



**REPORT ON THE DEVELOPMENT OF COST OPTIMAL  
CALCULATIONS AND GAP ANALYSIS FOR BUILDINGS IN  
IRELAND UNDER DIRECTIVE 2010/31/EU ON THE ENERGY  
PERFORMANCE OF BUILDINGS (RECAST)**

**Section 2 –Non Residential**

**IRELAND**

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# Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-Residential Buildings

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## 1. Introduction

This report details work undertaken for the Department of the Environment, Community and Local Government. It describes work to research and develop draft cost-optimal calculations and a gap analysis for non-residential buildings in accordance with Article 5 of *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)* (hereinafter referred to as the recast EPBD). In doing so, we have paid regard to *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* (hereinafter referred to as the Cost-Optimal Regulation) and the associated *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*.

We have based the format of this report upon the reporting template provided in Annex 3 of the Cost-Optimal Regulation. We have adapted the template where we have found it easier to present the data, although not losing any of the desired content.



## 2. Reference Buildings

### 2.1 New Buildings

According to Annex 1 of Cost Optimal Regulation, member states should establish at least one reference building for office buildings and also establish reference buildings for other non-residential building categories listed in Annex I of the recast EPBD for which specific energy performance requirements exist. We note that in Ireland, energy performance requirements are set for all non-residential buildings. Hence, we have considered the wider list of non-residential buildings included in the recast EPBD.

We have selected reference buildings based on the following four building categories.

1. Office buildings
2. Educational buildings
3. Hotels and restaurants
4. Wholesale and retail services buildings

In addition, hospitals and sport facilities were included in Annex I of the recast EPBD. We have chosen not to analyse such buildings in this work. The main reason for this is that the other buildings in this list encompass a wide range of servicing strategies and are representative of the majority of the non domestic building stock. Hence, this provides a sufficient understanding of the gap between current Regulations and the Cost Optimal Level. In addition, restricting the number of buildings allows for a more detailed analysis, so that a greater number of measures can be included in the cost-optimal calculations.

For the office building, hotel and restaurants, and wholesale and retail services buildings, we have started from building models used to develop Building Regulations for energy performance requirements within the UK. These typical building models (not actual buildings) have previously been agreed with Government and industry as being appropriate. Given the similar types of building construction in Ireland and the UK, we have adopted similar building models here.

However, we have amended these buildings such that their building floor area reflects Irish data. The planning permissions granted in 2010 were tabulated (Table 2.1). This Table only shows buildings relevant for this analysis. A typical building size for each Reference Building has been suggested by taking the mean building floor area.

The final floor areas for these buildings are shown in Table 2.2. These are slightly amended from those given in Table 2.1. As we are modelling a hotel, it was felt that the floor area should be greater than in Table 2.1 as this also encompassed smaller cafes etc.. The retail floor area has been rounded from that given in Table 2.1.

Table 2.1: 2010 Planning Permissions Granted

	<i>Total Number</i>	<i>Total Area (000 m<sup>2</sup>)</i>	<i>Reference Building</i>	<i>Mean Area (m<sup>2</sup>)</i>
Hotels, restaurants and cafes	69	122	Hotel	1,768 <sup>1</sup>
Buildings for trade and administration buildings for other economic activities	188	238	Retail	1,266
Office development, buildings for financing and insurance	92	164	Office	1,783

For the school building, we have used a primary school building. The model is based on an exemplar building provided by the Department of Education and Skills - <http://www.education.ie/en/School-Design/Exemplars-Template-Designs/Exemplars-and-Template-Designs.html>.

A summary of the buildings, construction type and servicing strategy are shown in Table 2.2. In total five Reference Buildings have been considered. Both natural ventilated and air conditioned serviced buildings have been considered – and splitting office buildings between both types. Furthermore both cavity wall and steel frame constructed buildings have been considered with the most appropriate construction type selected for each building category. This should provide a good estimate of the difference between national Regulations and cost optimal levels.

Table 2.2: Building Models

<i>Building Category</i>	<i>Construction type</i>	
	<i>Cavity Wall</i>	<i>Steel Frame</i>
Retail (Air Conditioned)		1,250 m <sup>2</sup>
Office (Natural Ventilation)	1,500 m <sup>2</sup>	
Office (Air Conditioned)		1,500 m <sup>2</sup>
School (Primary – Natural Ventilation)	2,300 m <sup>2</sup>	
Hotel (Air Conditioned)	2,500 m <sup>2</sup>	

Please note that the floor areas are calculated by taking linear measurements between the finished internal faces of the walls.

For the purpose of this work, it has been assumed that the buildings will be constructed in Dublin. This area is the focus of current construction activities. Hence, we have considered climate and cost data relevant for the Dublin geographical area.

Table 2.3 provides a more detailed summary of the Reference Buildings using the template provided with the Cost Optimal Regulation. The component level requirements that set the minimum performance standards for new non-residential buildings are outlined in Appendix A.

<sup>1</sup> An analysis of 2005-2007 (period of peak construction) planning permissions for 943 hotels had an average floor area of 2643 m<sup>2</sup>. This has been reflected in Table 2.2. Other average floor areas in the 2005 to 2007 period were similar to 2010.

Table 2.3: Reference Buildings for New Buildings

Building Category	Building Geometry		Shares of window area on the building envelope and windows with no solar access	Floor area m <sup>2</sup> as used in building code	Typical energy performance kWh/m <sup>2</sup> /yr	Component level requirements
	Area of N/W/S/E facade (m <sup>2</sup> )	Volume (m <sup>3</sup> )	Ratio of window area over total building envelope area separately for N/W/S/E facades		Primary energy for each building model according to current national regulations	These are minimum requirements for different elemental components
Retail (Air Conditioned)	200 / 100 / 200 / 100	4,900	0 / 0 / 0.3 / 0	1,250	726	See Appendix A
Office (Natural Ventilation)	280 / 126 / 280 / 126	5,040	0.4 / 0.4 / 0.4 / 0.4	1,500	247	
Office (Air Conditioned)	280 / 126 / 280 / 126	5,040	0.4 / 0.4 / 0.4 / 0.4	1,500	406	
School (Primary – Natural Ventilation)	413 / 339 / 392 / 331	8,700	0.23 / 0.31 / 0.3 / 0	2,300	110	
Hotel (Air Conditioned)	413 / 492 / 441 / 415	8,875	0.28 / 0.3 / 0.3 / 0.3	2,500	508	

Tables 2.4a-e provides a summary of the energy performance relevant data used in the modelling for each of the five reference buildings.

Table 2.4a: Energy Performance Relevant Data – Retail Building

<b>Building: Retail</b>			<b>Quantity</b>	<b>Unit</b>
<b>Calculation</b>	Method and tool(s)	SBEM v.3.5.b		
	Primary energy conversion factors (averaged over calculation period):	Gas	1.10	kWh/kWh
		Grid Supplied Electricity	1.97	
		On-site Generated Electricity	1.97	
<b>Climate</b>	Location	Dublin		
	Climate data	SBEM v.3.5.b climate data file		
	Terrain location	Sub-urban. The impact of surrounding buildings has not been included.		
<b>Geometry</b>	Length x Width x Height	50 x 25 x 4	m	
<b>Systems</b>	Ventilation system	Air changes per hour	1	1/hr
		Heat recovery efficiency	0	%
	Heating system	Generation	86	%
		Distribution	95	%
		Emission	-	%
		Control	-	%
	Cooling system	Generation	350	%
		Distribution	66	%
		Emission	-	%
		Control	-	%
	DHW system	Generation	75	%
		Distribution	60	%
		Emission	-	%
Control		-	%	
<b>Setpoints and Schedules</b>	Temperature setpoint	Winter	20	°C
		Summer	23	°C
	Operation schedules	All schedules are defined by the SBEM v.3.5.b activity database.		
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.	
		Daylight lighting control		
	Heating energy	69	kWh/m <sup>2</sup> /yr	
	Cooling energy	113	kWh/m <sup>2</sup> /yr	
	DHW energy	2	kWh/m <sup>2</sup> /yr	
	Lighting energy	179	kWh/m <sup>2</sup> /yr	
Auxiliary energy	35	kWh/m <sup>2</sup> /yr		
<b>Energy Generation</b>	This building has no on-site energy generation.			
<b>Energy Consumption</b>	Delivered energy	Fossil fuel	69	kWh/m <sup>2</sup> /yr
		Electricity	330	
		Other	0	kWh/m <sup>2</sup> /yr
	Primary energy	726	kWh/m <sup>2</sup> /yr	

Table 2.4b: Energy Performance Relevant Data – Office Naturally Ventilated

<b>Building: Office (NV)</b>			<b>Quantity</b>	<b>Unit</b>
<b>Calculation</b>	Method and tool(s)	SBEM v.3.5.b		
	Primary energy conversion factors (averaged over calculation period):	Gas	1.10	kWh/kWh
		Grid Supplied Electricity	1.97	
		On-site Generated Electricity	1.97	
<b>Climate</b>	Location	Dublin		
	Climate data	SBEM v.3.5.b climate data file		
	Terrain location	Sub-urban. The impact of surrounding buildings has not been included.		
<b>Geometry</b>	Length x Width x Height	14 x 18 x 7	m	
<b>Systems</b>	Ventilation system	Air changes per hour	-	1/hr
		Heat recovery efficiency	-	%
	Heating system	Generation	86	%
		Distribution	95	%
		Emission	-	%
		Control	-	%
	Cooling system	Generation	-	%
		Distribution	-	%
		Emission	-	%
		Control	-	%
	DHW system	Generation	75	%
		Distribution	60	%
		Emission	-	%
Control		-	%	
<b>Setpoints and Schedules</b>	Temperature setpoint	Winter	20	°C
		Summer	-	°C
	Operation schedules	All schedules are defined by the SBEM v.3.5.b activity database.		
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.	
		Daylight lighting control		
	Heating energy	91	kWh/m <sup>2</sup> /yr	
	Cooling energy	0	kWh/m <sup>2</sup> /yr	
	DHW energy	10	kWh/m <sup>2</sup> /yr	
	Lighting energy	59	kWh/m <sup>2</sup> /yr	
Auxiliary energy	6	kWh/m <sup>2</sup> /yr		
<b>Energy Generation</b>	This building has no on-site energy generation.			
<b>Energy Consumption</b>	Delivered energy	Fossil fuel	91	kWh/m <sup>2</sup> /yr
		Electricity	75	kWh/m <sup>2</sup> /yr
		Other	0	kWh/m <sup>2</sup> /yr
	Primary energy	247	kWh/m <sup>2</sup> /yr	

Table 2.4c: Energy Performance Relevant Data – Office Air Conditioned

<b>Building: Office (AC)</b>			<b>Quantity</b>	<b>Unit</b>
<b>Calculation</b>	Method and tool(s)	SBEM v.3.5.b		
	Primary energy conversion factors (averaged over calculation period):	Gas	1.10	kWh/kWh
		Grid Supplied Electricity	1.97	
		On-site Generated Electricity	1.97	
<b>Climate</b>	Location	Dublin		
	Climate data	SBEM v.3.5.b climate data file		
	Terrain location	Sub-urban. The impact of surrounding buildings has not been included.		
<b>Geometry</b>	Length x Width x Height	14 x 18 x 7	m	
<b>Systems</b>	Ventilation system	Air changes per hour	1.2	1/hr
		Heat recovery efficiency	-	%
	Heating system	Generation	86	%
		Distribution	95	%
		Emission	-	%
		Control	-	%
	Cooling system	Generation	350	%
		Distribution	66	%
		Emission	-	%
		Control	-	%
	DHW system	Generation	75	%
		Distribution	60	%
		Emission	-	%
Control		-	%	
<b>Setpoints and Schedules</b>	Temperature setpoint	Winter	20	°C
		Summer	23	°C
	Operation schedules	All schedules are defined by the SBEM v.3.5.b activity database.		
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation Daylight lighting control	These energy savings are not reported separately.	
	Heating energy		81	kWh/m <sup>2</sup> /yr
	Cooling energy		66	kWh/m <sup>2</sup> /yr
	DHW energy		10	kWh/m <sup>2</sup> /yr
	Lighting energy		59	kWh/m <sup>2</sup> /yr
	Auxiliary energy		26	kWh/m <sup>2</sup> /yr
<b>Energy Generation</b>	This building has no on-site energy generation.			
<b>Energy Consumption</b>	Delivered energy	Fossil fuel	81	kWh/m <sup>2</sup> /yr
		Electricity	161	kWh/m <sup>2</sup> /yr
		Other	0	kWh/m <sup>2</sup> /yr
	Primary energy		406	kWh/m <sup>2</sup> /yr

Table 2.4d: Energy Performance Relevant Data – Primary School

<b>Building: School (Primary)</b>			<b>Quantity</b>	<b>Unit</b>
<b>Calculation</b>	Method and tool(s)	SBEM v.3.5.b		
	Primary energy conversion factors (averaged over calculation period):	Gas	1.10	kWh/kWh
		Grid Supplied Electricity	1.85	
		On-site Generated Electricity	1.85	
<b>Climate</b>	Location	Dublin		
	Climate data	SBEM v.3.5.b climate data file		
	Terrain location	Sub-urban. The impact of surrounding buildings has not been included.		
<b>Geometry</b>	Length x Width x Height	60 x 40 x 8	m	
<b>Systems</b>	Ventilation system	Air changes per hour	-	1/hr
		Heat recovery efficiency	-	%
	Heating system	Generation	86	%
		Distribution	95	%
		Emission	-	%
		Control	-	%
	Cooling system	Generation	-	%
		Distribution	-	%
		Emission	-	%
		Control	-	%
	DHW system	Generation	75	%
		Distribution	60	%
		Emission	-	%
		Control	-	%
<b>Setpoints and Schedules</b>	Temperature setpoint	Winter	20	°C
		Summer	-	°C
	Operation schedules	All schedules are defined by the SBEM v.3.5.b activity database.		
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.	
		Daylight lighting control		
	Heating energy	48	kWh/m <sup>2</sup> /yr	
	Cooling energy	0	kWh/m <sup>2</sup> /yr	
	DHW energy	5	kWh/m <sup>2</sup> /yr	
	Lighting energy	27	kWh/m <sup>2</sup> /yr	
Auxiliary energy	1	kWh/m <sup>2</sup> /yr		
<b>Energy Generation</b>	This building has no on-site energy generation.			
<b>Energy Consumption</b>	Delivered energy	Fossil fuel	53	kWh/m <sup>2</sup> /yr
		Electricity	28	kWh/m <sup>2</sup> /yr
		Other	0	kWh/m <sup>2</sup> /yr
	Primary energy	110	kWh/m <sup>2</sup> /yr	

Table 2.4e: Energy Performance Relevant Data - Hotel

<b>Building: Hotel</b>			<b>Quantity</b>	<b>Unit</b>
<b>Calculation</b>	Method and tool(s)	SBEM v.3.5.b		
	Primary energy conversion factors (averaged over calculation period):	Gas	1.10	kWh/kWh
		Grid Supplied Electricity	1.97	
		On-site Generated Electricity	1.97	
<b>Climate</b>	Location	Dublin		
	Climate data	SBEM v.3.5.b climate data file		
	Terrain location	Sub-urban. The impact of surrounding buildings has not been included.		
<b>Geometry</b>	Length x Width x Height	43 x 12 x 14	m	
<b>Systems</b>	Ventilation system	Air changes per hour	3	1/hr
		Heat recovery efficiency	0	%
	Heating system	Generation	86	%
		Distribution	95	%
		Emission	-	%
		Control	-	%
	Cooling system	Generation	350	%
		Distribution	66	%
		Emission	-	%
		Control	-	%
	DHW system	Generation	75	%
		Distribution	60	%
		Emission	-	%
Control		-	%	
<b>Setpoints and Schedules</b>	Temperature setpoint	Winter	20	°C
		Summer	23	°C
	Operation schedules	All schedules are defined by the SBEM v.3.5.b activity database.		
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.	
		Daylight lighting control		
	Heating energy	84	kWh/m <sup>2</sup> /yr	
	Cooling energy	23	kWh/m <sup>2</sup> /yr	
	DHW energy	218	kWh/m <sup>2</sup> /yr	
	Lighting energy	31	kWh/m <sup>2</sup> /yr	
Auxiliary energy	35	kWh/m <sup>2</sup> /yr		
<b>Energy Generation</b>	This building has no on-site energy generation.			
<b>Energy Consumption</b>	Delivered energy	Fossil fuel	302	kWh/m <sup>2</sup> /yr
		Electricity	89	kWh/m <sup>2</sup> /yr
		Other	0	kWh/m <sup>2</sup> /yr
	Primary energy	508	kWh/m <sup>2</sup> /yr	

## 2.2 Existing Buildings

According to Annex 1 of Cost Optimal Regulation, member states should establish at least two reference buildings for each building category. Hence, we have considered two reference buildings for each of the five building categories considered for new buildings in Section 2.1.

