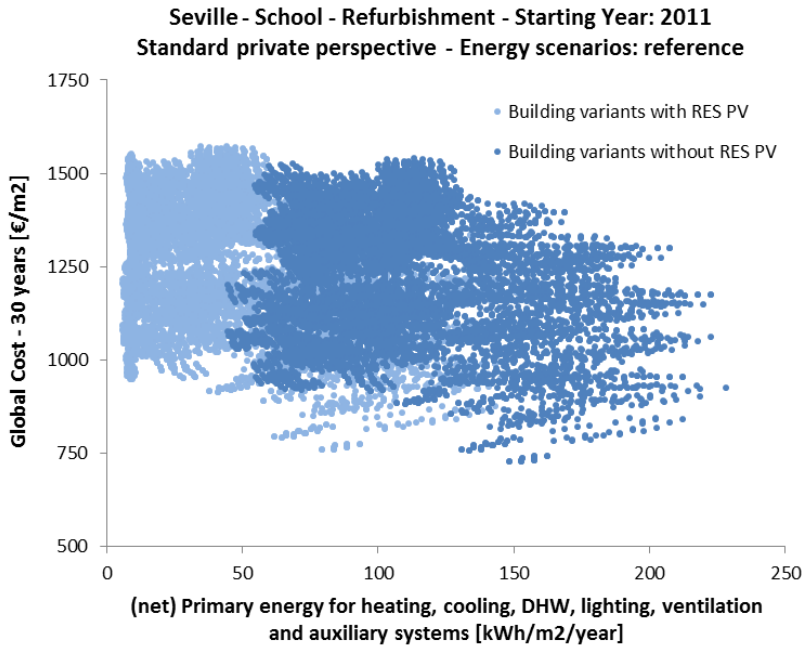

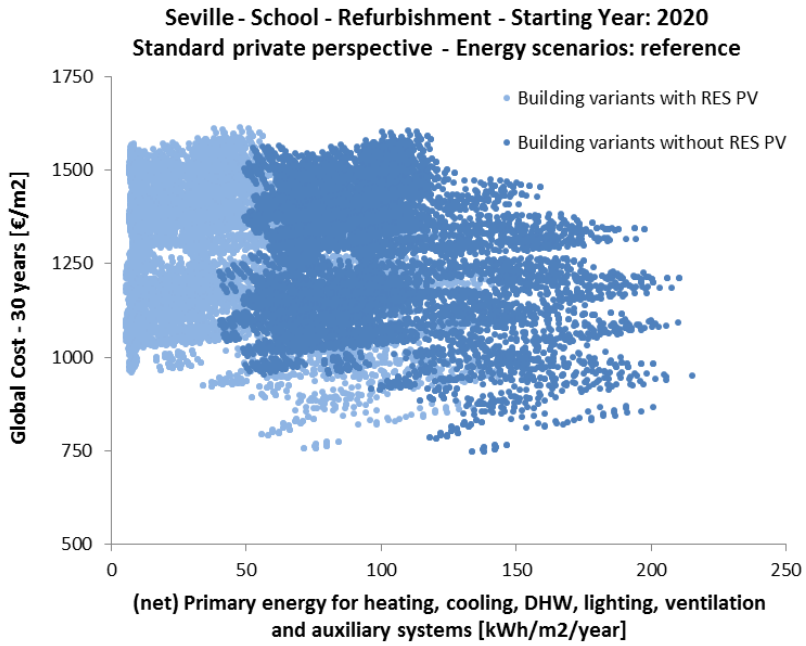

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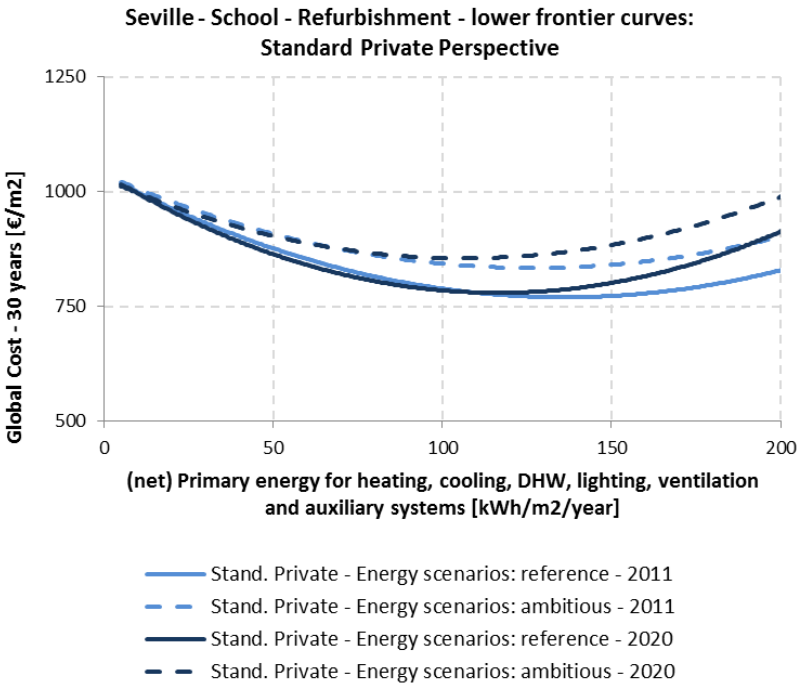

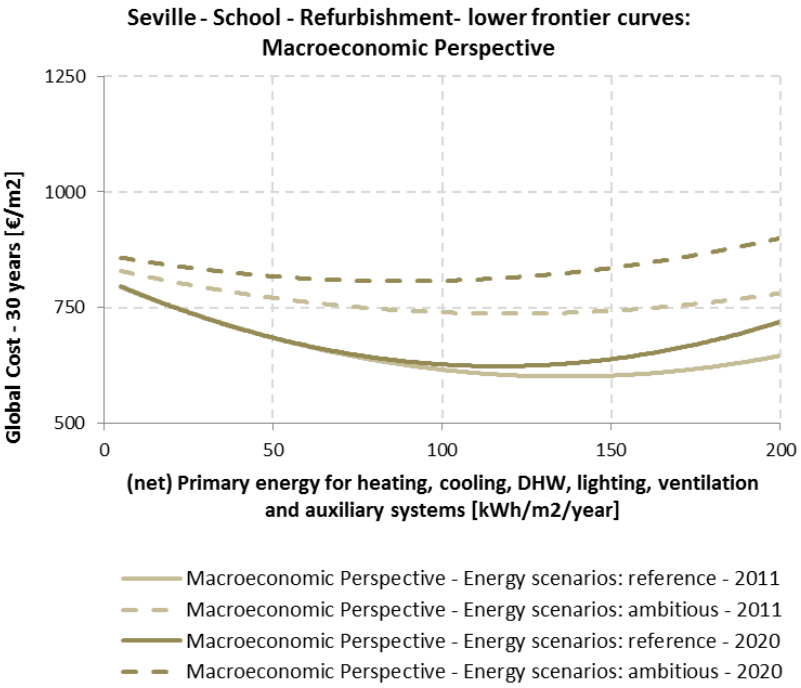

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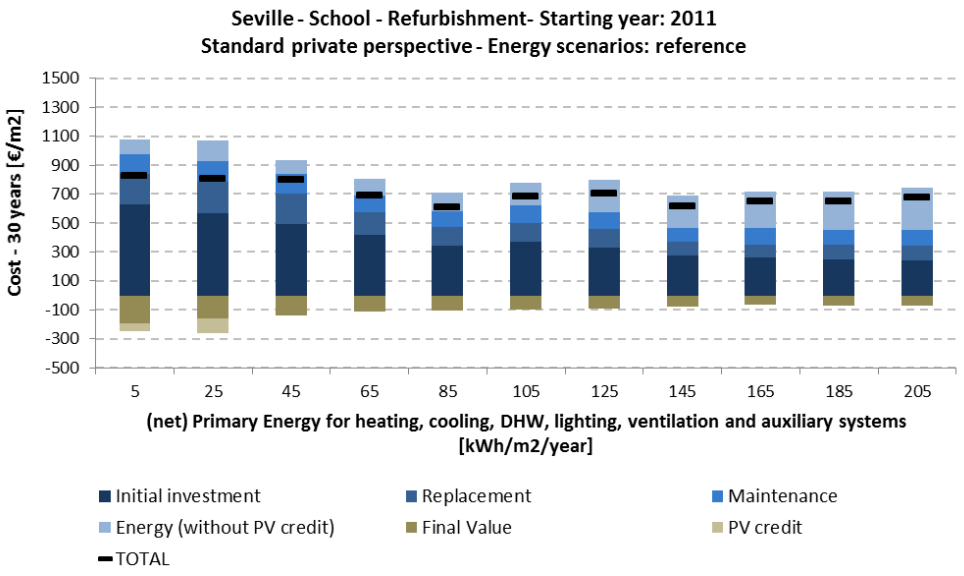

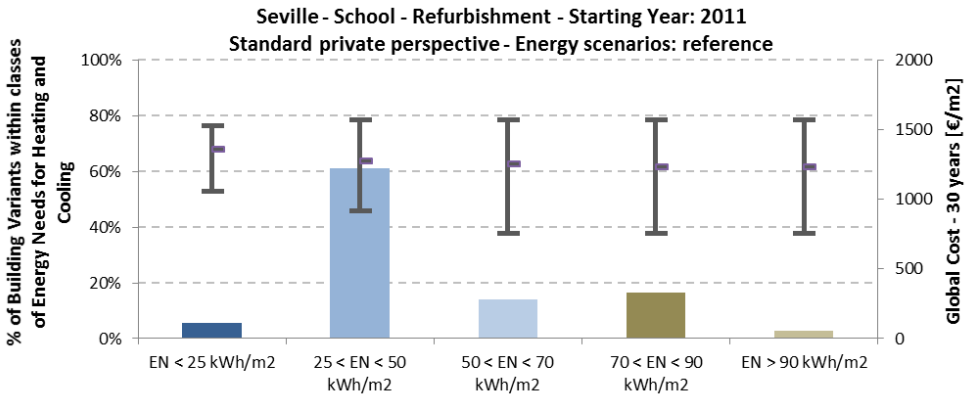

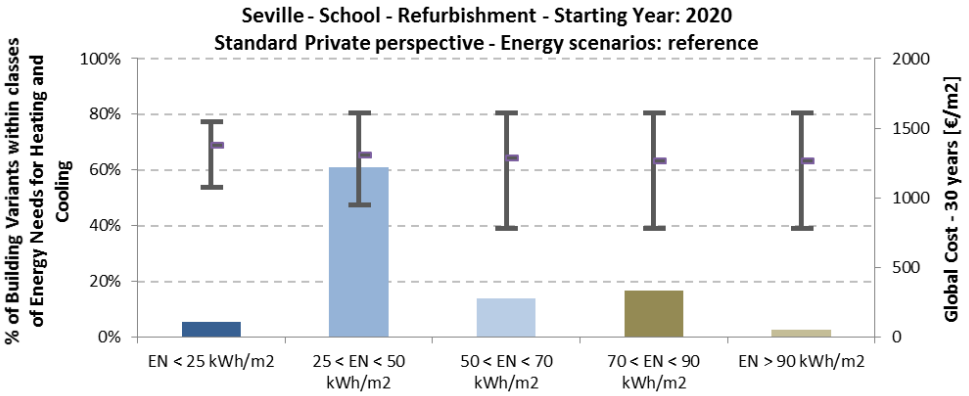

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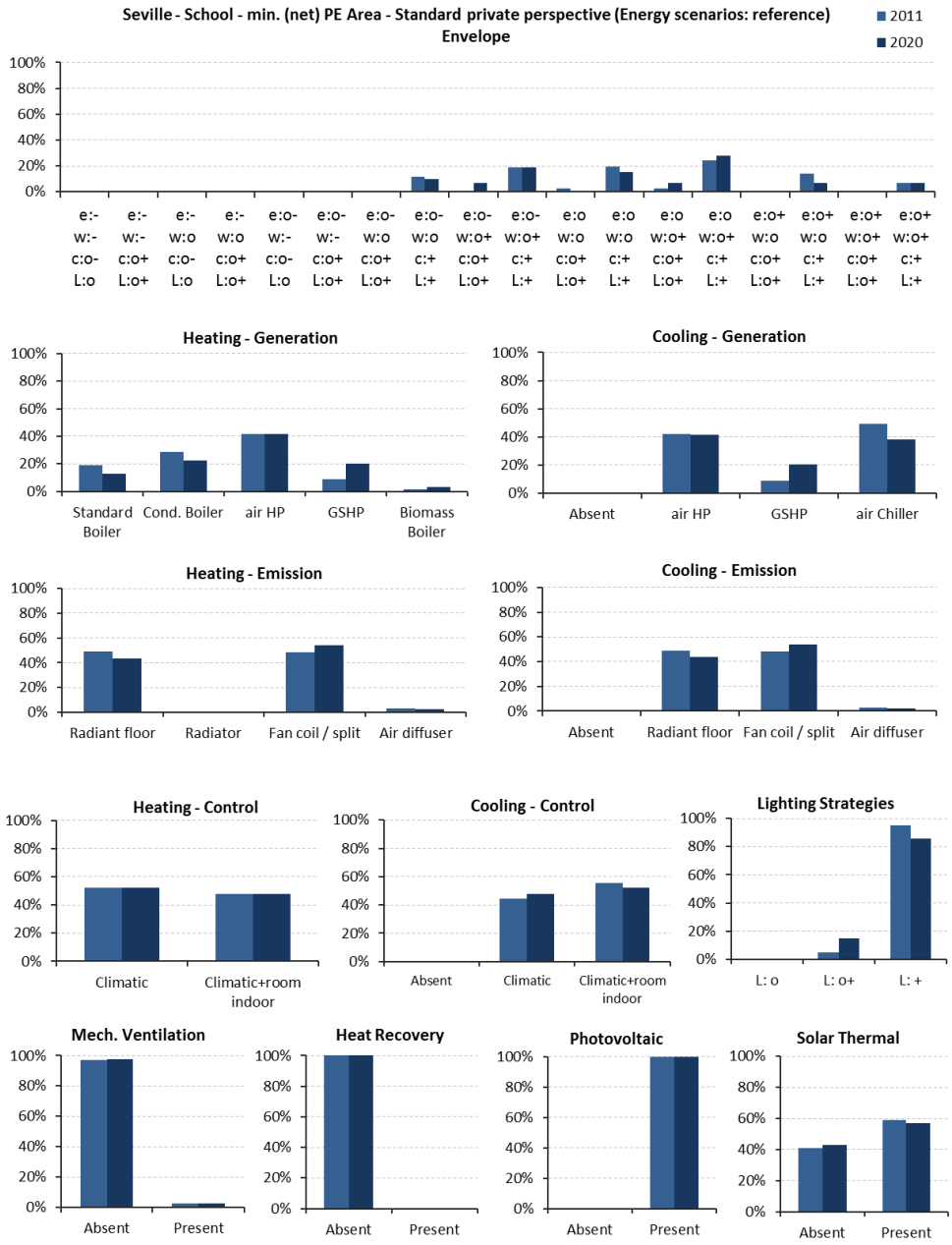
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	6	15	5	15
Range of Global Costs [€/m^2]:	1007	1058	991	1065
Number of Building Variants:	246		246	



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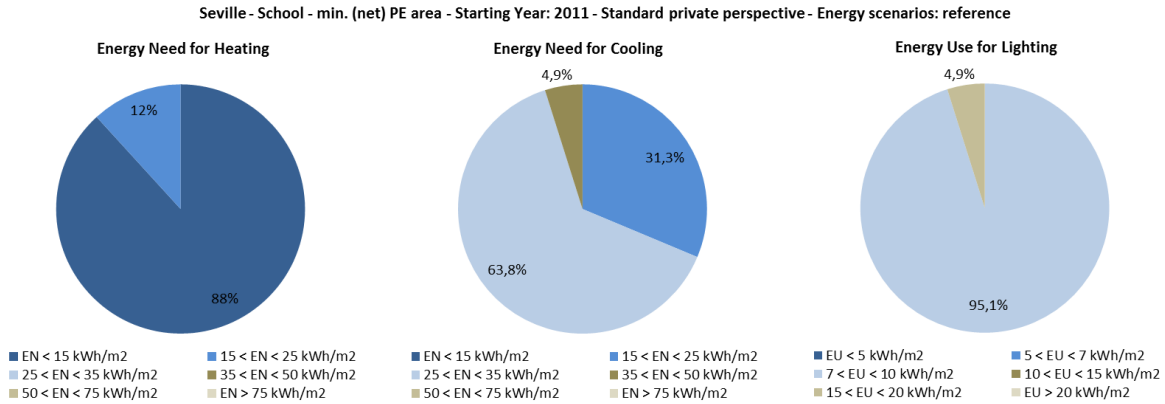

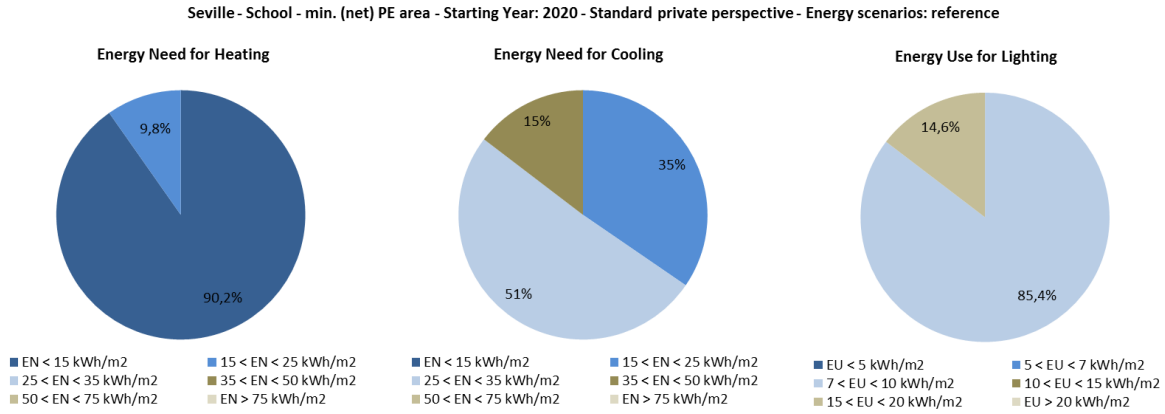

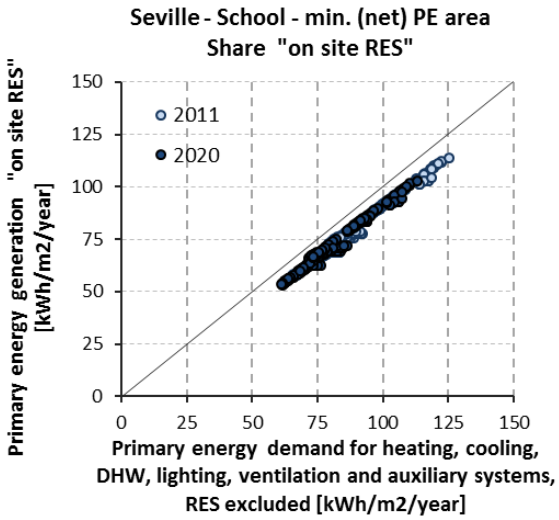

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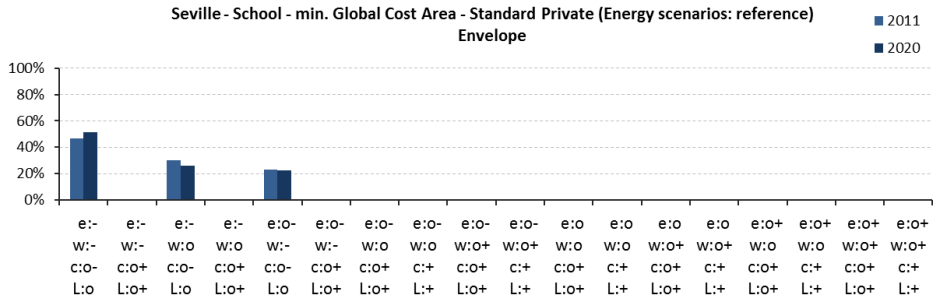
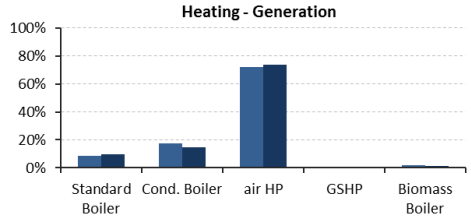
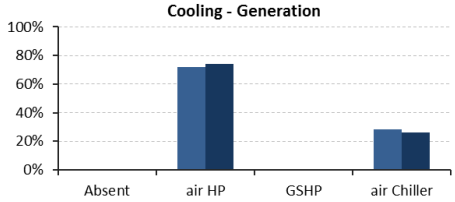
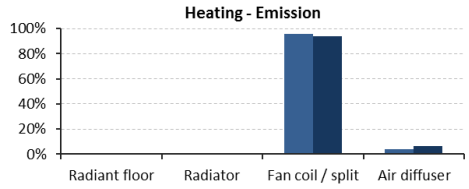
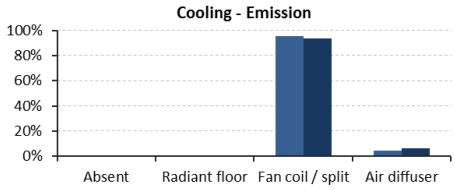
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	50	200	50	200
Range of Global Costs [€/m^2]:	727	837	748	855
Number of Building Variants:	142		142	

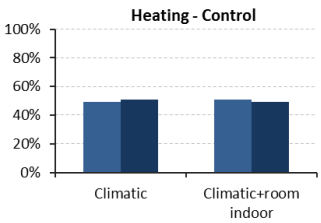


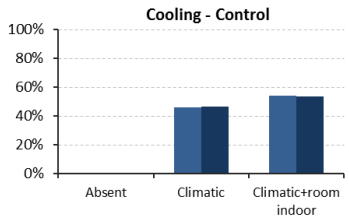


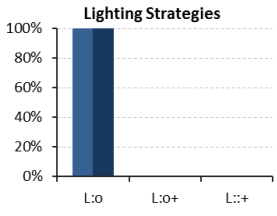


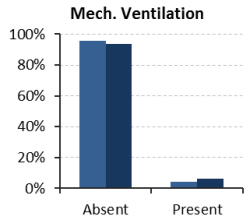


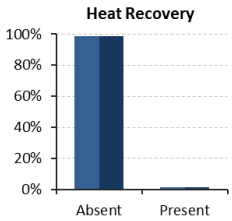


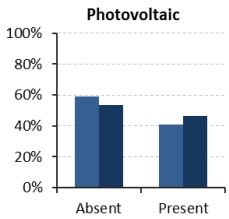


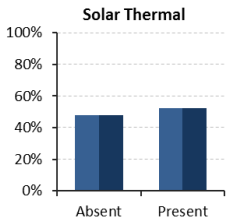












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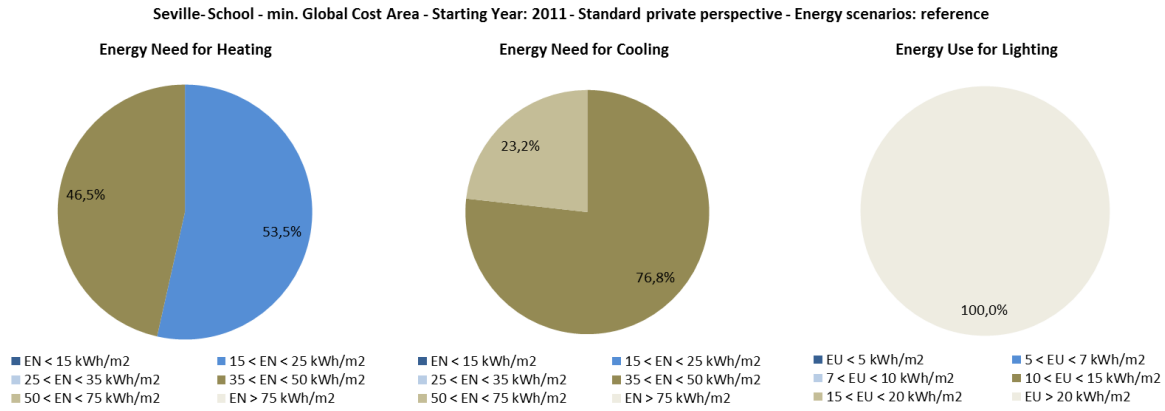

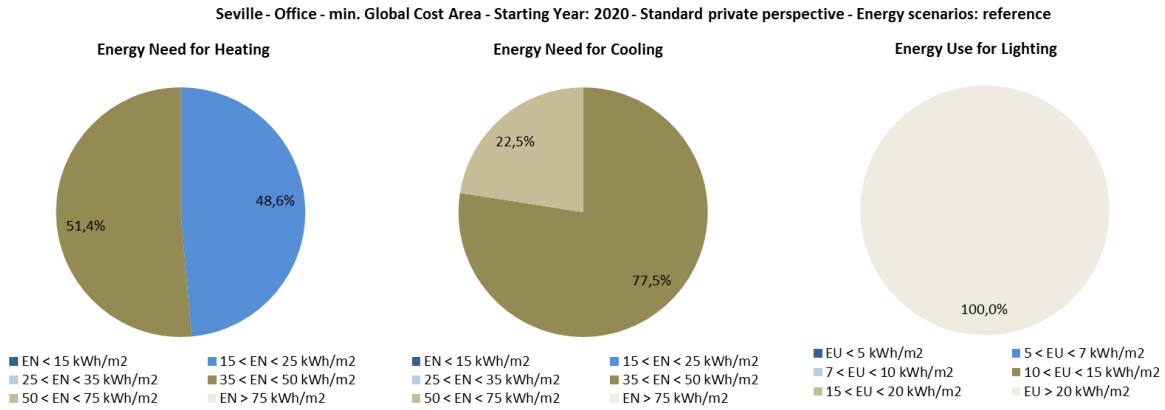

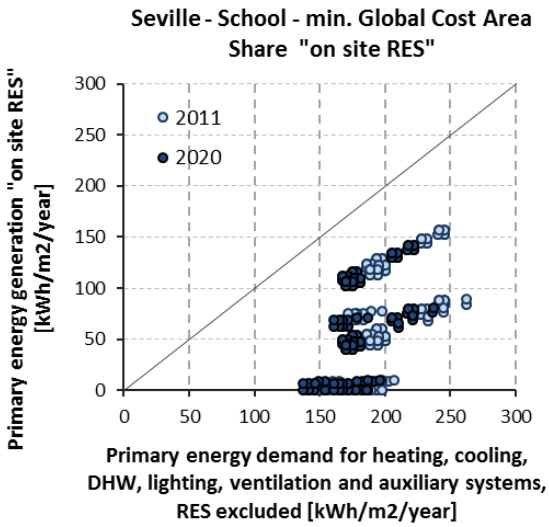

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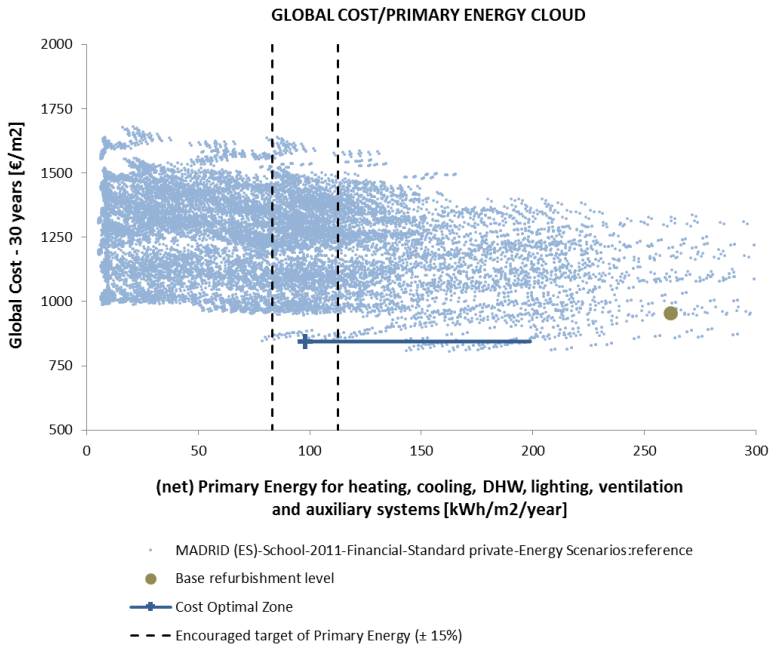
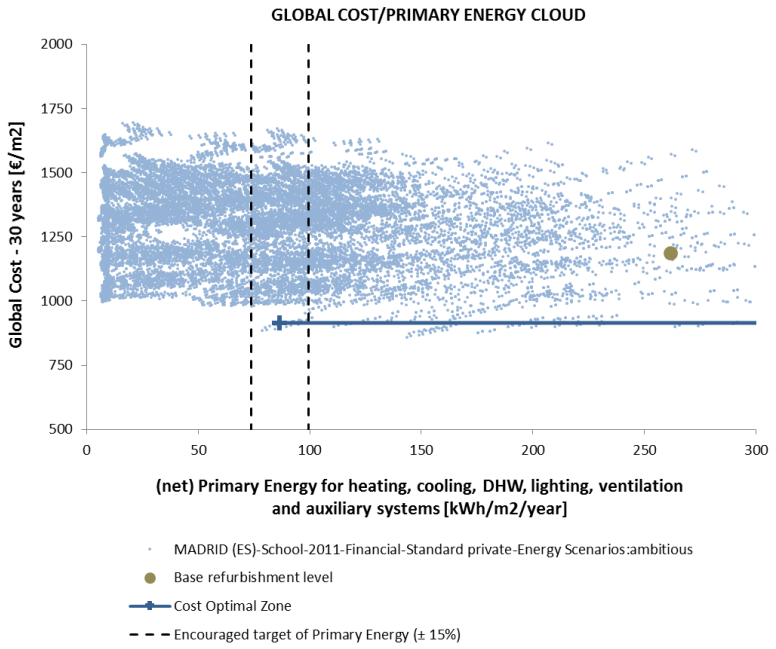
8.1.4.2 Madrid





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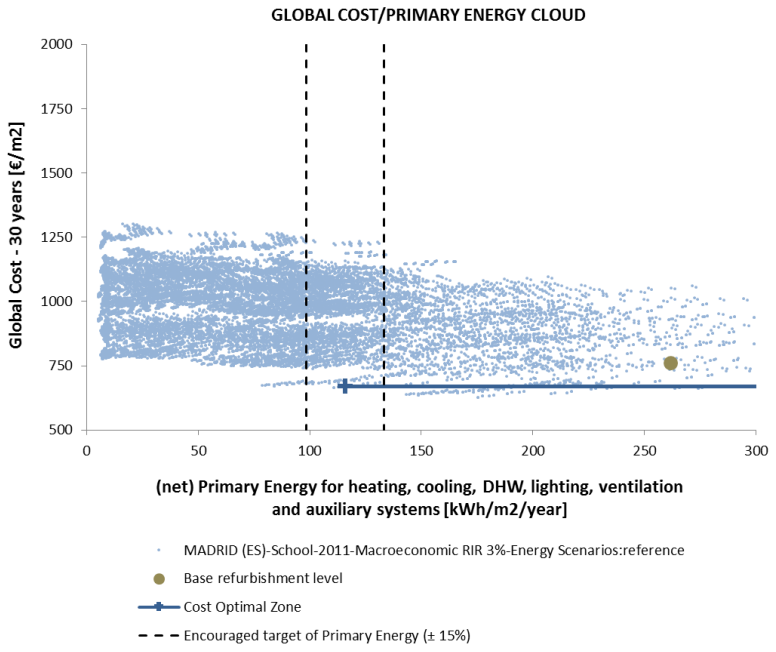

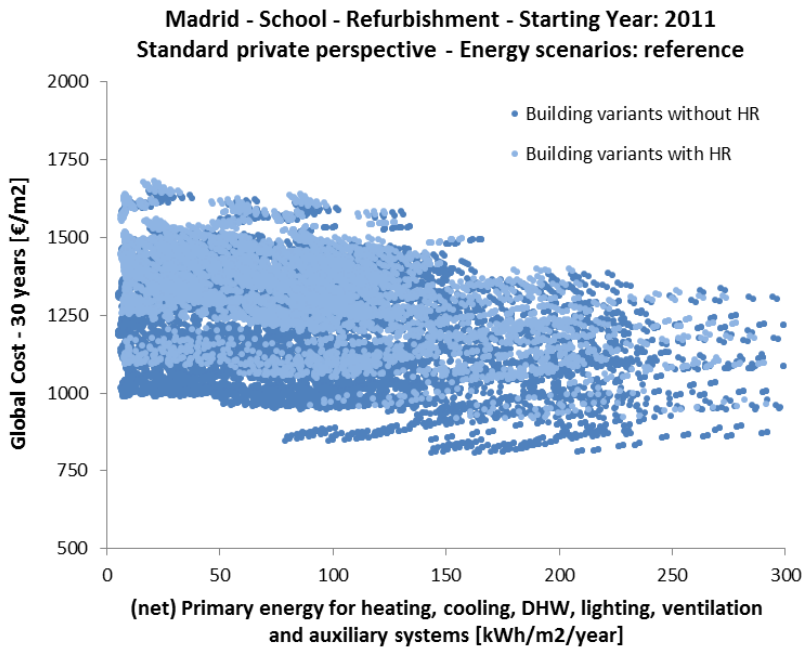

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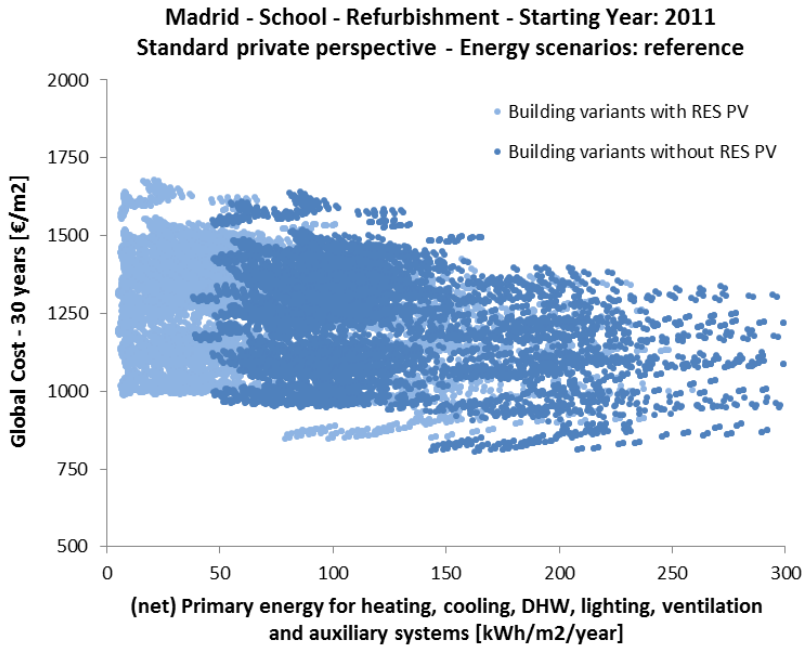

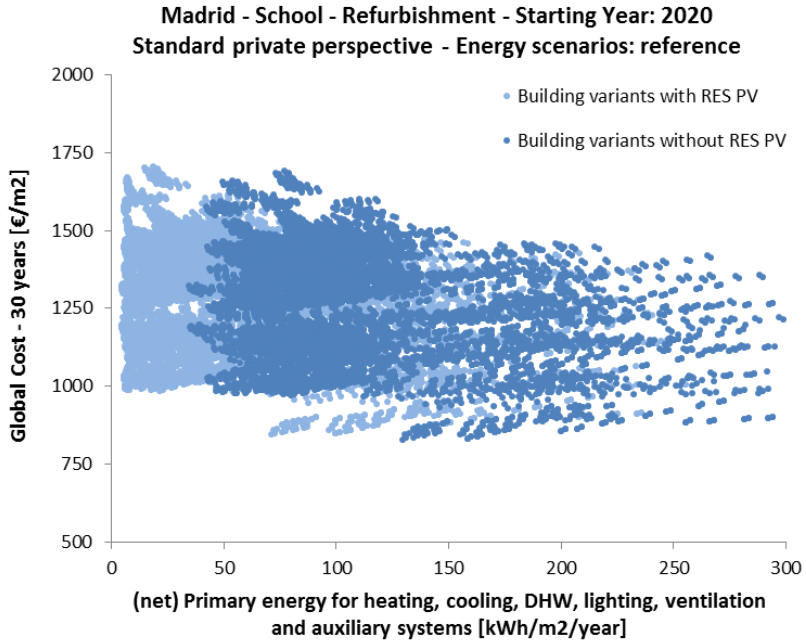

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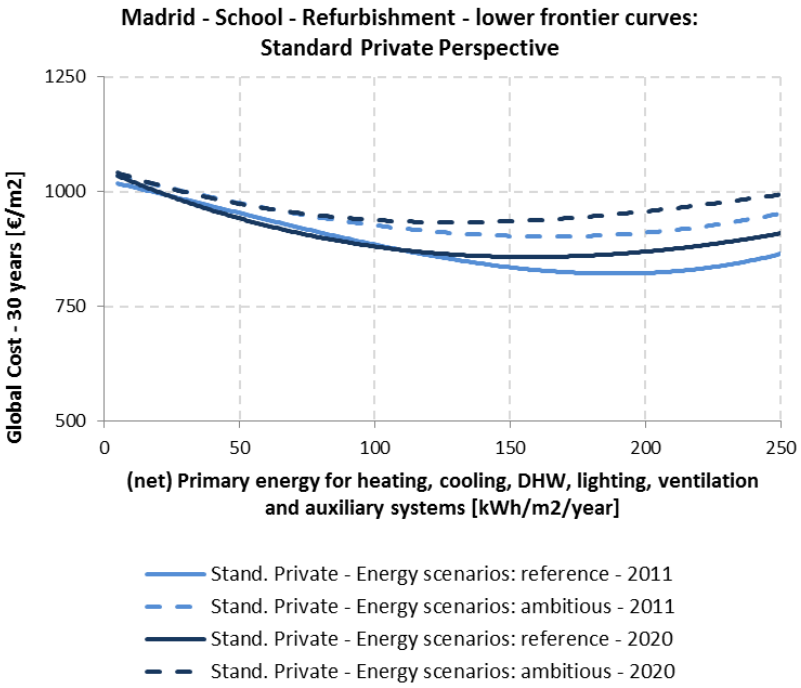

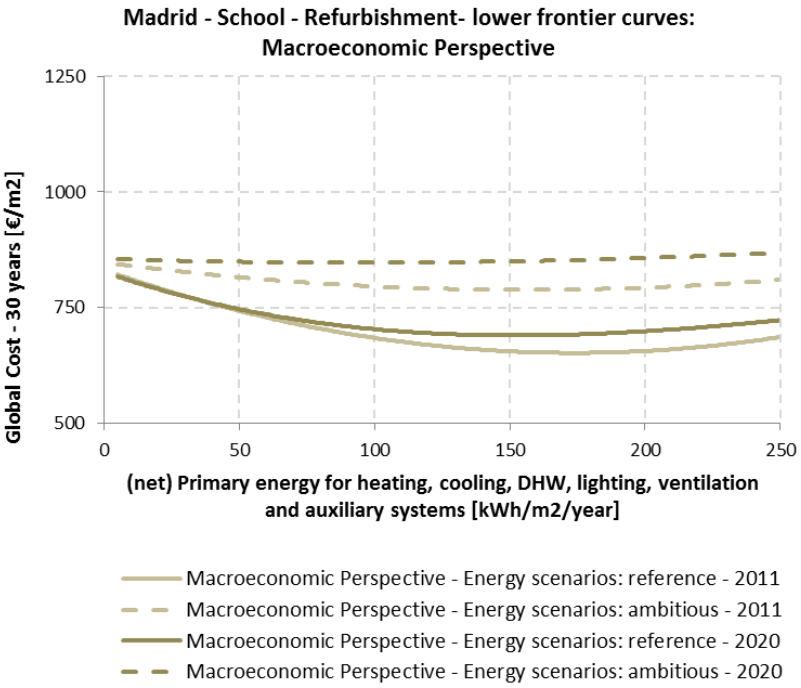

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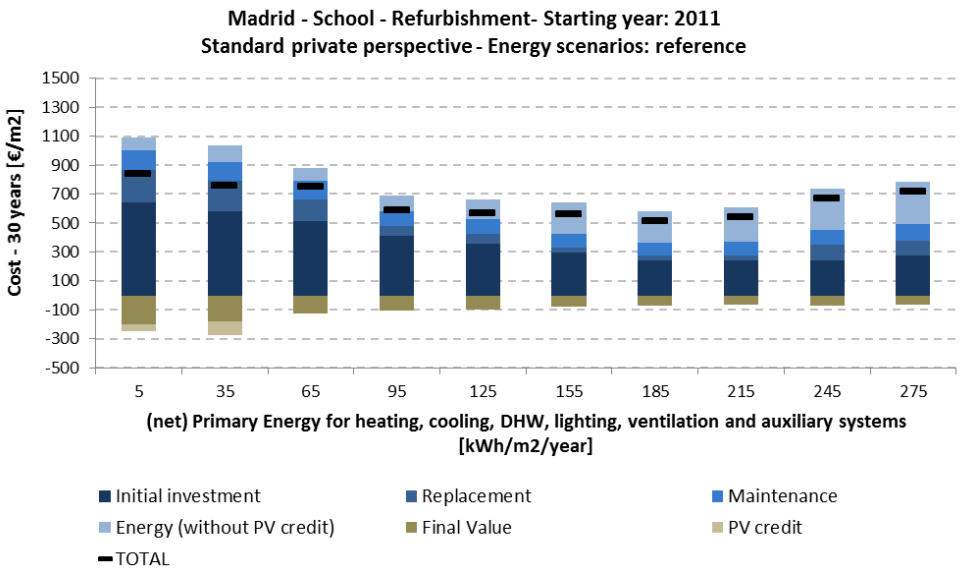