We have chosen to adopt the same five building models used for new build (i.e. same size and geometry). The principal reason for this is that it provides a useful comparison with the new-build results. Furthermore, it would be expected that the new-build floor areas selected are not significantly different to existing building floor areas and that the floor area is much less significant in determining the cost optimum level than the initial energy efficiencies assumed in the base case (i.e. current) existing building models.

For each of the five building models, we have assumed two different initial energy performance levels i.e. we have considered two reference buildings for each building category. For the purpose of this discussion, we have defined these here as energy efficiency 1 (EE1) and energy efficiency 2 (EE2) where EE2 is of a higher standard than EE1.

EE1 and EE2 have been determined by using the energy end-uses recorded for existing non-residential buildings in the Building Energy Rating (BER) certificate database. This is data used to produce energy performance certificates for existing buildings required under Article 7 of the original Energy Performance of Buildings Directive. There are currently 5,000 records, with large datasets for each of the building types we are considering for this study.

- For EE1: For each building type, we have taken the energy end uses from a building with the median primary energy consumption.
- For EE2: For each building type, we have taken the energy end uses from a building with the 75<sup>th</sup> percentile primary energy consumption.

The BER database also allows us to identify approximate building specifications (fabric u-values, service efficiencies) associated with EE1 and EE2 levels. These initial building specifications have been modified to provide the exact EE1 and EE2 levels.

Table 2.6 provides a summary of the reference buildings using the template provided in the Cost Optimal Regulation. We have omitted information on the building geometry, window area and floor area which are already provided in Table 2.3. We have also omitted information on the building technologies as these are provided in more detail in Table 7.

Table 2.7 provides a summary of the energy performance data. Again, we have omitted information on the buildings themselves which were provided in Tables 2.3 and 2.4.

Table 2.6: Reference Buildings for Existing Buildings

Building Category	Energy Efficiency Level	Construction type	Typical energy performance kWh/m <sup>2</sup> /yr	Component level requirements
Office (Natural Ventilation)	EE1	Cavity Wall	412	Refer to appendix A
	EE2	Cavity Wall	331	
Office (Air Conditioned)	EE1	Steel Frame	505	
	EE2	Steel Frame	393	
School (Primary – Natural Ventilation)	EE1	Cavity Wall	202	
	EE2	Cavity Wall	105	
Hotel (Air Conditioned)	EE1	Cavity Wall	677	
	EE2	Cavity Wall	515	
Retail (Air Conditioned)	EE1	Steel Frame	859	
	EE2	Steel Frame	659	

Table 2.7a: Energy Performance Relevant Data - Retail

<b>Building: Retail</b>			<b>Quantity</b>		<b>Unit</b>
			<b>EE1</b>	<b>EE2</b>	
<b>Systems</b>	Ventilation system	Air changes per hour	3	3	1/hr
		Heat recovery efficiency	0	0	%
	Heating system	Generation	74	74	%
		Distribution	95	95	%
		Emission	-	-	%
		Control	-	-	%
	Cooling system	Generation	200	300	%
		Distribution	66	66	%
		Emission	-	-	%
		Control	-	-	%
	DHW system	Generation	50	70	%
		Distribution	90	90	%
		Emission	-	-	%
Control		-	-	%	
<b>Building Elements</b>	Average U-value	Walls	0.45	0.45	W/m <sup>2</sup> K
		Roof	0.25	0.25	W/m <sup>2</sup> K
		Floor	0.45	0.45	W/m <sup>2</sup> K
		Windows	2.8	2.2	W/m <sup>2</sup> K
	Average g-value of glazing	0.7	0.7	-	
	Air permeability	15	15	m <sup>3</sup> /m <sup>2</sup> .hr	
	Lighting	Efficacy	25	40	lm/cW
Daylight controls		N	N	-	
Occupancy controls		Y	Y	-	
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.		
		Daylight lighting control			
	Heating energy	85	93	kWh/m <sup>2</sup> /yr	
	Cooling energy	88	45	kWh/m <sup>2</sup> /yr	
	DHW energy	1	1	kWh/m <sup>2</sup> /yr	
	Lighting energy	158	123	kWh/m <sup>2</sup> /yr	
Auxiliary energy	36	36	kWh/m <sup>2</sup> /yr		

Table 2.7b: Energy Performance Relevant Data – Office (NV)

			Quantity		Unit
			EE1	EE2	
<b>Building: Office (NV)</b>					
<b>Systems</b>	Ventilation system	Air changes per hour	3	3	1/hr
		Heat recovery efficiency	0	0	%
	Heating system	Generation	74	84	%
		Distribution	95	95	%
		Emission	-	-	%
		Control	-	-	%
	Cooling system	Generation	-	-	%
		Distribution	-	-	%
		Emission	-	-	%
		Control	-	-	%
	DHW system	Generation	50	70	%
		Distribution	90	90	%
		Emission	-	-	%
Control		-	-	%	
<b>Building Elements</b>	Average U-value	Walls	0.55	0.45	W/m <sup>2</sup> K
		Roof	0.61	0.25	W/m <sup>2</sup> K
		Floor	0.45	0.45	W/m <sup>2</sup> K
		Windows	3.6	2.8	W/m <sup>2</sup> K
	Average g-value of glazing	0.7	0.7	-	
	Air permeability	15	15	m <sup>3</sup> /m <sup>2</sup> .hr	
	Lighting	Efficacy	25	30	lm/cW
Daylight controls		N	N	-	
Occupancy controls		N	N	-	
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.		
		Daylight lighting control			
	Heating energy	175	132	kWh/m <sup>2</sup> /yr	
	Cooling energy	0	0	kWh/m <sup>2</sup> /yr	
	DHW energy	5	5	kWh/m <sup>2</sup> /yr	
	Lighting energy	72	60	kWh/m <sup>2</sup> /yr	
Auxiliary energy	4	45	kWh/m <sup>2</sup> /yr		

Table 2.7c: Energy Performance Relevant Data – Office (AC)

			Quantity		Unit
			EE1	EE2	
<b>Building: Office (AC)</b>					
<b>Systems</b>	Ventilation system	Air changes per hour	3	3	1/hr
		Heat recovery efficiency	0	65	%
	Heating system	Generation	78	88	%
		Distribution	95	95	%
		Emission	-	-	%
		Control	-	-	%
	Cooling system	Generation	220	220	%
		Distribution	66	66	%
		Emission	-	-	%
		Control	-	-	%
	DHW system	Generation	60	70	%
		Distribution	90	90	%
		Emission	-	-	%
Control		-	-	%	
<b>Building Elements</b>	Average U-value	Walls	0.45	0.35	W/m <sup>2</sup> K
		Roof	0.25	0.25	W/m <sup>2</sup> K
		Floor	0.45	0.25	W/m <sup>2</sup> K
		Windows	2.2	2.2	W/m <sup>2</sup> K
	Average g-value of glazing		0.7	0.7	-
	Air permeability		15	10	m <sup>3</sup> /m <sup>2</sup> .hr
	Lighting	Efficacy	45	55	lm/cW
Daylight controls		N	N	-	
Occupancy controls		N	N	-	
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.		
		Daylight lighting control			
	Heating energy		131	78	kWh/m <sup>2</sup> /yr
	Cooling energy		50	46	kWh/m <sup>2</sup> /yr
	DHW energy		5	5	kWh/m <sup>2</sup> /yr
	Lighting energy		45	33	kWh/m <sup>2</sup> /yr
Auxiliary energy		34	30	kWh/m <sup>2</sup> /yr	

Table 2.7e: Energy Performance Relevant Data – School (Primary)

<b>Building: School (Primary)</b>			<b>Quantity</b>		<b>Unit</b>
			<b>EE1</b>	<b>EE2</b>	
<b>Systems</b>	Ventilation system	Air changes per hour	3	3	1/hr
		Heat recovery efficiency	0	0	%
	Heating system	Generation	74	84	%
		Distribution	95	95	%
		Emission	-	-	%
		Control	-	-	%
	Cooling system	Generation	-	-	%
		Distribution	-	-	%
		Emission	-	-	%
		Control	-	-	%
	DHW system	Generation	50	70	%
		Distribution	90	90	%
		Emission	-	-	%
Control		-	-	%	
<b>Building Elements</b>	Average U-value	Walls	0.45	0.35	W/m <sup>2</sup> K
		Roof	0.50	0.25	W/m <sup>2</sup> K
		Floor	0.45	0.25	W/m <sup>2</sup> K
		Windows	3.6	2.2	W/m <sup>2</sup> K
	Average g-value of glazing	0.7	0.7	-	
	Air permeability	15	10	m <sup>3</sup> /m <sup>2</sup> .hr	
	Lighting	Efficacy	30	50	lm/cW
Daylight controls		N	N	-	
Occupancy controls		N	N	-	
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.		
		Daylight lighting control			
	Heating energy	104	61	kWh/m <sup>2</sup> /yr	
	Cooling energy	0	0	kWh/m <sup>2</sup> /yr	
	DHW energy	10	3	kWh/m <sup>2</sup> /yr	
	Lighting energy	25	11	kWh/m <sup>2</sup> /yr	
Auxiliary energy	2	2	kWh/m <sup>2</sup> /yr		

Table 2.7e: Energy Performance Relevant Data - Hotel

<b>Building: Hotel</b>			<b>Quantity</b>		<b>Unit</b>
			<b>EE1</b>	<b>EE2</b>	
<b>Systems</b>	Ventilation system	Air changes per hour	3	3	1/hr
		Heat recovery efficiency	0	0	%
	Heating system	Generation	80	84	%
		Distribution	95	95	%
		Emission	-	-	%
		Control	-	-	%
	Cooling system	Generation	200	220	%
		Distribution	66	66	%
		Emission	-	-	%
		Control	-	-	%
	DHW system	Generation	60	70	%
		Distribution	90	90	%
		Emission	-	-	%
Control		-	-	%	
<b>Building Elements</b>	Average U-value	Walls	0.45	0.45	W/m <sup>2</sup> K
		Roof	0.25	0.25	W/m <sup>2</sup> K
		Floor	0.45	0.45	W/m <sup>2</sup> K
		Windows	3.1	2.5	W/m <sup>2</sup> K
	Average g-value of glazing		0.7	0.7	-
	Air permeability		15	15	m <sup>3</sup> /m <sup>2</sup> .hr
	Lighting	Efficacy	15	35	lm/cW
Daylight controls		N	N	-	
Occupancy controls		N	N	-	
<b>Energy Use</b>	Energy contribution of main passive strategies	Natural ventilation	These energy savings are not reported separately.		
		Daylight lighting control			
	Heating energy	110	119	kWh/m <sup>2</sup> /yr	
	Cooling energy	24	14	kWh/m <sup>2</sup> /yr	
	DHW energy	172	148	kWh/m <sup>2</sup> /yr	
	Lighting energy	69	30	kWh/m <sup>2</sup> /yr	
Auxiliary energy	43	38	kWh/m <sup>2</sup> /yr		

## 3. Measures and Packages

### 3.1 New Buildings

A list of potential measures has been compiled using the Cost Optimisation Guidelines document and design experience. Since it is impractical to evaluate every permutation of the selected measures, we have grouped the measures into packages. These packages are listed in Tables 3.1a and 3.1b. The packages represent four different components of a building design (fabric, services, heating, photovoltaics (PV)), so that selecting one package from each component forms a complete building design. In total, we have considered 225 packages for each building (3 fabric x 3 services x 5 heating x 5 PV), with the exception of air conditioned offices where we have considered 450 packages in total.

The values selected for each of the measures (e.g. the fabric u-values and building services efficiencies) within the packages have been chosen to give a large spread of primary energies and lifecycle costs. This helps to obtain a clear cost optimal front and identification of the optimum point. It includes solutions that together might comprise a building model that performs more poorly than the primary energy target set by the current regulations.

It should be noted that some possible measures have been omitted from these packages. There are a number of reasons for this:

- **Site specific measures:** Various measures are particularly dependant on site constraints. For example, building orientation and the feasibility of wind turbines are likely to depend on the site and the surrounding context. Our assumption is that the cost optimal point should be based on measures that any designer can typically adopt, if not the cost optimal point may be unrealistic to achieve in many real cases. While we see the availability of Biomass to be site-specific, we do recognise the likelihood of Biomass being considered more widely in the near future. Therefore, have undertaken a sensitivity analysis on one building type to assess the impact of selecting Biomass as a heat source.
- **Design measures:** Some measures impact on design constraints that are not incorporated in the building primary energy requirement. In particular, our concern is that by modifying the percentage of glazing or introducing shading to optimise on primary energy, it may result in inadequate daylight levels. Furthermore, this is building dependent – a particular percentage of glazing may provide appropriate day lighting in one building design but not another. Therefore we have not considered these two measures in the list of packages.
- **Default measures:** There are other measures that are likely to be included in new buildings by default, for example, monitoring and metering, variable speed pumps and power factor correction. These have not been treated as options - they are simply be added into the base building models assumed in all cases. Since these measures do not vary, there is no need to identify separately costs for them.

Table 3.1c gives the details of the baseline and improved thermal bridging cases. In addition, Table 3.1d shows an example compliant specification to meet current national Regulations for all building types. As the national regulation is performance-based, a building may comply by adopting alternative measures.

Table 3.1a: Measures included in analysis (naturally ventilated buildings)

<i>Fabric (3 options)</i>	<b>A</b>	<b>B</b>	<b>C</b>
Wall U-value (W/m <sup>2</sup> K)	0.3	0.21	0.15
Roof U-value (W/m <sup>2</sup> K)	0.25	0.2	0.15
Floor U-value (W/m <sup>2</sup> K)	0.25	0.2	0.15
Window U-value (W/m <sup>2</sup> K)	1.8	1.4	0.9
Improved Thermal Bridging	NO	YES	YES
Air Tightness (m <sup>3</sup> /m <sup>2</sup> .hr @ 50 Pa)	7	5	3

<i>Services (3 options)</i>	<b>1</b>	<b>2</b>	<b>3</b>
Lighting (lm/cW)	55	60	65
Display Lighting (lm/W)	15	15	22
Daylight Lighting Control	NO	YES	YES
Occupancy Lighting Control	NO	YES	YES

<i>Heating (5 options)</i>					
Heating Source	Gas boiler (86% efficiency)	Gas boiler (91% efficiency) + Solar Hot Water	Combined Heat and Power (45% heat efficiency)	Ground Source Heat Pump (4.0 CoP)	Ground Source Heat Pump (4.0 CoP) + Solar Hot Water

<i>PV (5 options)</i>					
PV Installation (percentage of foundation area)	0%	10%	20%	30%	40%

Table 3.1b: Measures included in analysis (air conditioned buildings)

<i>Fabric (3 options)</i>	<b>A</b>	<b>B</b>	<b>C</b>
Wall U-value (W/m <sup>2</sup> K)	0.3	0.25	0.2
Roof U-value (W/m <sup>2</sup> K)	0.25	0.2	0.15
Floor U-value (W/m <sup>2</sup> K)	0.25	0.2	0.15
Window U-value (W/m <sup>2</sup> K)	1.8	1.4	0.9
Improved Thermal Bridging	NO	YES	YES
Air Tightness (m <sup>3</sup> /m <sup>2</sup> .hr @ 50 Pa)	7	5	3

<i>Services (3 options)</i>	<b>1</b>	<b>2</b>	<b>3</b>
Lighting (l/m/cW)	55	60	6
Daylight Lighting Control	NO	YES	YES
Occupancy Lighting Control	NO	YES	YES
Heat Recovery	NO	NO	65%
Chiller Efficiency (SEER)	3.5	4.5	5.5
AHU SFP	2.2	2	1.8
FCU SFP	0.6	0.3	0.3
Demand Control Ventilation*	NO	NO	YES

<i>Additional Services (2 options)*</i>		
Free Cooling (FC)	NO	YES

<i>Heating (5 options)</i>					
Heating Source	Gas boiler (86% efficient)	Gas boiler (91% efficient) + Solar Hot Water	Combined Heat and Power (45% heat efficiency)	Ground Source Heat Pump (4.0 CoP)	Ground Source Heat Pump (4.0 CoP) + Solar Hot Water

<i>PV (5 options)</i>					
PV Installation (percentage of foundation area)	0%	10%	20%	30%	40%

\*Only applicable to Office (air conditioned)

Table 3.1c: Thermal Bridging Details (W/mK)

<i>Junction</i>	<i>Baseline</i>	<i>Improved</i>
Roof – Wall	0.18	0.12
Wall – Ground	0.24	0.16
Wall – Wall	0.14	0.09
Wall – Floor	0.11	0.07
Lintel	0.45	0.3
Sill	0.08	0.04
Jamb	0.09	0.05
Roof – Wall (Metal Cladding)	0.42	0.28
Wall – Ground (Metal Cladding)	1.73	1.15
Wall – Wall (Metal Cladding)	0.38	0.25
Wall – Floor (Metal Cladding)	0.04	0.00
Lintel (Metal Cladding)	1.91	1.27
Sill (Metal Cladding)	1.91	1.27
Jamb (Metal Cladding)	1.91	1.27

Table 3.1d: Example compliant specification to meet current national Regulations

<u>Fabric</u>	
Wall U-value (W/m <sup>2</sup> K)	0.27
Roof U-value (W/m <sup>2</sup> K)	0.16
Floor U-value (W/m <sup>2</sup> K)	0.25
Window U-value (W/m <sup>2</sup> K)	2.2
Thermal Bridging (additional heat loss, %)	16
Air Tightness (m <sup>3</sup> /m <sup>2</sup> .hr @ 50 Pa)	10

<u>Services</u>	
Lighting in Occupied Areas (W/m <sup>2</sup> per 100 lux)	3.75
Lighting in Non-Occupied Areas (W/m <sup>2</sup> per 100 lux)	5.2
Daylight Lighting Control	NO
Occupancy Lighting Control	NO
Heat Recovery	NO
Chiller Efficiency (SEER)	2.5
AHU SFP (W/l/s)	2.0
FCU SFP (W/l/s)	0.8
Demand Control Ventilation	NO

<u>Heating</u>	
Naturally Ventilated Buildings (efficiency, %)	Gas boiler, 78%
Mechanically Ventilated Buildings (efficiency, %)	Gas boiler, 83%
Air Conditioned Buildings (efficiency, %)	Gas boiler, 88%

<u>PV</u>	
PV Installation (percentage of foundation area)	0%

## 3.2 Existing Buildings

We have considered the following building measures. These cover the most common renovation and replacement activities, focussing on those which have the most significant impact on energy use. We have investigated the cost optimum of changing each component in isolation at different levels of energy efficiency. We have undertaken this approach as it is most common to retrofit building components independent of each other and national standards for existing buildings are based on a building component level.

### *Renovation*

- Floors: We have investigated the resurfacing of external floors, including varying levels of insulation.
- Walls: There are a number of means of improving the thermal performance of external walls. We will consider including cavity wall insulation where appropriate, as well as internal insulation and the addition of external cladding.
- Roofs: We will consider the impact of varying levels of insulation in the roof-space.
- Heating system: We have included changes to the whole heating system in the building (the costs of pipework and emitters have been assumed to be the same).

### *Replacement*

- Windows
- Packaged chillers
- Central ventilation air handling units (AHUs)
- Light sources (lamp efficacy)

The different levels of energy efficiency investigated are provided in Table 3.2. Additional details of the fabric improvement measures are given in Tables 3.3a-e.

Table 3.2: Measures included in analysis

<i>Renovation</i>	<i>Building Types</i>	<i>Standard</i>								
Floors (W/m <sup>2</sup> K)	All	0.6	0.25	0.20	0.15	0.10				
Cavity Walls (W/m <sup>2</sup> K)	Office (NV), School, Hotel	0.6	0.30	0.19	0.14	0.16	0.1	0.39	0.21	
Metal Frame Walls (W/m <sup>2</sup> K)	Office (AC), Retail	0.6	0.47	0.36	0.27	0.21	0.20	0.151	0.15	0.11
Metal Seam Roof (W/m <sup>2</sup> K)	Retail, Office (AC)	0.35	0.29	0.18	0.14					
Pitched Roof (W/m <sup>2</sup> K)	Office (NV), Hotel, School,	0.35	0.25	0.20	0.15					
Heating system	All	Gas (84%)	Gas (84%)	Gas (91%)	Gas (91%) + SHW	ASHP	Gas CHP			

<i>Replacement</i>	<i>Building Types</i>	<i>Standard</i>								
Windows (W/m <sup>2</sup> K)	All	2.2	1.8	1.4	1.1	0.9				
Chiller Efficiency (SEER)	Retail, Office (AC), Hotel	1.67	3.5	4.5	5.5					
AHU SFP (W/l/s)	Retail, Office (AC), Hotel	3.0	2.2	2.0	1.8					
Lighting (lm/cW)	All	55	55	60	65					

Table 3.3a: Details of the improvement measures to solid floors

<u>Measure</u>	<u>U-Value (W/m<sup>2</sup>K)</u>
Concrete screed (70mm) Rigid PIR board (60mm) ( $\lambda=0.022$ ) 25mm edge insulation (1000 wide along perimeter, rigid PU ( $\lambda=0.022$ ))	0.25
Concrete screed (70mm) Rigid PIR board (85mm) ( $\lambda=0.022$ ) 25mm edge insulation (1000 wide along perimeter, rigid PU ( $\lambda=0.022$ ))	0.20
Concrete screed (70mm) Rigid PIR board (120mm) ( $\lambda=0.022$ ) 25mm edge insulation (1000 wide along perimeter, rigid PU ( $\lambda=0.022$ ))	0.15
Concrete screed (70mm) Rigid PIR board (180mm) ( $\lambda=0.022$ ) 25mm edge insulation (1000 wide along perimeter, rigid PU ( $\lambda=0.022$ ))	0.10

Table 3.3b: Details of the improvement measures to cavity walls

<u>Measure</u>	<u>U-Value (W/m<sup>2</sup>K)</u>
Fully filled cavity	0.30
Fully filled cavity and 50mm internal insulation	0.19
Fully filled cavity and 100mm internal insulation	0.14
Fully filled cavity and 100mm external insulation	0.16
Fully filled cavity and 200mm external insulation	0.10
50mm internal insulation (unfilled cavity)	0.39
100mm internal insulation (unfilled cavity)	0.21

Table 3.3c: Details of the improvement measures to metal frame walls

<u>Measure</u>	<u>U-Value (W/m<sup>2</sup>K)</u>
50mm external insulation (EPS ( $\lambda=0.031W/mK$ ))	0.47
100mm external insulation (EPS ( $\lambda=0.031W/mK$ ))	0.27
150mm external insulation (EPS ( $\lambda=0.031W/mK$ ))	0.20
200mm external insulation (EPS ( $\lambda=0.031W/mK$ ))	0.15
50mm external insulation (PIR ( $\lambda=0.022W/mK$ ))	0.36
100mm external insulation (PIR ( $\lambda=0.022W/mK$ ))	0.21
150mm external insulation (PIR ( $\lambda=0.022W/mK$ ))	0.15 (b)
200mm external insulation (PIR ( $\lambda=0.022W/mK$ ))	0.11

Table 3.3d: Details of the improvement measures to metal seam roofs

<i>Measure</i>	<i>U-Value (W/m<sup>2</sup>K)</i>
<i>Standing seam liner sheet            50mm PIR Insulation (<math>\lambda=0.022</math>) over rail            50mm insulation within rail (<math>\lambda=0.037</math>)            Air gap/thermally broken brackets and spacers            VCL            Profiled metal liner sheet            Purlin</i>	0.29
<i>Standing seam liner sheet            100mm PIR Insulation over rail (<math>\lambda=0.022</math>)            50mm insulation within rail (<math>\lambda=0.037</math>)            Air gap/thermally broken brackets and spacers            VCL            Profiled metal liner sheet            Purlin</i>	0.18
<i>Standing seam liner sheet            150mm PIR Insulation over rail (<math>\lambda=0.022</math>)            50mm insulation within rail (<math>\lambda=0.037</math>)            Air gap/thermally broken brackets and spacers            VCL            Profiled metal liner sheet            Purlin</i>	0.14

Table 3.3e: Details of the improvement measures to pitched roofs

<i>Measure</i>	<i>U-Value (W/m<sup>2</sup>K)</i>
<i>Tiling/batten Breather membrane Counter battens (CBs) Rigid PIR board (<math>\lambda=0.022\text{W/mK}</math> – Celotex/Kingspan) between 150mm rafters (100mm) Rafter space (50mm remaining) VCL Plasterboard</i>	0.25
<i>Tiling/batten Breather membrane Counter battens (CBs) PIR (20mm) over rafters Rigid PIR board (<math>\lambda=0.022\text{W/mK}</math> – Celotex/Kingspan) between 150mm rafters (100mm) Rafter space (50mm remaining) VCL Plasterboard</i>	0.20
<i>Tiling/batten Breather membrane Counter battens (CBs) PIR (50mm) over rafters Rigid PIR board (<math>\lambda=0.022\text{W/mK}</math> – Celotex/Kingspan) between 150mm rafters (110mm) Rafter space (40mm remaining) VCL Plasterboard</i>	0.15

## 4. Calculation of Primary Energy Demand for the Measures

### 4.1 New Buildings

#### 4.1.1 Energy Performance Assessment

This section outlines the procedure for determining the primary energy for each package of measures. Each of the five reference buildings were modelled in SBEM, the software provided by SEAI that implements the Non-domestic Energy Assessment Procedure (NEAP). NEAP is the Republic of Ireland's response to the requirement of the EPBD to develop a methodology for calculating the energy performance of buildings.

NEAP is Ireland's calculation methodology and software to the requirements of the EPBD (recast) Annex I and EN 13790 for calculating the energy performance of buildings. The requirements regarding conservation of fuel and energy for dwellings are laid out in Part L of the Second Schedule to the Building Regulations 1997 (Statutory Instrument No. 497 of 1997) as amended by the Building Regulations (Part L Amendment) Regulations 2008 (Statutory Instrument No. 259 of 2008). Part L of the Building regulations provides that the energy performance of the building is such as to limit the calculated primary energy consumption and related carbon dioxide (CO<sub>2</sub>) emissions insofar as is reasonably practicable, when both energy consumption and carbon dioxide (CO<sub>2</sub>) emissions are calculated using the Non domestic Energy Assessment Procedure (NEAP) published by Sustainable Energy Authority of Ireland. NEAP calculates whole building energy and carbon emissions performance compliance for the Irish Building Regulations Part L ..

This cost-optimal study identifies the gap (if any) between current whole dwelling energy performance as defined in Part L of the Building Regulations and the cost optimal level as calculated in NEAP.

To test each package of measures, the SBEM building model input files were updated accordingly and run through the SBEM calculation engine. The energy end uses (e.g. heating, cooling) were recorded directly from the SBEM output files. The end use energies were then summed for each energy carrier to find the delivered energy requirement. Any on-site generated energy was also determined at this stage. The primary energy factors were then applied to the delivered energy and on-site generated energy. The latter was subtracted from the former to give the net primary energy.

Annex 1 of the Cost Optimal Regulation state that "Member States shall use a calculation period of 30 years for residential and public buildings, and a calculation period of 20 years for commercial, non-residential buildings". For the purpose of this work, we have assumed a calculation period of 20 years for all of the buildings with the exception of 30 years for the primary school.

#### 4.1.2 Energy demand calculation

Tables 4.1a – 4.1e summarise the results of the energy performance calculation for the most cost-optimal packages in each of the five reference buildings. These tables include the energy breakdown by end use and the total energy requirement per fuel carrier. The primary energy factors used to calculate the total primary energy requirement and the primary energy reduction over the reference case are listed in Tables 2.4a – 2.4e. The delivered energy per carrier has been incorporated into Tables 4.1 as more helpful than producing separate tables.