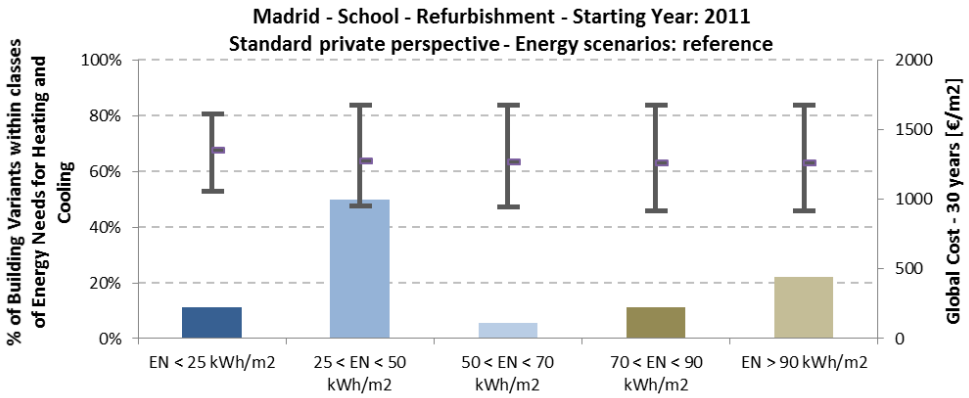

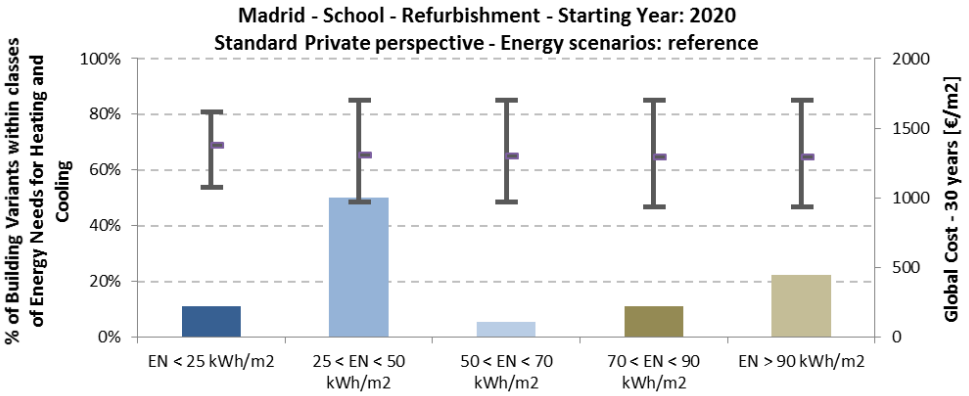

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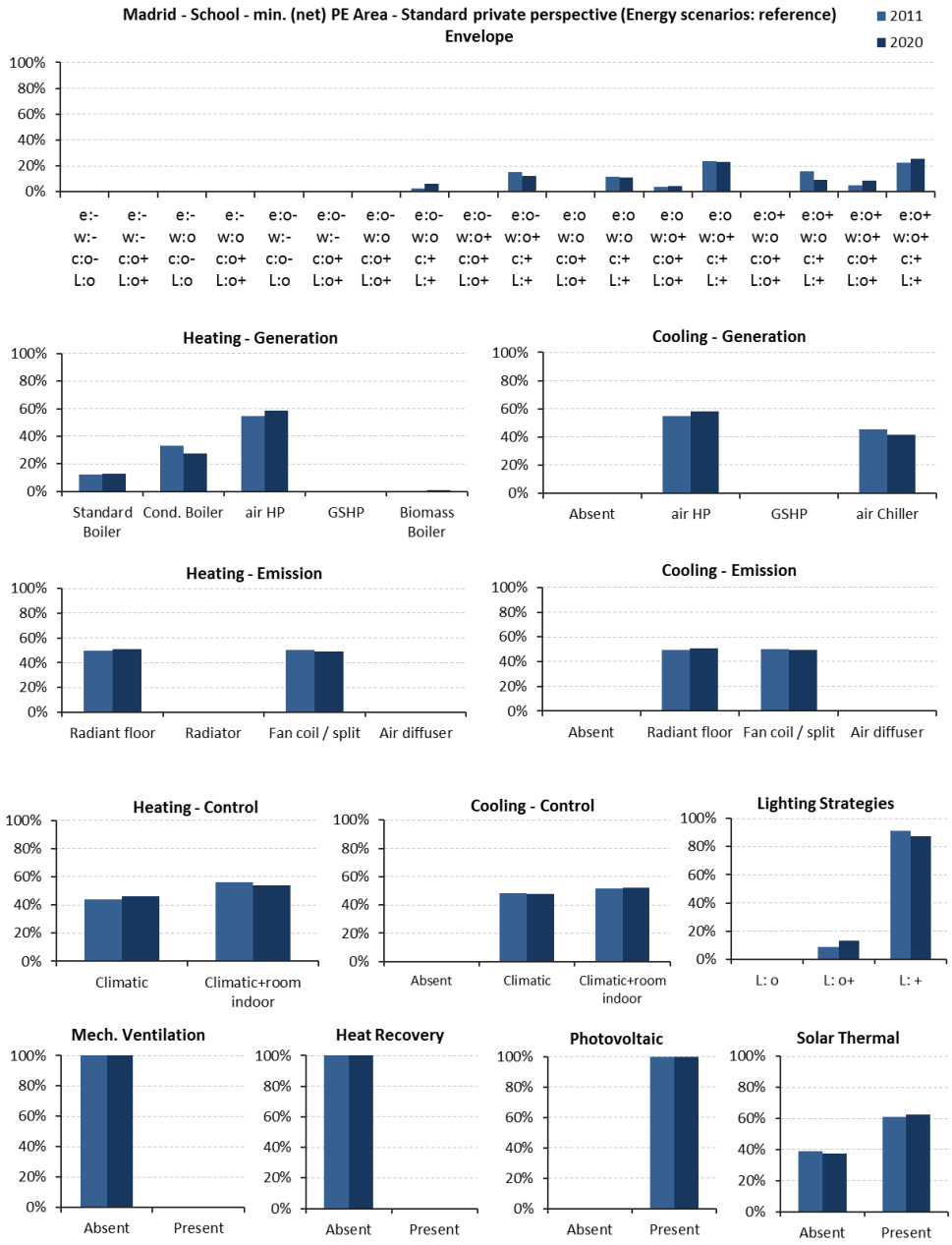
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	5	15	5	15
Range of Global Costs [€/m^2]:	997	1046	993	1071
Number of Building Variants:	185		185	



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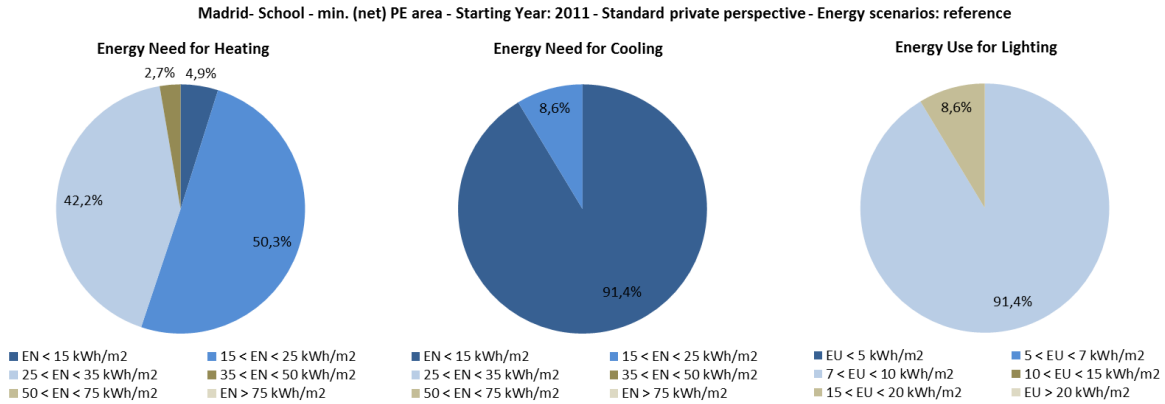

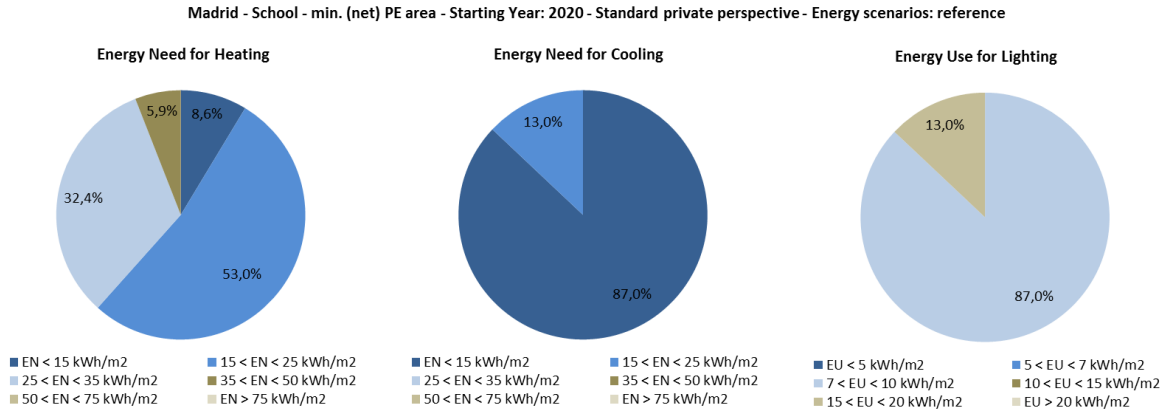

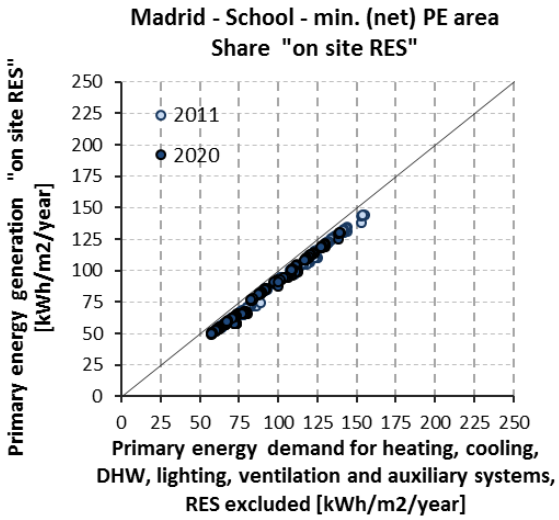

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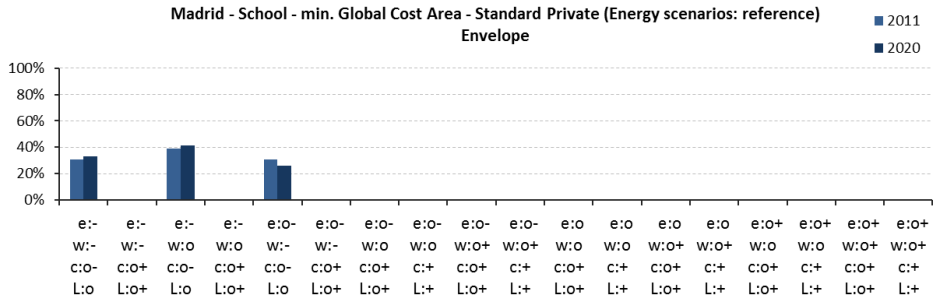
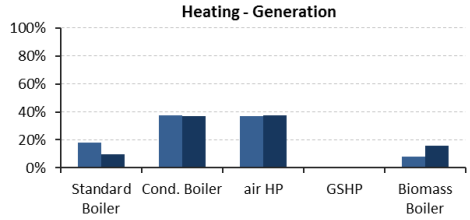
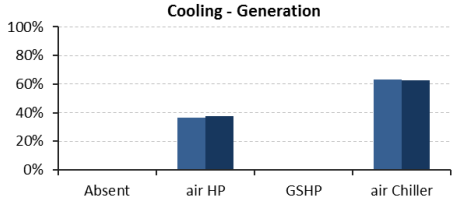
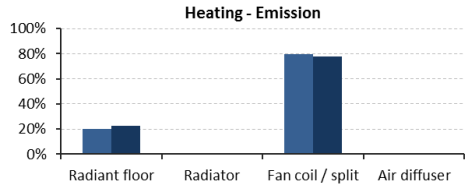
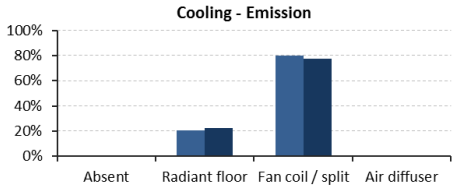
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	60	270	60	280
Range of Global Costs [€/m^2]:	807	888	830	911
Number of Building Variants:	255		255	

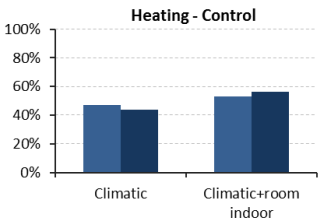


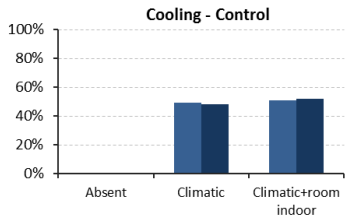


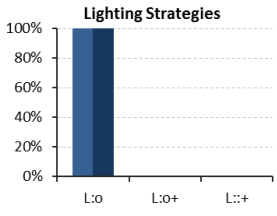


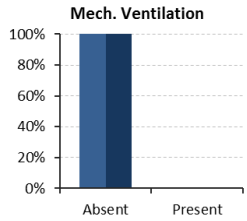


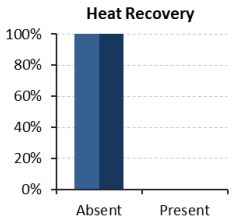


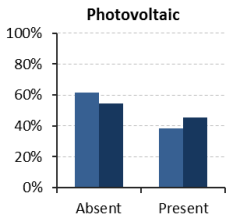


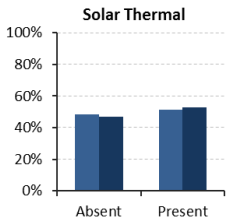


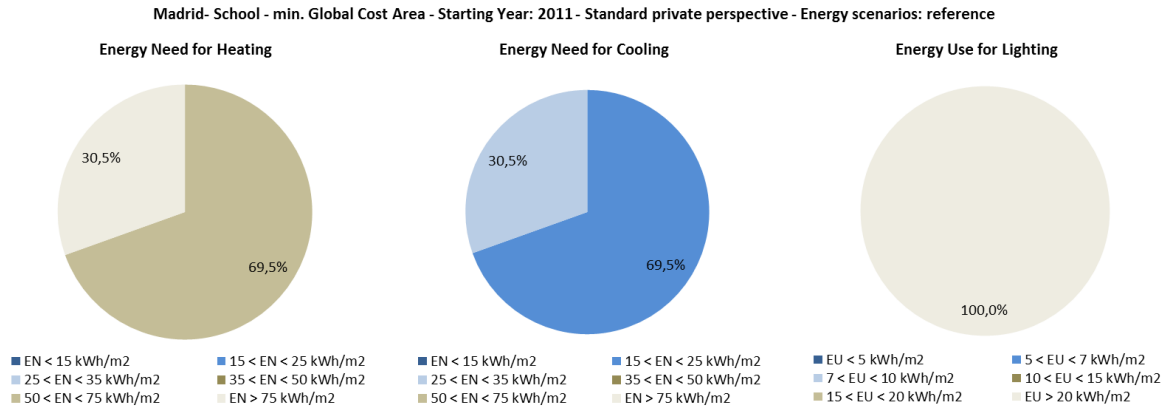


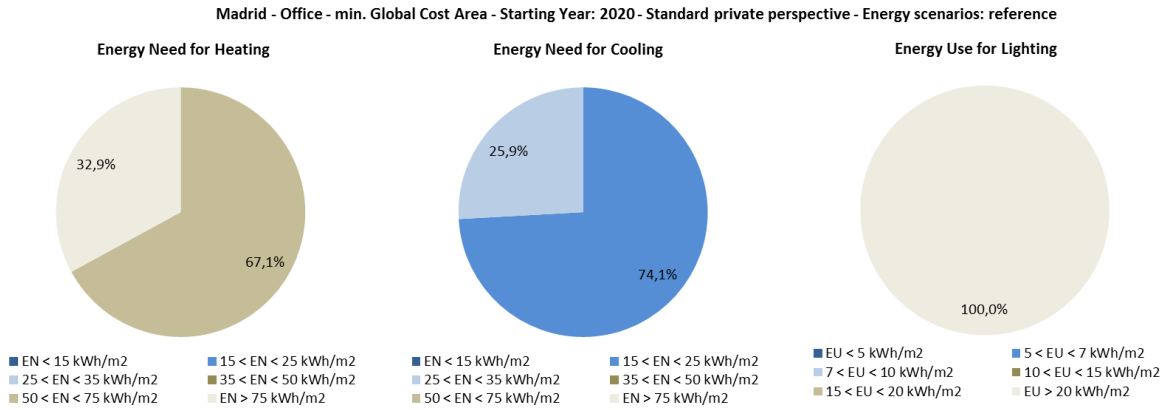


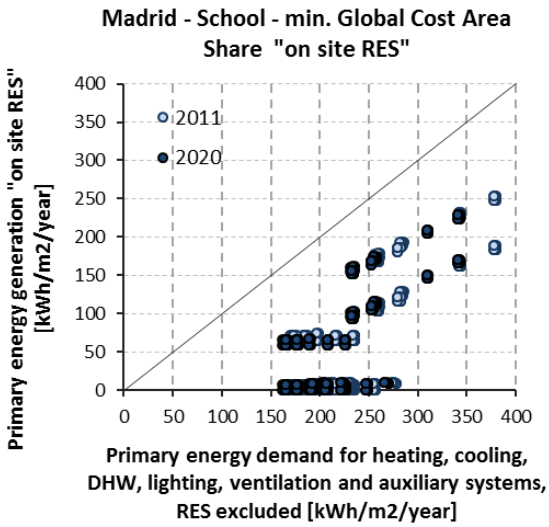












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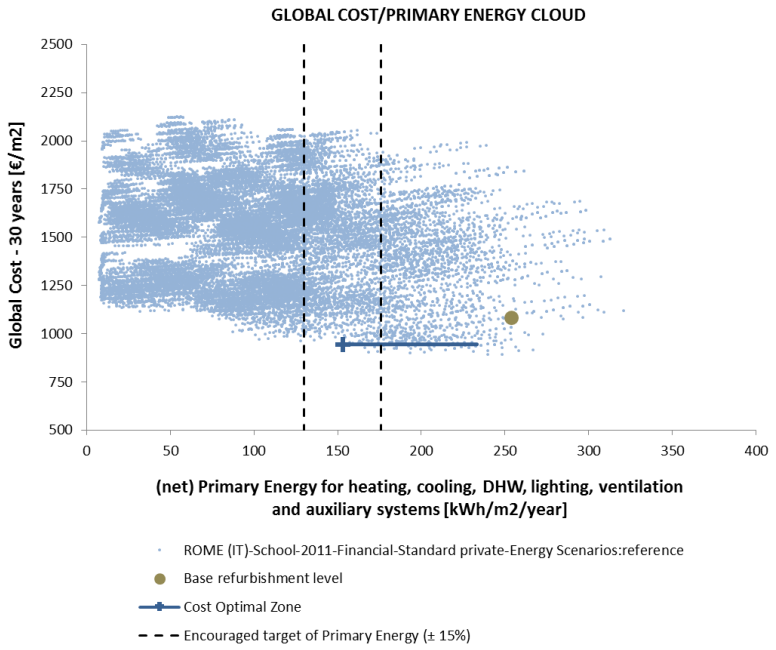
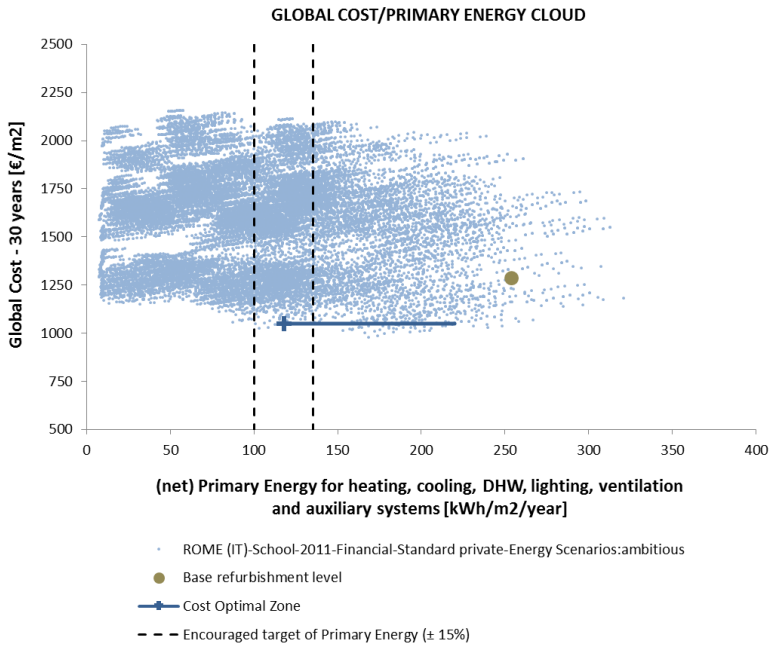
8.1.4.3 Rome





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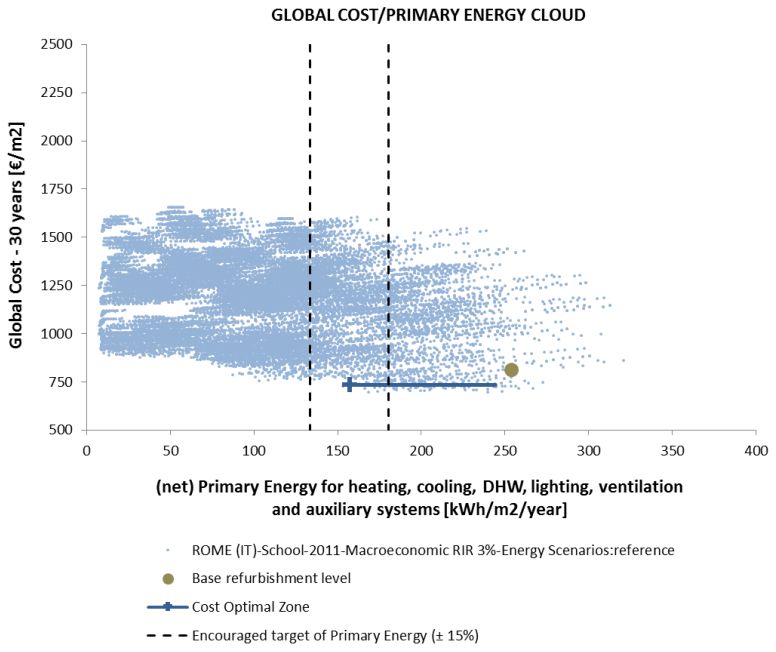

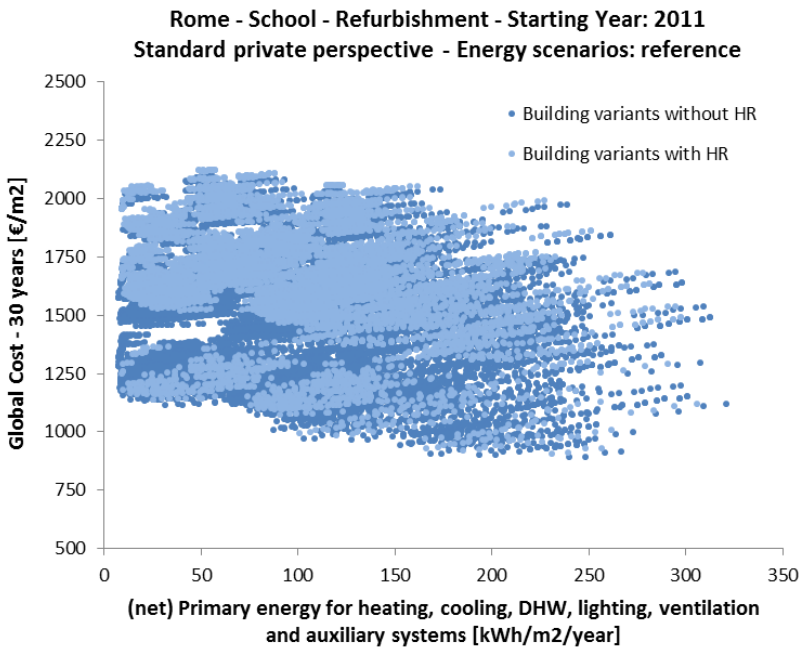

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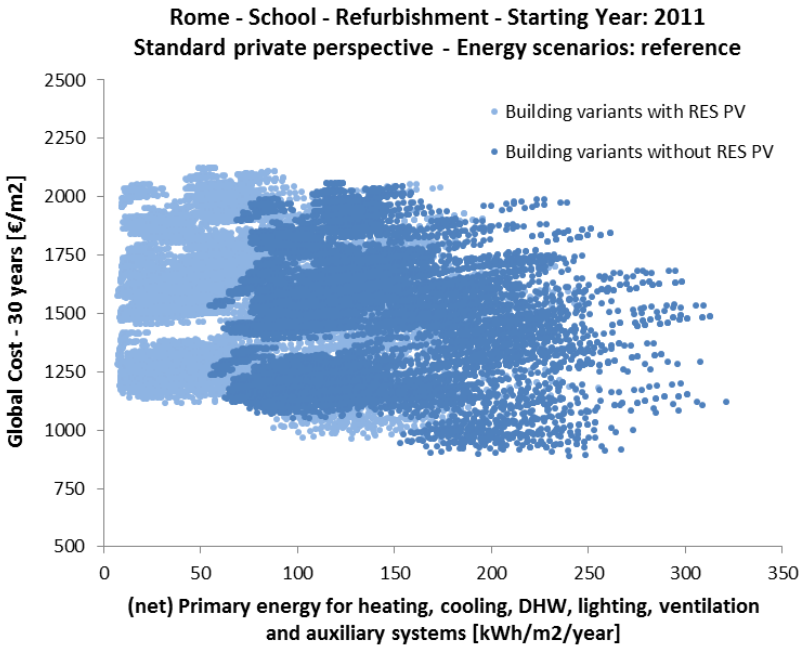

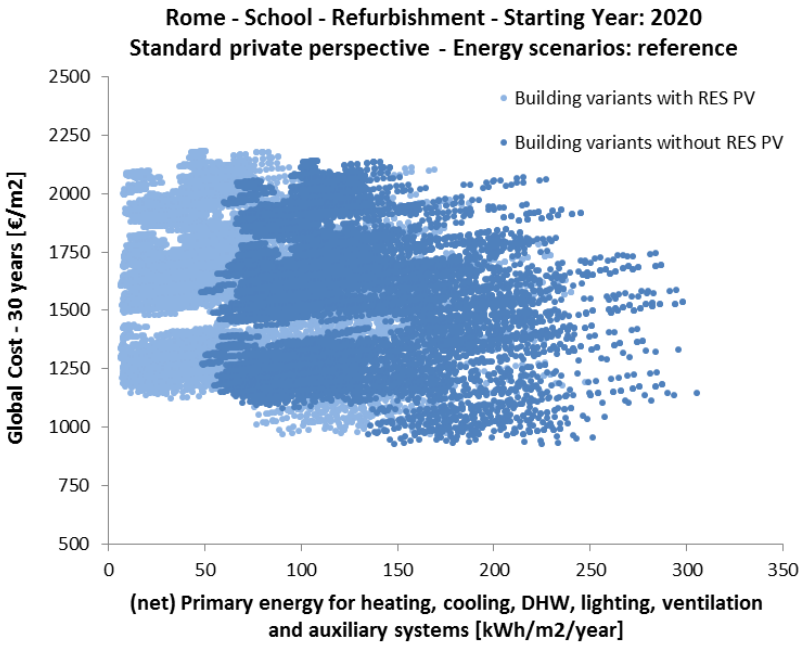

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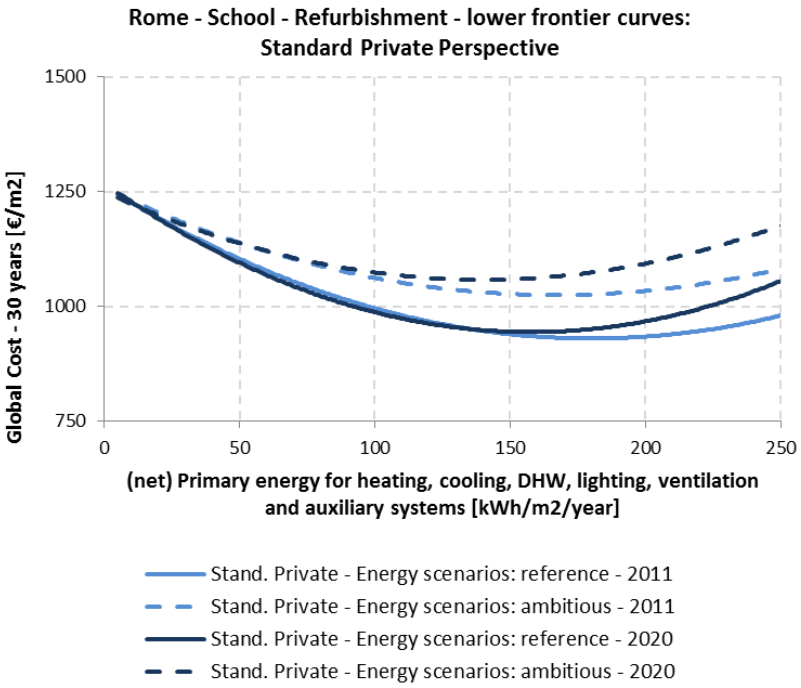

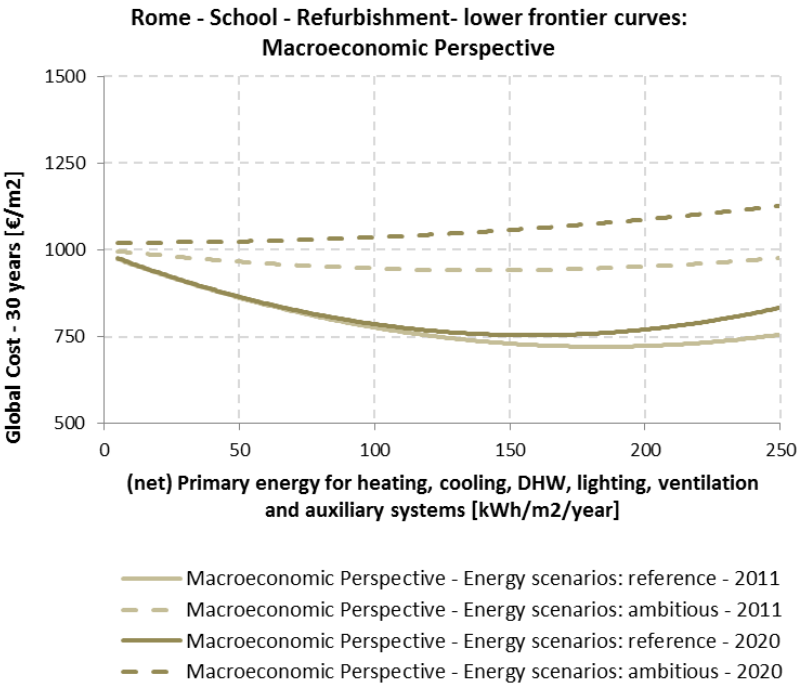

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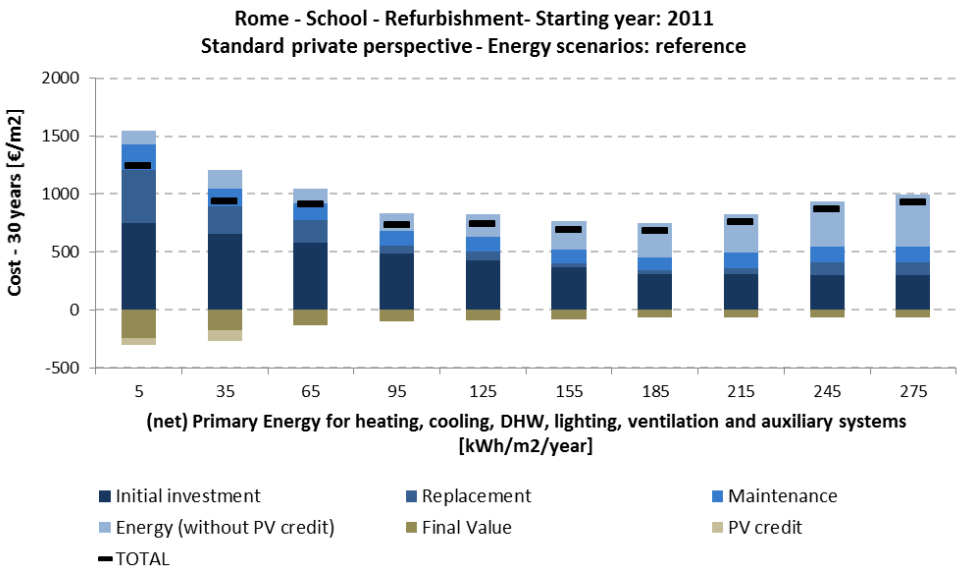

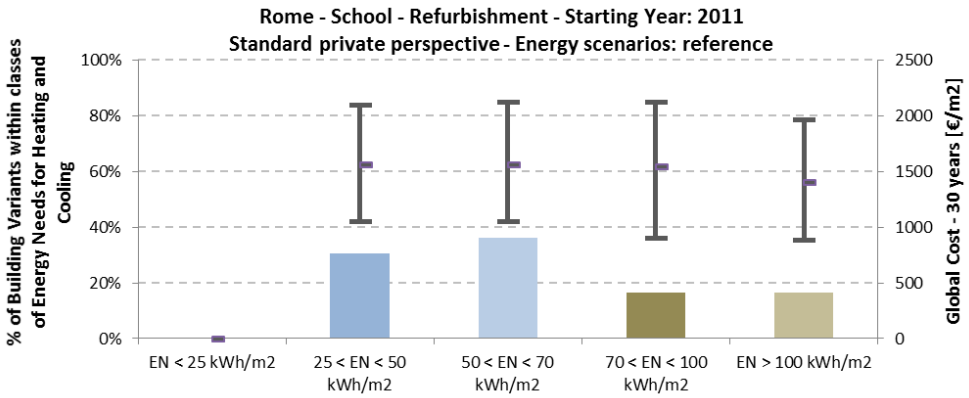

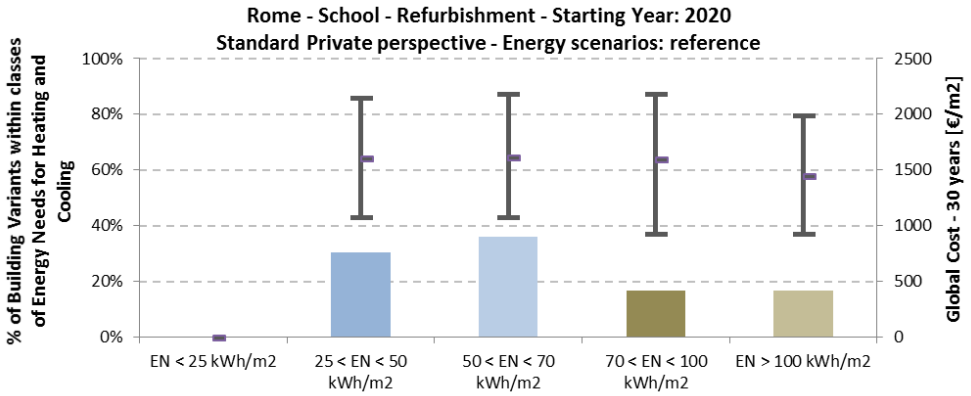

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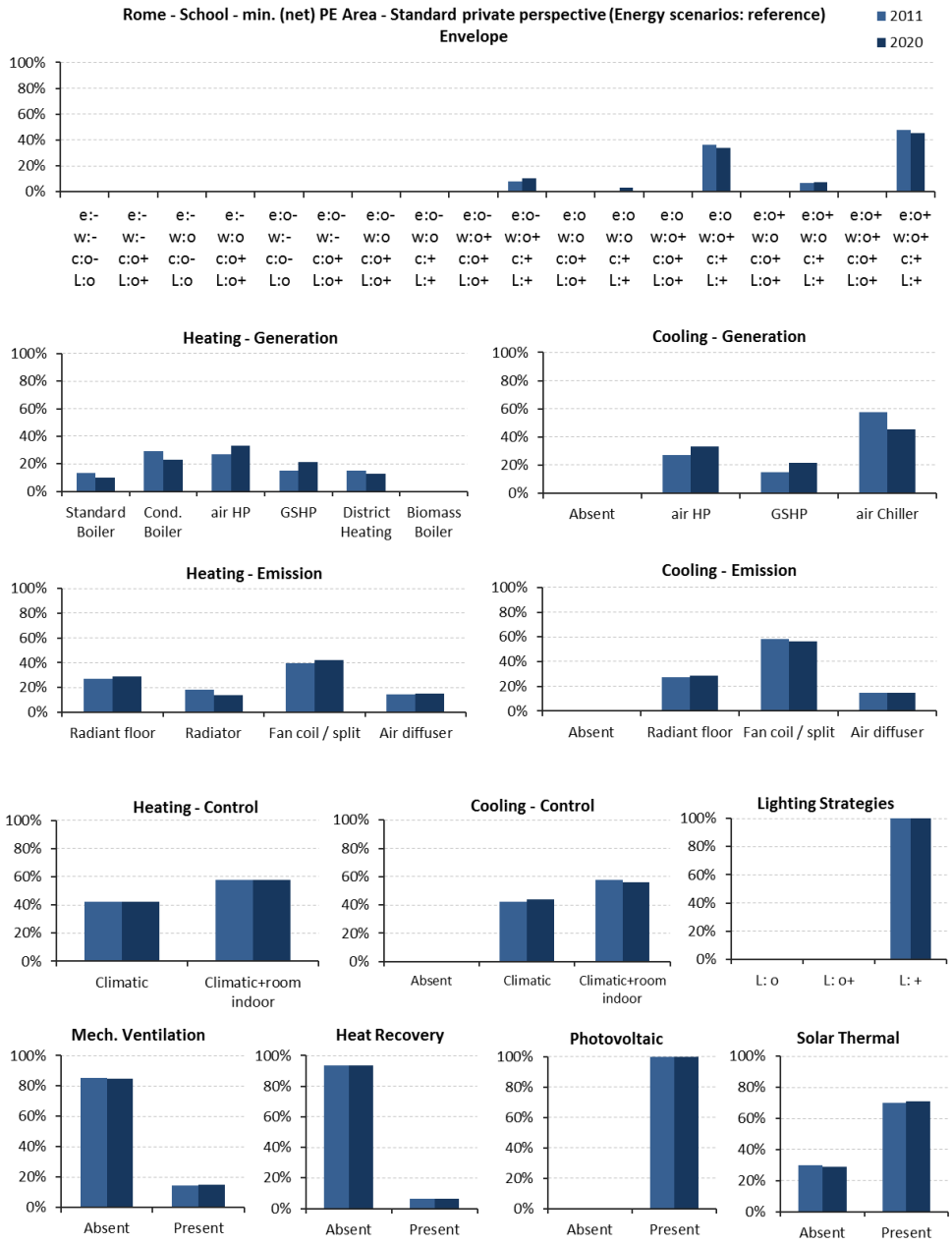
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	7	15	6	15
Range of Global Costs [€/m^2]:	1140	1310	1152	1342
Number of Building Variants:	206		206	