Table 4.1a: Energy Demand Output Table

**Building: Retail**

Package				Energy Use					Fuel Use			Primary Energy	
Fabric	Heating	Services	PV	Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction over Reference
				kWh/m <sup>2</sup>									
C	GSHP	3	40%	3	25	30	1	102	0	161	46	227	69%
B	GSHP	3	40%	6	22	30	1	102	0	161	46	228	69%
C	Gas(86%)	3	40%	16	25	30	1	102	16	158	46	239	67%
C	Gas(86%)	3	20%	16	25	30	1	102	16	158	23	284	61%
C	Gas(86%)	3	0%	16	25	30	1	102	16	158	0	329	55%
B	Gas(86%)	3	0%	29	22	30	1	102	29	155	0	338	53%
A	Gas(86%)	3	0%	39	23	30	1	102	39	155	0	349	52%
A	Gas(86%)	2	0%	55	29	33	1	105	55	168	0	390	46%
B	Gas(86%)	1	0%	43	38	36	1	107	43	183	0	408	44%
A	Gas(86%)	1	0%	54	39	36	1	107	54	183	0	420	42%

Table 4.1b: Energy Demand Output Table

**Building: Office (NV)**

Package				Energy Use					Fuel Use			Primary Energy	
Fabric	Heating	Services	PV	Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction over Reference
				kWh/m <sup>2</sup>									
C	GSHP	3	40%	4	0	4	5	28	0	41	24	35	86%
B	GSHP	3	40%	10	0	4	5	28	0	47	24	45	82%
A	GSHP	3	40%	13	0	4	5	28	0	50	24	52	79%
A	GSHP	3	30%	13	0	4	5	28	0	50	18	64	74%
A	GSHP	3	10%	13	0	4	5	28	0	50	6	88	65%
A	GSHP	3	0%	13	0	4	5	28	0	50	0	99	60%
A	GSHP	1	10%	18	0	4	5	33	0	60	6	106	57%
A	GSHP	1	0%	18	0	4	5	33	0	60	0	118	52%
A	Gas(86%)	3	0%	64	0	4	5	28	64	37	0	143	42%
A	Gas(86%)	1	0%	87	0	4	5	33	87	41	0	177	28%

Table 4.1c: Energy Demand Output Table

**Building: Office (AC)**

Package					Energy Use					Fuel Use			Primary Energy	
Fabric	Heating	Services	PV	FC	Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction over Reference
					kWh/m <sup>2</sup>									
C	GSHP	3	40%	OFF	11	17	25	5	18	0	75	24	101	72%
B	GSHP	3	40%	OFF	16	12	25	5	18	0	76	24	102	72%
B	GSHP	2	30%	OFF	16	15	28	5	19	0	83	18	128	65%
B	GSHP	2	0%	OFF	16	15	28	5	19	0	83	0	164	55%
A	GSHP	2	0%	OFF	19	21	28	5	19	0	91	0	179	51%
B	GSHP	1	0%	ON	15	18	37	5	33	0	107	0	212	42%
A	GSHP	1	0%	OFF	18	32	30	5	33	0	117	0	230	37%
A	Gas(86%)	2	0%	OFF	89	21	28	5	19	89	72	0	241	34%
B	Gas(86%)	1	0%	ON	72	18	37	5	33	72	92	0	261	29%
A	Gas(86%)	1	0%	OFF	84	32	30	5	33	84	99	0	287	22%

Table 4.1d: Energy Demand Output Table

**Building: School (Primary)**

Package				Energy Use					Fuel Use			Primary Energy	
Fabric	Heating	Services	PV	Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction over Reference
				kWh/m <sup>2</sup>									
C	GSHP	3	40%	6	0	2	3	8	3	16	27	-17	115%
C	GSHP	2	40%	6	0	2	3	9	3	17	27	-16	114%
A	GSHP	2	40%	11	0	2	3	9	3	22	27	-6	106%
C	Gas(86%)	2	40%	28	0	2	3	9	31	11	27	4	96%
C	Gas(86%)	2	30%	28	0	2	3	9	31	11	20	17	85%
C	Gas(86%)	2	10%	28	0	2	3	9	31	11	7	42	62%
C	Gas(86%)	2	0%	28	0	2	3	9	31	11	0	55	50%
B	Gas(86%)	2	0%	43	0	2	3	9	46	11	0	71	36%
B	Gas(86%)	1	0%	41	0	2	3	16	44	18	0	80	27%
A	Gas(86%)	1	0%	50	0	2	3	16	53	18	0	91	17%

Table 4.1e: Energy Demand Output Table

**Building: Hotel**

Package				Energy Use					Fuel Use			Primary Energy	
Fabric	Heating	Services	PV	Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction over Reference
				kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
C	GSHP+SHW	3	40%	8	6	33	132	16	132	63	13	243	52%
B	GSHP+SHW	3	40%	12	4	33	132	16	132	65	13	246	51%
A	GSHP	3	40%	14	6	33	141	16	141	69	13	266	48%
B	GSHP	1	40%	15	6	38	141	19	141	78	13	284	44%
A	GSHP	1	30%	17	10	38	141	19	141	84	10	302	41%
A	GSHP	1	0%	17	10	38	141	19	141	84	0	321	37%
A	Gas(86%)	3	0%	69	6	33	141	16	210	55	0	339	33%
B	Gas(86%)	1	10%	71	6	38	141	19	212	64	3	352	31%
B	Gas(86%)	1	0%	71	6	38	141	19	212	64	0	359	29%
A	Gas(86%)	1	0%	80	10	38	141	19	221	67	0	376	26%

## **4.2 Existing Buildings**

### **4.2.1 *Energy Performance Assessment***

The primary energy was determined using the same approach as for new buildings.

### **4.2.2 *Energy demand calculation***

Tables 4.2a – 4.2e summarise the results of the energy performance calculation for each of the five reference buildings. These tables include the energy breakdown by end use and the total energy requirement per fuel carrier. The primary energy factors used to calculate the total primary energy requirement and the primary energy reduction over the reference case are listed in Tables 2.4a – 2.4e. The delivered energy per carrier has been incorporated into Tables 4.2 as more helpful than producing separate tables.

Table 4.2a (EE1): Energy Demand Output Table

**Building: Retail**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.11	77	89	36	1	158	77	285	0	646	1%
Wall U-Value	0.15 (b)	78	89	36	1	158	78	284	0	647	1%
Wall U-Value	0.15	78	89	36	1	158	78	284	0	647	1%
Wall U-Value	0.2	80	89	36	1	158	80	284	0	648	1%
Wall U-Value	0.21	80	89	36	1	158	80	284	0	648	1%
Wall U-Value	0.27	81	89	36	1	158	81	284	0	649	1%
Wall U-Value	0.36	83	88	36	1	158	83	284	0	651	1%
Wall U-Value	0.47	86	88	36	1	158	86	283	0	653	0%
Roof U-value	0.14	80	88	36	1	158	80	284	0	648	1%
Roof U-value	0.18	82	88	36	1	158	82	284	0	649	1%
Roof U-value	0.29	87	88	36	1	158	87	283	0	654	0%
Heating Source	ASHP	20	88	36	1	158	0	283	0	558	15%
Heating Source	Gas CHP	18	88	36	1	158	118	283	35	620	5%
Heating Source	Gas (91%)	80	88	36	1	158	80	283	0	646	1%
Heating Source	Gas (91%) + SHW	80	88	36	1	158	80	283	0	646	1%
Heating Source	Gas (86%)	86	88	36	1	158	86	283	0	653	0%
Floor U-value	0.25	75	94	36	1	158	75	289	0	652	1%
Floor U-value	0.2	72	95	36	1	158	72	291	0	652	1%
Floor U-value	0.15	70	97	36	1	158	70	292	0	653	1%
Floor U-value	0.1	67	98	36	1	158	67	294	0	653	1%
Window U-value	1.4	83	85	36	1	158	83	280	0	644	1%
Window U-value	1.1	82	85	36	1	158	82	281	0	644	1%
Window U-value	0.9	82	87	36	1	158	82	283	0	647	1%
Window U-value	1.8	83	89	36	1	158	83	285	0	653	0%
Chiller Efficiency	5.5	85	28	36	1	158	85	223	0	533	19%
Chiller Efficiency	4.5	85	34	36	1	158	85	229	0	545	17%
Chiller Efficiency	3.5	85	43	36	1	158	85	239	0	564	14%
AHU SFP	1.8	85	88	30	1	158	85	277	0	641	5%
AHU SFP	2	85	88	33	1	158	85	280	0	646	4%
AHU SFP	2.2	85	88	36	1	158	85	283	0	652	3%
Lighting Efficacy	65	100	55	36	1	101	100	193	0	490	4%
Lighting Efficacy	60	99	56	36	1	104	99	197	0	498	2%
Lighting Efficacy	55	98	58	36	1	107	98	203	0	508	0%

Table 4.2a (EE2): Energy Demand Output Table

**Building: Retail**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.11	85	46	36	1	123	85	206	0	501	2%
Wall U-Value	0.15 (b)	86	46	36	1	123	86	206	0	502	2%
Wall U-Value	0.15	86	46	36	1	123	86	206	0	502	2%
Wall U-Value	0.2	88	46	36	1	123	88	206	0	503	2%
Wall U-Value	0.21	88	46	36	1	123	88	206	0	503	2%
Wall U-Value	0.27	89	46	36	1	123	89	206	0	504	1%
Wall U-Value	0.36	91	46	36	1	123	91	206	0	506	1%
Wall U-Value	0.47	94	45	36	1	123	94	206	0	509	1%
Roof U-value	0.14	88	45	36	1	123	88	206	0	503	2%
Roof U-value	0.18	90	45	36	1	123	90	206	0	505	2%
Roof U-value	0.29	95	45	36	1	123	95	206	0	511	1%
Heating Source	ASHP	22	45	36	1	123	0	206	0	406	20%
Heating Source	Gas CHP	19	45	36	1	123	129	206	38	473	7%
Heating Source	Gas (91%)	87	45	36	1	123	87	206	0	502	2%
Heating Source	Gas (91%) + SHW	87	45	36	1	123	87	206	0	502	2%
Heating Source	Gas (86%)	95	45	36	1	123	95	206	0	510	0%
Floor U-value	0.1	71	52	36	1	123	71	212	0	496	3%
Floor U-value	0.15	74	51	36	1	123	74	211	0	497	3%
Floor U-value	0.2	76	50	36	1	123	76	210	0	498	3%
Floor U-value	0.25	82	49	36	1	123	82	209	0	502	2%
Window U-value	1.1	92	43	36	1	123	92	203	0	502	1%
Window U-value	1.4	93	43	36	1	123	93	203	0	502	1%
Window U-value	0.9	91	44	36	1	123	91	205	0	504	1%
Window U-value	1.8	92	46	36	1	123	92	206	0	508	0%
Chiller Efficiency	5.5	93	21	36	1	123	93	182	0	461	17%
Chiller Efficiency	4.5	93	26	36	1	123	93	186	0	470	16%
Chiller Efficiency	3.5	93	33	36	1	123	93	194	0	485	13%
AHU SFP	1.8	93	45	30	1	123	93	200	0	497	7%
AHU SFP	2	93	45	33	1	123	93	203	0	503	5%
AHU SFP	2.2	93	45	36	1	123	93	206	0	508	4%
Lighting Efficacy	65	98	37	36	1	101	98	175	0	453	3%
Lighting Efficacy	60	97	38	36	1	104	97	179	0	460	2%
Lighting Efficacy	55	97	39	36	1	107	97	184	0	469	0%

Table 4.2b (EE1): Energy Demand Output Table

**Building: Office (NV)**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.1	164	0	4	5	72	164	81	0	340	4%
Wall U-Value	0.14	165	0	4	5	72	165	81	0	341	4%
Wall U-Value	0.16	166	0	4	5	72	166	81	0	342	4%
Wall U-Value	0.19	167	0	4	5	72	167	81	0	343	3%
Wall U-Value	0.21	167	0	4	5	72	167	81	0	343	3%
Wall U-Value	0.3	169	0	4	5	72	169	81	0	346	2%
Wall U-Value	0.39	171	0	4	5	72	171	81	0	348	2%
Roof U-value	0.15	159	0	4	5	72	159	81	0	334	2%
Roof U-value	0.2	161	0	4	5	72	161	81	0	336	2%
Roof U-value	0.25	162	0	4	5	72	162	81	0	338	1%
Heating Source	ASHP	35	0	4	5	72	0	81	0	160	52%
Heating Source	Gas CHP	36	0	4	5	72	239	81	70	284	14%
Heating Source	Gas (91%) + SHW	143	0	4	5	72	143	81	0	316	4%
Heating Source	Gas (91%)	143	0	4	5	72	143	81	0	316	4%
Heating Source	Gas (86%)	155	0	4	5	72	155	81	0	330	0%
Floor U-value	0.1	162	0	4	5	72	162	81	0	337	6%
Floor U-value	0.15	164	0	4	5	72	164	81	0	340	5%
Floor U-value	0.2	166	0	4	5	72	166	81	0	342	5%
Floor U-value	0.25	168	0	4	5	72	168	81	0	344	4%
Window U-value	0.9	131	0	4	5	72	131	81	0	303	6%
Window U-value	1.1	139	0	4	5	72	139	81	0	312	3%
Window U-value	1.8	141	0	4	5	72	141	81	0	315	3%
Window U-value	1.4	145	0	4	5	72	145	81	0	319	1%
Lighting Efficacy	65	197	0	4	5	28	197	36	0	288	2%
Lighting Efficacy	60	196	0	4	5	30	196	39	0	292	1%
Lighting Efficacy	55	194	0	4	5	33	194	41	0	295	0%

Table 4.2b (EE2): Energy Demand Output Table

**Building: Office (NV)**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.1	123	0	4	5	60	123	69	0	271	5%
Wall U-Value	0.14	124	0	4	5	60	124	69	0	272	4%
Wall U-Value	0.16	125	0	4	5	60	125	69	0	273	4%
Wall U-Value	0.19	126	0	4	5	60	126	69	0	274	4%
Wall U-Value	0.21	126	0	4	5	60	126	69	0	275	3%
Wall U-Value	0.3	129	0	4	5	60	129	69	0	277	3%
Wall U-Value	0.39	131	0	4	5	60	131	69	0	279	2%
Roof U-value	0.15	129	0	4	5	60	129	69	0	277	3%
Roof U-value	0.2	130	0	4	5	60	130	69	0	279	2%
Roof U-value	0.25	132	0	4	5	60	132	69	0	281	1%
Heating Source	ASHP	30	0	4	5	60	0	69	0	136	52%
Heating Source	Gas CHP	30	0	4	5	60	204	69	60	242	14%
Heating Source	Gas (91%) + SHW	122	0	4	5	60	122	69	0	270	4%
Heating Source	Gas (91%)	122	0	4	5	60	122	69	0	270	4%
Heating Source	Gas (86%)	132	0	4	5	60	132	69	0	281	0%
Floor U-value	0.1	119	0	4	5	60	119	69	0	267	7%
Floor U-value	0.15	122	0	4	5	60	122	69	0	269	6%
Floor U-value	0.2	123	0	4	5	60	123	69	0	271	5%
Floor U-value	0.25	125	0	4	5	60	125	69	0	273	5%
Window U-value	0.9	106	0	4	5	60	106	69	0	252	6%
Window U-value	1.1	112	0	4	5	60	112	69	0	259	4%
Window U-value	1.8	115	0	4	5	60	115	69	0	262	3%
Window U-value	1.4	118	0	4	5	60	118	69	0	266	1%
Lighting Efficacy	65	145	0	4	5	28	145	36	0	231	3%
Lighting Efficacy	60	144	0	4	5	30	144	39	0	235	2%
Lighting Efficacy	55	143	0	4	5	33	143	41	0	239	0%