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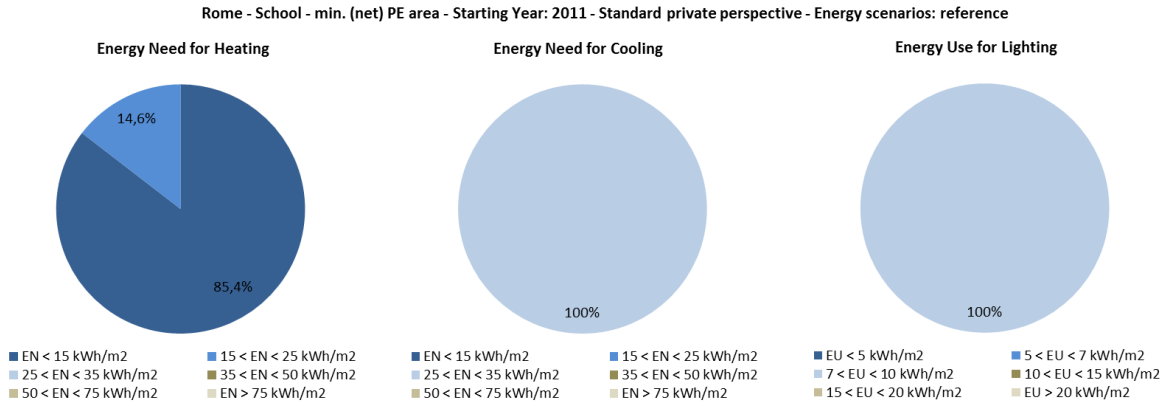

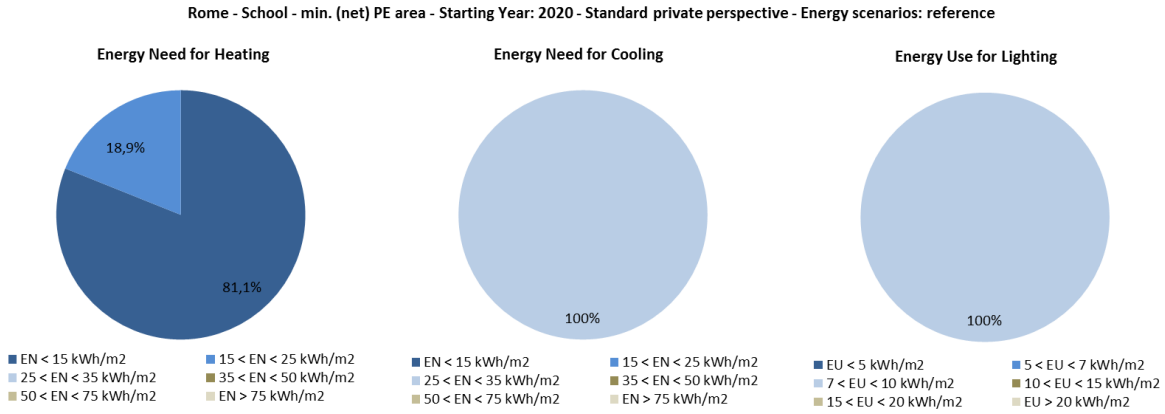

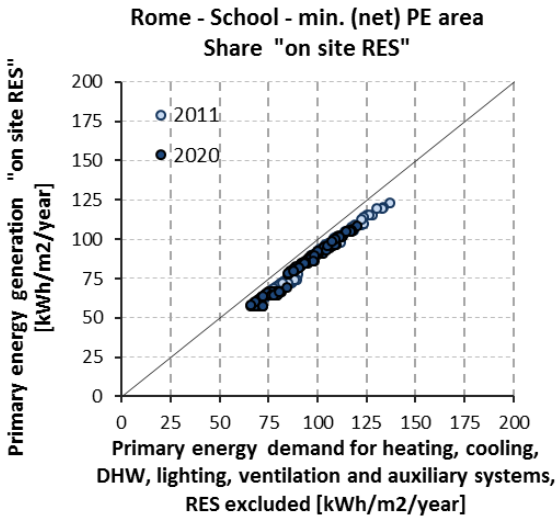

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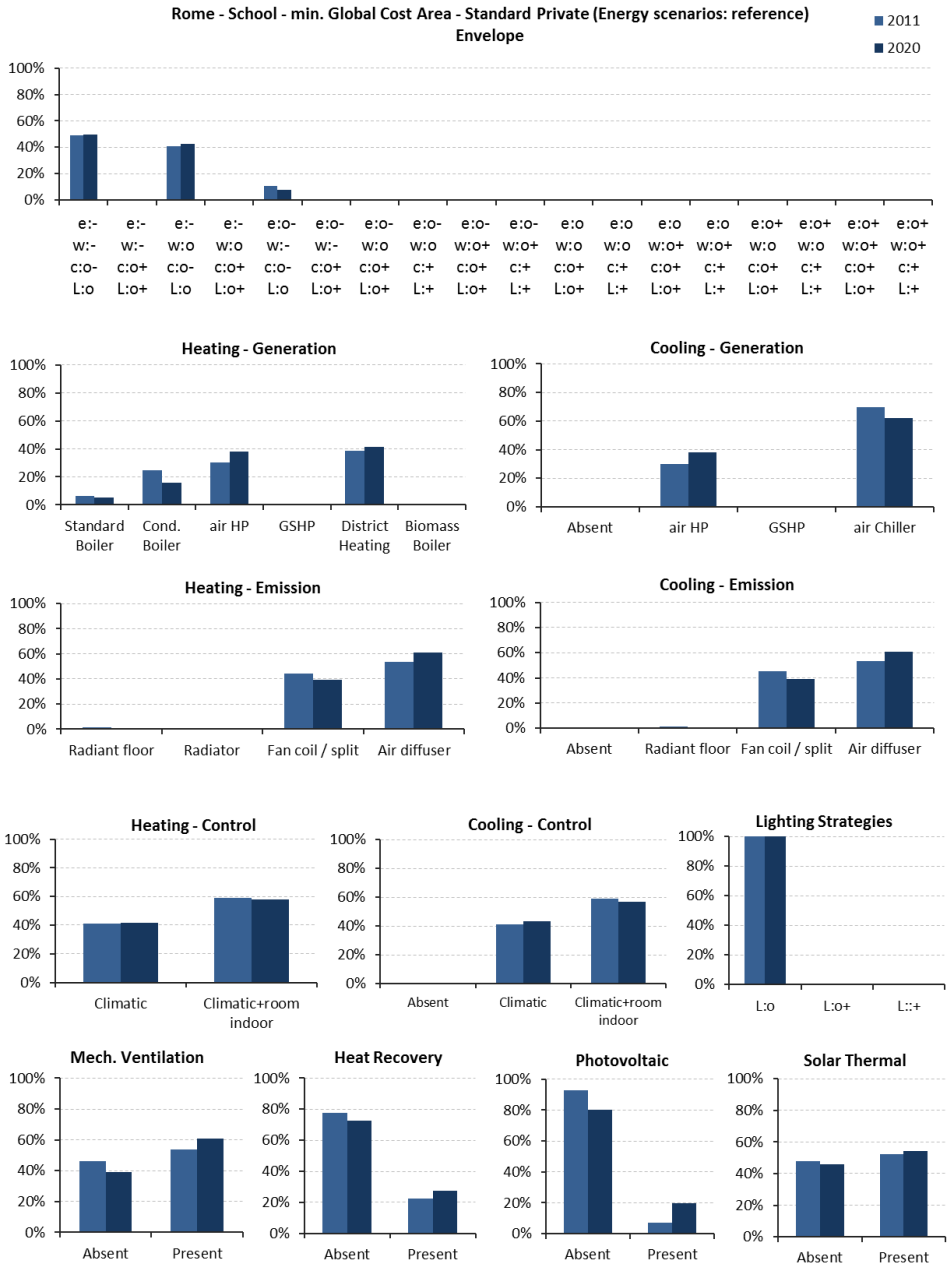
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	100	260	90	260
Range of Global Costs [€/m^2]:	891	980	929	1010
Number of Building Variants:	153		153	



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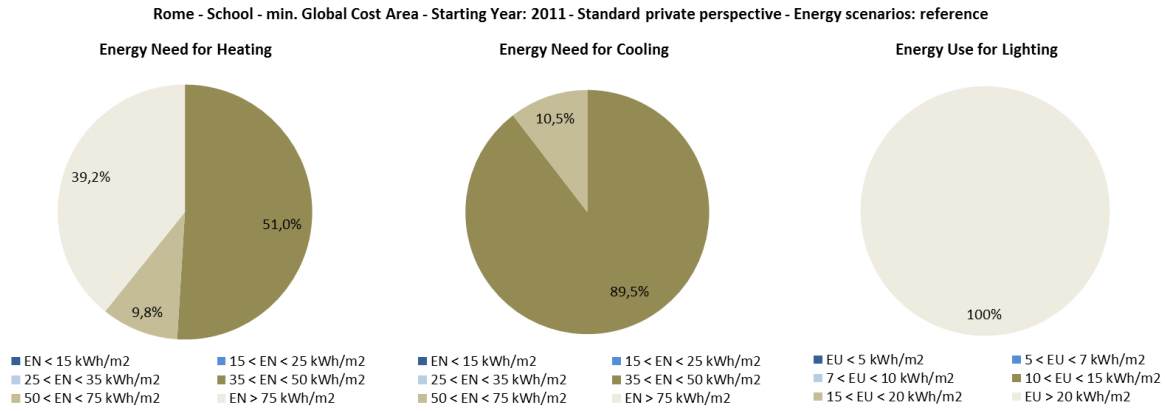

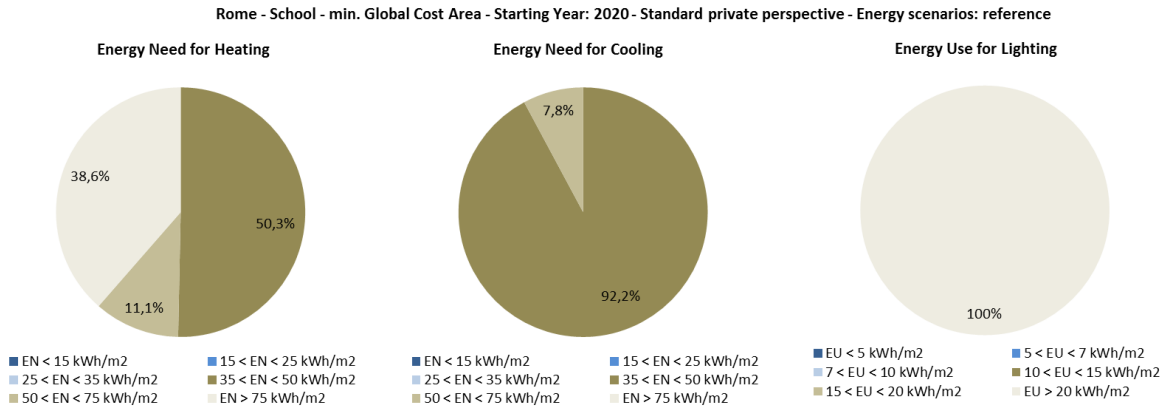

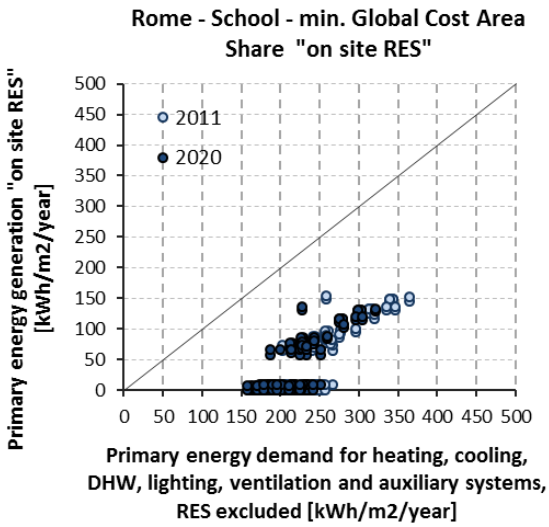

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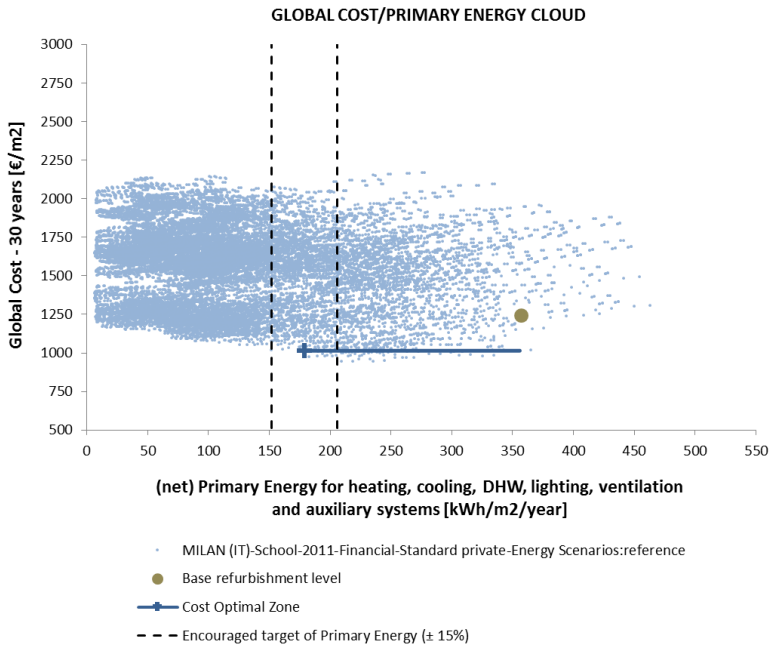
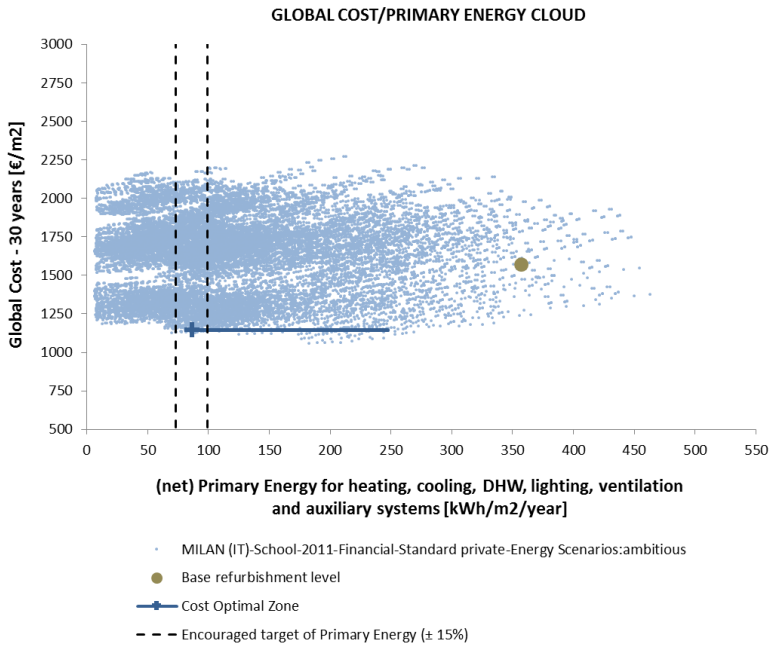
8.1.4.4 Milan





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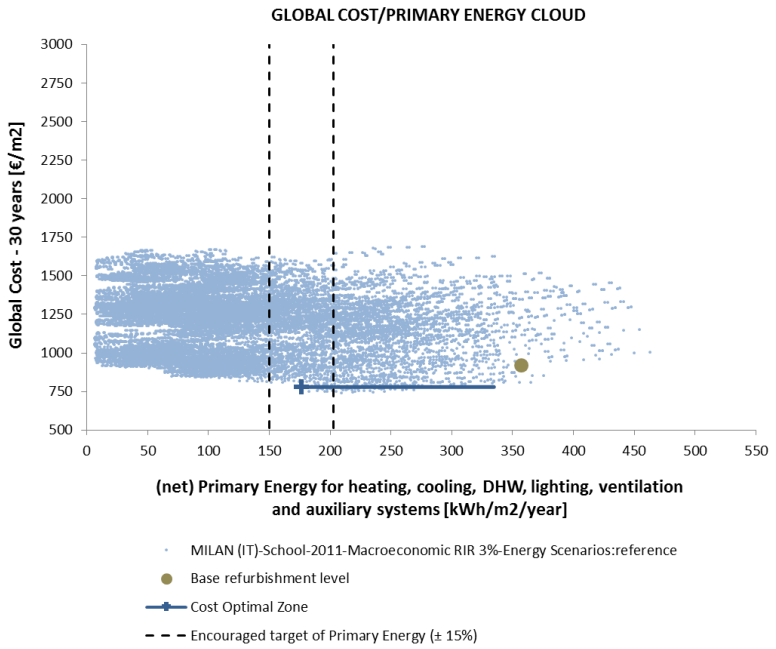

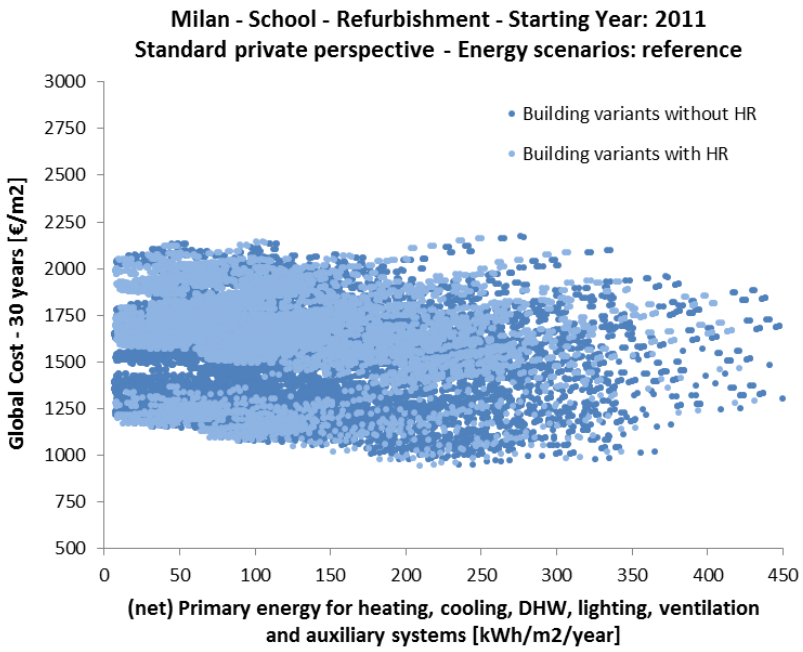

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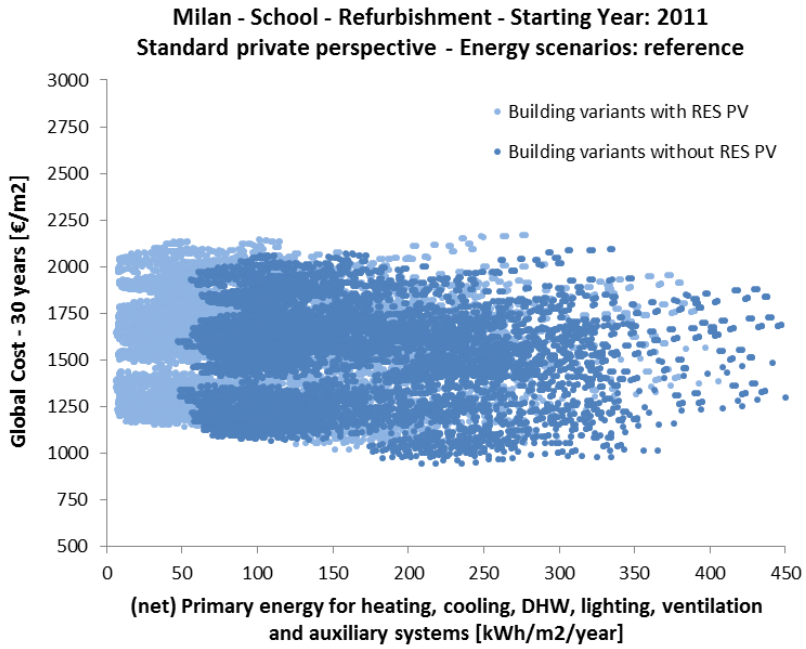

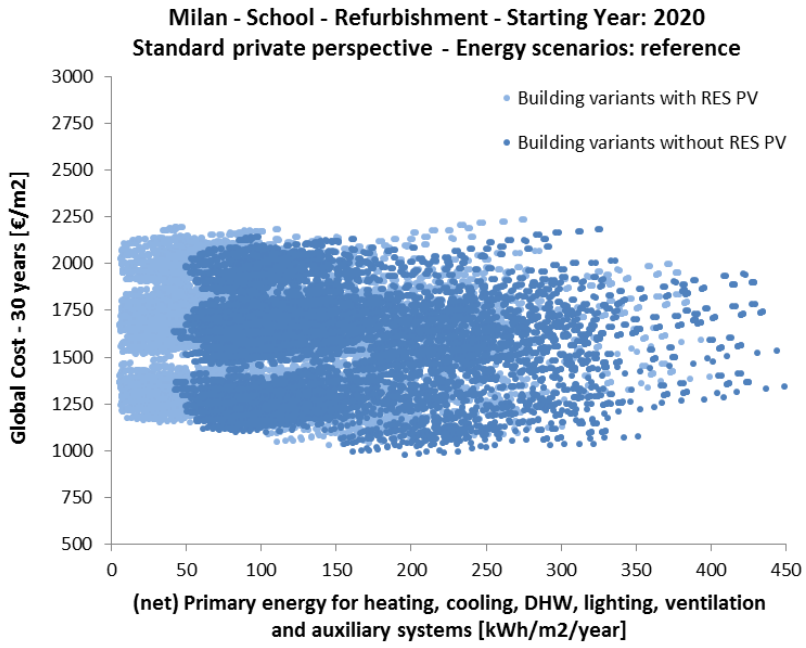

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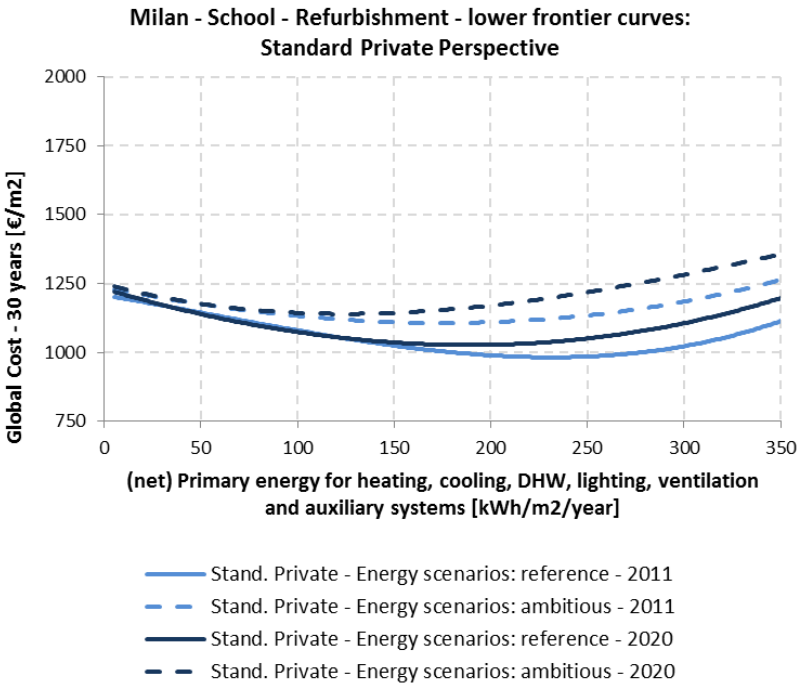

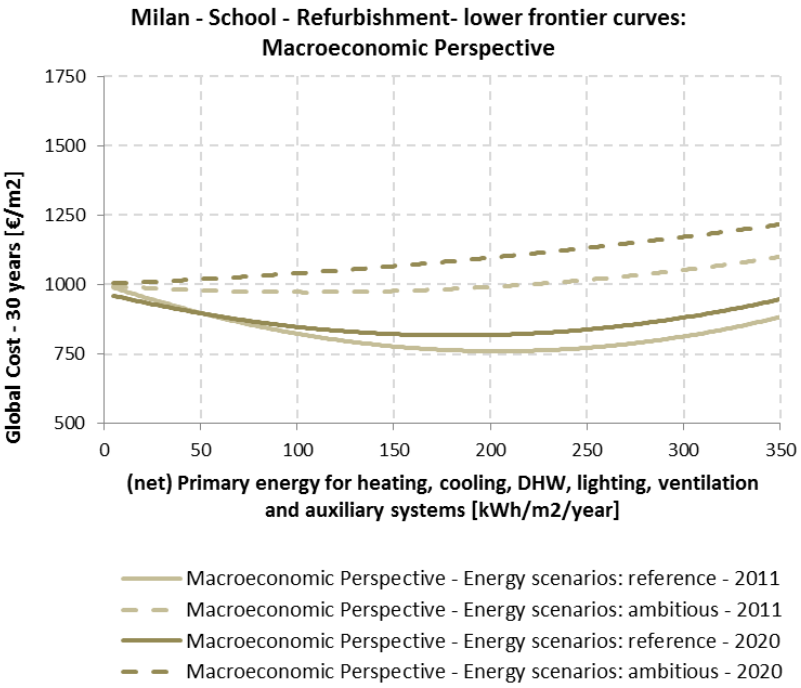

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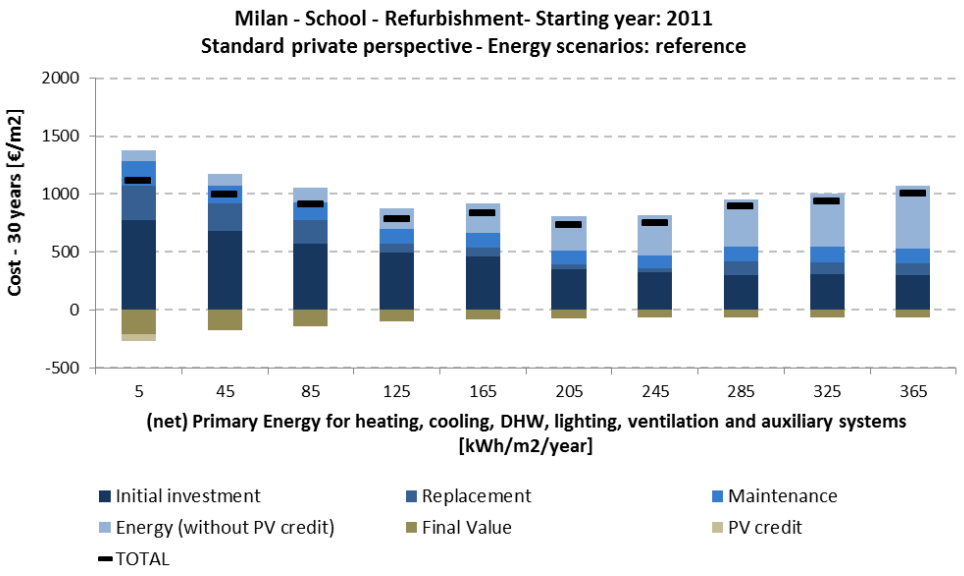
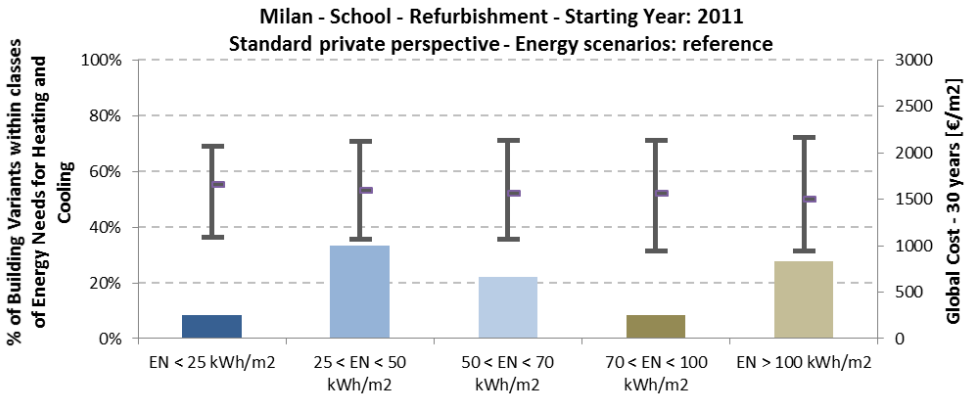
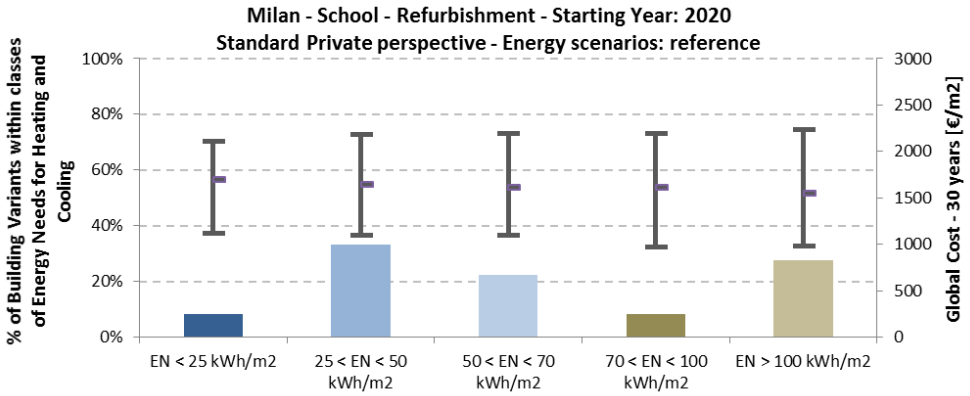
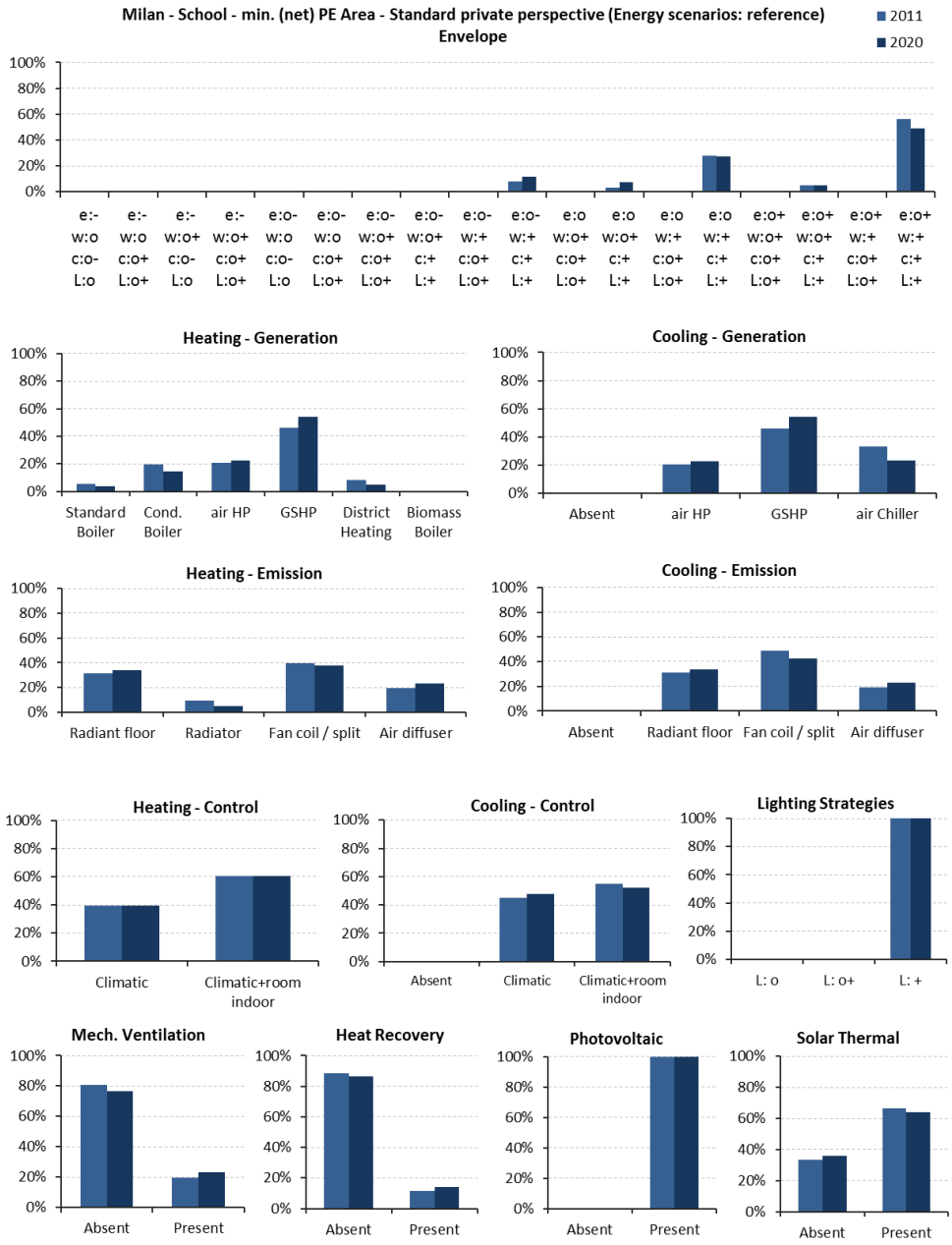

Milan - School - Refurbishment- Starting year: 2011
Standard private perspective - Energy scenarios: reference
Cost - 30 years [€/m2]
2000
1500
1000
500
0
-500
5
45
85
125
165
205
245
285
325
365
(net) Primary Energy for heating, cooling, DHW, lighting, ventilation and auxiliary systems [kWh/m2/year]
Initial investment
Replacement
Maintenance
Energy (without PV credit)
Final Value
PV credit
TOTAL


Milan - School - Refurbishment - Starting Year: 2011
Standard private perspective - Energy scenarios: reference
% of Building Variants within classes of Energy Needs for Heating and Cooling
100%
80%
60%
40%
20%
0%
3000
2500
2000
1500
1000
500
0
Global Cost - 30 years [€/m2]
EN < 25 kWh/m2
25 < EN < 50 kWh/m2
50 < EN < 70 kWh/m2
70 < EN < 100 kWh/m2
EN > 100 kWh/m2


Milan - School - Refurbishment - Starting Year: 2020
Standard Private perspective - Energy scenarios: reference
% of Building Variants within classes of Energy Needs for Heating and Cooling
100%
80%
60%
40%
20%
0%
3000
2500
2000
1500
1000
500
0
Global Cost - 30 years [€/m2]
EN < 25 kWh/m2
25 < EN < 50 kWh/m2
50 < EN < 70 kWh/m2
70 < EN < 100 kWh/m2
EN > 100 kWh/m2

min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	6	15	6	15
Range of Global Costs [€/m^2]:	1168	1402	1172	1430
Number of Building Variants:	159		159	



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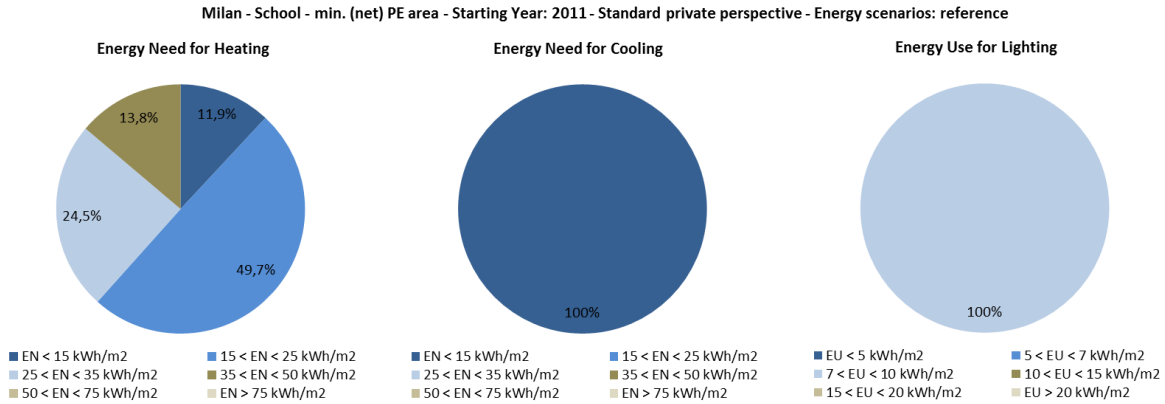

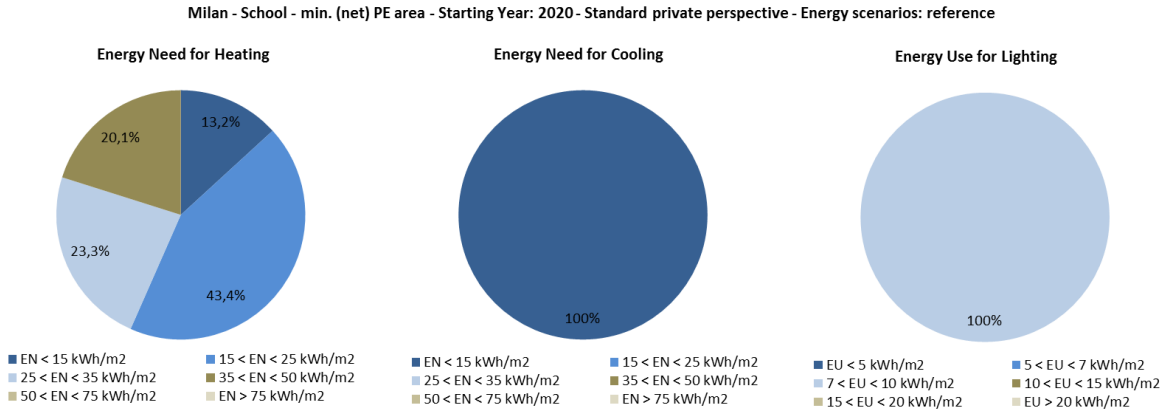

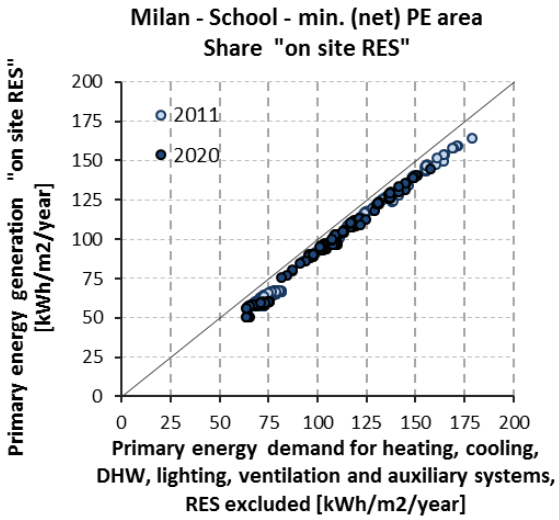

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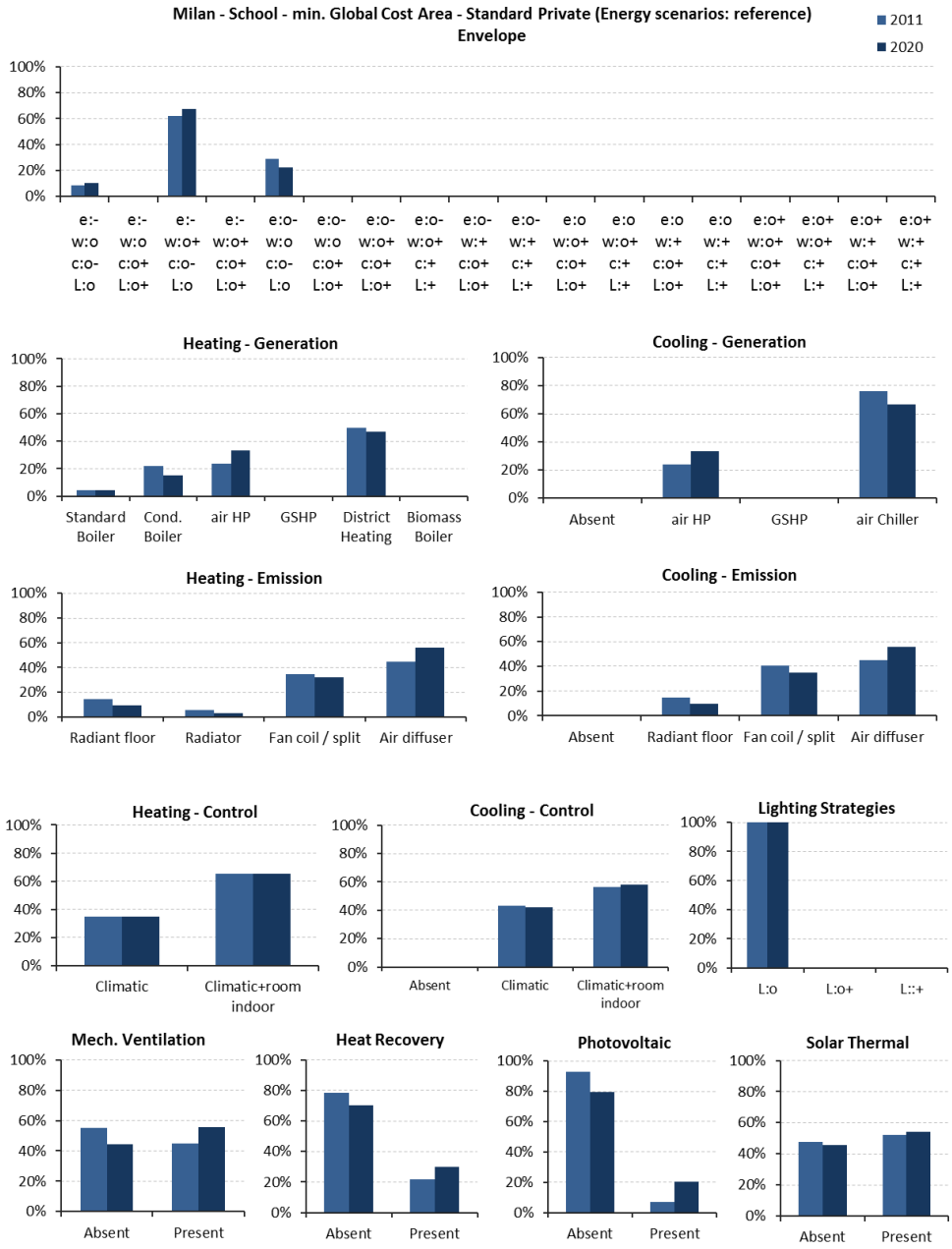
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	110	310	95	295
Range of Global Costs [€/m^2]:	947	1051	979	1089
Number of Building Variants:	138		138	



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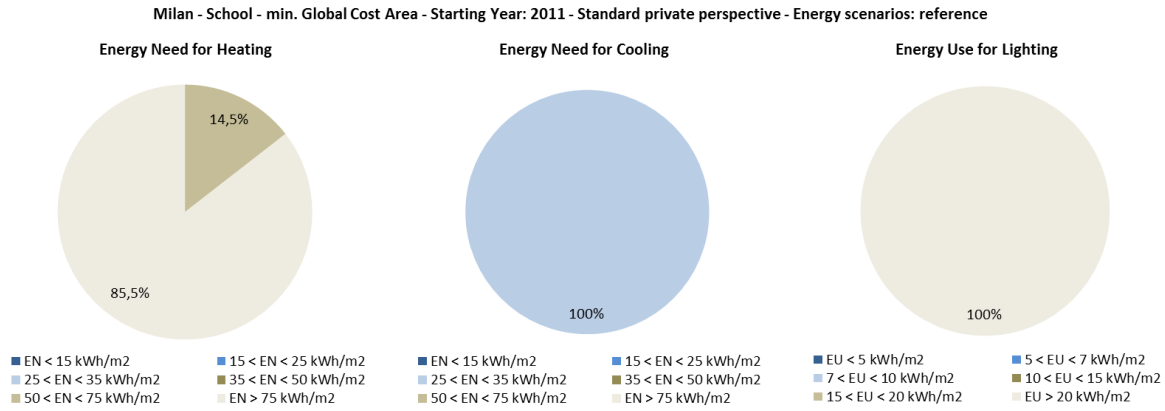

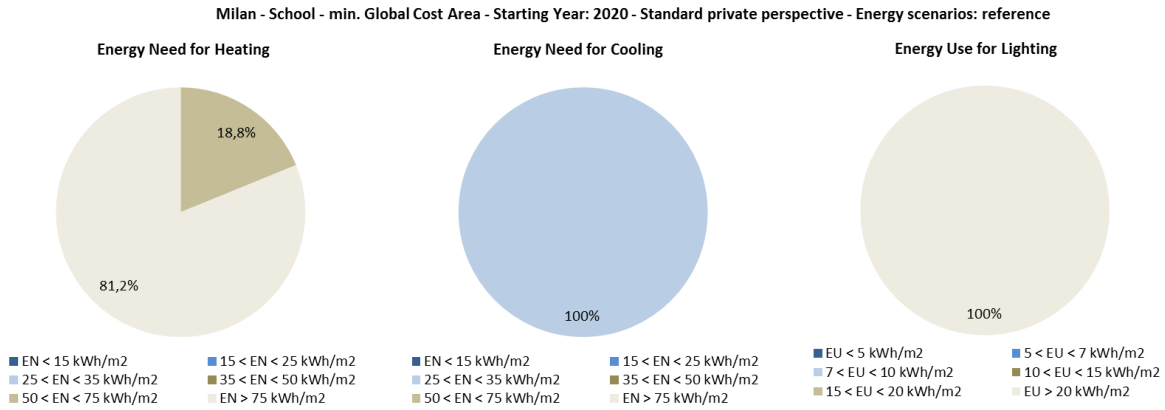

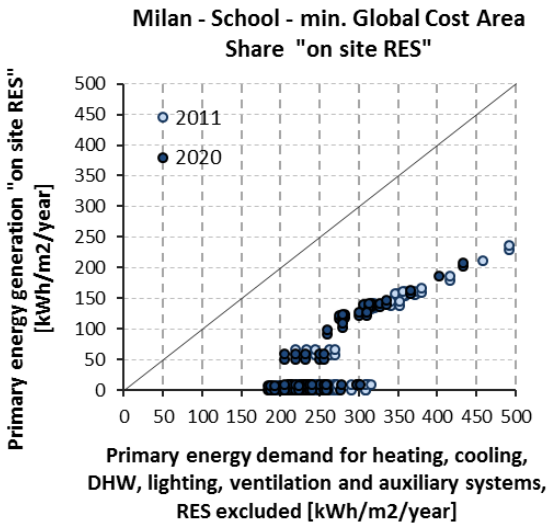

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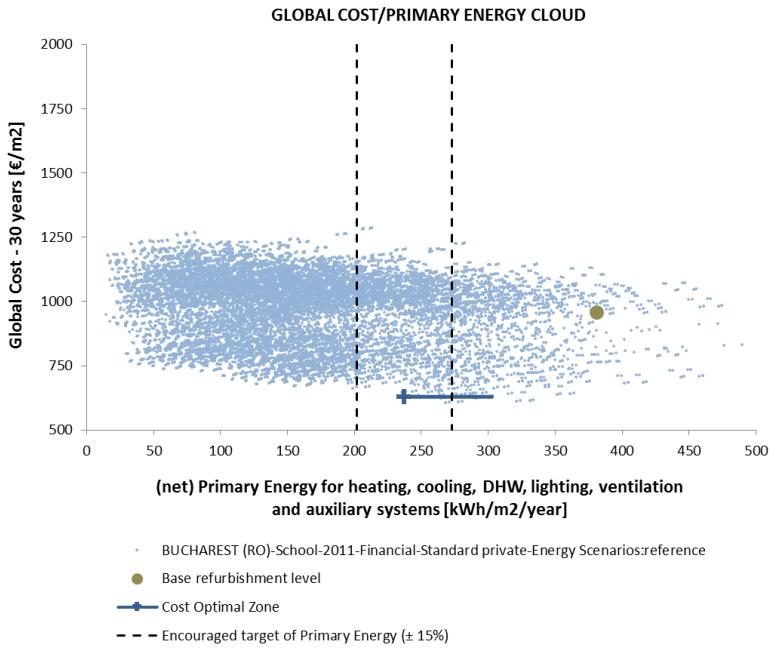
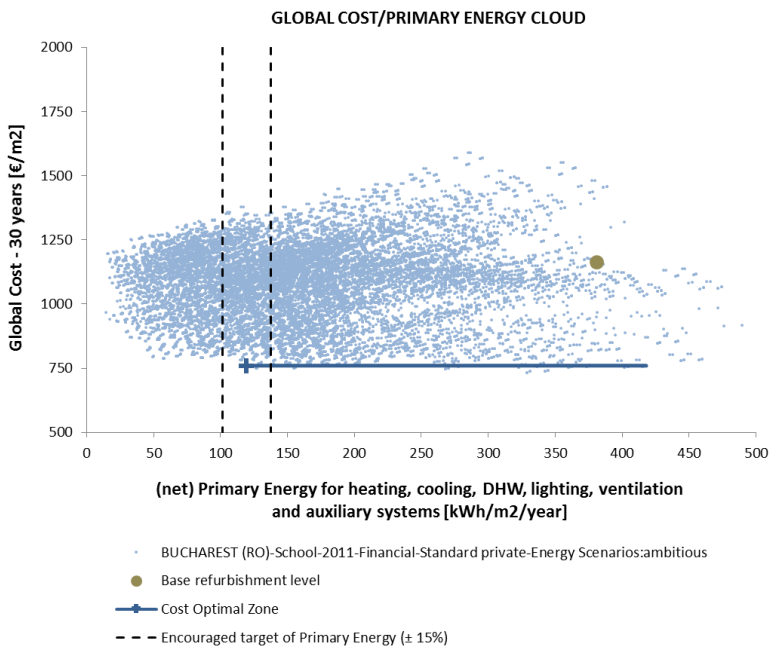
8.1.4.5 Bucharest





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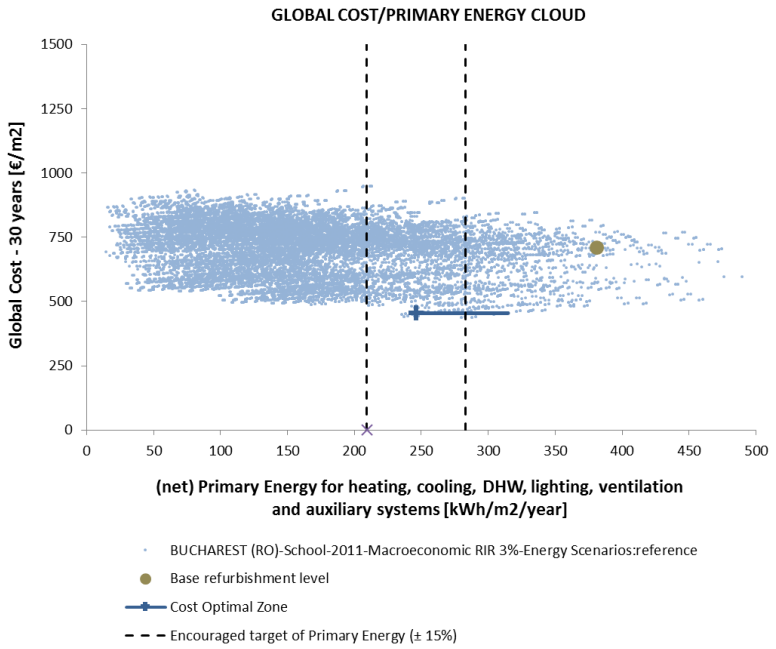

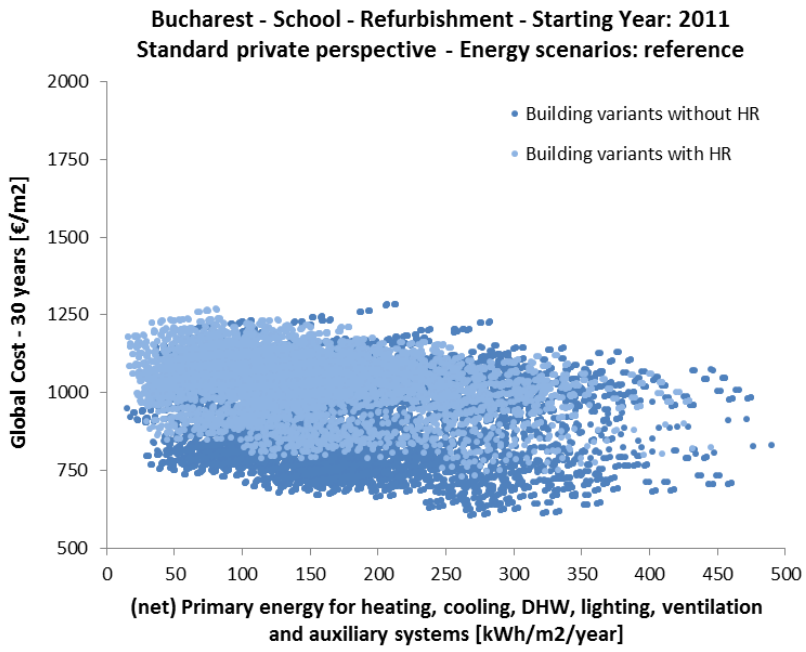

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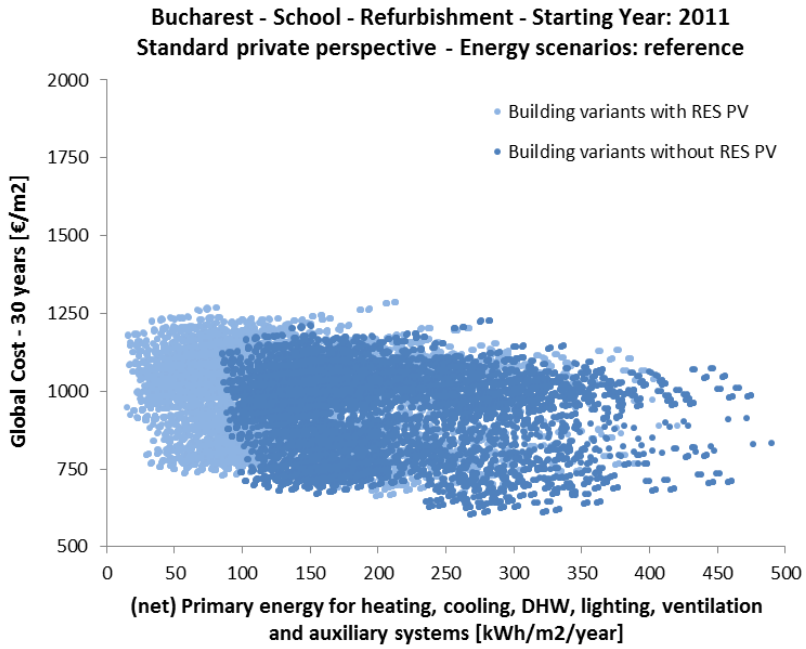

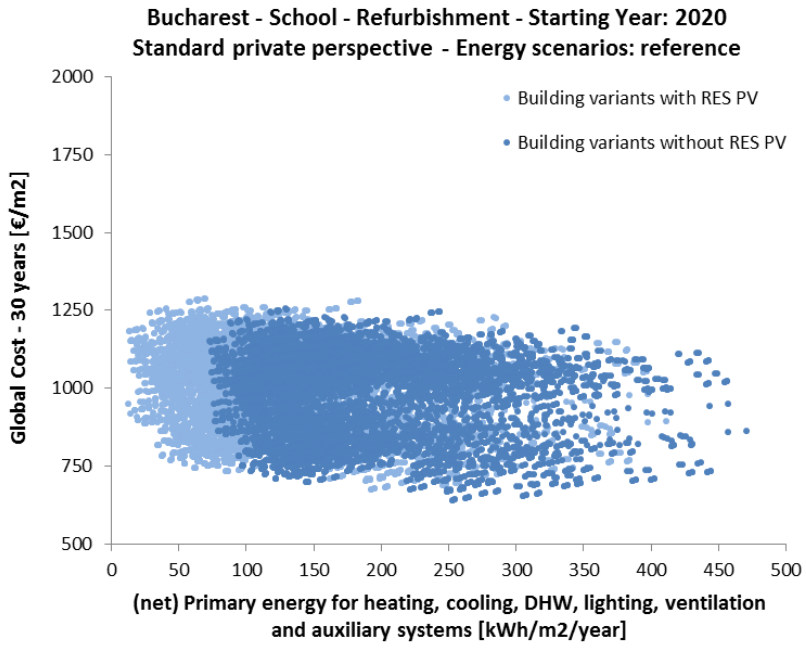

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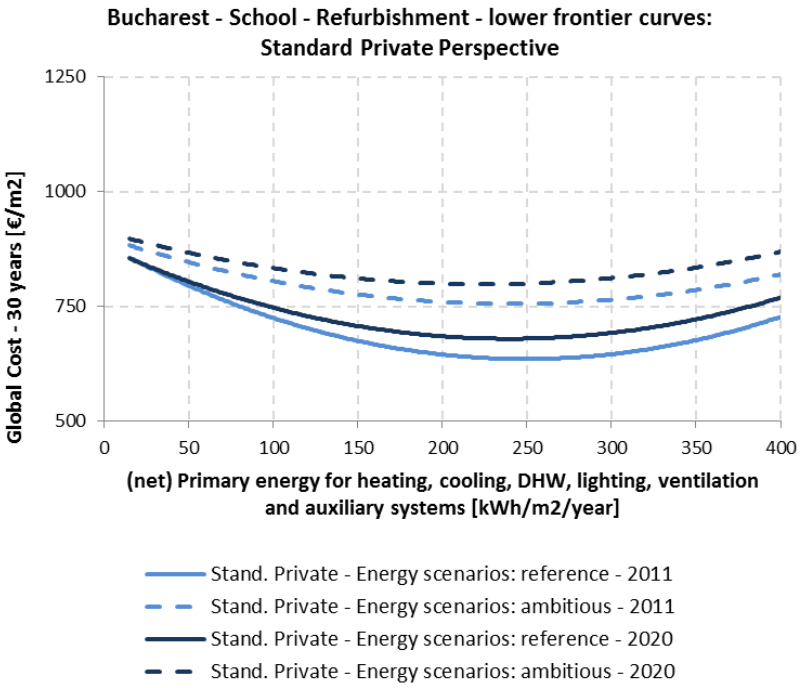

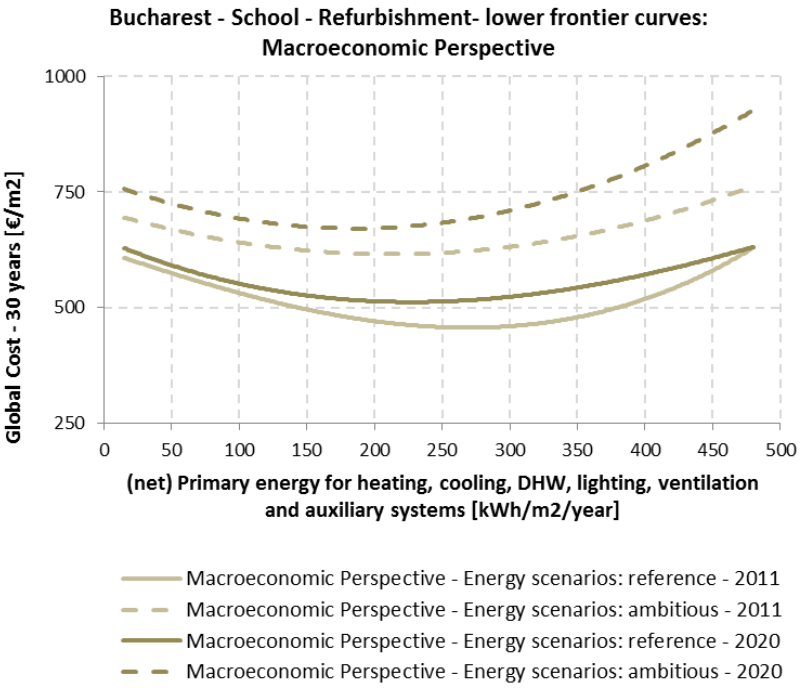

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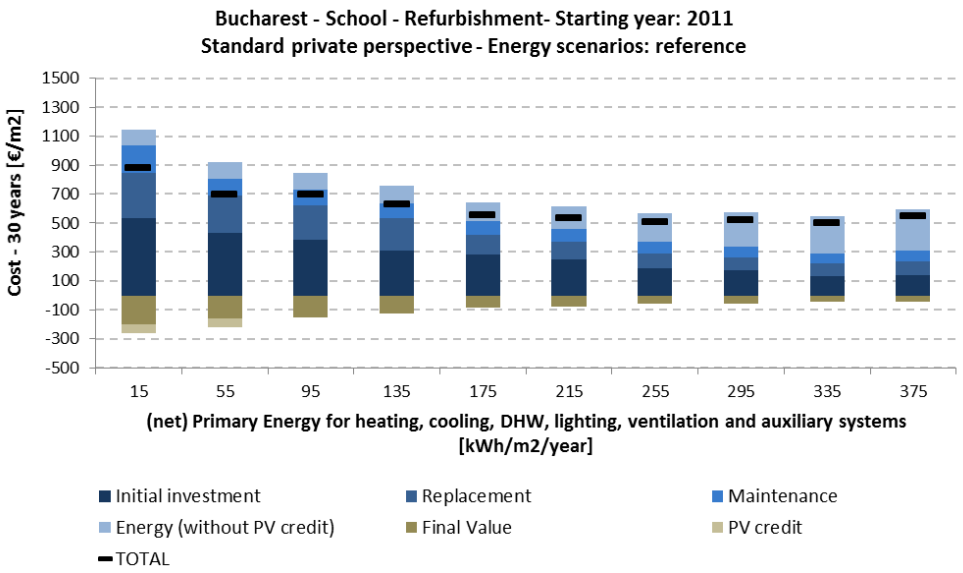

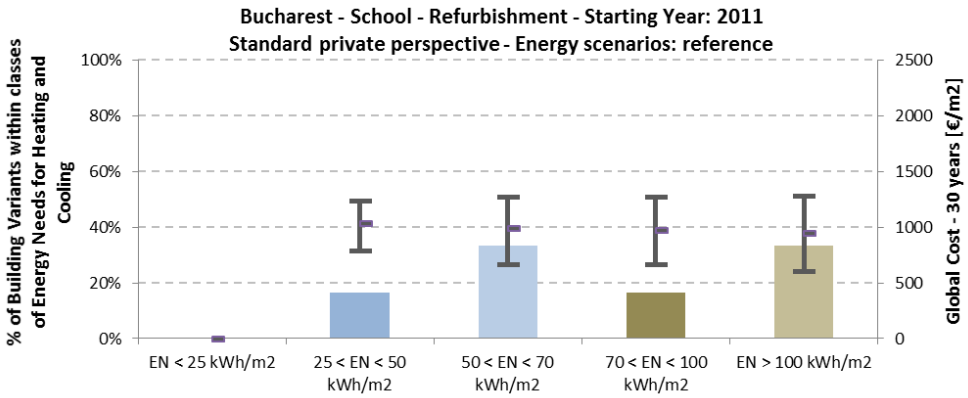

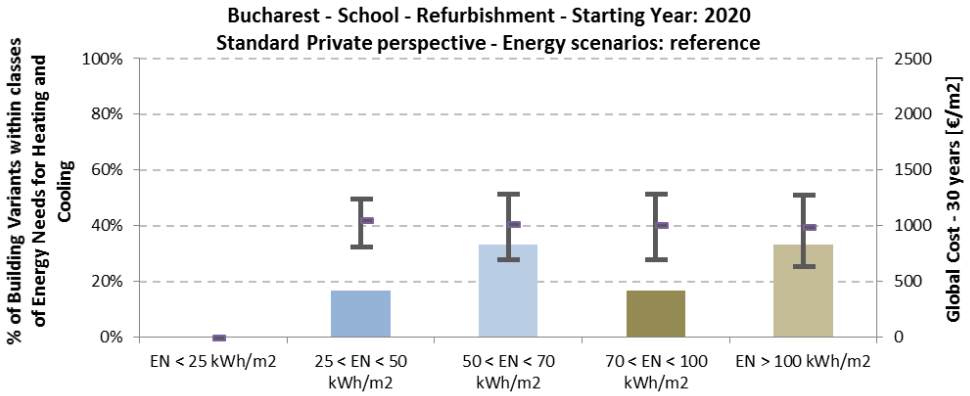

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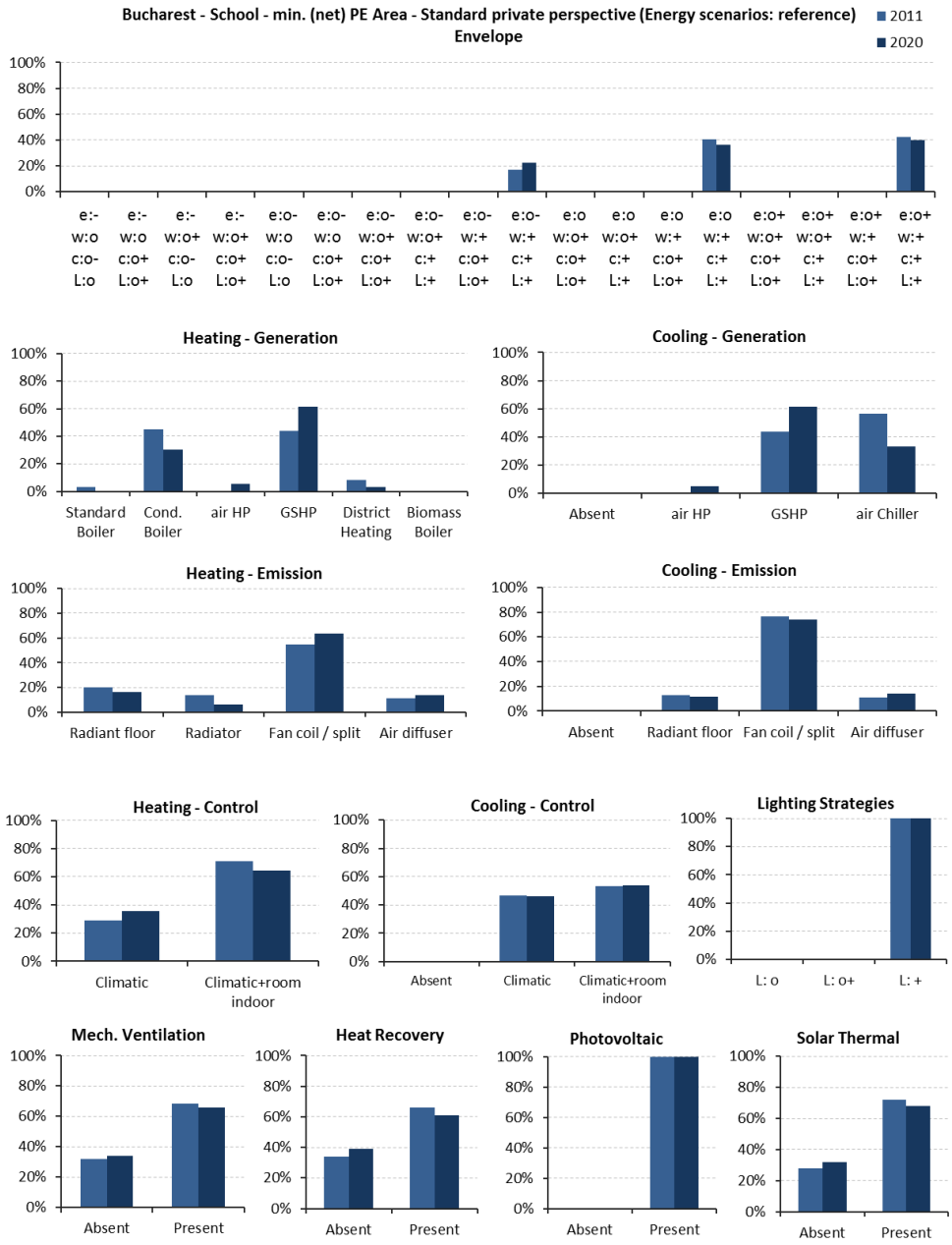
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	15	35	13	35
Range of Global Costs [€/m^2]:	769	1077	785	1092
Number of Building Variants:	135		135	



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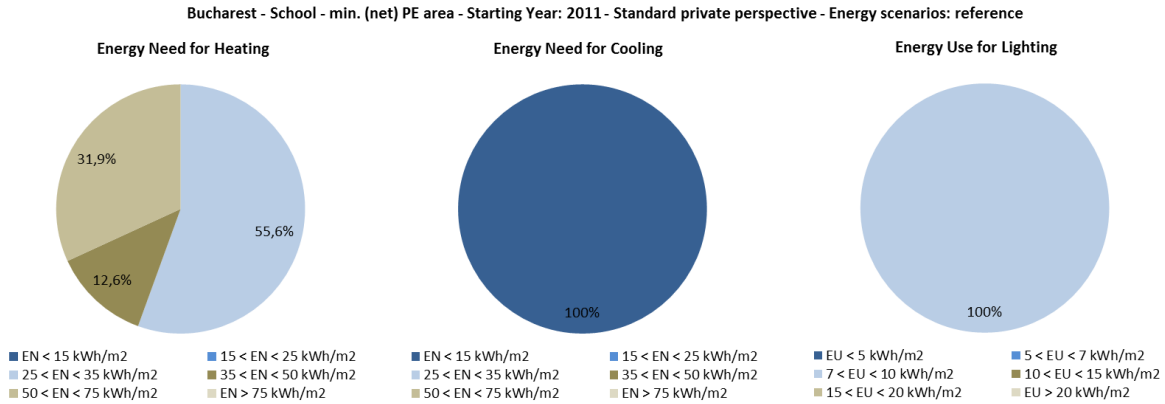

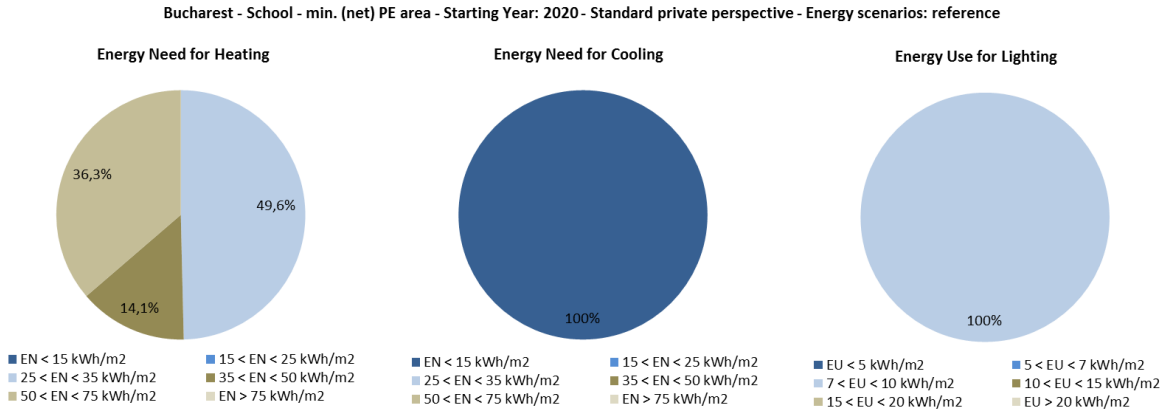

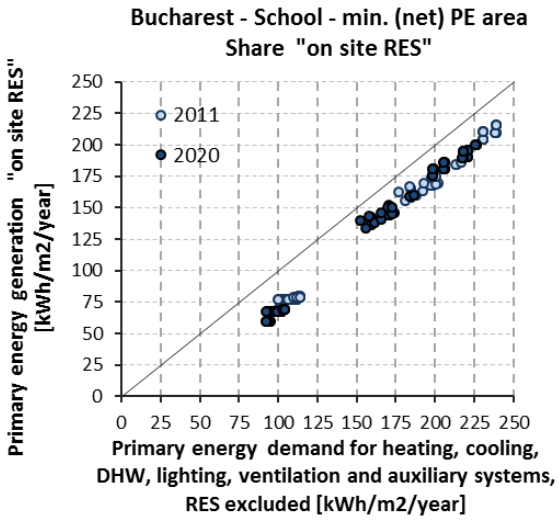

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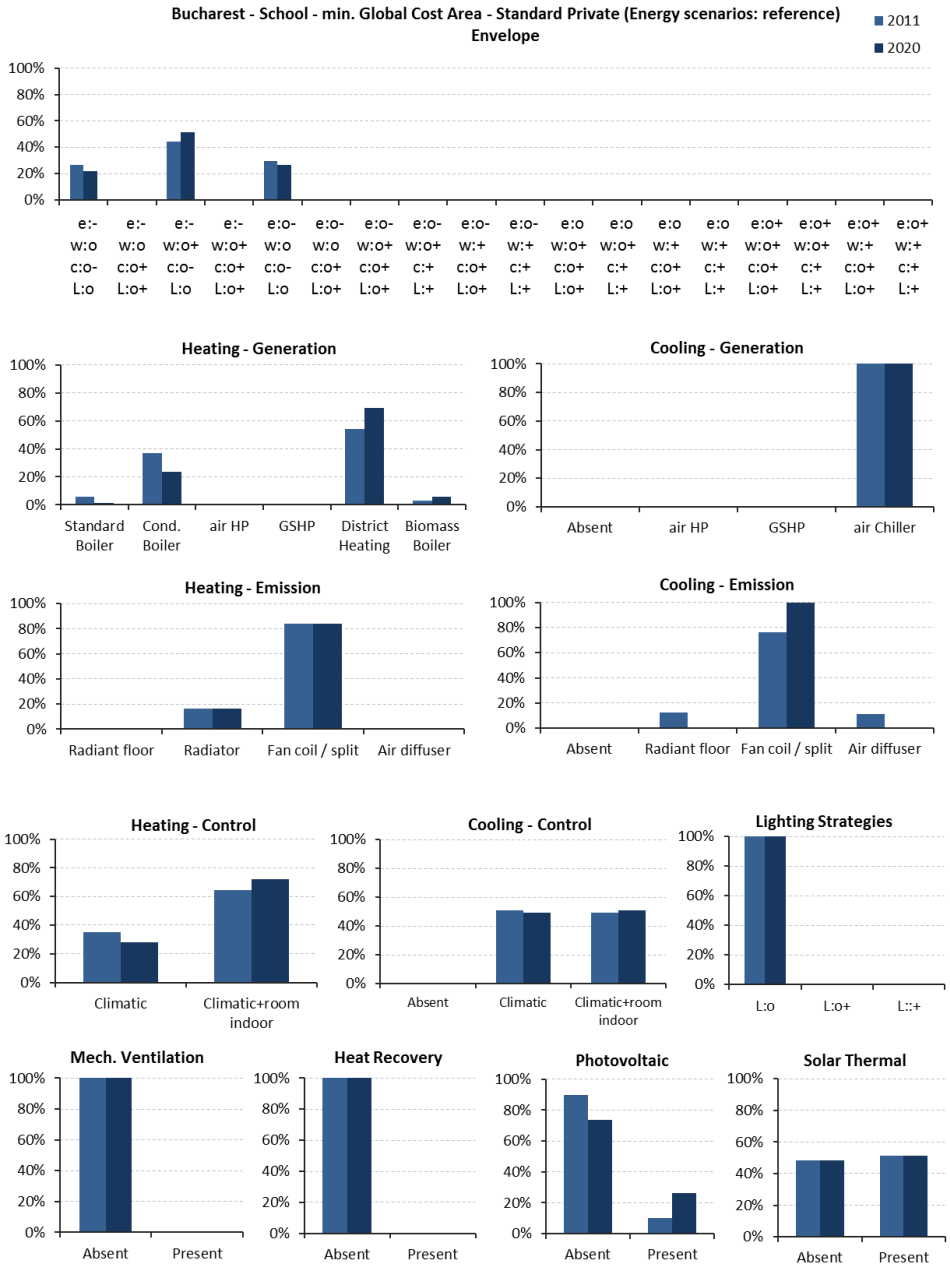
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	200	340	175	335
Range of Global Costs [€/m^2]:	606	678	641	718
Number of Building Variants:	136		136	



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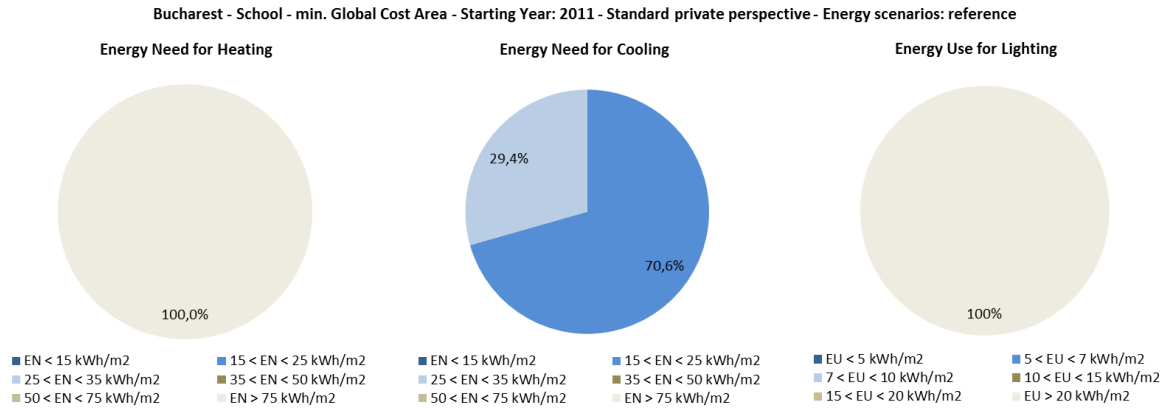

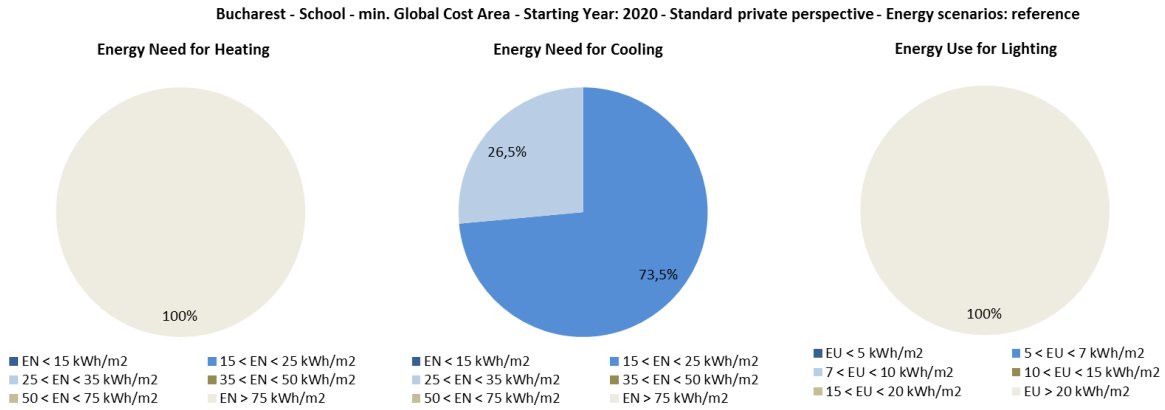

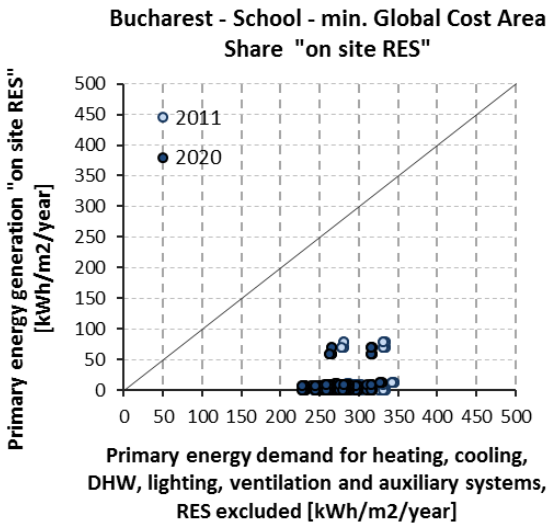

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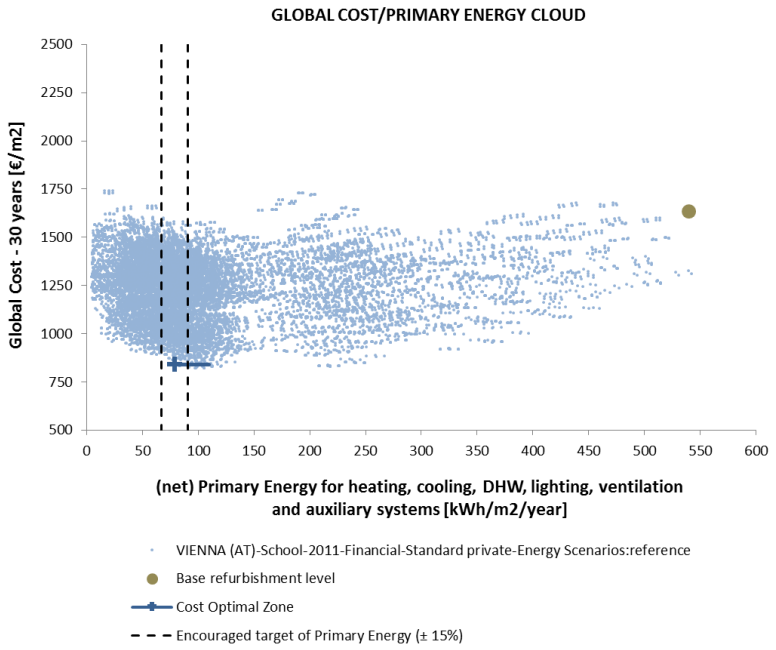
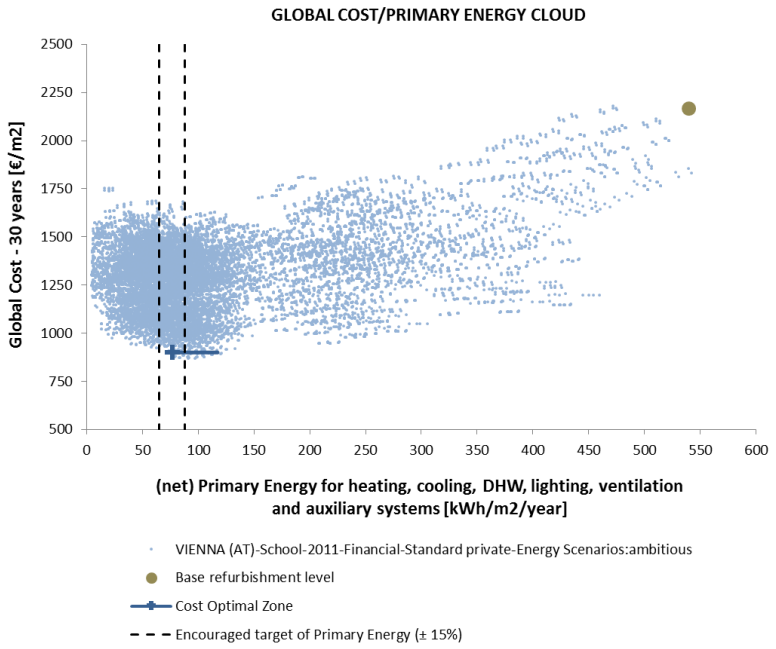
8.1.4.6 Vienna