Table 4.2c (EE1): Energy Demand Output Table

**Building: Office (AC)**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.11	124	51	34	5	45	124	135	0	401	2%
Wall U-Value	0.15 (b)	124	51	34	5	45	124	135	0	402	2%
Wall U-Value	0.15	124	51	34	5	45	124	135	0	402	2%
Wall U-Value	0.2	126	51	34	5	45	126	134	0	403	2%
Wall U-Value	0.21	126	51	34	5	45	126	134	0	403	2%
Wall U-Value	0.27	127	51	34	5	45	127	134	0	404	1%
Wall U-Value	0.36	129	50	34	5	45	129	134	0	406	1%
Wall U-Value	0.47	132	50	34	5	45	132	133	0	408	1%
Roof U-value	0.14	128	50	34	5	45	128	134	0	404	2%
Roof U-value	0.18	129	50	34	5	45	129	134	0	405	1%
Roof U-value	0.29	133	50	34	5	45	133	133	0	409	0%
Heating Source	ASHP	32	50	34	5	45	0	133	0	263	37%
Heating Source	Gas CHP	28	50	34	5	45	190	133	56	362	14%
Heating Source	Gas (91%)	130	50	34	5	45	130	133	0	406	3%
Heating Source	Gas (91%) + SHW	130	50	34	5	45	130	133	0	406	3%
Heating Source	Gas (86%)	141	50	34	5	45	141	133	0	418	0%
Floor U-value	0.1	119	51	34	5	45	119	134	0	395	4%
Floor U-value	0.15	120	51	34	5	45	120	134	0	397	4%
Floor U-value	0.2	122	50	34	5	45	122	134	0	398	4%
Floor U-value	0.25	124	50	34	5	45	124	134	0	400	3%
Window U-value	1.1	123	40	34	5	45	123	123	0	377	7%
Window U-value	1.4	128	38	34	5	45	128	122	0	380	7%
Window U-value	0.9	115	46	34	5	45	115	130	0	383	6%
Window U-value	1.8	125	52	34	5	45	125	136	0	405	1%
Chiller Efficiency	5.5	131	17	34	5	45	131	100	0	342	18%
Chiller Efficiency	4.5	131	21	34	5	45	131	104	0	349	16%
Chiller Efficiency	3.5	131	26	34	5	45	131	110	0	361	14%
AHU SFP	1.8	131	50	25	5	45	131	125	0	391	7%
AHU SFP	2	131	50	28	5	45	131	127	0	395	6%
AHU SFP	2.2	131	50	30	5	45	131	130	0	400	5%
Lighting Efficacy	65	139	42	34	5	28	139	108	0	366	3%
Lighting Efficacy	60	138	43	34	5	30	138	112	0	371	2%
Lighting Efficacy	55	136	44	34	5	33	136	116	0	378	0%

Table 4.2c (EE2): Energy Demand Output Table

**Building: Office (AC)**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.11	71	48	30	5	33	71	115	0	305	3%
Wall U-Value	0.15 (b)	73	47	30	5	33	73	115	0	306	3%
Wall U-Value	0.15	73	47	30	5	33	73	115	0	306	3%
Wall U-Value	0.2	74	47	30	5	33	74	115	0	307	3%
Wall U-Value	0.21	74	47	30	5	33	74	115	0	307	3%
Wall U-Value	0.27	76	47	30	5	33	76	114	0	309	2%
Wall U-Value	0.36	78	46	30	5	33	78	114	0	311	2%
Wall U-Value	0.47	81	46	30	5	33	81	113	0	313	1%
Roof U-value	0.14	74	47	30	5	33	74	114	0	307	2%
Roof U-value	0.18	76	47	30	5	33	76	114	0	308	2%
Roof U-value	0.29	79	46	30	5	33	79	114	0	312	1%
Heating Source	ASHP	21	46	30	5	33	0	114	0	225	31%
Heating Source	Gas CHP	19	46	30	5	33	125	114	37	290	11%
Heating Source	Gas (91%)	86	46	30	5	33	86	114	0	319	2%
Heating Source	Gas (91%) + SHW	86	46	30	5	33	86	114	0	319	2%
Heating Source	Gas (86%)	93	46	30	5	33	93	114	0	327	0%
Floor U-value	0.1	72	47	30	5	33	72	115	0	305	6%
Floor U-value	0.15	74	47	30	5	33	74	114	0	306	6%
Floor U-value	0.2	76	47	30	5	33	76	114	0	308	5%
Floor U-value	0.25	78	46	30	5	33	78	114	0	310	4%
Window U-value	1.1	64	37	30	5	33	64	104	0	276	11%
Window U-value	1.4	71	35	30	5	33	71	102	0	280	10%
Window U-value	0.9	57	44	30	5	33	57	111	0	282	9%
Window U-value	1.8	70	49	30	5	33	70	116	0	307	1%
Chiller Efficiency	5.5	78	16	30	5	33	78	83	0	250	22%
Chiller Efficiency	4.5	78	20	30	5	33	78	87	0	257	20%
Chiller Efficiency	3.5	78	25	30	5	33	78	93	0	268	17%
AHU SFP	1.8	78	46	25	5	33	78	109	0	301	9%
AHU SFP	2	78	46	28	5	33	78	111	0	306	7%
AHU SFP	2.2	78	46	30	5	33	78	114	0	310	6%
Lighting Efficacy	65	80	44	30	5	28	80	107	0	298	4%
Lighting Efficacy	60	79	45	30	5	30	79	110	0	303	2%
Lighting Efficacy	55	78	46	30	5	33	78	114	0	310	0%

Table 4.2d (EE1): Energy Demand Output Table

**Building: School (Primary)**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.1	91	0	2	4	29	95	31	0	162	11%
Wall U-Value	0.14	93	0	2	4	29	97	31	0	164	10%
Wall U-Value	0.16	93	0	2	4	29	98	31	0	164	10%
Wall U-Value	0.19	94	0	2	4	29	99	31	0	166	9%
Wall U-Value	0.21	95	0	2	4	29	100	31	0	166	9%
Wall U-Value	0.3	99	0	2	4	29	103	31	0	170	7%
Wall U-Value	0.39	102	0	2	4	29	106	31	0	174	5%
Roof U-value	0.15	101	0	2	4	29	105	31	0	172	1%
Roof U-value	0.2	101	0	2	4	29	105	31	0	173	1%
Roof U-value	0.25	102	0	2	4	29	106	31	0	173	1%
Heating Source	ASHP	21	0	2	4	29	4	31	0	62	62%
Heating Source	Gas CHP	21	0	2	4	29	146	31	42	140	14%
Heating Source	Gas (91%) + SHW	85	0	2	4	29	89	31	0	155	5%
Heating Source	Gas (91%)	85	0	2	4	29	89	31	0	155	5%
Heating Source	Gas (86%)	92	0	2	4	29	96	31	0	163	0%
Floor U-value	0.1	88	0	2	4	29	92	31	0	158	14%
Floor U-value	0.15	90	0	2	4	29	94	31	0	161	13%
Floor U-value	0.2	92	0	2	4	29	97	31	0	163	11%
Floor U-value	0.25	95	0	2	4	29	99	31	0	166	10%
Window U-value	0.9	73	0	2	4	29	77	31	0	142	9%
Window U-value	1.1	78	0	2	4	29	82	31	0	147	6%
Window U-value	1.8	80	0	2	4	29	85	31	0	150	4%
Window U-value	1.4	82	0	2	4	29	86	31	0	152	3%
Lighting Efficacy	65	113	0	2	4	13	117	15	0	157	2%
Lighting Efficacy	60	112	0	2	4	14	116	16	0	158	1%
Lighting Efficacy	55	111	0	2	4	16	116	18	0	160	0%

Table 4.2d (EE2): Energy Demand Output Table

**Building: School (Primary)**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.1	52	0	2	3	11	55	13	0	84	19%
Wall U-Value	0.14	53	0	2	3	11	56	13	0	86	17%
Wall U-Value	0.16	54	0	2	3	11	57	13	0	87	16%
Wall U-Value	0.19	55	0	2	3	11	58	13	0	88	15%
Wall U-Value	0.21	56	0	2	3	11	59	13	0	89	14%
Wall U-Value	0.3	59	0	2	3	11	62	13	0	92	11%
Wall U-Value	0.39	62	0	2	3	11	65	13	0	96	8%
Roof U-value	0.15	60	0	2	3	11	63	13	0	93	2%
Roof U-value	0.2	60	0	2	3	11	64	13	0	94	1%
Roof U-value	0.25	61	0	2	3	11	64	13	0	94	1%
Heating Source	ASHP	14	0	2	3	11	3	13	0	27	72%
Heating Source	Gas CHP	15	0	2	3	11	102	13	29	82	16%
Heating Source	Gas (91%) + SHW	59	0	2	3	11	62	13	0	92	6%
Heating Source	Gas (91%)	59	0	2	3	11	62	13	0	92	6%
Heating Source	Gas (86%)	64	0	2	3	11	67	13	0	97	0%
Floor U-value	0.1	54	0	2	3	11	57	13	0	87	21%
Floor U-value	0.15	56	0	2	3	11	60	13	0	89	19%
Floor U-value	0.2	59	0	2	3	11	62	13	0	92	17%
Floor U-value	0.25	61	0	2	3	11	64	13	0	94	14%
Window U-value	0.9	49	0	2	3	11	52	13	0	81	14%
Window U-value	1.1	53	0	2	3	11	56	13	0	86	9%
Window U-value	1.8	56	0	2	3	11	59	13	0	89	6%
Window U-value	1.4	57	0	2	3	11	60	13	0	90	4%
Lighting Efficacy	65	62	0	2	3	9	65	10	0	91	2%
Lighting Efficacy	60	62	0	2	3	9	65	11	0	92	1%
Lighting Efficacy	55	61	0	2	3	10	64	12	0	93	0%

Table 4.2e (EE1): Energy Demand Output Table

**Building: Hotel**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.1	97	25	43	69	172	269	137	0	566	3%
Wall U-Value	0.14	98	25	43	69	172	271	137	0	568	3%
Wall U-Value	0.16	99	25	43	69	172	271	137	0	568	3%
Wall U-Value	0.19	100	25	43	69	172	272	137	0	569	2%
Wall U-Value	0.21	101	25	43	69	172	273	137	0	570	2%
Wall U-Value	0.3	105	24	43	69	172	277	136	0	573	2%
Wall U-Value	0.39	108	24	43	69	172	280	136	0	576	1%
Roof U-value	0.15	108	24	43	69	172	280	136	0	576	1%
Roof U-value	0.2	109	24	43	69	172	281	136	0	577	1%
Roof U-value	0.25	110	24	43	69	172	282	136	0	578	0%
Heating Source	ASHP	27	24	43	69	172	172	136	0	457	22%
Heating Source	Gas CHP	24	24	43	69	172	335	136	48	542	8%
Heating Source	Gas (91%) + SHW	109	24	43	69	160	268	136	0	563	4%
Heating Source	Gas (91%)	109	24	43	69	172	281	136	0	576	2%
Heating Source	Gas (86%)	118	24	43	69	172	290	136	0	586	0%
Floor U-value	0.1	102	24	43	69	172	274	136	0	570	2%
Floor U-value	0.15	103	24	43	69	172	275	136	0	571	2%
Floor U-value	0.2	104	24	43	69	172	276	136	0	572	2%
Floor U-value	0.25	105	24	43	69	172	278	136	0	573	1%
Window U-value	1.1	87	21	43	69	172	259	133	0	547	4%
Window U-value	0.9	79	26	43	69	172	251	138	0	548	3%
Window U-value	1.4	92	20	43	69	172	264	132	0	550	3%
Window U-value	1.8	87	29	43	69	172	260	141	0	563	1%
Chiller Efficiency	5.5	110	7	43	69	172	282	119	0	546	6%
Chiller Efficiency	4.5	110	9	43	69	172	282	121	0	549	5%
Chiller Efficiency	3.5	110	11	43	69	172	282	123	0	554	4%
AHU SFP	1.8	110	24	33	69	172	282	125	0	558	6%
AHU SFP	2	110	24	35	69	172	282	128	0	564	5%
AHU SFP	2.2	110	24	38	69	172	282	131	0	569	4%
Lighting Efficacy	65	145	12	43	16	172	317	71	0	489	1%
Lighting Efficacy	60	144	12	43	17	172	316	73	0	491	0%
Lighting Efficacy	55	143	13	43	19	172	315	74	0	493	0%

Table 4.2e (EE2): Energy Demand Output Table

**Building: Hotel**

Measure	Value	Energy Use					Fuel Use			Primary Energy	
		Heat	Cool	Aux	DHW	Light	Gas	Grid Elec.	Gen. Elec.	Total	Reduction
		kWh/m <sup>2</sup>					kWh/m <sup>2</sup>			kWh/m <sup>2</sup>	%
Wall U-Value	0.1	105	15	38	148	30	253	83	0	442	4%
Wall U-Value	0.14	107	15	38	148	30	254	83	0	444	4%
Wall U-Value	0.16	107	15	38	148	30	255	83	0	445	4%
Wall U-Value	0.19	109	15	38	148	30	256	83	0	446	3%
Wall U-Value	0.21	109	15	38	148	30	257	83	0	446	3%
Wall U-Value	0.3	113	15	38	148	30	260	83	0	450	2%
Wall U-Value	0.39	116	14	38	148	30	264	83	0	453	2%
Roof U-value	0.15	117	14	38	148	30	264	82	0	453	1%
Roof U-value	0.2	118	14	38	148	30	265	82	0	454	1%
Roof U-value	0.25	119	14	38	148	30	266	82	0	455	1%
Heating Source	ASHP	30	14	38	148	30	148	82	0	325	31%
Heating Source	Gas CHP	27	14	38	148	30	330	82	54	420	11%
Heating Source	Gas (91%) + SHW	121	14	38	137	30	258	82	0	446	5%
Heating Source	Gas (91%)	121	14	38	148	30	269	82	0	458	2%
Heating Source	Gas (86%)	131	14	38	148	30	279	82	0	469	0%
Floor U-value	0.1	110	14	38	148	30	258	83	0	446	3%
Floor U-value	0.15	111	14	38	148	30	259	83	0	448	3%
Floor U-value	0.2	113	14	38	148	30	260	82	0	449	2%
Floor U-value	0.25	114	14	38	148	30	261	82	0	450	2%
Window U-value	0.9	98	13	38	148	30	246	81	0	431	4%
Window U-value	1.1	107	10	38	148	30	254	78	0	434	4%
Window U-value	1.4	113	9	38	148	30	260	77	0	439	3%
Window U-value	1.8	106	16	38	148	30	253	84	0	445	1%
Chiller Efficiency	5.5	119	5	38	148	30	266	73	0	437	5%
Chiller Efficiency	4.5	119	6	38	148	30	266	74	0	439	4%
Chiller Efficiency	3.5	119	8	38	148	30	266	76	0	442	4%
AHU SFP	1.8	119	14	33	148	30	266	77	0	444	7%
AHU SFP	2	119	14	35	148	30	266	79	0	450	6%
AHU SFP	2.2	119	14	38	148	30	266	82	0	455	5%
Lighting Efficacy	65	128	12	38	148	16	276	67	0	434	1%
Lighting Efficacy	60	127	12	38	148	17	275	68	0	436	1%
Lighting Efficacy	55	126	13	38	148	19	274	70	0	439	0%

## 5. Global Cost Calculation

### 5.1 New Buildings

In undertaking this work, we have assumed various underpinning costs.