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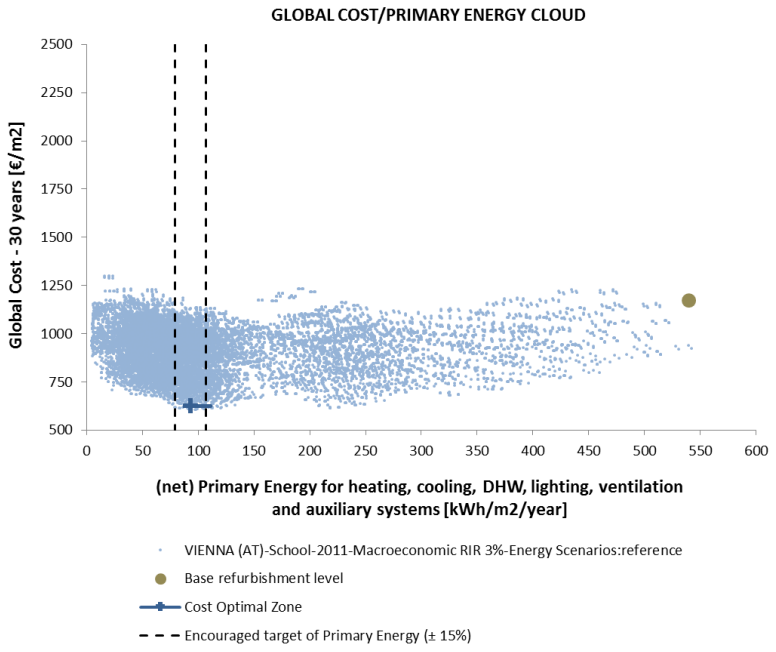

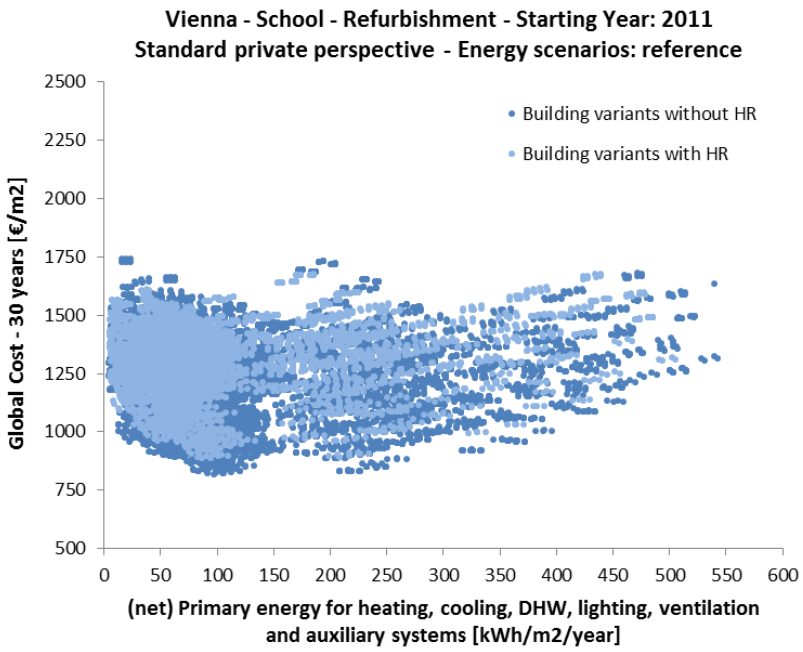

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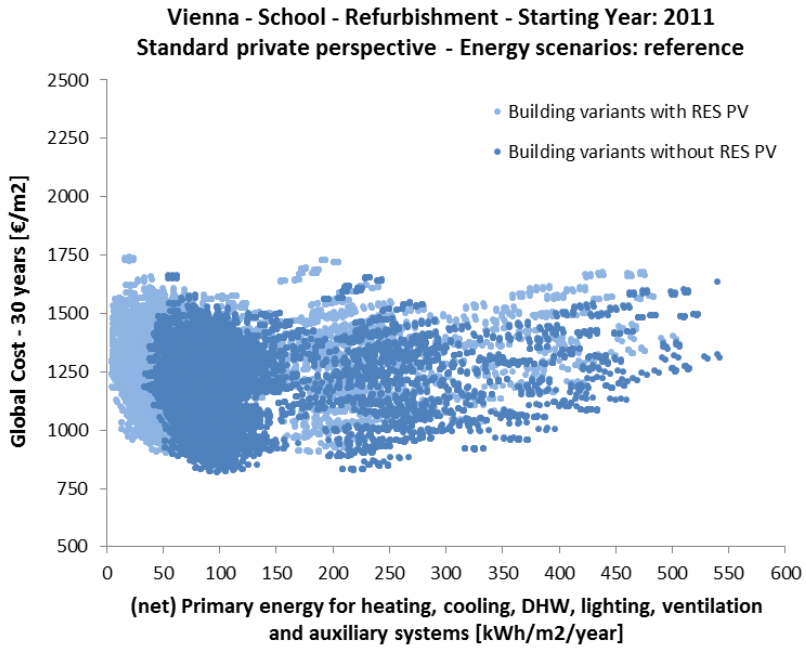

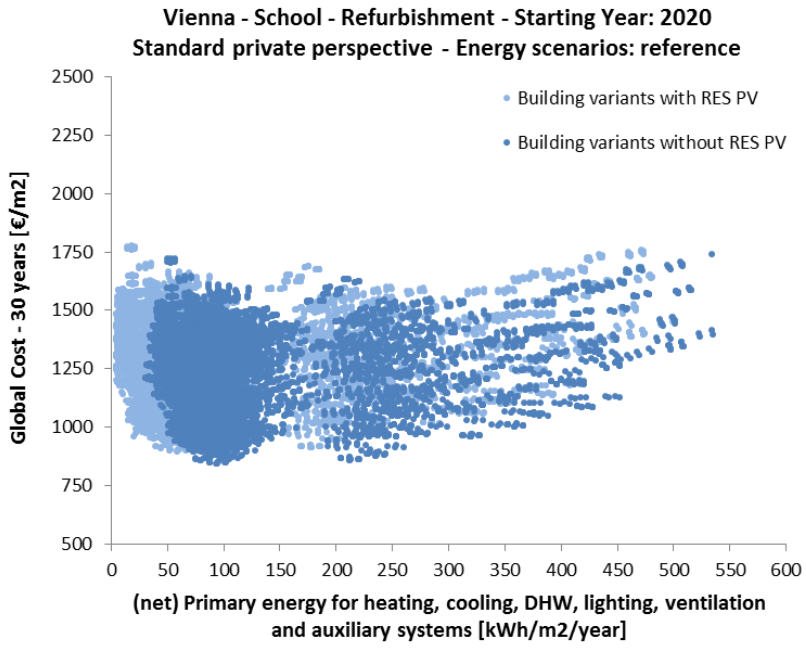

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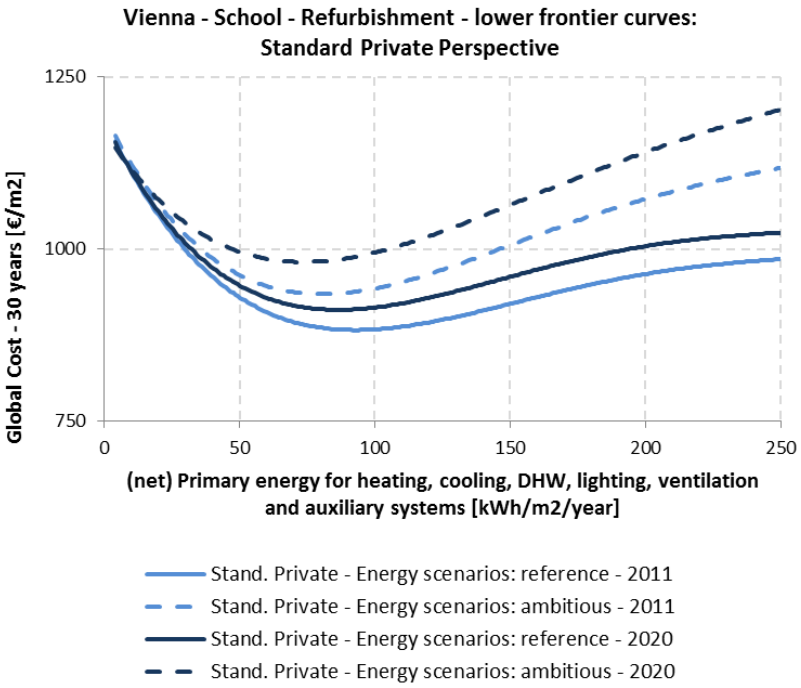

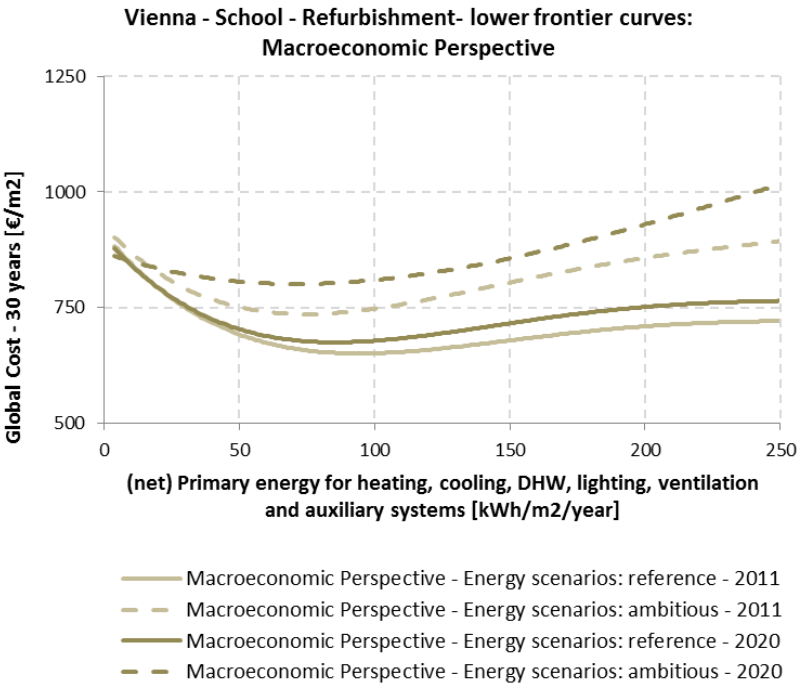

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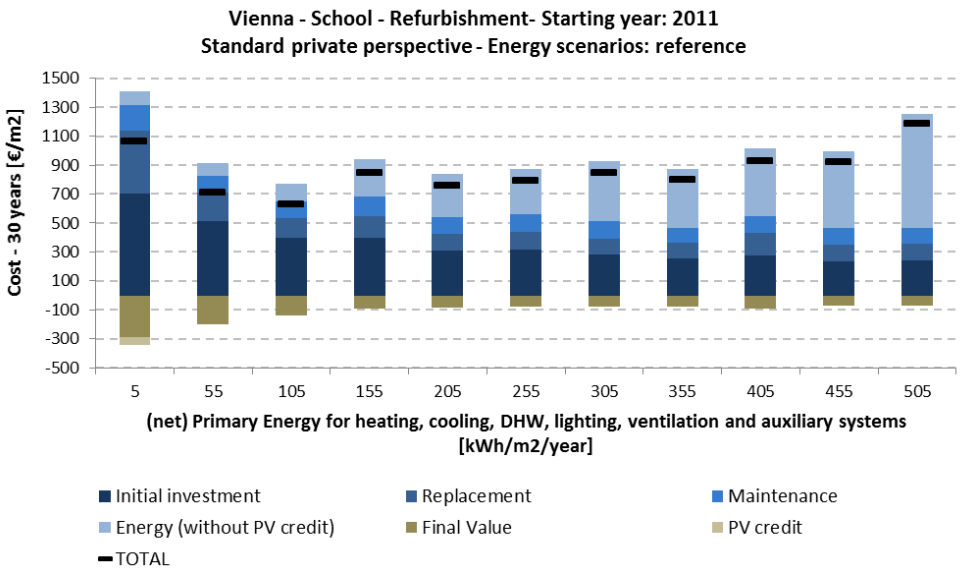

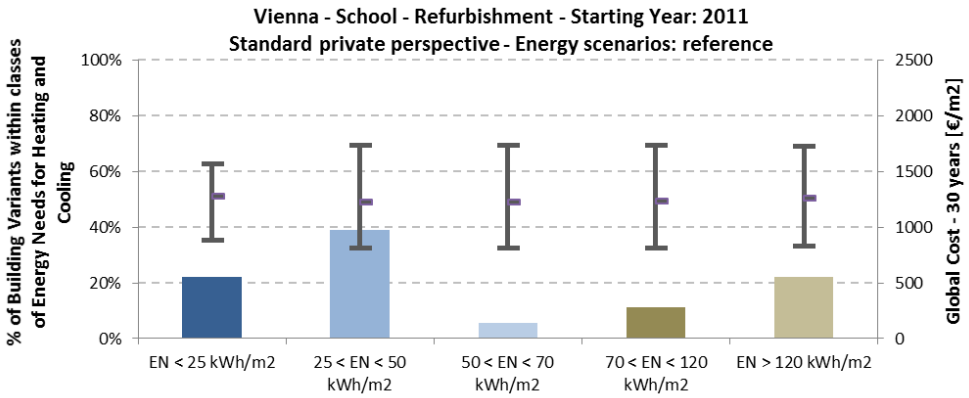

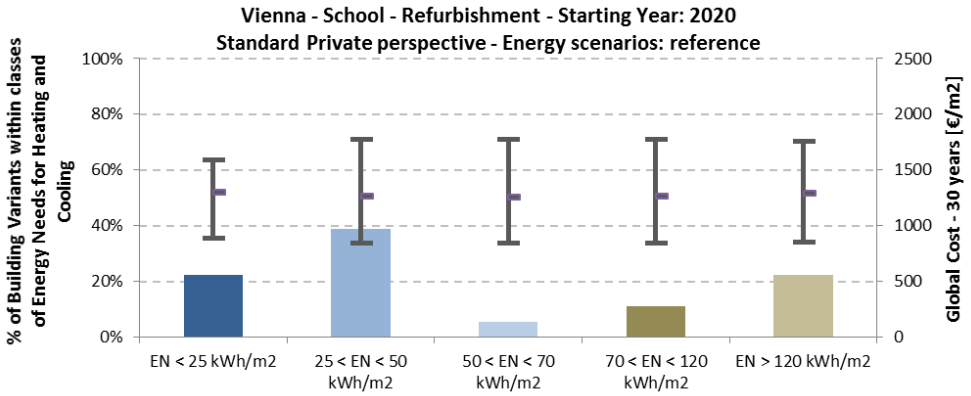

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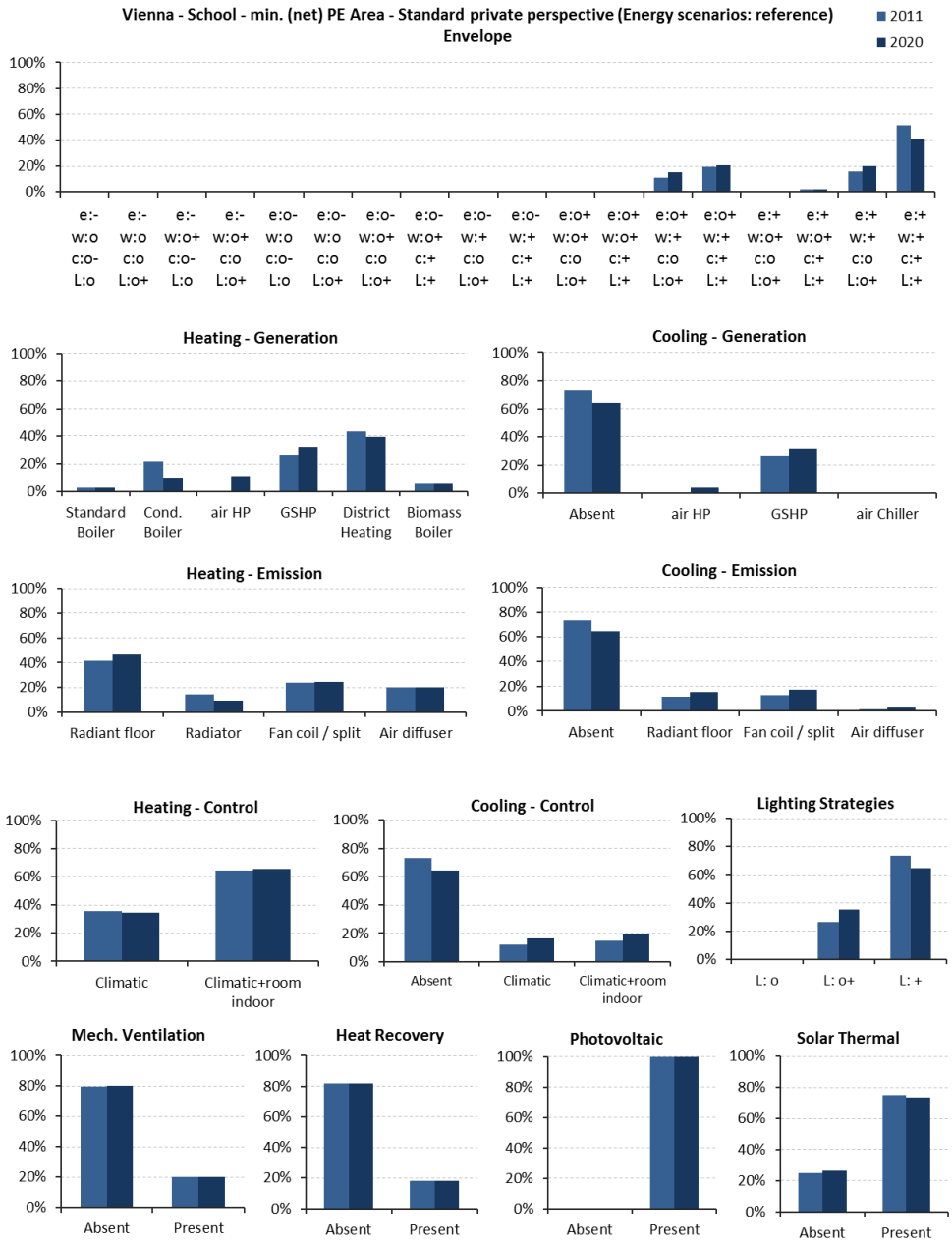
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	4	25	4	25
Range of Global Costs [€/m^2]:	968	1162	989	1181
Number of Building Variants:	110		110	



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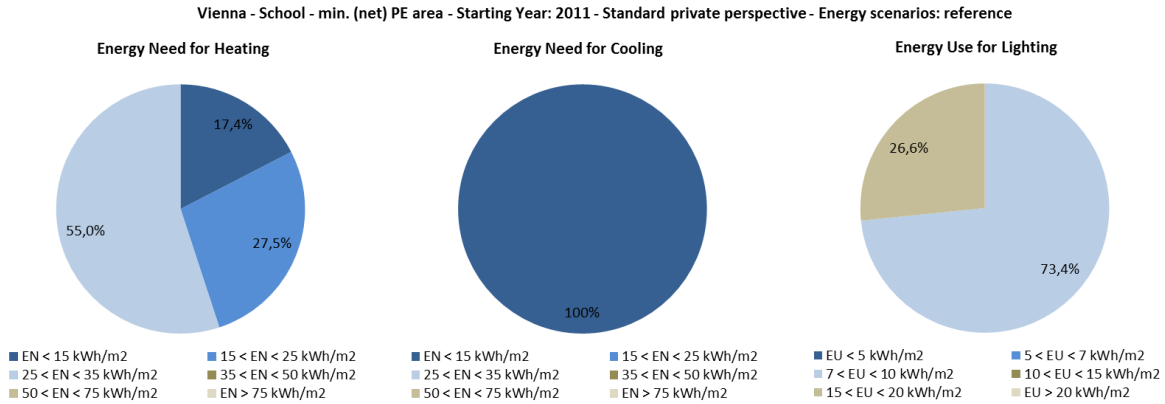

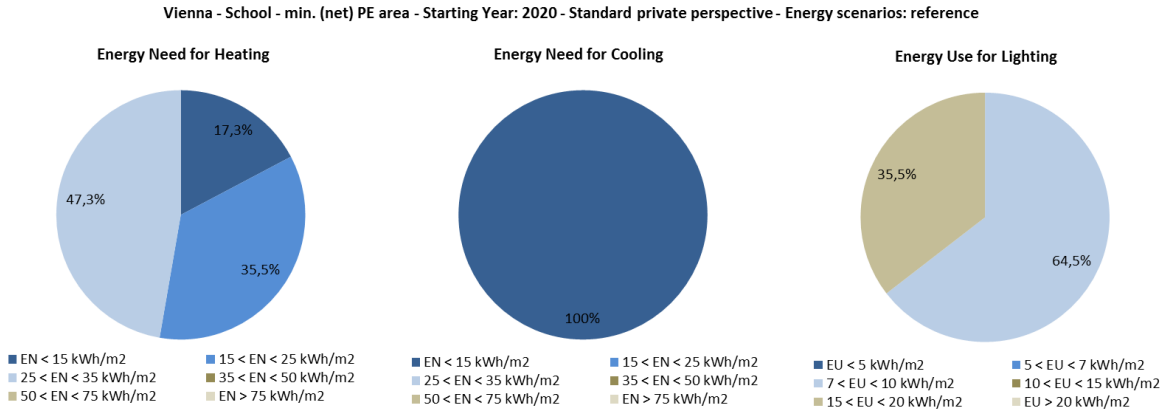

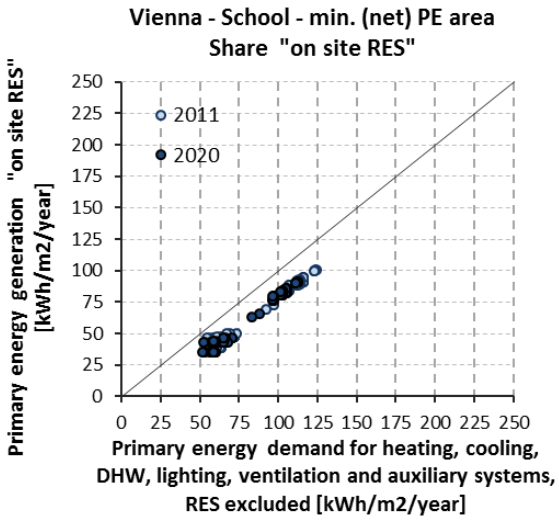

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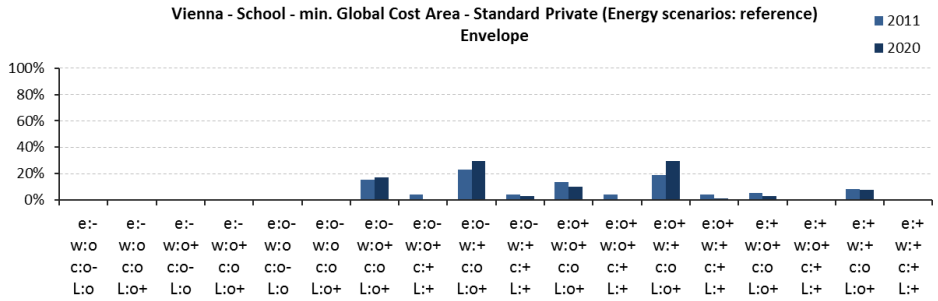
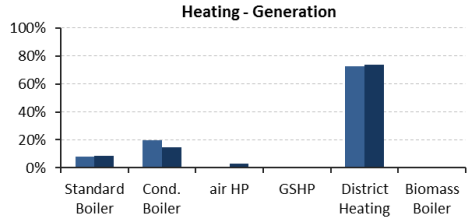
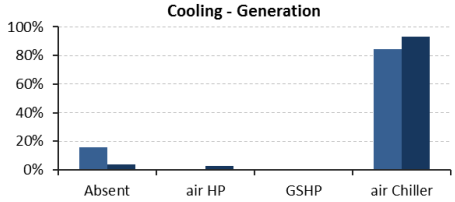
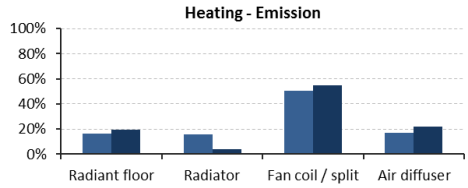
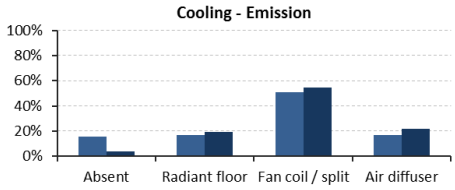
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	40	150	40	150
Range of Global Costs [€/m^2]:	821	903	844	937
Number of Building Variants:	205		205	

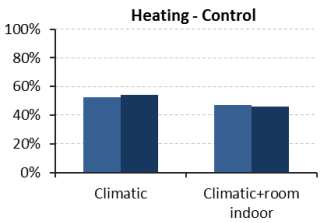


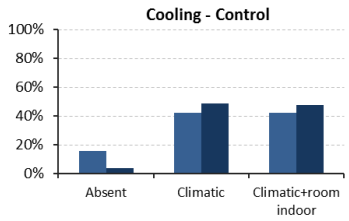


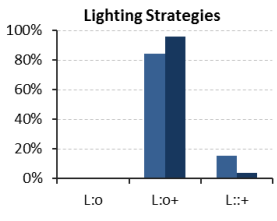


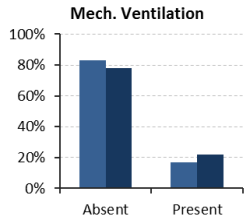


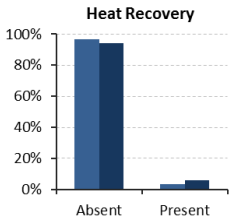


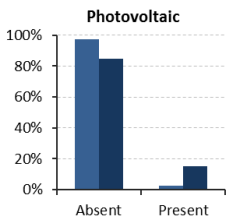


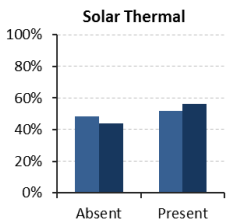












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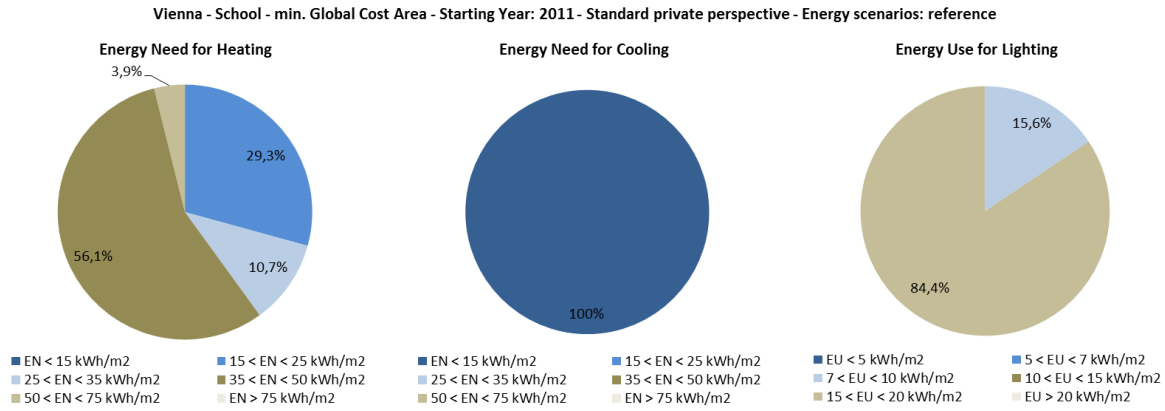

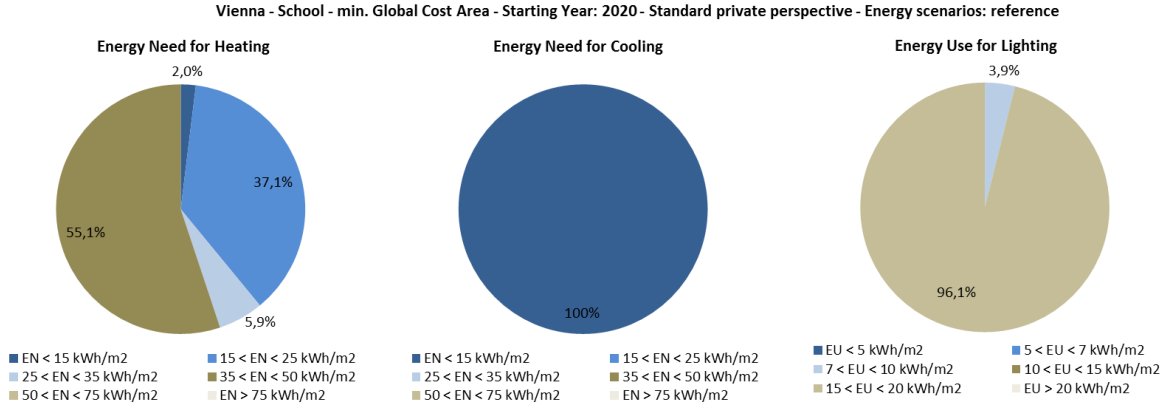

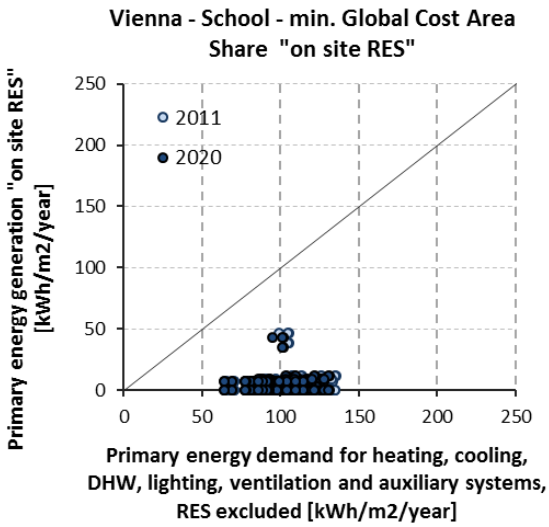

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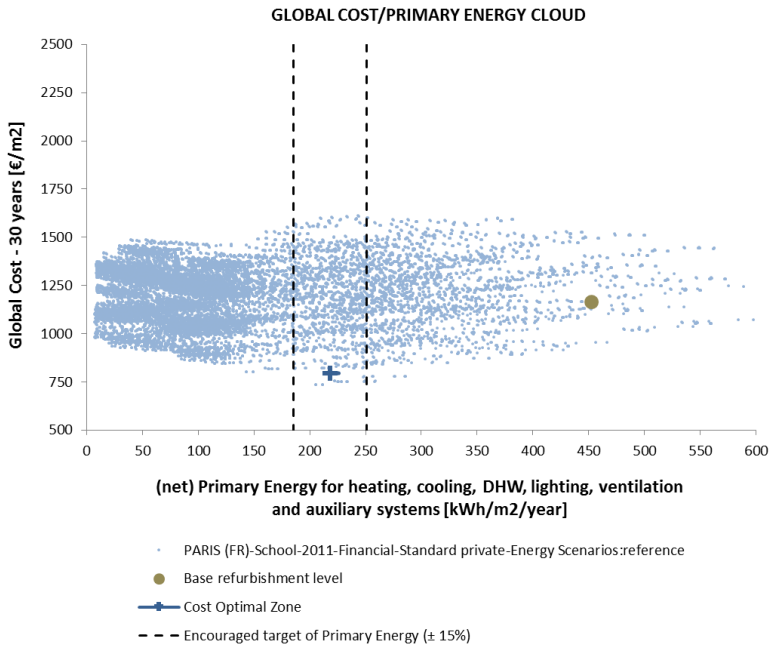
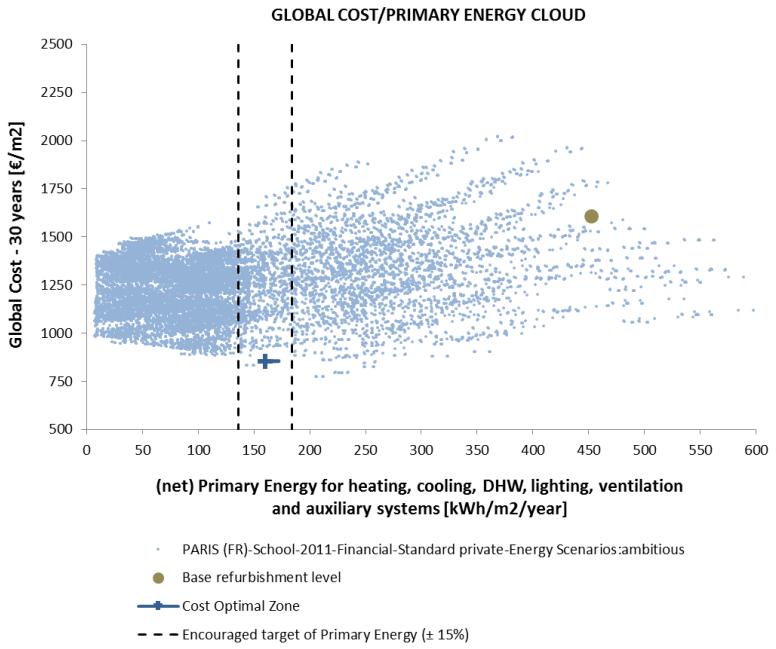
8.1.4.7 Paris





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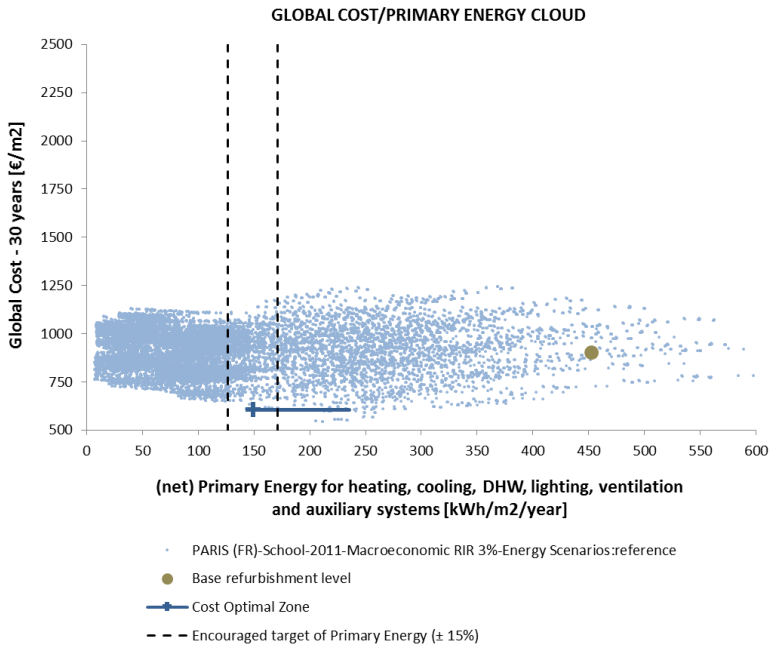

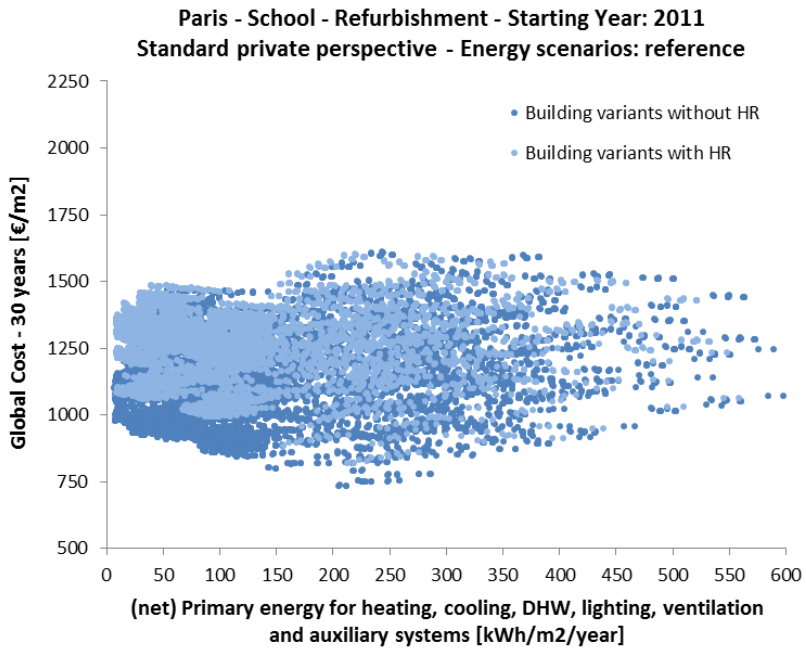

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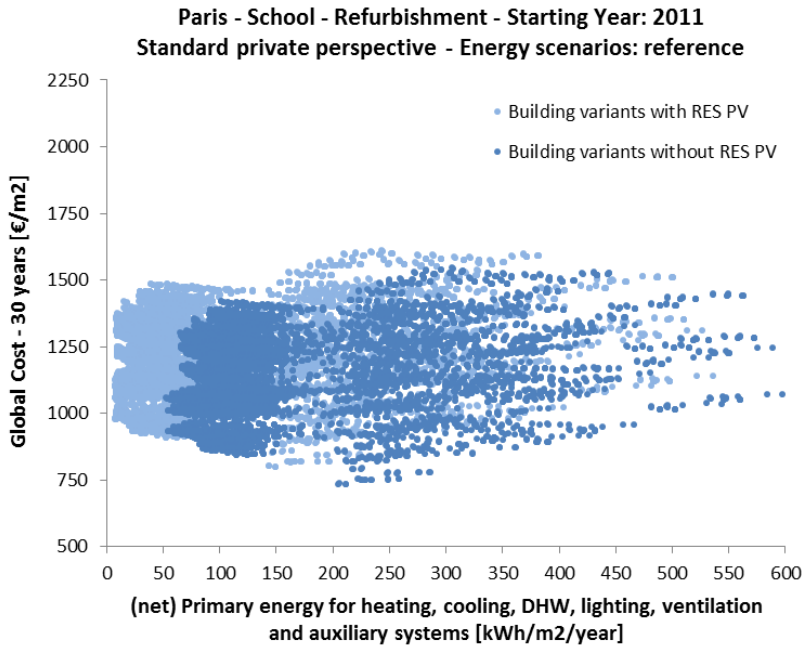

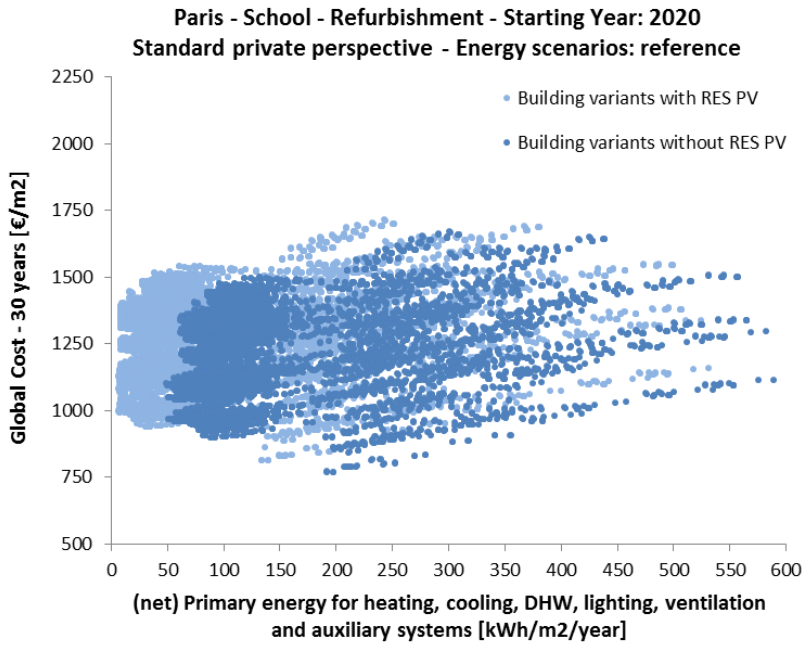

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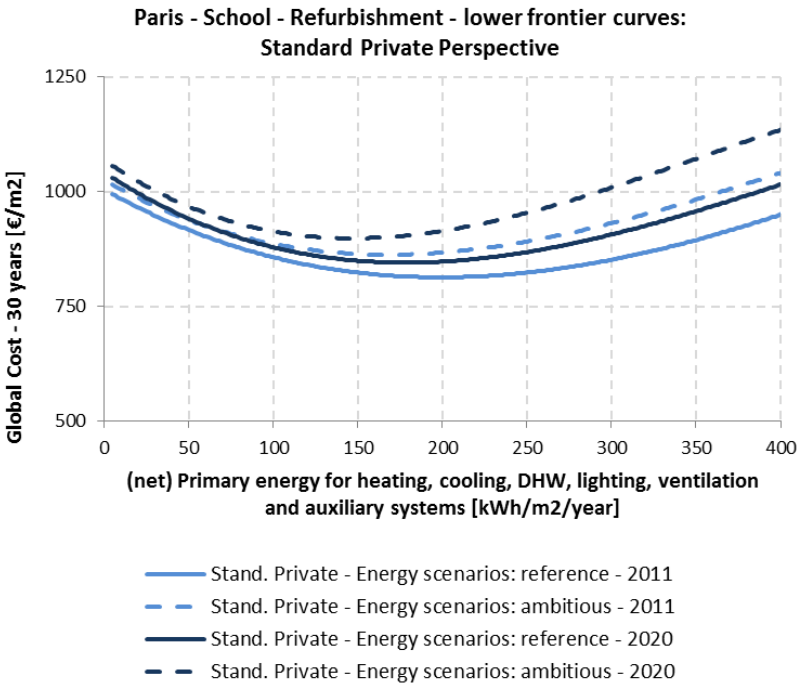

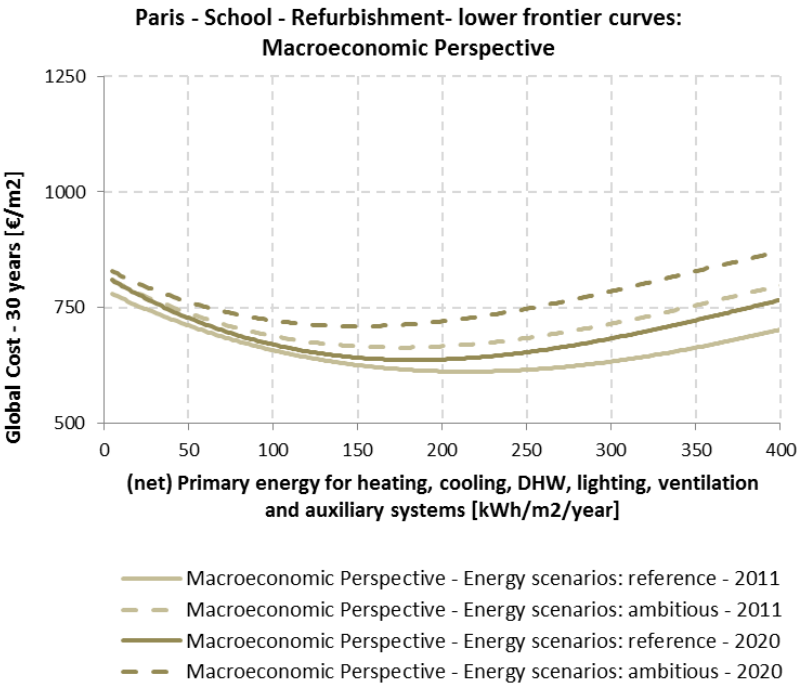

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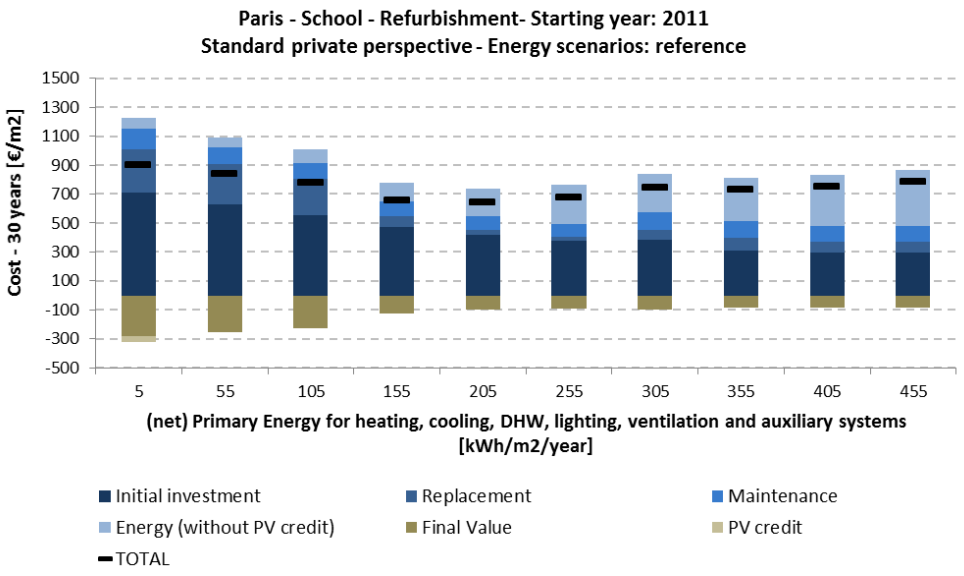

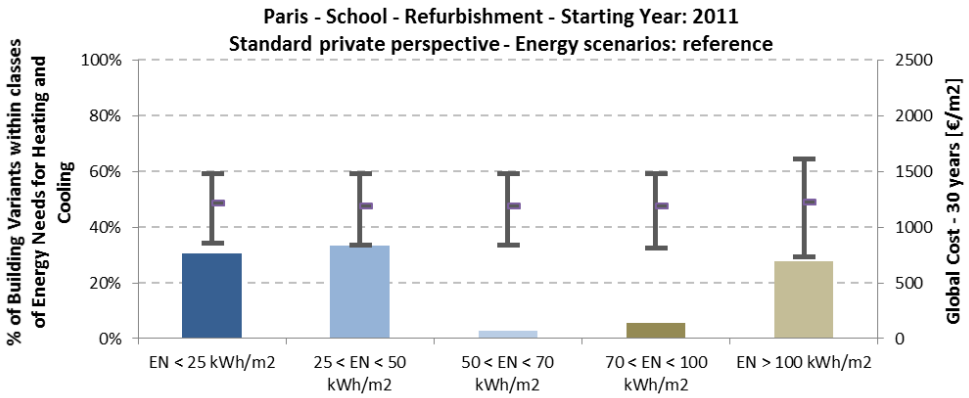

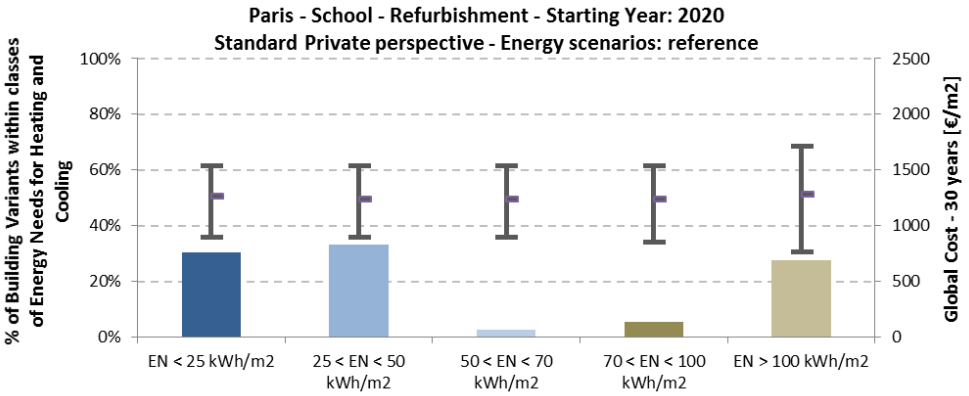

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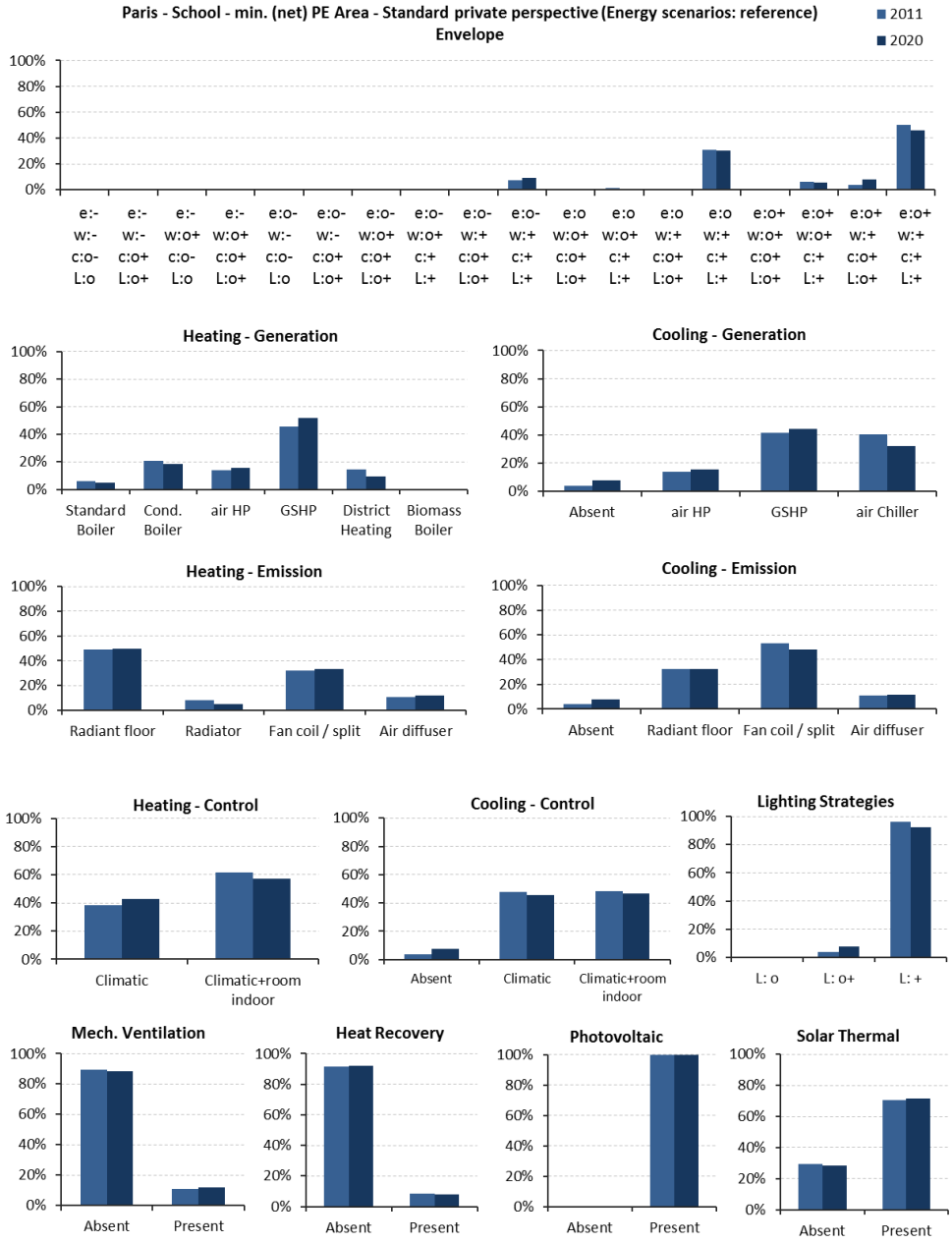
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	7	15	7	15
Range of Global Costs [€/m^2]:	972	1118	985	1140
Number of Building Variants:	204		204	



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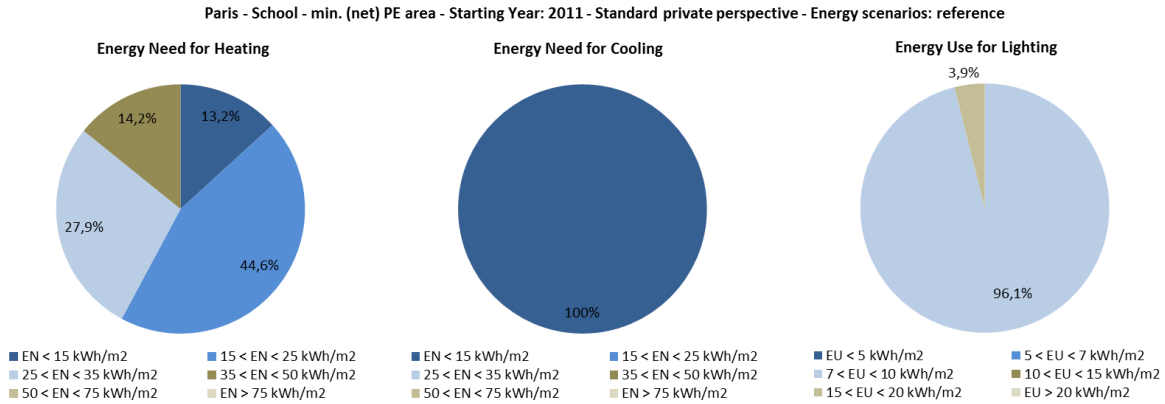

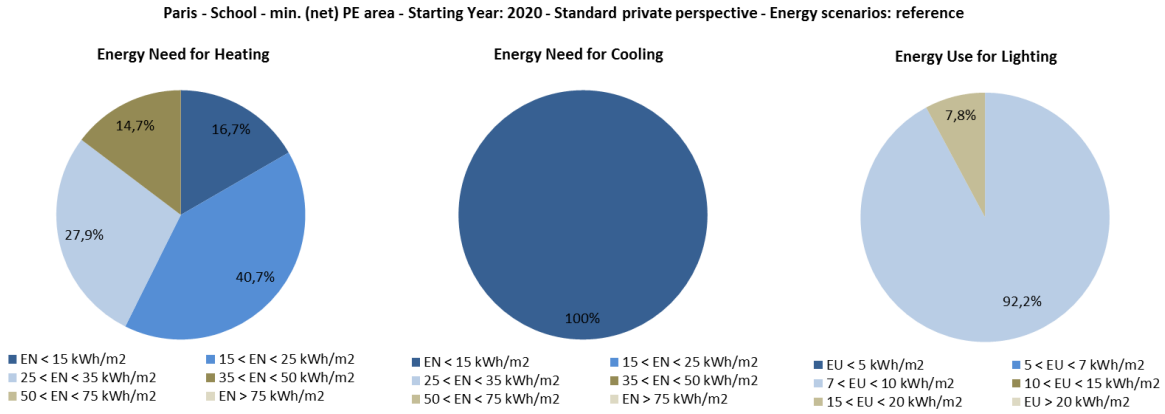

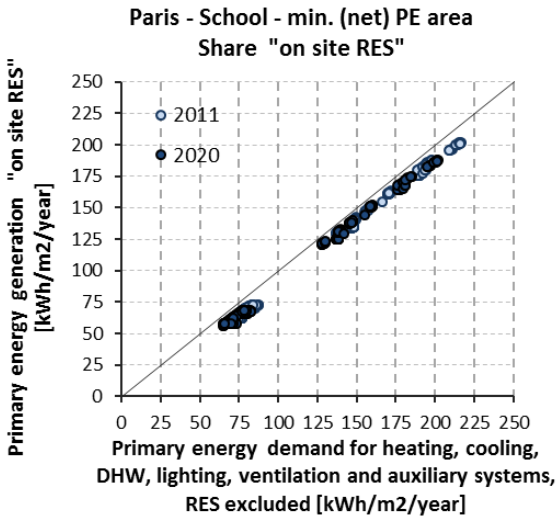

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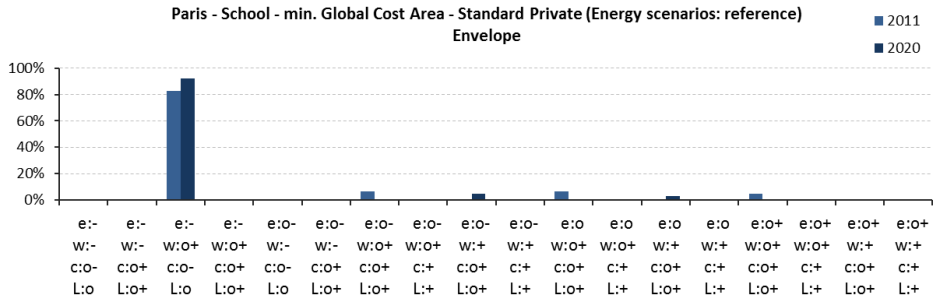
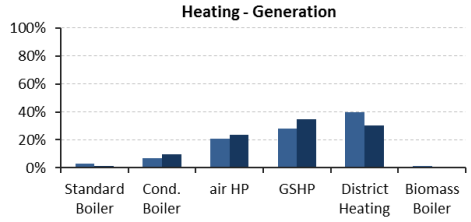
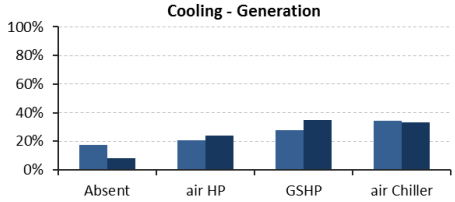
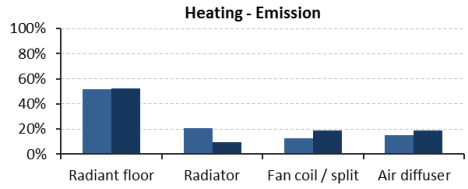
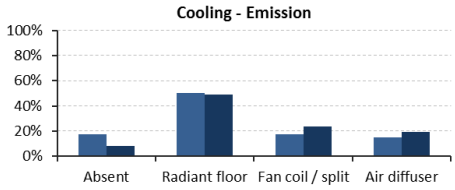
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	110	310	95	295
Range of Global Costs [€/m^2]:	734	859	771	909
Number of Building Variants:	126		126	

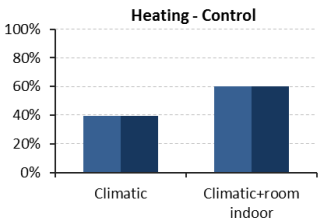


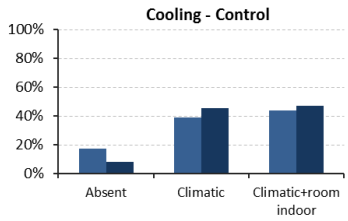


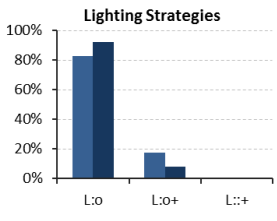


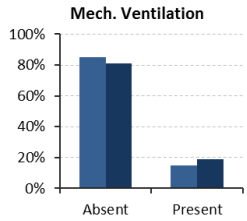


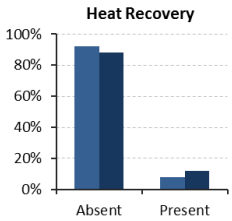


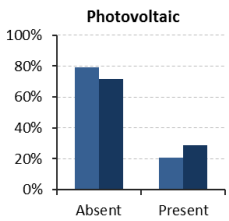


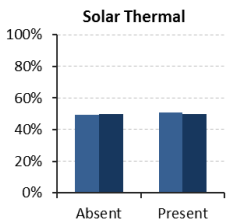












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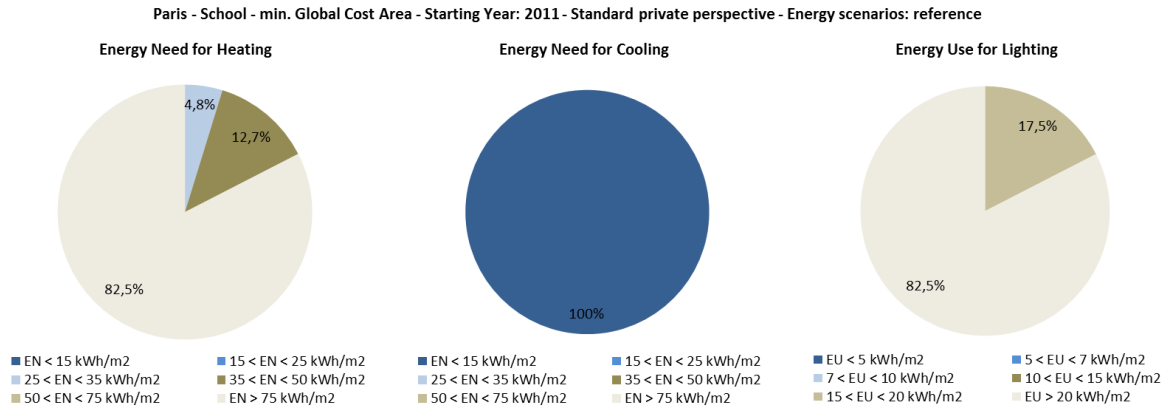

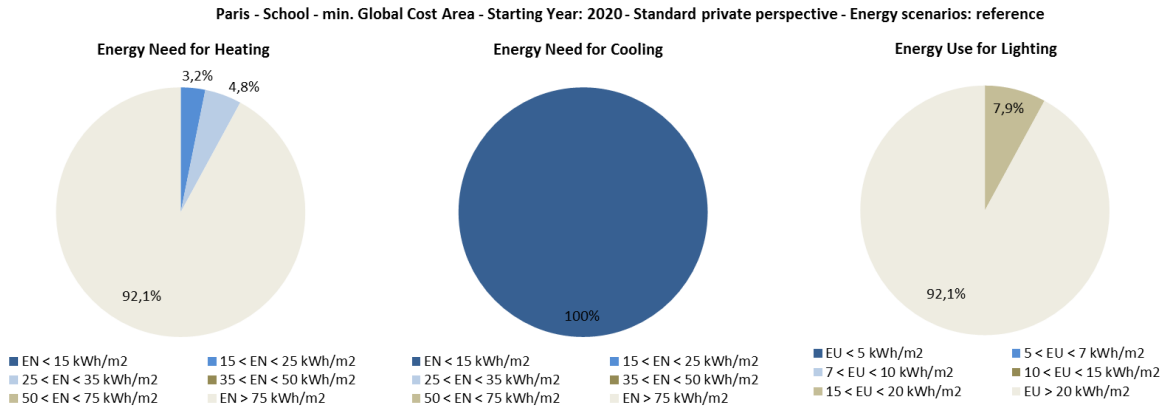

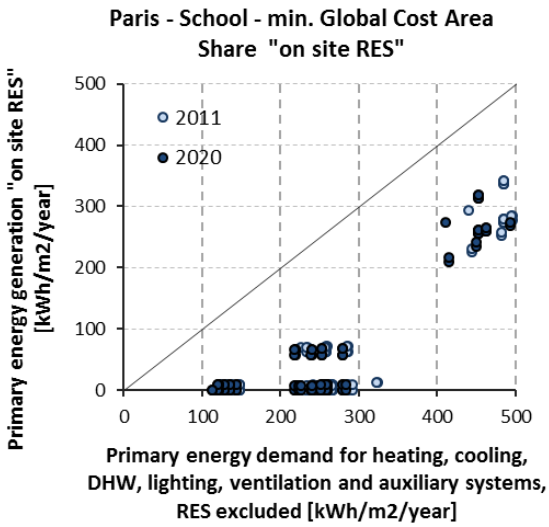

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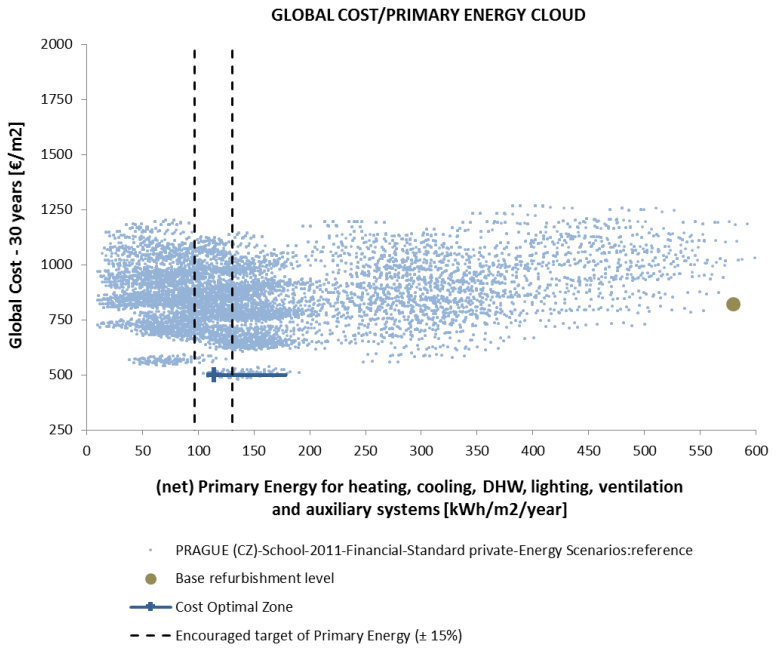
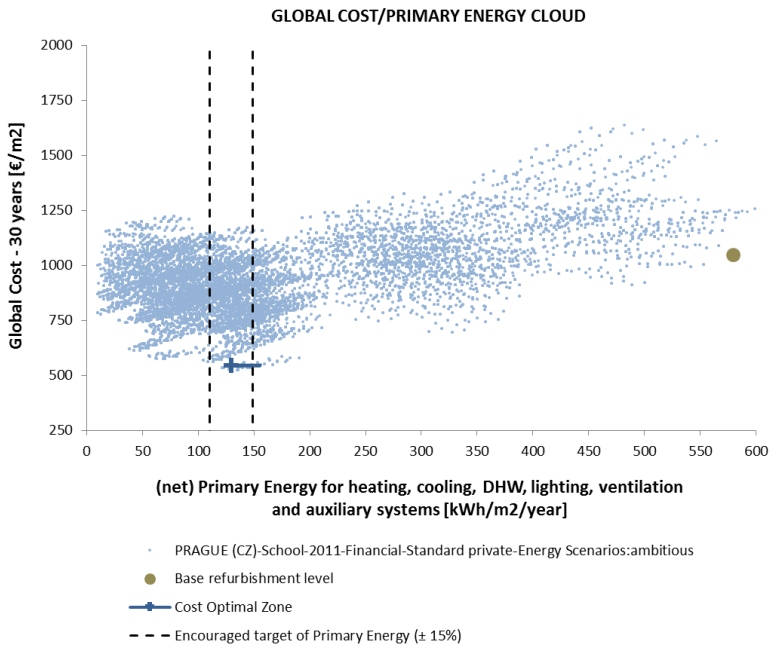
8.1.4.8 Prague





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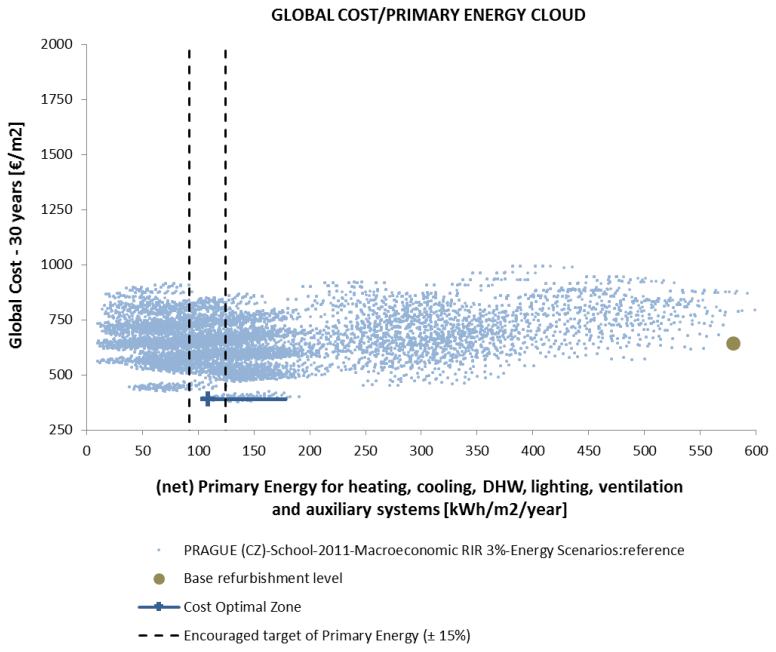

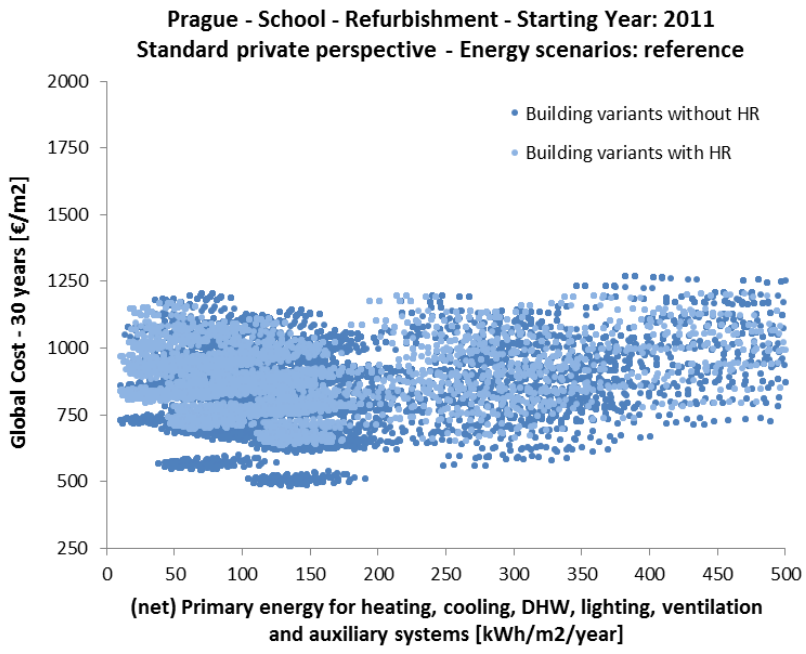

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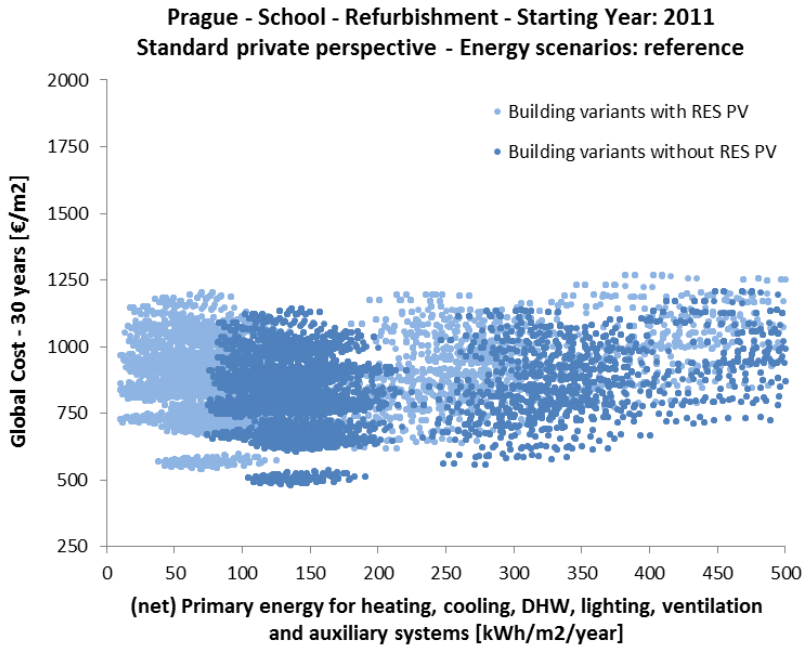
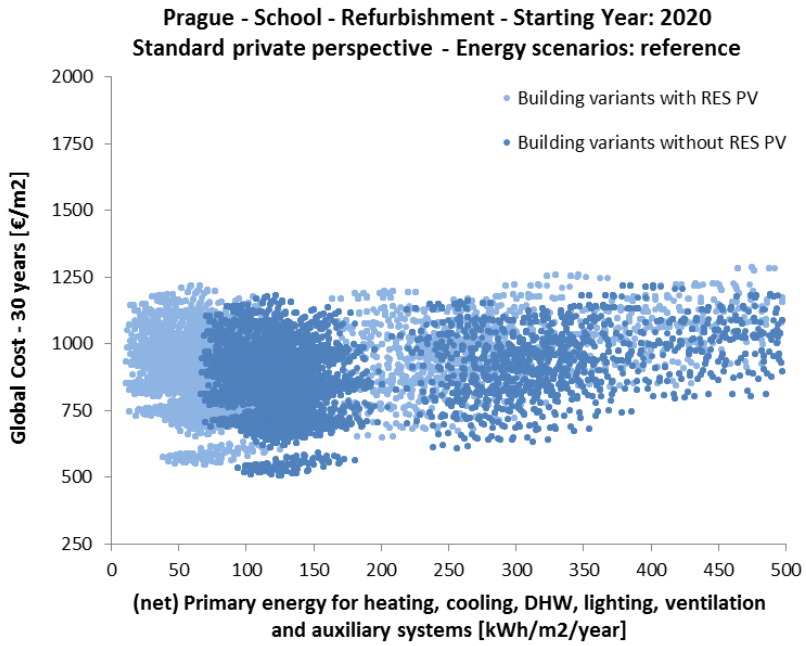

Prague - School - Refurbishment - Starting Year: 2011
Standard private perspective - Energy scenarios: reference
Building variants with RES PV
Building variants without RES PV
Global Cost - 30 years [€/m2]
2000
1750
1500
1250
1000
750
500
250
0
50
100
150
200
250
300
350
400
450
500
(net) Primary energy for heating, cooling, DHW, lighting, ventilation and auxiliary systems [kWh/m2/year]


Prague - School - Refurbishment - Starting Year: 2020
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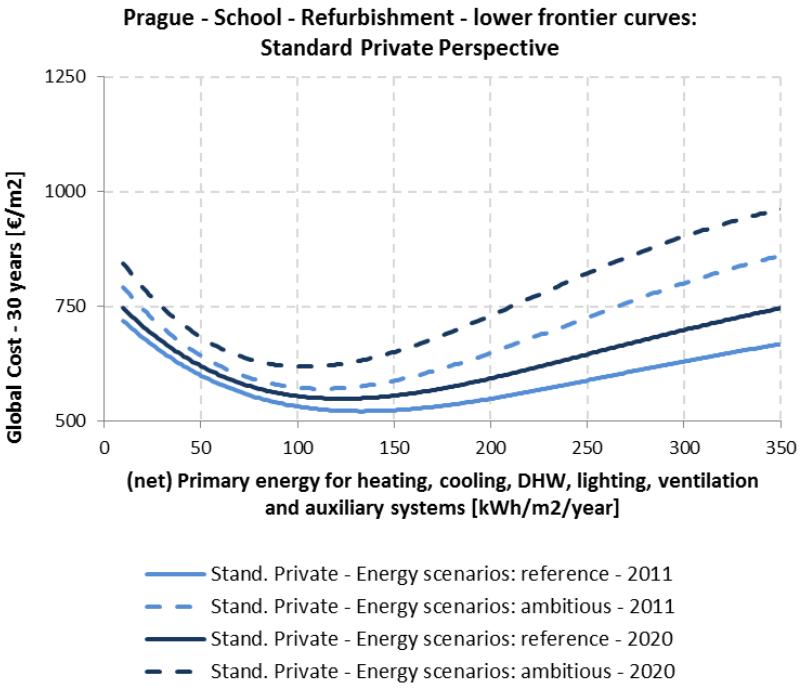

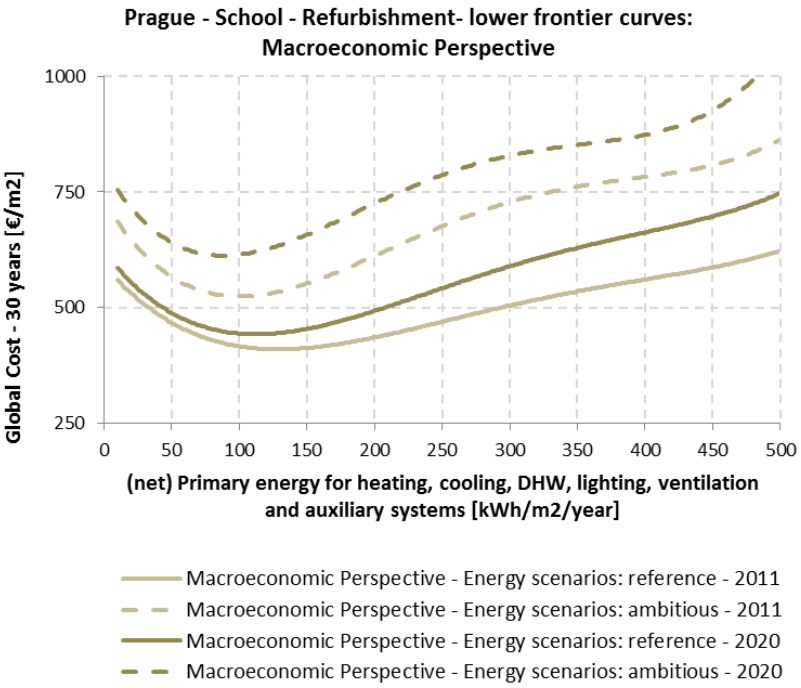

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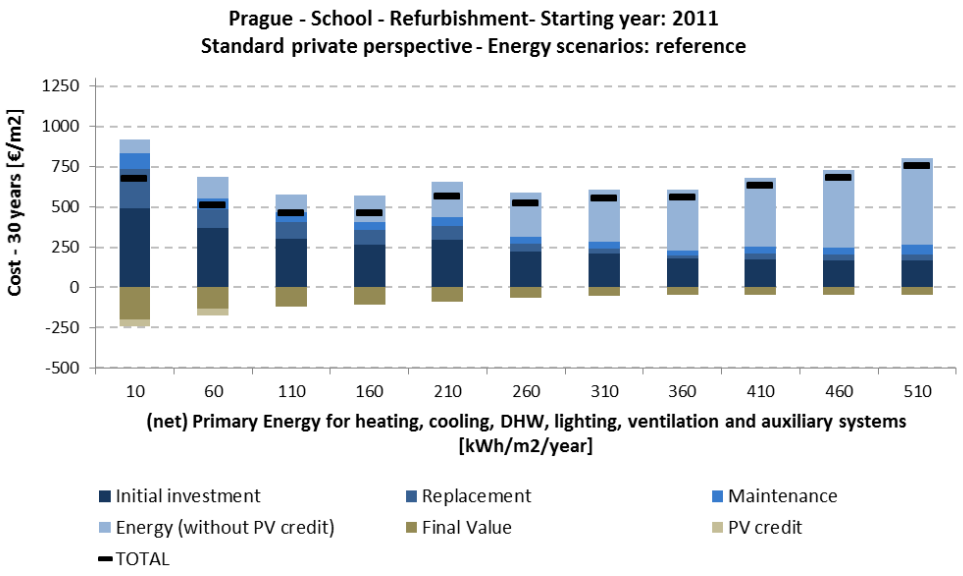