- The costs for the various measures that we have considered in this work are shown in Tables 5.1a – 5.1c. The costs for each measure include both labour and technologies. Furthermore, for the purpose of this work, we have assumed no learning rates to be applied when any measures are replaced. In practice, some of the newer technologies will reduce in cost over time. However, given that the calculation period being considered is similar to the lifetime of the technologies, replacements are limited and any benefits from learning are uncertain and will be significantly discounted in calculated NPV costs. Finally, we have assumed that the maintenance costs for most of the building services (e.g. lighting) are the same between the three building services packages and have thus not been included in the analysis.
- We have assumed a central discount rate for the macroeconomics calculation of 4% (as used by Ireland for Government policy Impact Assessments) with sensitivities of 3% as required by the Commission and an additional sensitivity at 6%.
- We have assumed a central real discount rate for the financial calculation of 7%, with an additional sensitivity at 13%.
- For the purposes of this work, we have assumed a central energy costs as shown in Table 5.2a as well as low and high energy costs to allow for a sensitivity of +/- 30% for gas and +/- 20% electricity (as gas is the most significant primary energy source for electricity, we have assumed that the low scenario includes both the low gas and electricity prices and the high scenario includes both the high gas and electricity prices). The central energy costs have been taken from Energy Trends 2009 document referenced in Annex 2 of the Cost Optimal Regulations. The sensitivities have been derived based on a review of the approach taken for energy price sensitivity analysis within Impact Assessments in England and based on the preliminary data contained in the draft 2012 scenario.
- Whilst not explicitly a cost, in the analysis we have also undertaken a sensitivity analysis on the primary emission factors based on a different set of assumptions on the future source of electricity power generation. These sensitivities are primary emission factors of 2.15 and 2.11 over 20 year and 30 year calculation period respectively.
- The assumed cost of greenhouse gas emissions for the macroeconomic calculations is shown in Table 5.2b. These have been taken from the projected emissions trading system (ETS) carbon prices defined in the Commission reference scenario up to 2050. This scenario assumes the implementation of existing legislation, but takes no account of further decarbonisation. Again, this data is referred to in Annex 2 of the Cost Optimal Regulations. We have also included set of data for sensitivity analysis in Table 5.2c based on Irish data.

The following Tables summarise the results of the cost calculations for the most cost-optimal packages in each of the five reference buildings. Tables 5.3 relate to the macroeconomic calculations and Tables 5.4 relate to the financial calculations.

- Tables 5.3a/5.4a: Central energy price, central discount factors
- Tables 5.3b/5.4b: Low energy price, central discount factors
- Tables 5.3c/5.4c: High energy price, central discount factors

- Tables 5.3d/5.4d: Central energy price, low discount factors for macro-economic and high discount factor for financial.
- Table 5.3e: Central energy price, high discount factor (macro-economic calculation only)
- Table 5.3f: Central energy price, central discount factors, alternative primary emission factors (macro-economic calculation only)
- Table 5.3g: Central energy price, central discount factors, alternative carbon price (macro-economic calculation only)

The sensitivity analysis shows the following.

- Discount rate: Increasing the discount rate had the tendency to make solutions with higher primary energy demand relatively more attractive. This is presumably due to the cost of energy consumption over the calculation period becoming cheaper in terms of net present value. For the macro-economic calculations, going from the low to high discount rates, as much as doubled the cost optimal primary energy.
- Energy price: There is a tendency for the solutions with higher primary energy to become relatively less attractive as energy prices increase. For the macro-economic calculations, going from the low to high energy prices, reduced the cost optimum primary energy by up to 20%. This is due to the preference for lower net energy consumption as energy prices increase.
- Primary emission factor (PEF): The higher PEFs in the sensitivity case simply increased the cost optimum primary energy in most cases. For the air conditioned office building, it changed the optimum technology to one of a less energy efficient servicing strategy.
- Price of carbon: The sensitivity case for the price of carbon was approximately 25% less than the central case. The impact on the overall macroeconomic costs was very small and, in the main, did not impact on the cost optimal level. The exception was an increase in cost optimum primary energy of 25% for the air conditioned office.

When comparing the results from the central macro-economic and financial calculations, there is a tendency for solutions with higher primary energy to be more attractive and for lower primary energy to be less attractive in the financial case. This is partly explained by the higher discount rates used for the financial calculations which effectively make energy consumption cheaper in a net present value calculation.

Table 5.1a: Elemental Capital Costs per m<sup>2</sup> of Fabric (EUR/m<sup>2</sup>)

Construction	Value (W/m <sup>2</sup> K)	Cost (EUR/m <sup>2</sup> )
Roof: Tiled Pitched	0.25	26
	0.2	31
	0.15	34
	0.1	45
Roof: Profiled Metal	0.25	3
	0.2	4
	0.15	5
	0.1	8
Roof: Flat	0.25	15
	0.2	19
	0.15	25
	0.1	37
Wall: Masonry Cavity	0.3	6
	0.25	8
	0.21	12
	0.15	20
Wall: Lightweight Metal Frame (LMF)	0.3	11
	0.25	12
	0.21	14
	0.15	18
Floor: Solid	0.25	12
	0.2	14
	0.15	19
	0.1	26
Window: Timber Frame	1.8	300
	1.4	385
	0.9	530
Window: uPVC	1.8	265
	1.4	310
	0.9	427

Table 5.1b: Elemental Capital Costs per Building (EUR)

Building Type	Air Permeability (m <sup>3</sup> /m <sup>2</sup> .hr)			Thermal Bridging	
	7	5	3	Standard	Improved
Retail (AC)	0	0	10,500	0	3,100
Office (NV)	0	0	10,500	0	3,100
Office (AC)	0	0	11,400	0	3,100
School (Primary)	0	0	14,100	0	3,700
Hotel (AC)	0	0	11,400	0	3,100

Building Type	Chiller SEER			AHU SFP			PHX (65%)			FCU SFP		DCV
	3.5	4.5	5.5	2.2	2.0	1.8	2.2	2.0	1.8	0.6	0.3	
Retail (AC)	30,996	33,321	37,970	20,295	21,310	23,339	23,339	24,506	26,840	31,926	38,311	0
Office (NV)	0	0	0	0	0	0	0	0	0	0	0	0
Office (AC)	31,673	34,048	38,799	15,191	15,950	17,469	17,469	18,343	20,089	38,007	45,608	6,550
School (Primary)	0	0	0	0	0	0	0	0	0	0	0	0
Hotel (AC)	63,345	68,096	77,598	22,817	23,957	26,239	26,239	27,551	30,175	76,774	92,129	0

Building Type	Gas Boiler	GSHP	ASHP	Gas CHP
Retail (AC)	13,948	66,728	39,305	151,235
Office (NV)	13,948	66,728	39,305	151,235
Office (AC)	25,584	173,430	97,908	203,688
School (Primary)	57,810	428,963	240,158	384,683
Hotel (AC)	18,819	129,796	73,154	183,854

Building Type	SHW	PV				
	10%	0%	10%	20%	30%	40%
Retail (AC)	115,620	0	32,134	64,268	96,401	110,173
Office (NV)	70,387	0	19,280	38,561	57,841	77,121
Office (AC)	70,387	0	19,280	38,561	57,841	77,121
School (Primary)	129,494	0	35,990	71,980	92,545	123,394
Hotel (AC)	69,913	0	18,638	37,275	55,913	74,550

Table 5.1c: Elemental Maintenance Costs per Building per Year (EUR)

Building Type	DCV
Retail (AC)	0
Office (NV)	0
Office (AC)	400
School (Primary)	0
Hotel (AC)	0

Building Type	Gas Boiler	GSHP	ASHP	Gas CHP
Retail (AC)	738	738	747	4,705
Office (NV)	738	738	747	4,705
Office (AC)	2,460	2,460	2,491	10,978
School (Primary)	6,150	6,150	6,227	18,494
Hotel (AC)	1,845	1,845	1,868	9,133

Building Type	SHW	PV				
	10%	0%	10%	20%	30%	40%
Retail (AC)	191	0	154	246	277	369
Office (NV)	160	0	123	185	215	277
Office (AC)	160	0	123	185	215	277
School (Primary)	191	0	154	246	308	369
Hotel (AC)	129	0	92	154	215	246

Table 5.2a: Energy Costs

			2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Low</b>	<b>Electricity</b>	<i>c/kWh</i>	12.5	12.8	13.1	13.4	13.6	13.8	14.1	14.3	14.5	14.6
<b>Low</b>	<b>Gas</b>	<i>c/kWh</i>	4.9	5.1	5.3	5.6	5.8	6.0	6.3	6.5	6.7	6.8
<b>Central</b>	<b>Electricity</b>	<i>c/kWh</i>	15.7	16.0	16.4	16.7	17.0	17.3	17.6	17.9	18.1	18.3
<b>Central</b>	<b>Gas</b>	<i>c/kWh</i>	7.0	7.3	7.6	8.0	8.3	8.6	9.0	9.3	9.5	9.7
<b>High</b>	<b>Electricity</b>	<i>c/kWh</i>	18.8	19.2	19.7	20.0	20.4	20.8	21.1	21.5	21.7	21.9
<b>High</b>	<b>Gas</b>	<i>c/kWh</i>	9.1	9.5	9.9	10.4	10.8	11.2	11.6	12.1	12.4	12.6

			2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
<b>Low</b>	<b>Electricity</b>	<i>c/kWh</i>	14.7	14.9	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
<b>Low</b>	<b>Gas</b>	<i>c/kWh</i>	7.0	7.1	7.3	7.4	7.6	7.8	7.9	8.1	8.3	8.5
<b>Central</b>	<b>Electricity</b>	<i>c/kWh</i>	18.4	18.6	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
<b>Central</b>	<b>Gas</b>	<i>c/kWh</i>	10.0	10.2	10.4	10.6	10.9	11.1	11.3	11.5	11.8	12.2
<b>High</b>	<b>Electricity</b>	<i>c/kWh</i>	22.1	22.3	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
<b>High</b>	<b>Gas</b>	<i>c/kWh</i>	12.9	13.2	13.5	13.8	14.1	14.4	14.7	15.0	15.4	15.8

			2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
<b>Low</b>	<b>Electricity</b>	<i>c/kWh</i>	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
<b>Low</b>	<b>Gas</b>	<i>c/kWh</i>	8.8	9.0	9.3	9.5	9.8	10.1	10.3	10.6	10.9	11.2
<b>Central</b>	<b>Electricity</b>	<i>c/kWh</i>	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
<b>Central</b>	<b>Gas</b>	<i>c/kWh</i>	12.5	12.9	13.2	13.6	14.0	14.4	14.8	15.2	15.6	16.1
<b>High</b>	<b>Electricity</b>	<i>c/kWh</i>	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
<b>High</b>	<b>Gas</b>	<i>c/kWh</i>	16.3	16.7	17.2	17.7	18.2	18.7	19.2	19.7	20.3	20.9

Table 5.2b: Cost of Carbon

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Reference (frag. action, ref. fossil f. prices)</b>	<i>EUR/TCO<sub>2</sub></i>	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	21.9	21.9

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
<b>Reference (frag. action, ref. fossil f. prices)</b>	<i>EUR/TCO<sub>2</sub></i>	21.9	21.9	21.9	39.4	39.4	39.4	39.4	39.4	54.7	54.7

		2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
<b>Reference (frag. action, ref. fossil f. prices)</b>	<i>EUR/TCO<sub>2</sub></i>	54.7	54.7	54.7	56.9	56.9	56.9	56.9	56.9	55.8	55.8

Table 5.2c: Cost of Carbon Sensitivity

<b>Ireland Reference Scenario</b>	<i>EUR/TCO<sub>2</sub></i>	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
		12.0	12.0	8.6	8.6	8.6	8.6	8.6	10.7	10.7	10.7
<b>Ireland Reference Scenario</b>	<i>EUR/TCO<sub>2</sub></i>	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
		10.7	10.7	15.0	15.0	15.0	15.0	15.0	34.3	34.3	34.3
<b>Ireland Reference Scenario</b>	<i>EUR/TCO<sub>2</sub></i>	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
		34.3	34.3	53.6	53.6	53.6	53.6	53.6	73.0	73.0	73.0

Table 5.3a: Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	318	17	408	20	-25	738
	A	GSHP	3	40%	-	232	288	17	417	20	-17	725
	C	Gas(86%)	3	40%	-	239*	257	17	428	21	-25	697
	B	Gas(86%)	3	40%	-	248	236	17	444	22	-20	699
	B	Gas(86%)	3	20%	-	293	199	16	499	26	-16	724
	C	Gas(86%)	3	10%	-	306	194	15	511	27	-19	727
	B	Gas(86%)	3	0%	-	338	148	13	554	30	-11	734
	A	Gas(86%)	3	0%	-	349	138	13	573	31	-8	747
	B	Gas(86%)	2	0%	-	378	136	13	621	34	-11	793
A	Gas(86%)	1	0%	-	420	116	13	690	37	-8	848	
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	281	9	76	3	-34	335
	B	GSHP	3	40%	-	45	241	9	93	4	-25	321
	A	GSHP	3	40%	-	52*	222	9	105	5	-21	319
	A	GSHP	3	30%	-	64	209	8	119	6	-20	323
	A	GSHP	3	10%	-	88	183	8	148	8	-17	329
	A	GSHP	3	0%	-	99	171	6	162	9	-16	332
	A	GSHP	1	10%	-	106	160	8	178	9	-17	337
	A	GSHP	1	0%	-	118	147	6	192	10	-16	339
	A	Gas(86%)	3	0%	-	143	135	6	239	14	-16	378
A	Gas(86%)	1	0%	-	177	111	6	295	17	-16	414	
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	352	12	184	9	-29	528
	B	GSHP	3	40%	OFF	102*	314	12	186	9	-22	500
	B	GSHP	2	30%	OFF	128	277	8	224	11	-20	501
	B	GSHP	2	0%	OFF	164	239	6	267	14	-17	510
	A	GSHP	2	0%	OFF	179	223	6	293	16	-13	525
	B	GSHP	1	0%	ON	212	210	6	346	18	-17	564
	A	GSHP	1	0%	OFF	230	195	6	376	20	-13	583
	A	Gas(86%)	2	0%	OFF	241	188	6	399	23	-13	603
	B	Gas(86%)	1	0%	ON	261	175	6	432	24	-17	621
A	Gas(86%)	1	0%	OFF	287	159	6	476	26	-13	655	
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	270	14	32	-2	-30	285
	C	GSHP	2	40%	-	-16	254	14	34	-1	-29	272
	A	GSHP	2	40%	-	-6	219	14	50	-1	-26	258
	C	Gas(86%)	2	40%	-	4	189	14	68	1	-21	250
	C	Gas(86%)	2	30%	-	17	176	14	74	2	-19	247
	C	Gas(86%)	2	10%	-	42	152	13	87	4	-15	242
	C	Gas(86%)	2	0%	-	55*	137	12	94	5	-12	237

	B	Gas(86%)	2	0%	-	71	115	12	122	7	-10	246
	B	Gas(86%)	1	0%	-	80	100	12	138	8	-9	249
	A	Gas(86%)	1	0%	-	91	88	12	156	9	-7	258
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	243	396	12	417	24	-29	819
	B	GSHP+SHW	3	40%	-	246	358	12	423	24	-21	795
	A	GSHP	3	40%	-	266	312	11	455	26	-17	787
	B	GSHP	1	40%	-	284*	277	11	484	27	-21	779
	A	GSHP	1	30%	-	302	252	11	511	29	-16	786
	A	GSHP	1	0%	-	321	229	10	535	31	-14	791
	A	Gas(86%)	3	0%	-	339	238	10	569	33	-14	836
	B	Gas(86%)	1	10%	-	352	210	10	593	35	-19	829
	B	Gas(86%)	1	0%	-	359	203	10	601	35	-18	831
	A	Gas(86%)	1	0%	-	376	185	10	630	37	-14	847

Table 5.3b: Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	318	17	327	20	-25	656
	A	GSHP	3	40%	-	232	288	17	333	20	-17	641
	C	Gas(86%)	3	40%	-	239	257	17	339	21	-25	608
	B	Gas(86%)	3	40%	-	248*	236	17	350	22	-20	605
	B	Gas(86%)	3	20%	-	293	199	16	394	26	-16	619
	C	Gas(86%)	3	10%	-	306	194	15	405	27	-19	622
	B	Gas(86%)	3	0%	-	338	148	13	438	30	-11	618
	A	Gas(86%)	3	0%	-	349	138	13	451	31	-8	625
	B	Gas(86%)	2	0%	-	378	136	13	489	34	-11	660
	A	Gas(86%)	1	0%	-	420	116	13	542	37	-8	700
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	281	9	61	3	-34	320
	B	GSHP	3	40%	-	45	241	9	74	4	-25	303
	A	GSHP	3	40%	-	52*	222	9	84	5	-21	298
	A	GSHP	3	30%	-	64	209	8	95	6	-20	299
	A	GSHP	3	10%	-	88	183	8	118	8	-17	300
	A	GSHP	3	0%	-	99	171	6	130	9	-16	300
	A	GSHP	1	10%	-	106	160	8	142	9	-17	301
	A	GSHP	1	0%	-	118	147	6	154	10	-16	301
	A	Gas(86%)	3	0%	-	143	135	6	179	14	-16	318
	A	Gas(86%)	1	0%	-	177	111	6	220	17	-16	339
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	352	12	147	9	-29	491
	B	GSHP	3	40%	OFF	102	314	12	149	9	-22	463
	B	GSHP	2	30%	OFF	128*	277	8	179	11	-20	456

	B	GSHP	2	0%	OFF	164	239	6	214	14	-17	457
	A	GSHP	2	0%	OFF	179	223	6	234	16	-13	466
	B	GSHP	1	0%	ON	212	210	6	277	18	-17	495
	A	GSHP	1	0%	OFF	230	195	6	301	20	-13	508
	A	Gas(86%)	2	0%	OFF	241	188	6	303	23	-13	507
	B	Gas(86%)	1	0%	ON	261	175	6	332	24	-17	521
	A	Gas(86%)	1	0%	OFF	287	159	6	365	26	-13	544
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	270	14	25	-2	-30	278
	C	GSHP	2	40%	-	-16	254	14	26	-1	-29	265
	A	GSHP	2	40%	-	-6	219	14	40	-1	-26	247
	C	Gas(86%)	2	40%	-	4	189	14	48	1	-21	230
	C	Gas(86%)	2	30%	-	17	176	14	53	2	-19	226
	C	Gas(86%)	2	10%	-	42	152	13	64	4	-15	219
	C	Gas(86%)	2	0%	-	55*	137	12	69	5	-12	212
	B	Gas(86%)	2	0%	-	71	115	12	89	7	-10	213
	B	Gas(86%)	1	0%	-	80	100	12	102	8	-9	214
Hotel – 20 year calc	A	Gas(86%)	1	0%	-	91	88	12	115	9	-7	217
	C	GSHP+SHW	3	40%	-	243	396	12	309	24	-29	711
	B	GSHP+SHW	3	40%	-	246	358	12	314	24	-21	686
	A	GSHP	3	40%	-	266	312	11	337	26	-17	670
	B	GSHP	1	40%	-	284*	277	11	361	27	-21	655
	A	GSHP	1	30%	-	302	252	11	382	29	-16	658
	A	GSHP	1	0%	-	321	229	10	402	31	-14	657
	A	Gas(86%)	3	0%	-	339	238	10	416	33	-14	683
	B	Gas(86%)	1	10%	-	352	210	10	435	35	-19	671
	B	Gas(86%)	1	0%	-	359	203	10	441	35	-18	671
A	Gas(86%)	1	0%	-	376	185	10	463	37	-14	680	

Table 5.3c: Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	318	17	490	20	-25	819
	B	GSHP	3	40%	-	228	298	17	491	20	-20	806
	C	Gas(86%)	3	40%	-	239*	257	17	517	21	-25	786
	C	Gas(86%)	3	20%	-	284	220	16	583	25	-22	821
	C	Gas(86%)	3	0%	-	329	168	13	649	29	-17	842
	B	Gas(86%)	3	0%	-	338	148	13	671	30	-11	850
	A	Gas(86%)	3	0%	-	349	138	13	695	31	-8	869
	A	Gas(86%)	2	0%	-	390	126	13	781	35	-8	946
	B	Gas(86%)	1	0%	-	408	125	13	811	36	-11	975

	A	Gas(86%)	1	0%	-	420	116	13	838	37	-8	996
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	281	9	91	3	-34	350
	B	GSHP	3	40%	-	45*	241	9	111	4	-25	340
	A	GSHP	3	40%	-	52	222	9	126	5	-21	340
	A	GSHP	3	30%	-	64	209	8	143	6	-20	347
	A	GSHP	3	10%	-	88	183	8	178	8	-17	359
	A	GSHP	3	0%	-	99	171	6	195	9	-16	365
	A	GSHP	1	10%	-	106	160	8	213	9	-17	372
	A	GSHP	1	0%	-	118	147	6	231	10	-16	378
	A	Gas(86%)	3	0%	-	143	135	6	298	14	-16	438
	A	Gas(86%)	1	0%	-	177	111	6	371	17	-16	489
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	352	12	221	9	-29	565
	B	GSHP	3	40%	OFF	102*	314	12	224	9	-22	538
	B	GSHP	2	30%	OFF	128	277	8	269	11	-20	546
	B	GSHP	2	0%	OFF	164	239	6	321	14	-17	564
	A	GSHP	2	0%	OFF	179	223	6	351	16	-13	583
	B	GSHP	1	0%	ON	212	210	6	415	18	-17	633
	A	GSHP	1	0%	OFF	230	195	6	451	20	-13	659
	A	Gas(86%)	2	0%	OFF	241	188	6	496	23	-13	700
	B	Gas(86%)	1	0%	ON	261	175	6	532	24	-17	720
	A	Gas(86%)	1	0%	OFF	287	159	6	586	26	-13	765
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	270	14	39	-2	-30	291
	C	GSHP	2	40%	-	-16	254	14	41	-1	-29	279
	A	GSHP	2	40%	-	-6	219	14	61	-1	-26	268
	C	Gas(86%)	2	40%	-	4	189	14	87	1	-21	269
	C	Gas(86%)	2	30%	-	17	176	14	95	2	-19	268
	C	Gas(86%)	2	10%	-	42	152	13	111	4	-15	266
	C	Gas(86%)	2	0%	-	55*	137	12	119	5	-12	262
	B	Gas(86%)	2	0%	-	71	115	12	155	7	-10	279
	B	Gas(86%)	1	0%	-	80	100	12	174	8	-9	285
	A	Gas(86%)	1	0%	-	91	88	12	197	9	-7	299
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	243	396	12	525	24	-29	927
	B	GSHP+SHW	3	40%	-	246	358	12	532	24	-21	905
	A	GSHP	3	40%	-	266	312	11	572	26	-17	904
	B	GSHP	1	40%	-	284*	277	11	608	27	-21	902
	A	GSHP	1	30%	-	302	252	11	639	29	-16	915
	A	GSHP	1	0%	-	321	229	10	668	31	-14	924
	A	Gas(86%)	3	0%	-	339	238	10	722	33	-14	989
	B	Gas(86%)	1	10%	-	352	210	10	751	35	-19	987
	B	Gas(86%)	1	0%	-	359	203	10	761	35	-18	990
	A	Gas(86%)	1	0%	-	376	185	10	797	37	-14	1015

Table 5.3d: Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	318	18	460	22	-30	789
	B	GSHP	3	40%	-	228	298	18	461	22	-24	776
	C	Gas(86%)	3	40%	-	239*	257	18	483	24	-30	751
	C	Gas(86%)	3	30%	-	261	245	17	514	26	-29	774
	C	Gas(86%)	3	0%	-	329	168	14	607	33	-20	802
	B	Gas(86%)	3	0%	-	338	148	14	626	34	-13	808
	A	Gas(86%)	3	0%	-	349	138	14	647	35	-10	825
	B	Gas(86%)	2	0%	-	378	136	14	701	38	-13	877
	A	Gas(86%)	2	0%	-	390	126	14	725	40	-10	895
	A	Gas(86%)	1	0%	-	420	116	14	779	43	-10	942
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	281	10	86	3	-41	339
	B	GSHP	3	40%	-	45*	241	10	104	4	-31	329
	A	GSHP	3	40%	-	52	222	10	118	5	-25	330
	A	GSHP	3	30%	-	64	209	9	134	6	-24	335
	A	GSHP	3	10%	-	88	183	8	167	9	-21	346
	A	GSHP	3	0%	-	99	171	7	183	10	-19	351
	A	GSHP	1	10%	-	106	160	8	200	10	-21	358
	A	GSHP	1	0%	-	118	147	7	217	12	-19	362
	A	Gas(86%)	3	0%	-	143	135	7	271	16	-19	410
	A	Gas(86%)	1	0%	-	177	111	7	336	20	-19	454
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	352	14	208	10	-35	547
	B	GSHP	3	40%	OFF	102*	314	14	210	10	-26	522
	B	GSHP	2	30%	OFF	128	277	9	253	13	-24	527
	B	GSHP	2	0%	OFF	164	239	7	301	16	-20	543
	A	GSHP	2	0%	OFF	179	223	7	330	18	-16	562
	B	GSHP	1	0%	ON	212	210	7	390	21	-20	608
	A	GSHP	1	0%	OFF	230	195	7	424	23	-16	632
	A	Gas(86%)	2	0%	OFF	241	188	7	453	26	-16	658
	B	Gas(86%)	1	0%	ON	261	175	7	489	28	-20	679
	A	Gas(86%)	1	0%	OFF	287	159	7	539	30	-16	719
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	283	16	36	-2	-40	293
	C	GSHP	2	40%	-	-16	266	16	38	-2	-38	280
	A	GSHP	2	40%	-	-6	231	16	57	-1	-34	269
	C	Gas(86%)	2	40%	-	4	196	16	77	1	-28	262
	C	Gas(86%)	2	30%	-	17	182	16	85	2	-25	260
	C	Gas(86%)	2	10%	-	42	157	15	99	5	-19	257
	C	Gas(86%)	2	0%	-	55*	141	14	107	6	-16	252

	B	Gas(86%)	2	0%	-	71	118	14	139	8	-13	266
	B	Gas(86%)	1	0%	-	80	102	14	157	9	-11	271
	A	Gas(86%)	1	0%	-	91	90	14	178	11	-10	283
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	243	396	13	474	27	-35	875
	B	GSHP+SHW	3	40%	-	246	358	13	481	28	-25	854
	A	GSHP	3	40%	-	266	312	12	517	30	-20	851
	B	GSHP	1	40%	-	284*	277	12	550	32	-25	846
	A	GSHP	1	30%	-	302	252	12	580	33	-19	858
	A	GSHP	1	0%	-	321	229	11	607	35	-17	866
	A	Gas(86%)	3	0%	-	339	238	11	648	39	-17	919
	B	Gas(86%)	1	10%	-	352	210	11	675	40	-23	914
	B	Gas(86%)	1	0%	-	359	203	11	684	41	-22	916
	A	Gas(86%)	1	0%	-	376	185	11	717	43	-17	938

Table 5.3e: Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (kWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	318	14	329	16	-18	659
	B	GSHP	3	40%	-	228	298	14	329	16	-14	643
	C	Gas(86%)	3	40%	-	239	257	14	344	16	-18	613
	B	Gas(86%)	3	40%	-	248*	236	14	356	17	-14	610
	C	Gas(86%)	3	0%	-	329	168	11	433	23	-12	623
	B	Gas(86%)	3	0%	-	338	148	11	445	23	-8	620
	A	Gas(86%)	3	0%	-	349	138	11	460	24	-6	628
	A	Gas(86%)	2	0%	-	390	126	11	515	27	-6	673
	B	Gas(86%)	1	0%	-	408	125	11	537	28	-8	694
	A	Gas(86%)	1	0%	-	420	116	11	553	29	-6	703
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	281	8	61	2	-24	328
	B	GSHP	3	40%	-	45	241	8	75	3	-18	309
	A	GSHP	3	40%	-	52	222	8	84	4	-15	303
	A	GSHP	3	30%	-	64	209	7	96	4	-14	303
	A	GSHP	3	10%	-	88	183	6	119	6	-12	303
	A	GSHP	3	0%	-	99*	171	5	131	7	-11	302
	A	GSHP	1	10%	-	106	160	6	143	7	-12	304
	A	GSHP	1	0%	-	118	147	5	155	8	-11	304
	A	Gas(86%)	3	0%	-	143	135	5	189	10	-11	330
	A	Gas(86%)	1	0%	-	177	111	5	234	13	-11	353
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	352	11	148	7	-20	497
	B	GSHP	3	40%	OFF	102	314	11	150	7	-15	467
	B	GSHP	2	30%	OFF	128	277	7	181	9	-14	460