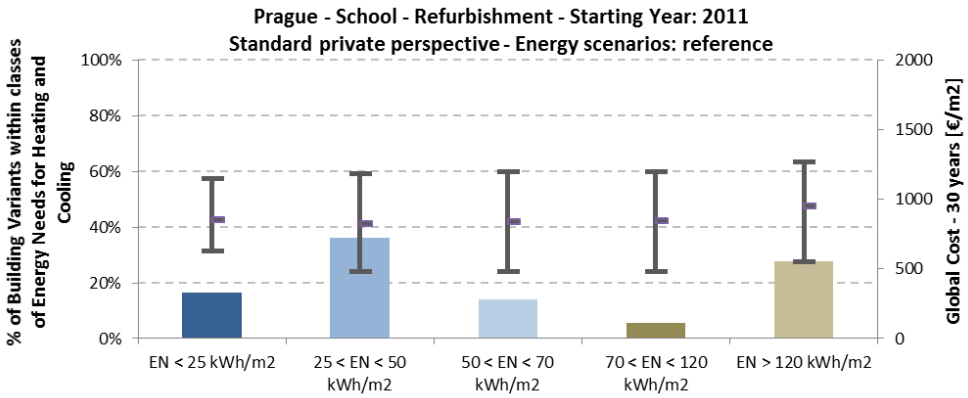

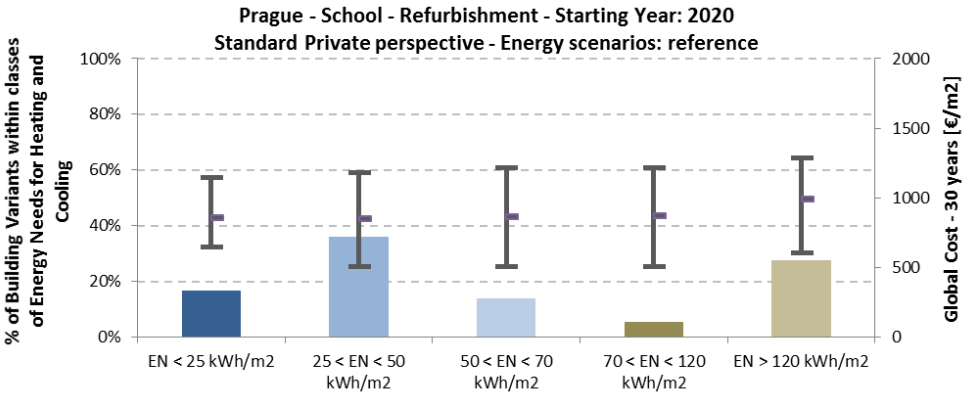

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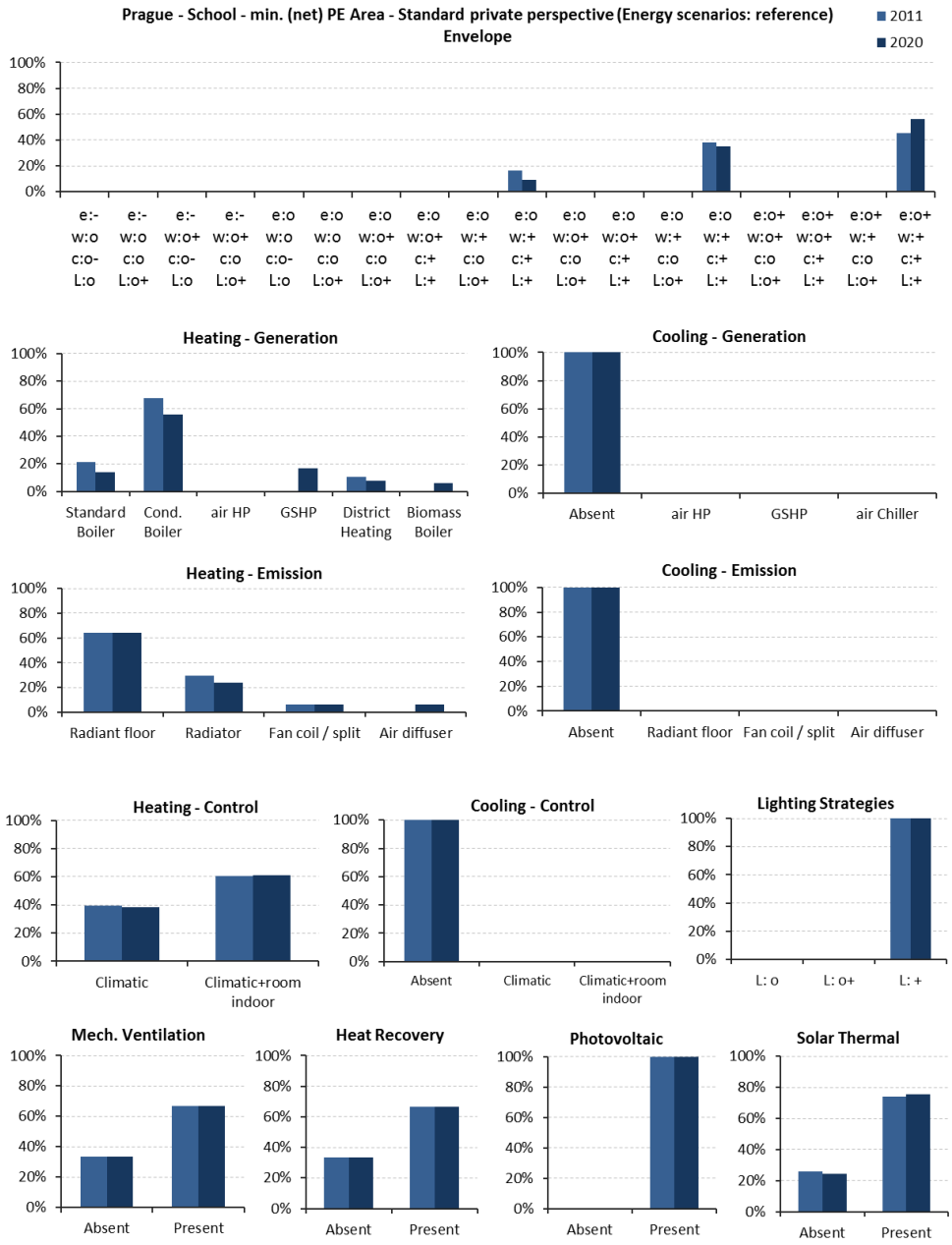
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	10	25	11	25
Range of Global Costs [€/m²]:	716	859	736	949
Number of Building Variants:	168		168	



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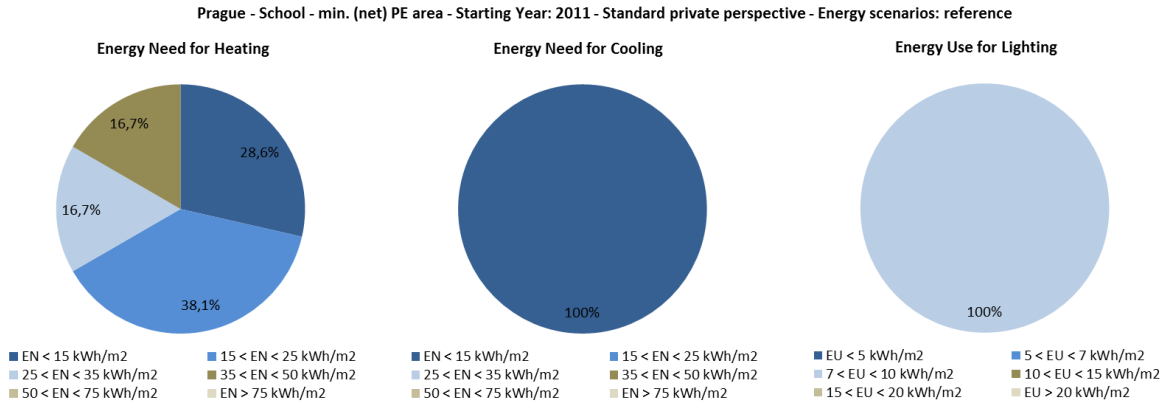

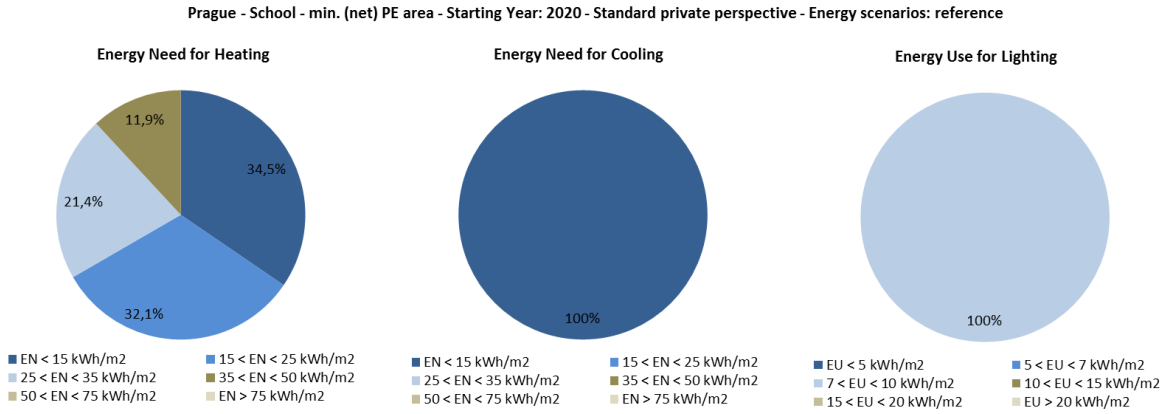

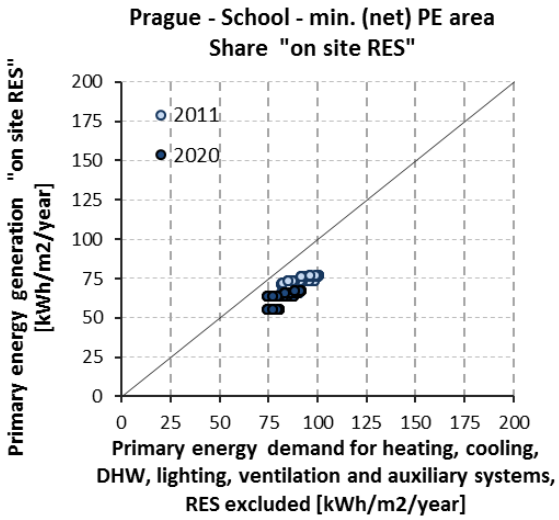

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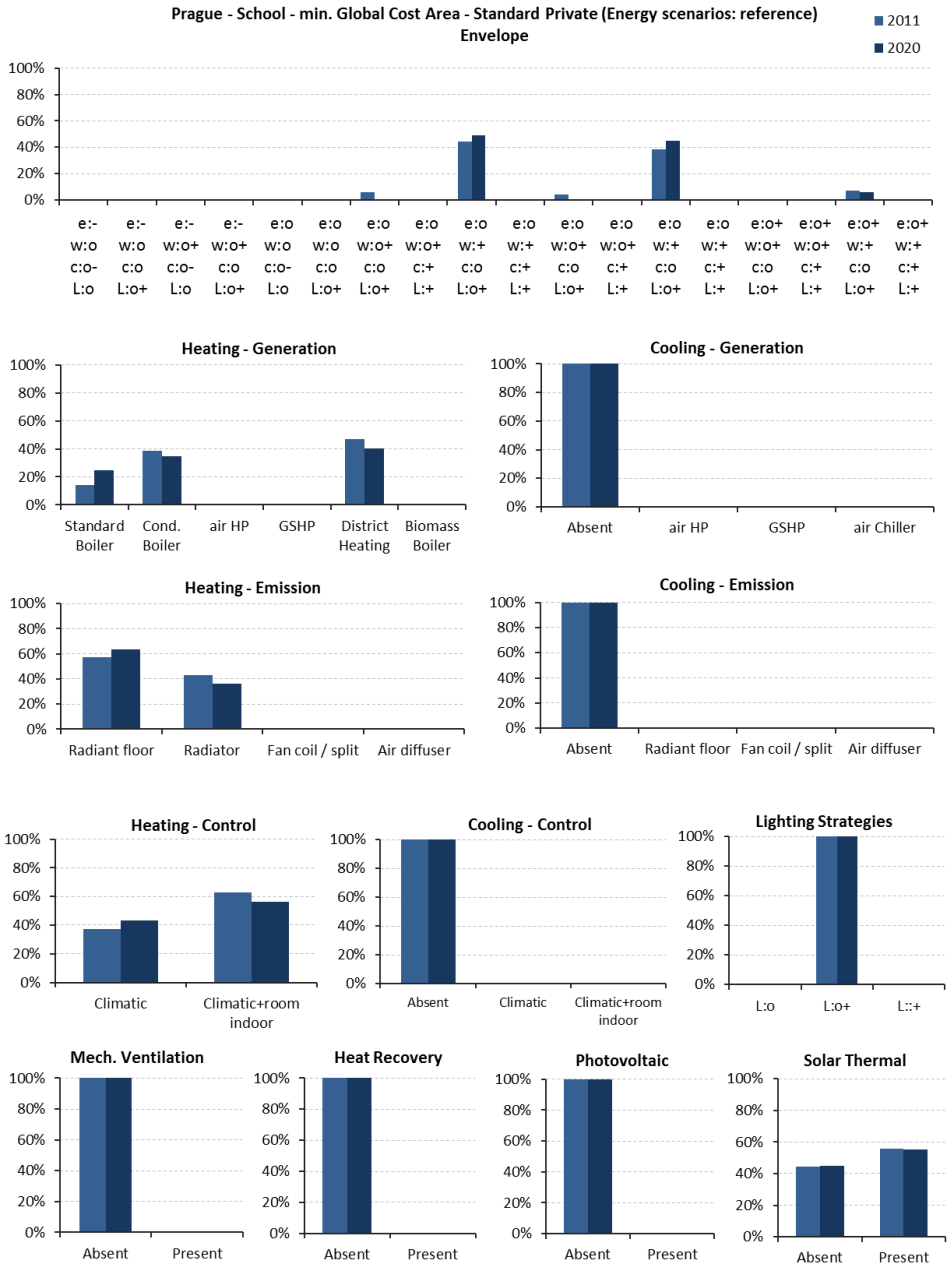
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	100	200	85	195
Range of Global Costs [€/m^2]:	482	506	507	536
Number of Building Variants:	140		138	



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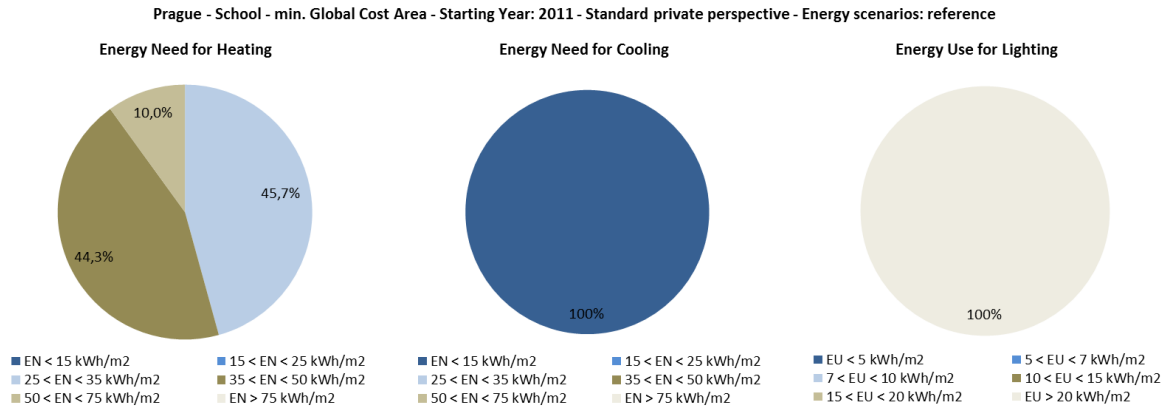

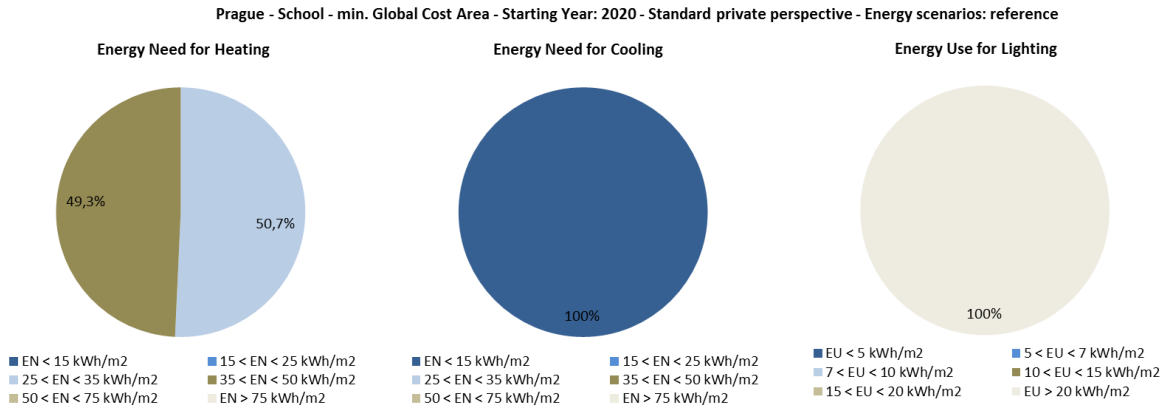

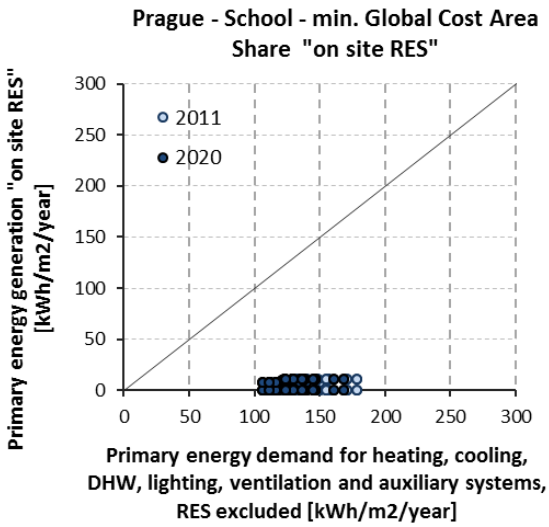

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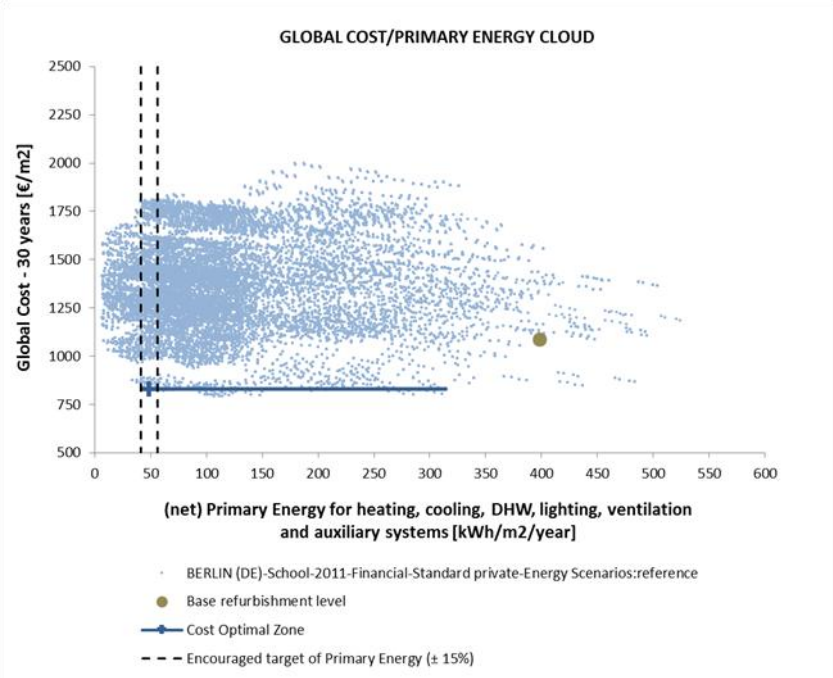
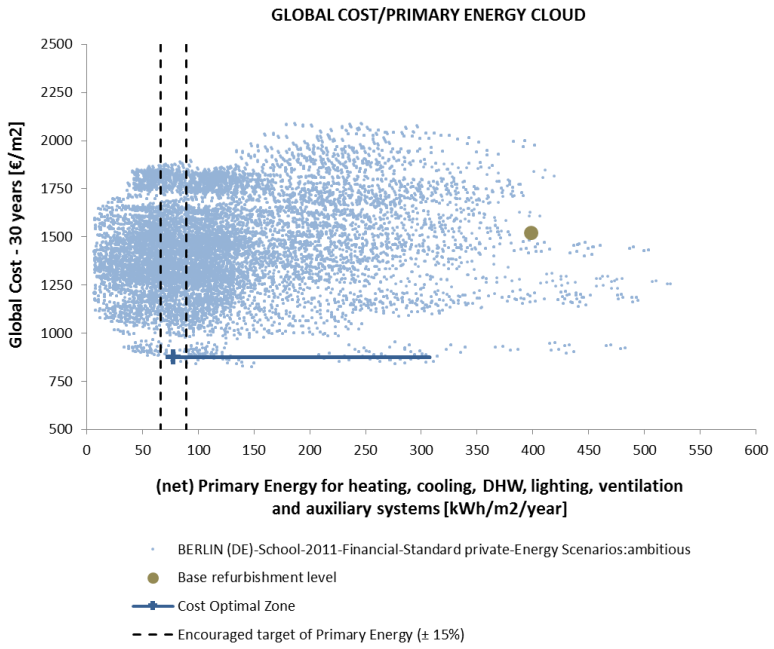
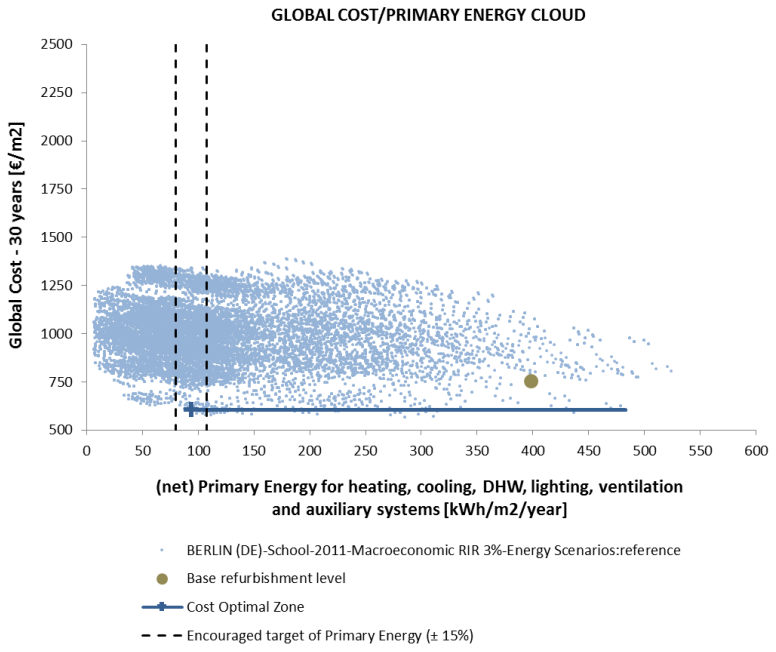
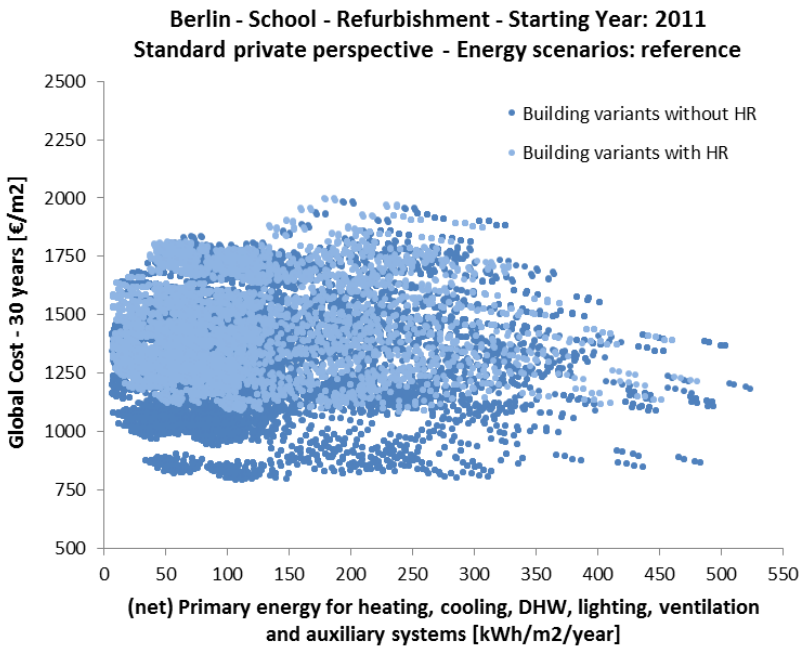
8.1.4.9 Berlin





Co-funded by the Intelligent Energy Europe Programme of the European Union





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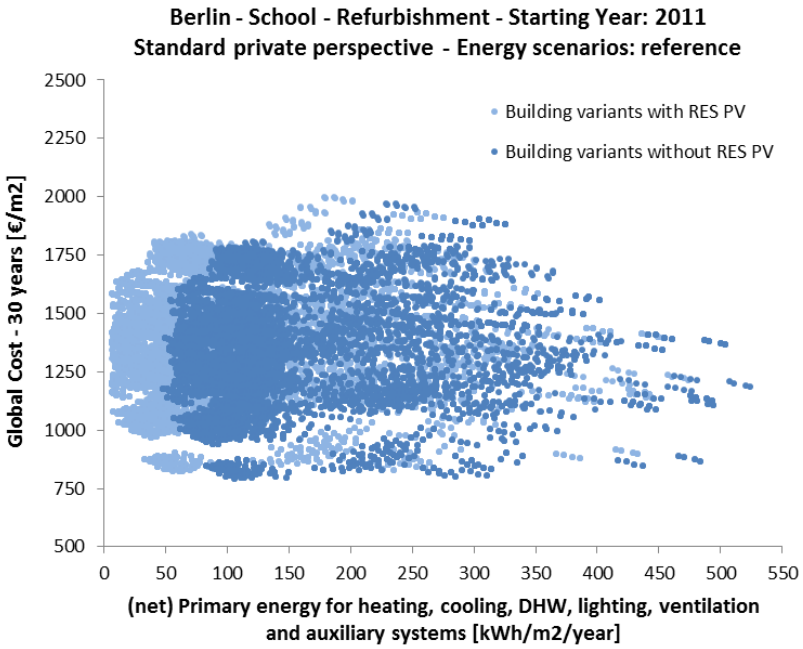

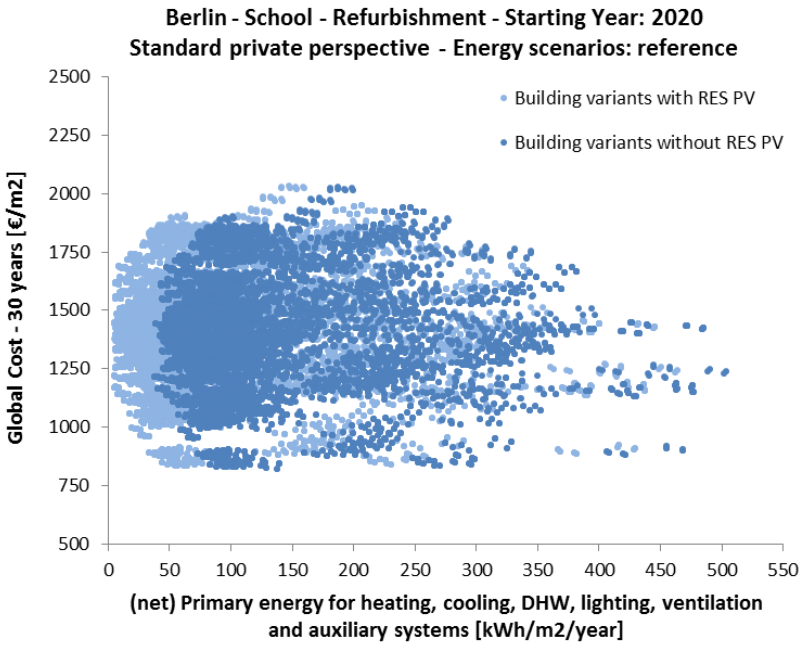

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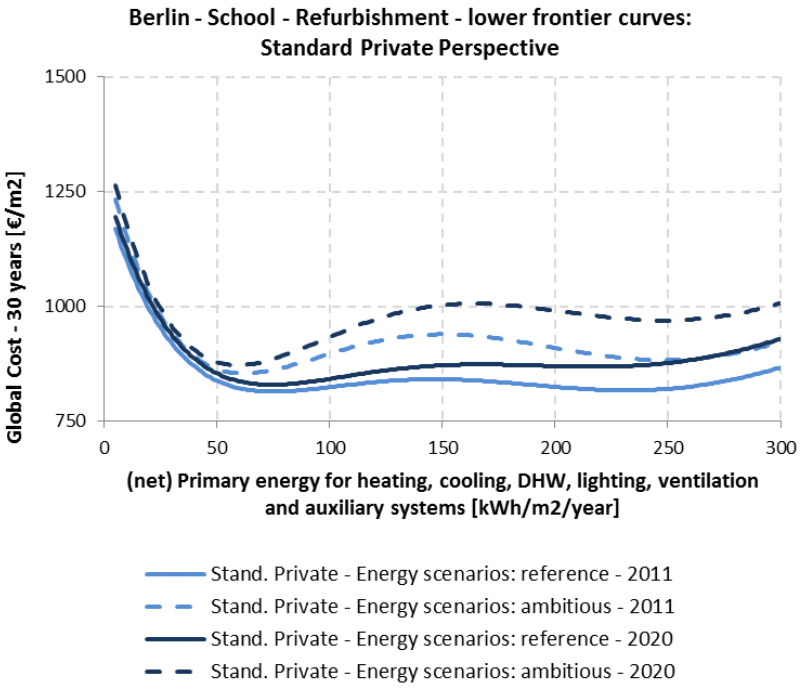

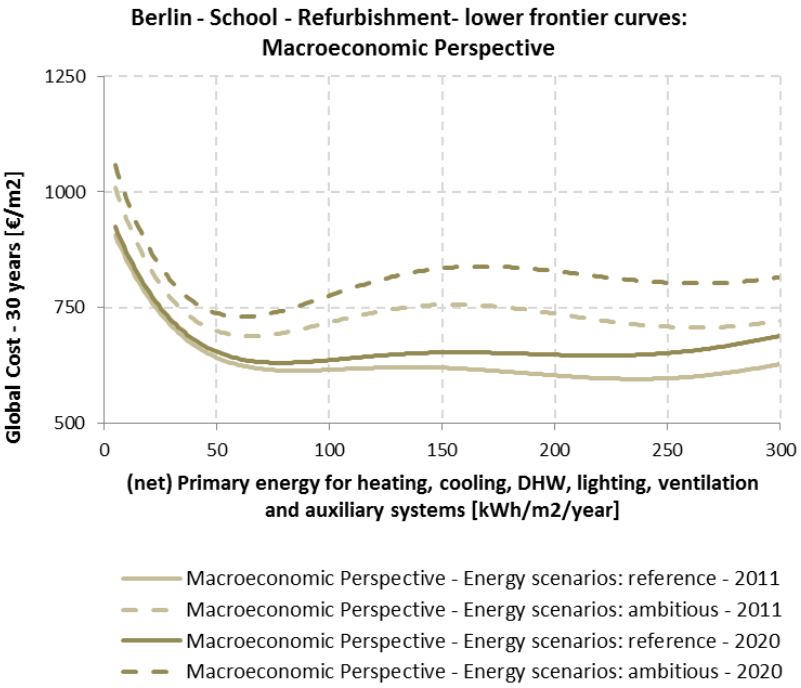

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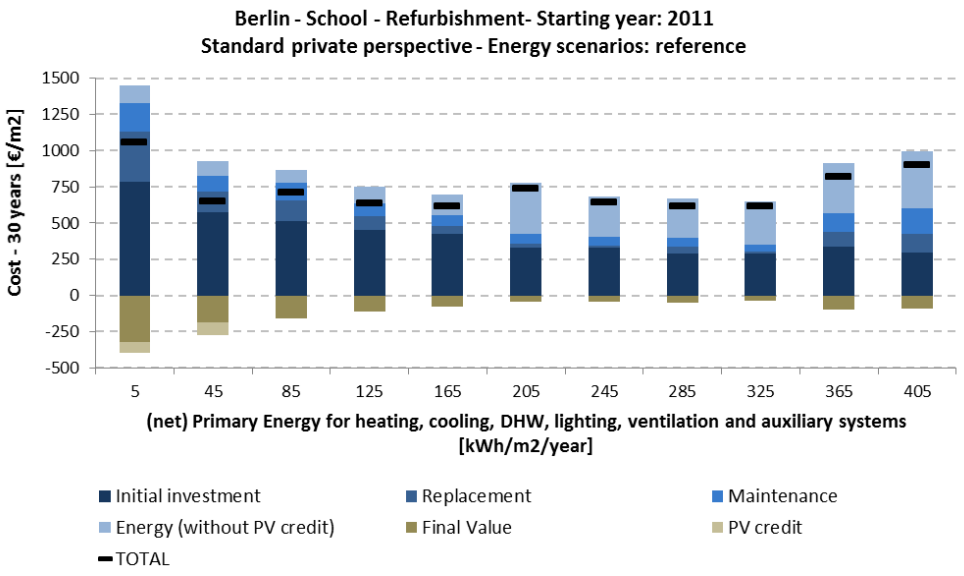

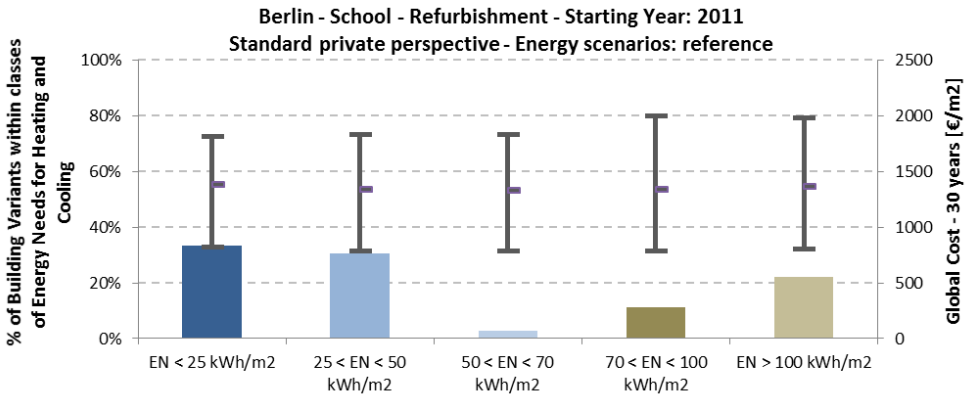

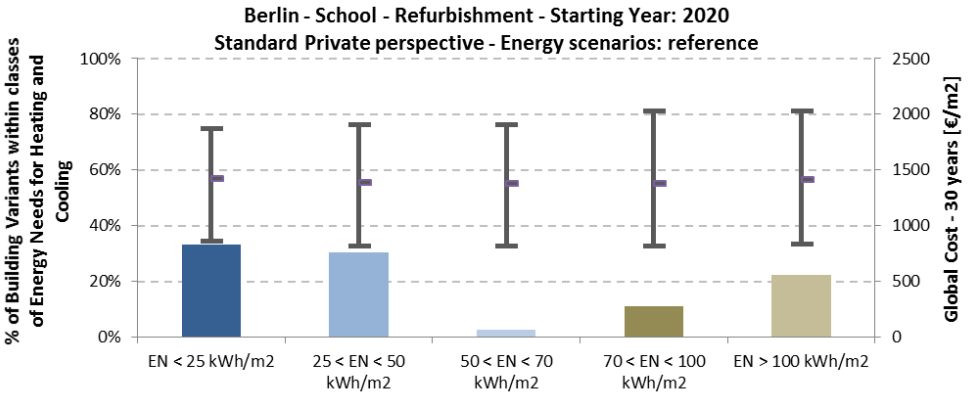

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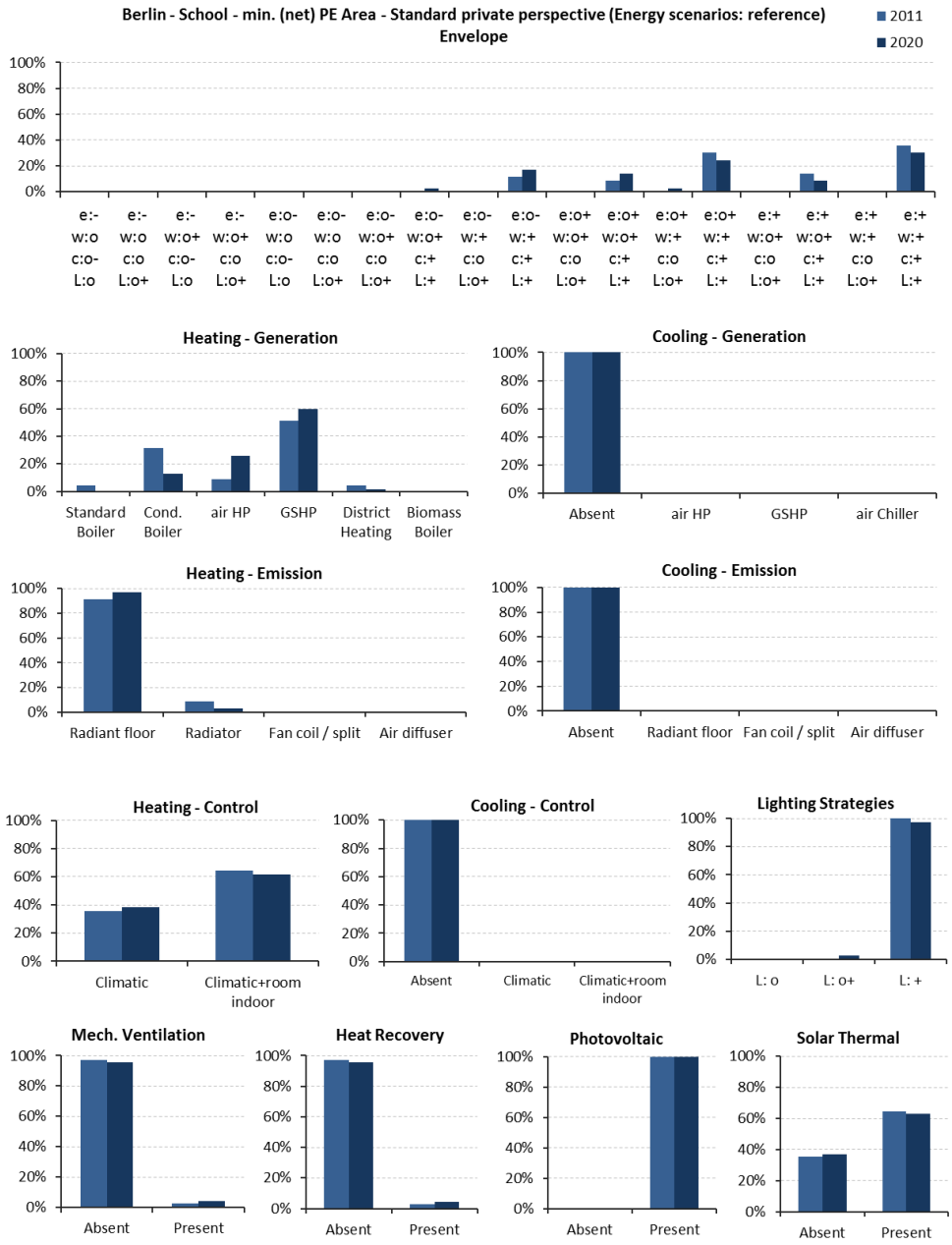
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	6	20	5	20
Range of Global Costs [€/m^2]:	1025	1230	996	1265
Number of Building Variants:	140		140	



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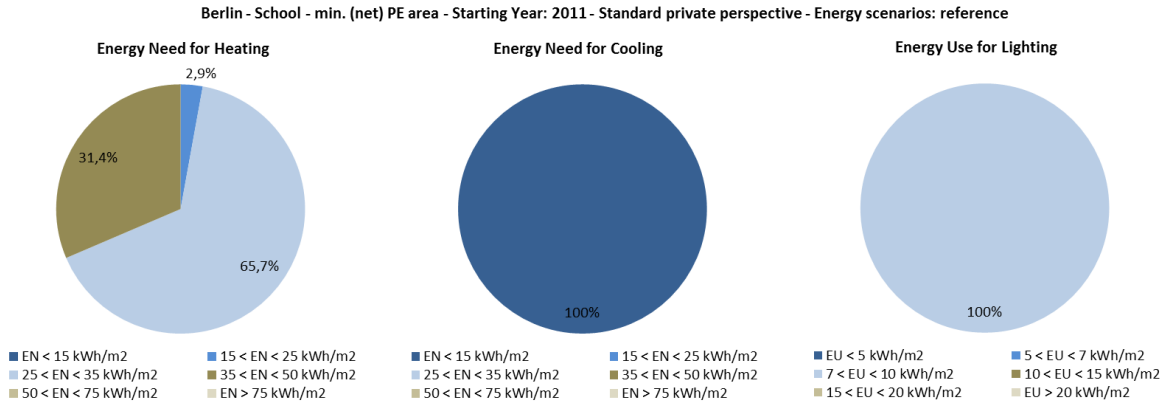

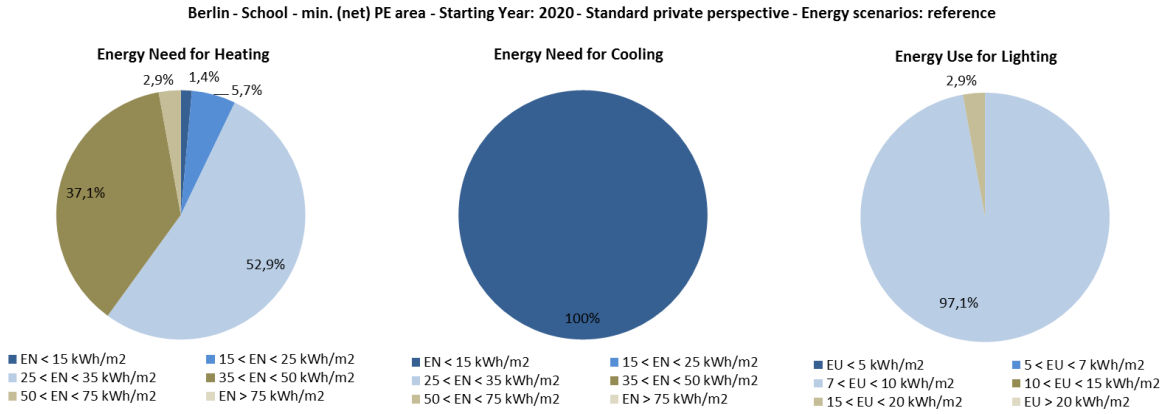

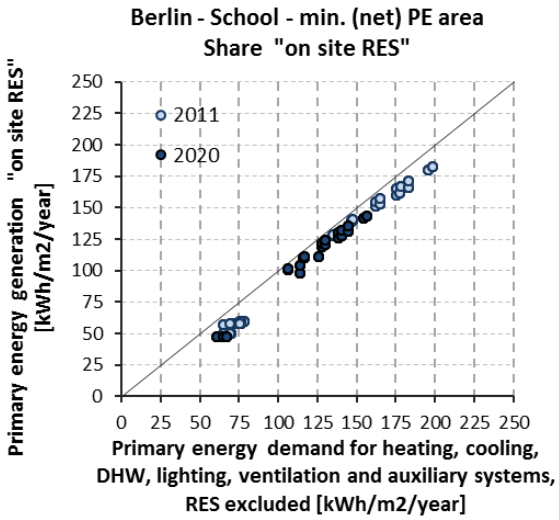

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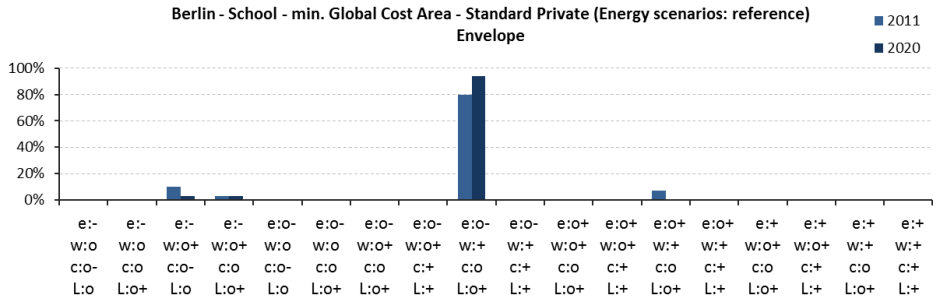
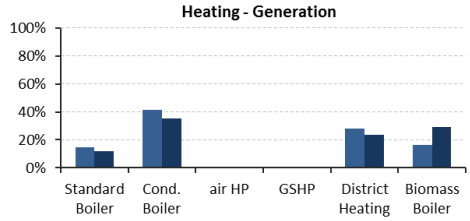
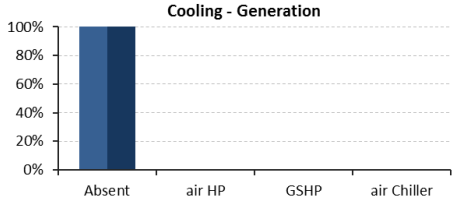
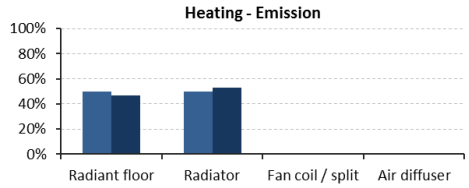
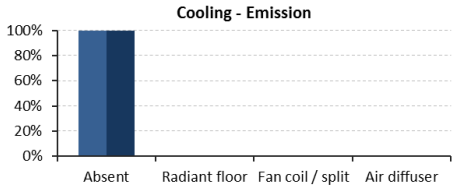
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	25	245	25	245
Range of Global Costs [€/m²]:	794	834	824	856
Number of Building Variants:	136		136	

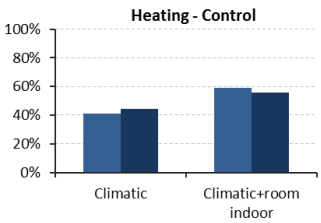


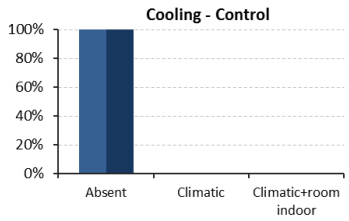


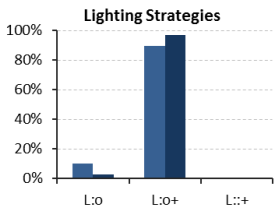


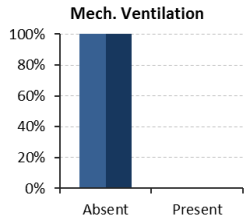


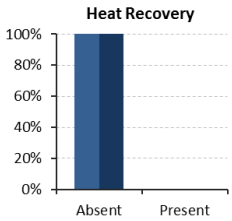


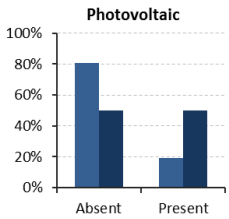


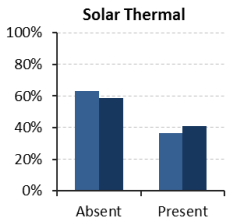












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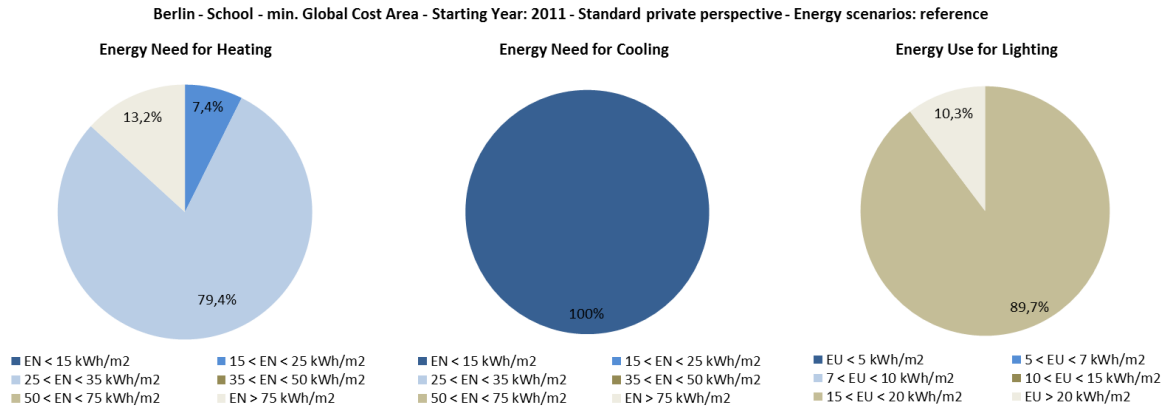

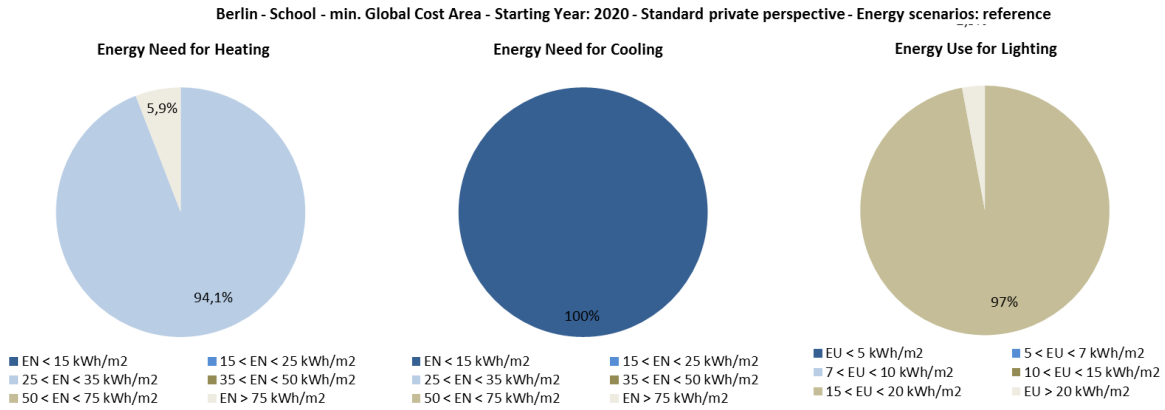

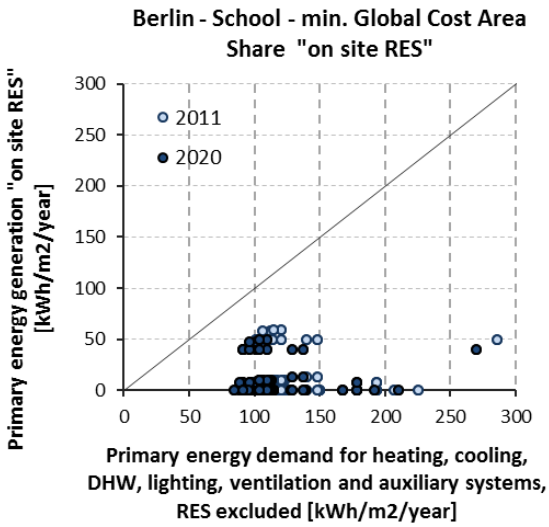

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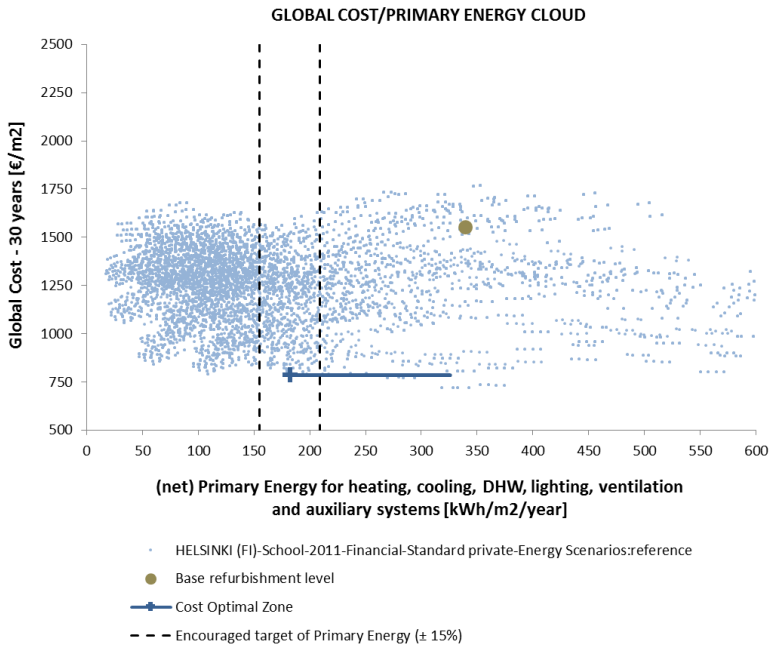
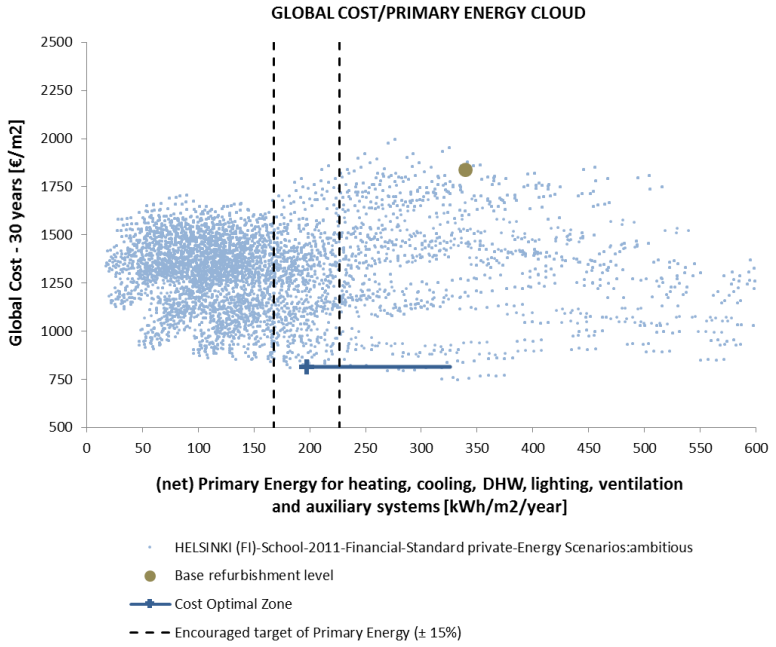
8.1.4.10 Helsinki





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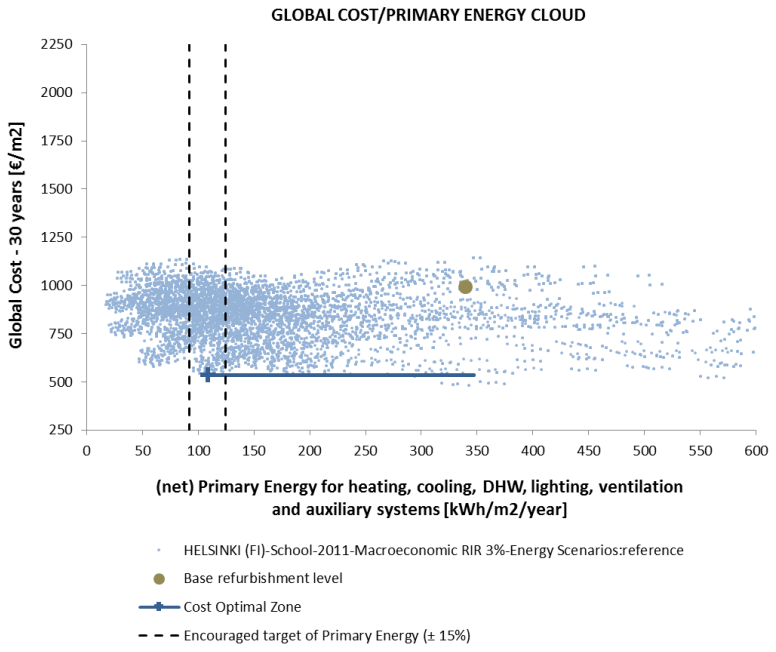

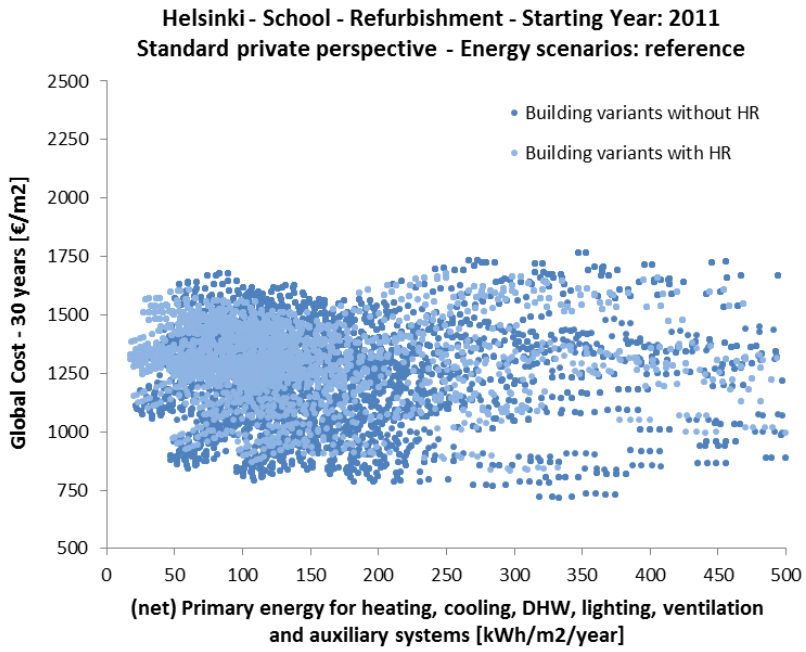

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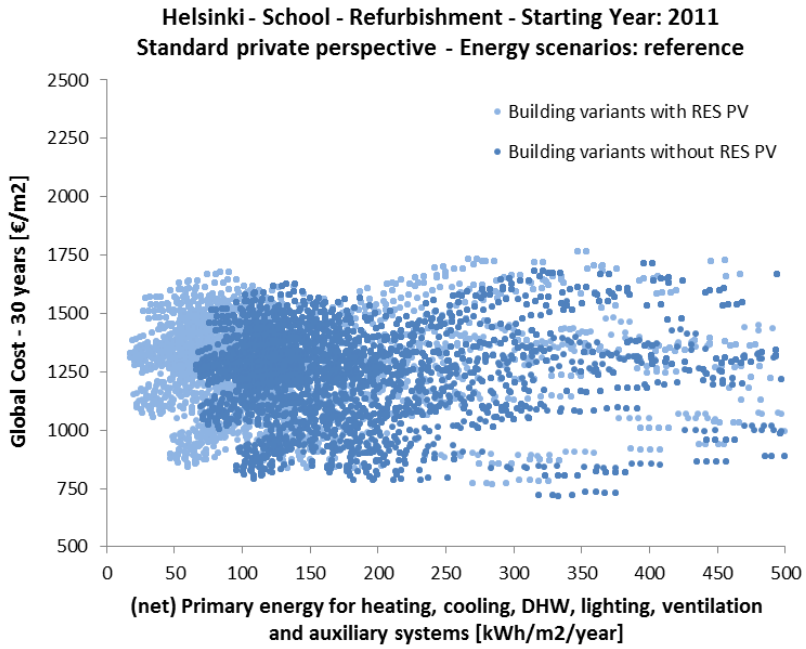

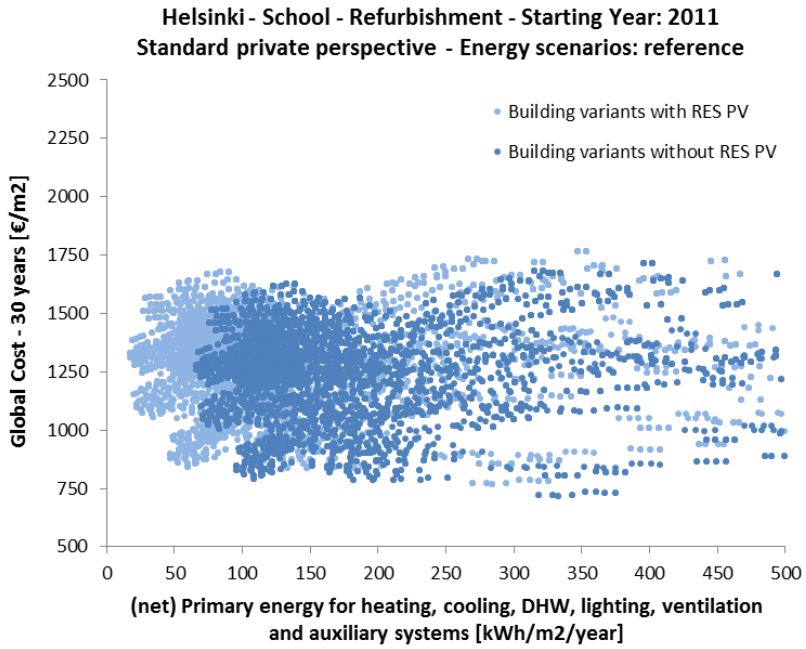

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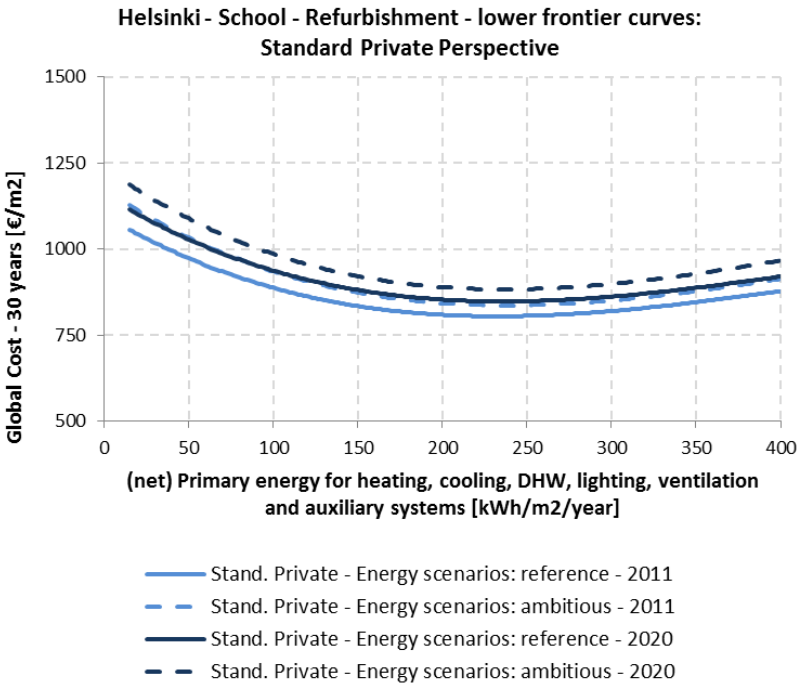

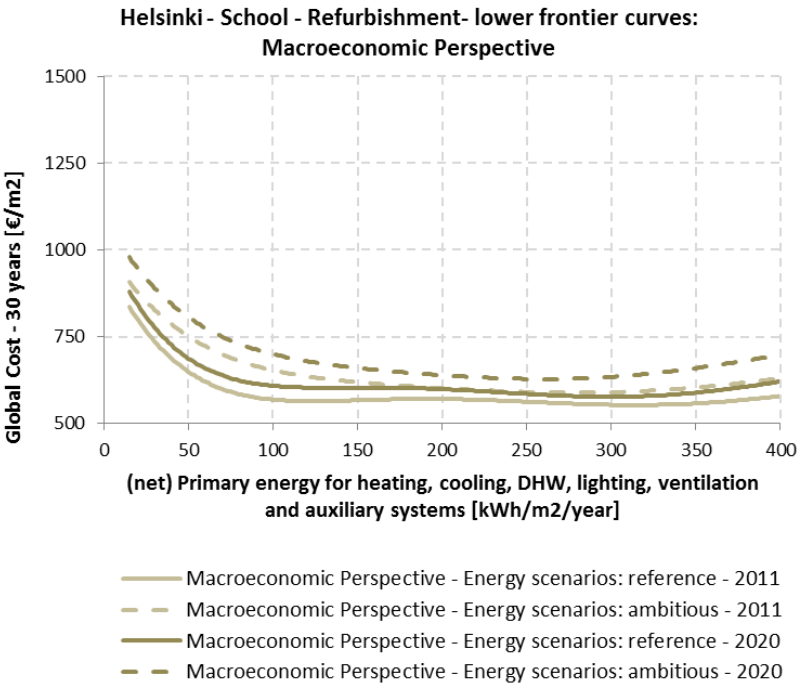

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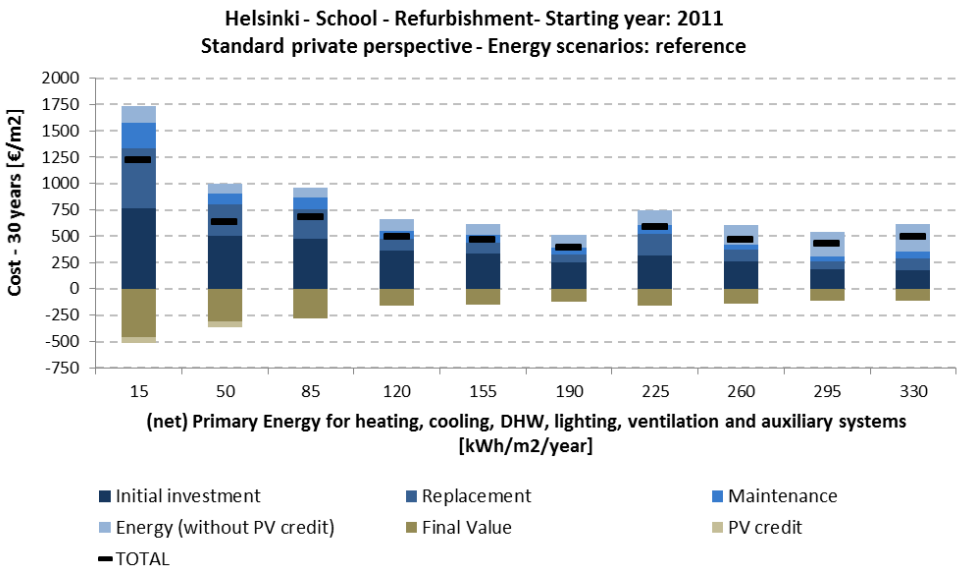

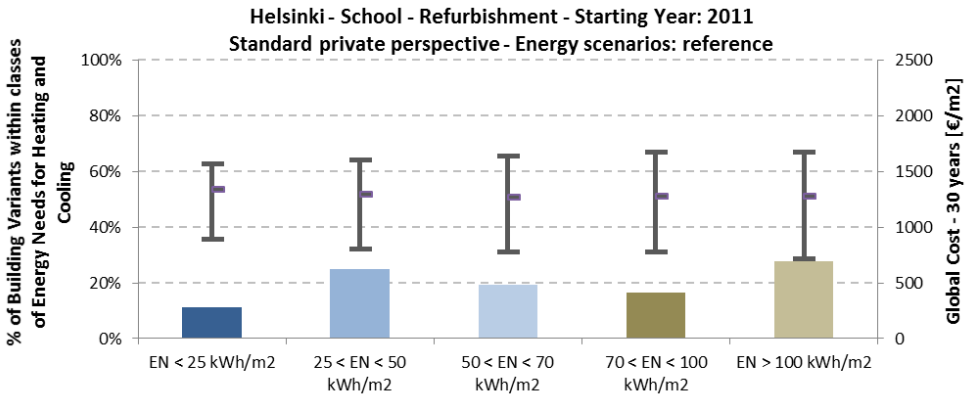

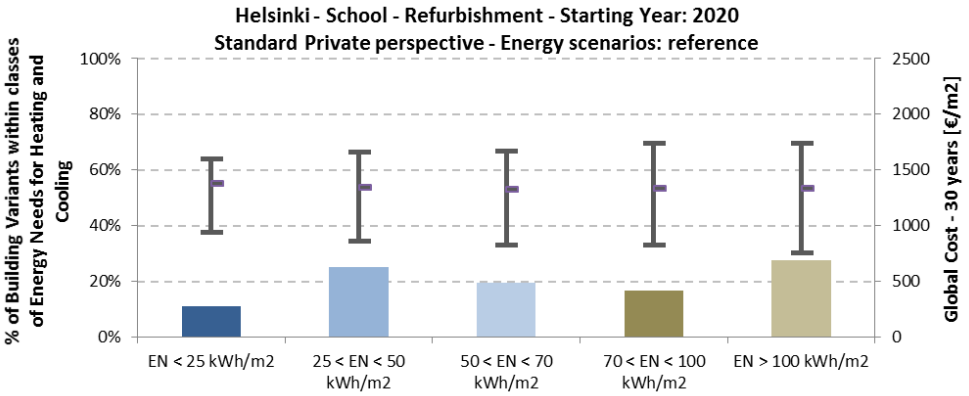

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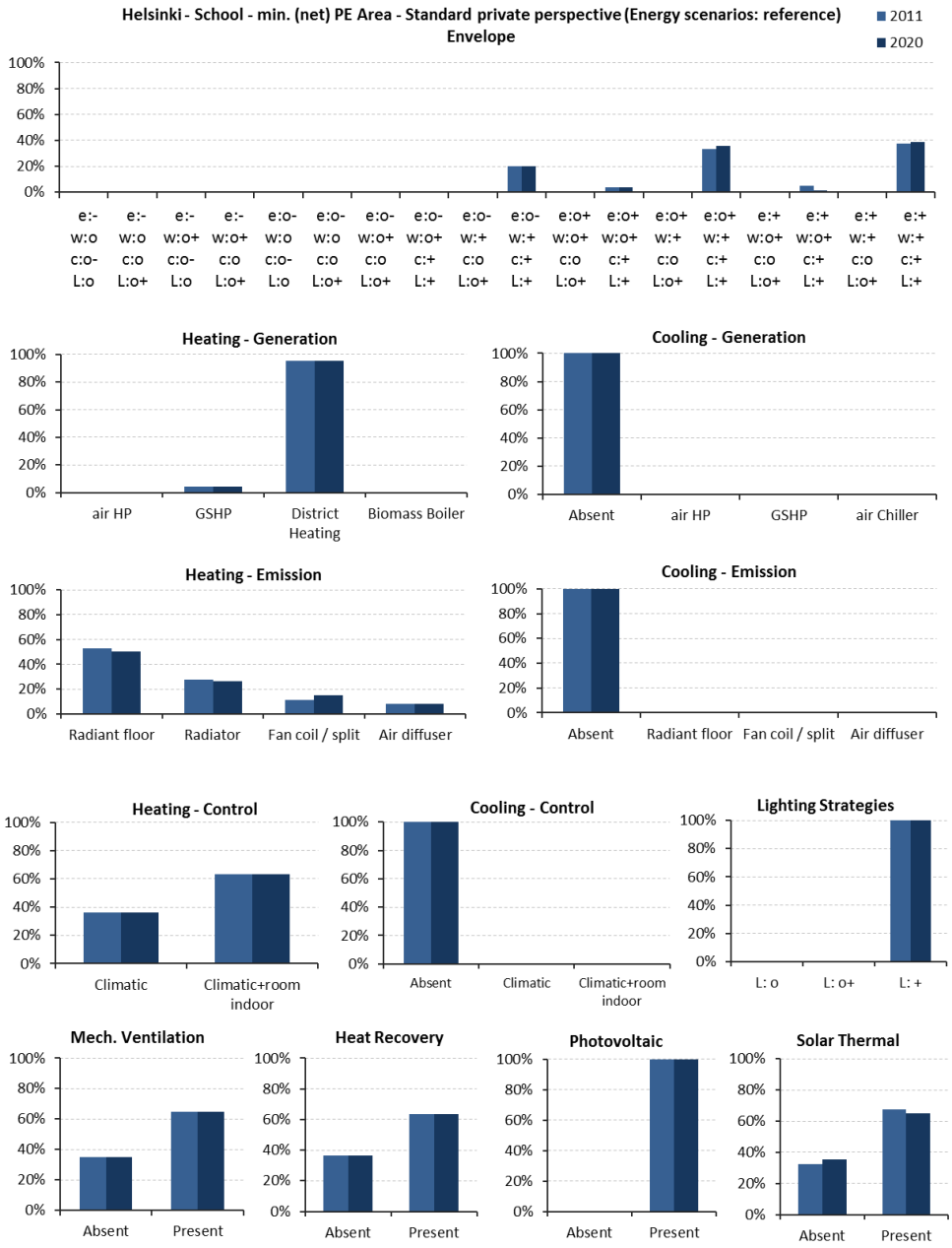
min. (net) Primary Energy Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m²/y]:	17	35	17	35
Range of Global Costs [€/m²]:	1056	1367	1106	1448
Number of Building Variants:	159		159	



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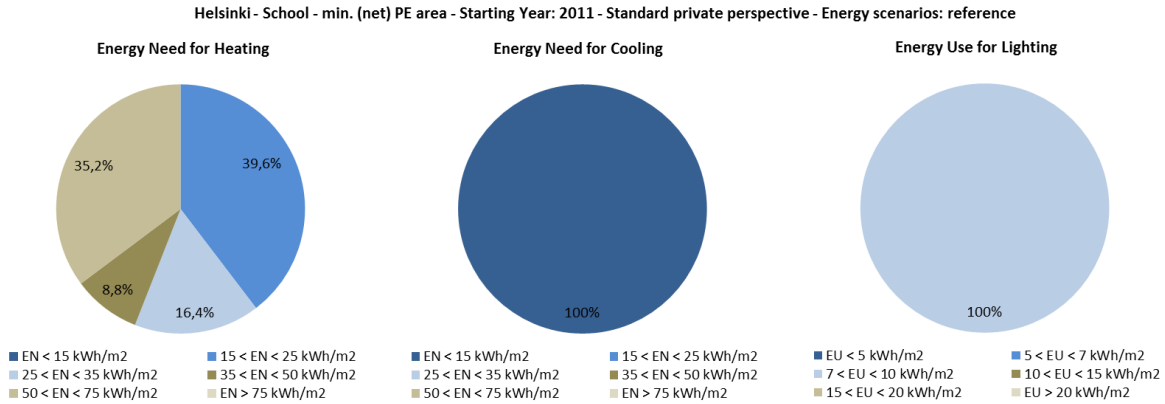

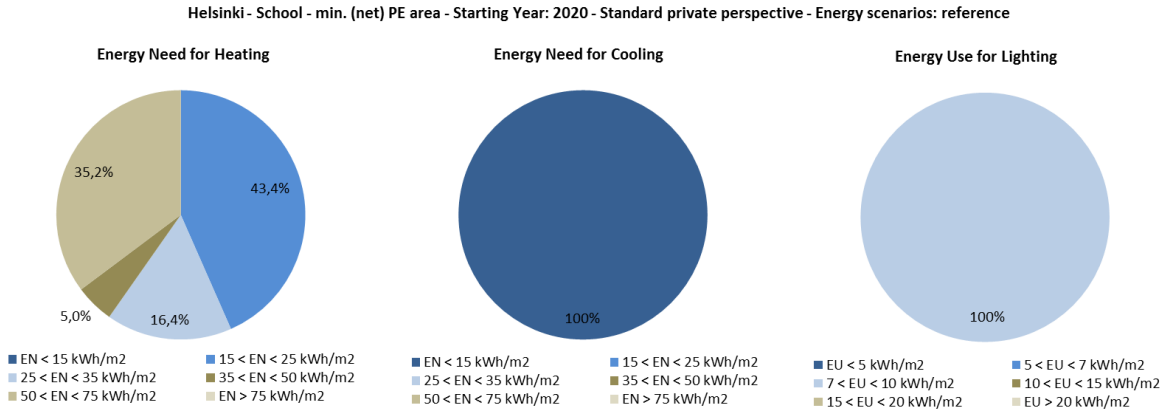

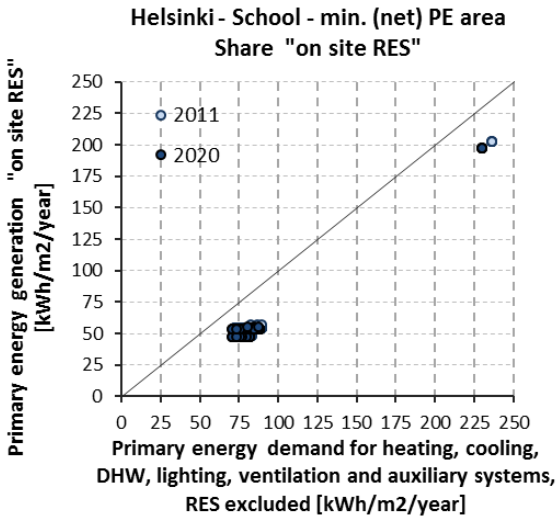

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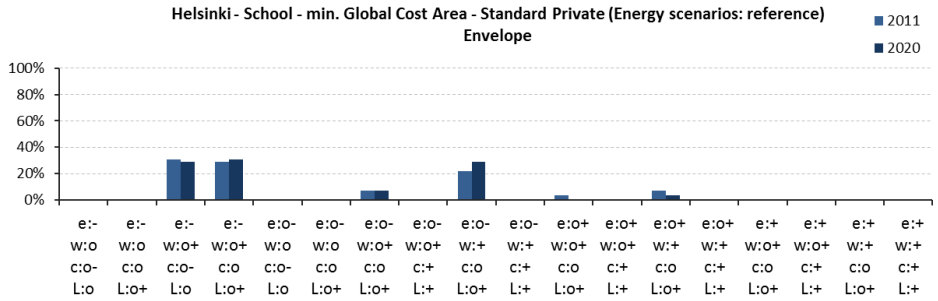
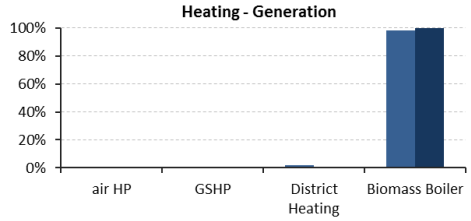
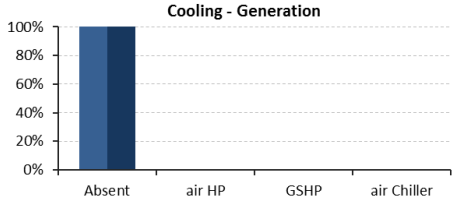
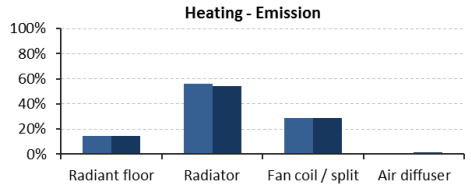
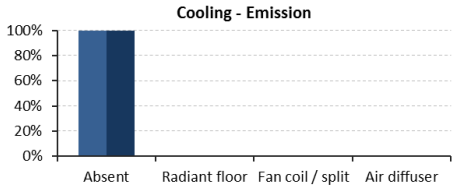
min. Global Cost Area	2011		2020	
	Min	Max	Min	Max
Range of (net) Primary Energy [kWh/m^2/y]:	130	400	130	400
Range of Global Costs [€/m^2]:	719	827	761	871
Number of Building Variants:	110		110	

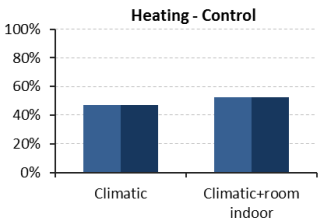


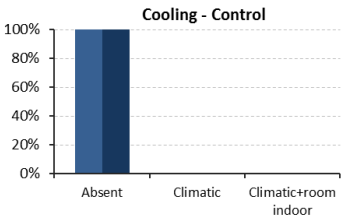


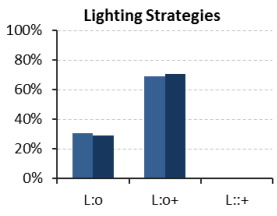


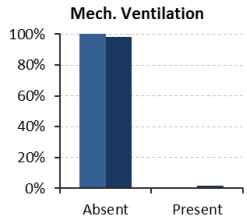


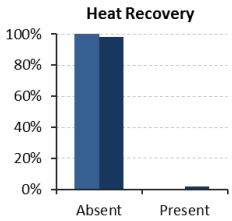


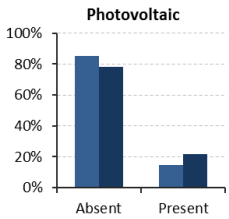


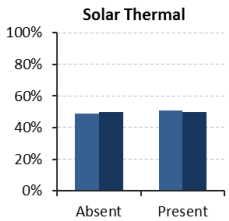












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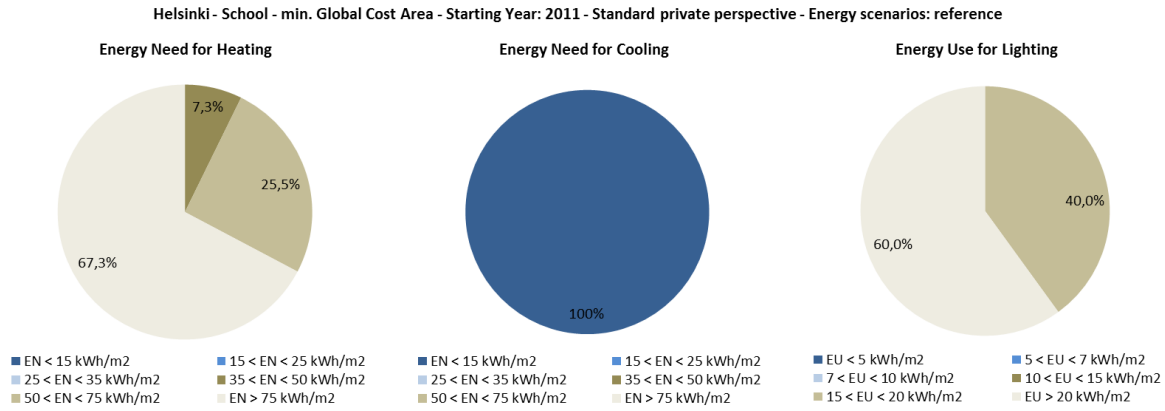

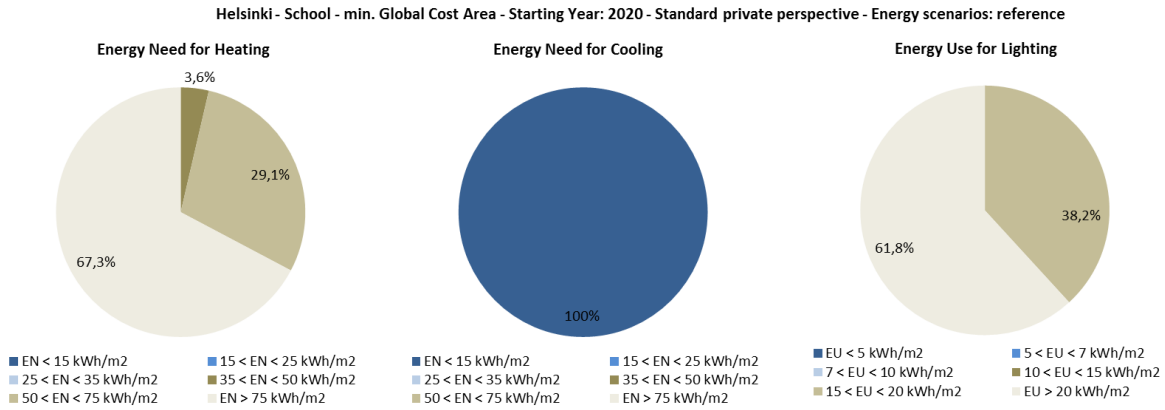

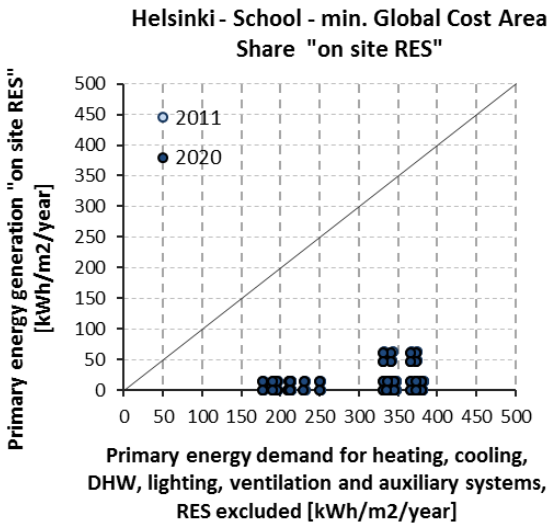

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