	B	GSHP	2	0%	OFF	164*	239	5	215	11	-12	459
	A	GSHP	2	0%	OFF	179	223	5	236	12	-9	467
	B	GSHP	1	0%	ON	212	210	5	279	14	-12	497
	A	GSHP	1	0%	OFF	230	195	5	303	16	-9	509
	A	Gas(86%)	2	0%	OFF	241	188	5	318	17	-9	519
	B	Gas(86%)	1	0%	ON	261	175	5	345	19	-12	532
	A	Gas(86%)	1	0%	OFF	287	159	5	379	21	-9	555
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	252	11	25	-1	-17	270
	C	GSHP	2	40%	-	-16	237	11	27	-1	-16	258
	A	GSHP	2	40%	-	-6	202	11	40	0	-15	239
	C	Gas(86%)	2	40%	-	4	178	11	53	1	-12	231
	C	Gas(86%)	2	30%	-	17	166	11	58	1	-11	226
	C	Gas(86%)	2	10%	-	42	145	11	69	3	-8	220
	C	Gas(86%)	2	0%	-	55*	132	10	74	4	-7	213
	B	Gas(86%)	2	0%	-	71	109	10	96	5	-6	215
	B	Gas(86%)	1	0%	-	80	96	10	109	6	-5	216
Hotel – 20 year calc	A	Gas(86%)	1	0%	-	91	84	10	123	7	-4	220
	C	GSHP+SHW	3	40%	-	243	396	10	330	18	-20	734
	B	GSHP+SHW	3	40%	-	246	358	10	335	18	-15	707
	A	GSHP	3	40%	-	266	312	9	360	20	-12	690
	B	GSHP	1	40%	-	284	277	9	384	21	-15	677
	A	GSHP	1	30%	-	302	252	9	405	22	-11	677
	A	GSHP	1	0%	-	321*	229	8	425	24	-10	676
	A	Gas(86%)	3	0%	-	339	238	8	449	26	-10	711
	B	Gas(86%)	1	10%	-	352	210	9	468	26	-13	701
	B	Gas(86%)	1	0%	-	359	203	8	475	27	-13	700
A	Gas(86%)	1	0%	-	376	185	8	498	28	-10	709	

Table 5.3f: Macroeconomic Costs (Central energy price, 4% discount rate, Alternative PEF, EUR/m<sup>2</sup>)

Building	Package					PE (kWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	248	318	17	408	23	-25	741
	A	GSHP	3	40%	-	254	288	17	417	23	-17	728
	C	Gas(86%)	3	40%	-	259*	257	17	428	24	-25	700
	B	Gas(86%)	3	40%	-	268	236	17	444	25	-20	702
	B	Gas(86%)	3	20%	-	317	199	16	499	30	-16	728
	C	Gas(86%)	3	10%	-	332	194	15	511	31	-19	731
	B	Gas(86%)	3	0%	-	366	148	13	554	34	-11	738
	A	Gas(86%)	3	0%	-	377	138	13	573	35	-8	752
	B	Gas(86%)	2	0%	-	408	136	13	621	38	-11	797

	A	Gas(86%)	1	0%	-	453	116	13	690	43	-8	853
Office (NV) – 20 year calc	C	GSHP	3	40%	-	38	281	9	76	4	-34	335
	B	GSHP	3	40%	-	49	241	9	93	5	-25	322
	A	GSHP	3	40%	-	57*	222	9	105	5	-21	320
	A	GSHP	3	30%	-	70	209	8	119	6	-20	324
	A	GSHP	3	20%	-	83	196	8	134	8	-19	327
	A	GSHP	3	0%	-	108	171	6	162	10	-16	333
	A	GSHP	1	0%	-	128	147	6	192	12	-16	341
	A	Gas(86%)	3	0%	-	150	135	6	239	15	-16	379
	B	Gas(86%)	1	0%	-	170	131	6	272	17	-21	405
	A	Gas(86%)	1	0%	-	184	111	6	295	18	-16	415
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	110	352	12	184	10	-29	529
	B	GSHP	3	40%	OFF	112	314	12	186	10	-22	502
	B	GSHP	2	40%	OFF	127*	290	9	210	12	-22	499
	B	GSHP	2	10%	OFF	166	252	8	253	15	-18	510
	A	GSHP	2	0%	OFF	195	223	6	293	18	-13	527
	B	GSHP	1	0%	ON	231	210	6	346	21	-17	567
	A	GSHP	1	0%	OFF	251	195	6	376	23	-13	587
	A	Gas(86%)	2	0%	OFF	253	188	6	399	25	-13	605
	B	Gas(86%)	1	0%	ON	278	175	6	432	27	-17	623
	A	Gas(86%)	1	0%	OFF	305	159	6	476	29	-13	657
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-20	270	14	32	-2	-30	284
	C	GSHP	2	40%	-	-18	254	14	34	-2	-29	272
	A	GSHP	2	40%	-	-7	219	14	50	-1	-26	257
	C	Gas(86%)	2	40%	-	0	189	14	68	0	-21	249
	C	Gas(86%)	2	30%	-	15	176	14	74	2	-19	247
	C	Gas(86%)	2	10%	-	43	152	13	87	4	-15	242
	C	Gas(86%)	2	0%	-	58*	137	12	94	6	-12	237
	B	Gas(86%)	2	0%	-	74	115	12	122	7	-10	246
	A	Gas(86%)	2	0%	-	85	103	12	140	9	-9	254
	A	Gas(86%)	1	0%	-	96	88	12	156	10	-7	258
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	252	396	12	417	25	-29	820
	B	GSHP+SHW	3	40%	-	256	358	12	423	25	-21	797
	A	GSHP	3	40%	-	276	312	11	455	27	-17	789
	B	GSHP	1	40%	-	295*	277	11	484	29	-21	781
	A	GSHP	1	30%	-	315	252	11	511	31	-16	788
	B	GSHP	1	0%	-	324	247	10	517	32	-18	787
	A	GSHP	1	0%	-	336	229	10	535	33	-14	793
	A	Gas(86%)	3	0%	-	349	238	10	569	35	-14	838
	B	Gas(86%)	1	0%	-	370	203	10	601	37	-18	832
	A	Gas(86%)	1	0%	-	388	185	10	630	39	-14	849

Table 5.3g: Macroeconomic Costs (Central energy price, 4% discount rate, Alternative Cost of Carbon, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	318	17	408	13	-25	731
	A	GSHP	3	40%	-	232	288	17	417	13	-17	718
	C	Gas(86%)	3	40%	-	239*	257	17	428	14	-25	690
	B	Gas(86%)	3	40%	-	248	236	17	444	15	-20	692
	B	Gas(86%)	3	20%	-	293	199	16	499	17	-16	715
	C	Gas(86%)	3	10%	-	306	194	15	511	18	-19	718
	B	Gas(86%)	3	0%	-	338	148	13	554	20	-11	724
	A	Gas(86%)	3	0%	-	349	138	13	573	21	-8	737
	B	Gas(86%)	2	0%	-	378	136	13	621	22	-11	781
A	Gas(86%)	1	0%	-	420	116	13	690	25	-8	835	
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	281	9	76	2	-34	334
	B	GSHP	3	40%	-	45	241	9	93	3	-25	320
	A	GSHP	3	40%	-	52*	222	9	105	3	-21	318
	A	GSHP	3	30%	-	64	209	8	119	4	-20	321
	A	GSHP	3	10%	-	88	183	8	148	5	-17	327
	A	GSHP	3	0%	-	99	171	6	162	6	-16	329
	A	GSHP	1	10%	-	106	160	8	178	6	-17	334
	A	GSHP	1	0%	-	118	147	6	192	7	-16	336
	A	Gas(86%)	3	0%	-	143	135	6	239	9	-16	374
A	Gas(86%)	1	0%	-	177	111	6	295	12	-16	409	
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	352	12	184	6	-29	525
	B	GSHP	3	40%	OFF	102	314	12	186	6	-22	497
	B	GSHP	2	30%	OFF	128*	277	8	224	7	-20	497
	B	GSHP	2	0%	OFF	164	239	6	267	9	-17	505
	A	GSHP	2	0%	OFF	179	223	6	293	10	-13	519
	B	GSHP	1	0%	ON	212	210	6	346	12	-17	558
	A	GSHP	1	0%	OFF	230	195	6	376	13	-13	577
	A	Gas(86%)	2	0%	OFF	241	188	6	399	15	-13	596
	B	Gas(86%)	1	0%	ON	261	175	6	432	16	-17	613
A	Gas(86%)	1	0%	OFF	287	159	6	476	18	-13	646	
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	270	14	32	-1	-30	285
	C	GSHP	2	40%	-	-16	254	14	34	-1	-29	272
	A	GSHP	2	40%	-	-6	219	14	50	0	-26	258
	C	Gas(86%)	2	40%	-	4	189	14	68	1	-21	250
	C	Gas(86%)	2	30%	-	17	176	14	74	1	-19	246
	C	Gas(86%)	2	10%	-	42	152	13	87	3	-15	241
	C	Gas(86%)	2	0%	-	55*	137	12	94	4	-12	235

	B	Gas(86%)	2	0%	-	71	115	12	122	5	-10	243
	B	Gas(86%)	1	0%	-	80	100	12	138	5	-9	247
	A	Gas(86%)	1	0%	-	91	88	12	156	6	-7	255
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	243	396	12	417	16	-29	811
	B	GSHP+SHW	3	40%	-	246	358	12	423	16	-21	788
	A	GSHP	3	40%	-	266	312	11	455	18	-17	779
	B	GSHP	1	40%	-	284*	277	11	484	19	-21	770
	A	GSHP	1	30%	-	302	252	11	511	20	-16	777
	A	GSHP	1	0%	-	321	229	10	535	21	-14	781
	A	Gas(86%)	3	0%	-	339	238	10	569	23	-14	826
	B	Gas(86%)	1	10%	-	352	210	10	593	24	-19	818
	B	Gas(86%)	1	0%	-	359	203	10	601	24	-18	819
	A	Gas(86%)	1	0%	-	376	185	10	630	25	-14	836

Table 5.4a: Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	361	13	338	-	-17	696
	A	GSHP	3	40%	-	232	327	13	345	-	-11	674
	C	Gas(86%)	3	40%	-	239	291	13	353	-	-17	641
	B	Gas(86%)	3	40%	-	248	268	13	366	-	-13	634
	B	Gas(86%)	3	20%	-	293	226	12	412	-	-11	640
	C	Gas(86%)	3	10%	-	306	220	11	422	-	-13	641
	B	Gas(86%)	3	0%	-	338*	168	10	457	-	-7	628
	A	Gas(86%)	3	0%	-	349	157	10	473	-	-6	634
	A	Gas(86%)	2	0%	-	390	144	10	528	-	-6	676
Office (NV) – 20 year calc	A	Gas(86%)	1	0%	-	420	131	10	568	-	-6	704
	C	GSHP	3	40%	-	35	319	7	63	-	-23	366
	B	GSHP	3	40%	-	45	274	7	77	-	-17	341
	A	GSHP	3	40%	-	52	252	7	87	-	-14	332
	A	GSHP	3	30%	-	64	237	7	99	-	-13	330
	A	GSHP	3	10%	-	88	208	6	123	-	-11	325
	A	GSHP	3	0%	-	99	194	5	135	-	-11	323
	A	GSHP	1	10%	-	106	181	6	147	-	-11	323
	A	GSHP	1	0%	-	118*	166	5	159	-	-11	320
Office (AC) – 20 year calc	A	Gas(86%)	3	0%	-	143	154	5	194	-	-11	342
	A	Gas(86%)	1	0%	-	177	127	5	239	-	-11	360
	C	GSHP	3	40%	OFF	101	399	10	153	-	-19	542
	B	GSHP	3	40%	OFF	102	357	10	154	-	-14	507
	B	GSHP	2	30%	OFF	128	315	7	186	-	-13	494
	B	GSHP	2	0%	OFF	164*	271	5	221	-	-11	486
	A	GSHP	2	0%	OFF	179	253	5	242	-	-9	492
	B	GSHP	1	0%	ON	212	238	5	287	-	-11	519
	A	GSHP	1	0%	OFF	230	221	5	311	-	-9	528
School (Primary) – 30 year calc	A	Gas(86%)	2	0%	OFF	241	214	5	325	-	-9	535
	B	Gas(86%)	1	0%	ON	261	198	5	353	-	-11	546
	A	Gas(86%)	1	0%	OFF	287	181	5	389	-	-9	566
	C	GSHP	3	40%	-	-17	278	10	26	-	-15	299
	C	GSHP	2	40%	-	-16	261	10	28	-	-14	285
	A	GSHP	2	40%	-	-6	222	10	42	-	-13	261
	C	Gas(86%)	2	40%	-	4	197	10	54	-	-11	251
C	Gas(86%)	2	30%	-	17	185	10	59	-	-9	245	
C	Gas(86%)	2	10%	-	42	162	10	70	-	-7	235	
C	Gas(86%)	2	0%	-	55	147	9	76	-	-6	226	

	B	Gas(86%)	2	0%	-	71	122	9	98	-	-5	223
	B	Gas(86%)	1	0%	-	80*	107	9	111	-	-4	223
	A	Gas(86%)	1	0%	-	91	93	9	126	-	-4	225
Hotel – 20 year calc	C	GSHP+SH W	3	40%	-	243	449	9	337	-	-19	776
	B	GSHP+SH W	3	40%	-	246	407	9	342	-	-14	744
	A	GSHP	3	40%	-	266	354	9	368	-	-11	720
	B	GSHP	1	40%	-	284	315	9	392	-	-14	702
	A	GSHP	1	30%	-	302	286	9	414	-	-11	698
	A	GSHP	1	0%	-	321*	260	8	434	-	-9	693
	A	Gas(86%)	3	0%	-	339	270	8	458	-	-9	727
	B	Gas(86%)	1	10%	-	352	239	8	478	-	-12	712
	B	Gas(86%)	1	0%	-	359	230	8	484	-	-12	710
	A	Gas(86%)	1	0%	-	376	210	8	508	-	-9	716

Table 5.4b: Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	361	13	271	-	-17	628
	A	GSHP	3	40%	-	232	327	13	276	-	-11	605
	C	Gas(86%)	3	40%	-	239	291	13	280	-	-17	568
	B	Gas(86%)	3	40%	-	248	268	13	288	-	-13	557
	B	Gas(86%)	3	20%	-	293	226	12	325	-	-11	553
	C	Gas(86%)	3	10%	-	306	220	11	335	-	-13	554
	B	Gas(86%)	3	0%	-	338*	168	10	362	-	-7	532
	A	Gas(86%)	3	0%	-	349	157	10	372	-	-6	534
	A	Gas(86%)	2	0%	-	390	144	10	415	-	-6	563
	A	Gas(86%)	1	0%	-	420	131	10	447	-	-6	583
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	319	7	50	-	-23	354
	B	GSHP	3	40%	-	45	274	7	61	-	-17	325
	A	GSHP	3	40%	-	52	252	7	70	-	-14	315
	A	GSHP	3	30%	-	64	237	7	79	-	-13	310
	A	GSHP	3	10%	-	88	208	6	98	-	-11	301
	A	GSHP	3	0%	-	99	194	5	108	-	-11	296
	A	GSHP	1	10%	-	106	181	6	118	-	-11	293
	A	GSHP	1	0%	-	118*	166	5	127	-	-11	288
	A	Gas(86%)	3	0%	-	143	154	5	145	-	-11	294
	A	Gas(86%)	1	0%	-	177	127	5	178	-	-11	299
Office (AC) –	C	GSHP	3	40%	OFF	101	399	10	122	-	-19	512
	B	GSHP	3	40%	OFF	102	357	10	123	-	-14	476

20 year calc	B	GSHP	2	30%	OFF	128	315	7	149	-	-13	456
	B	GSHP	2	0%	OFF	164*	271	5	177	-	-11	442
	A	GSHP	2	0%	OFF	179	253	5	194	-	-9	444
	B	GSHP	1	0%	ON	212	238	5	229	-	-11	462
	A	GSHP	1	0%	OFF	230	221	5	249	-	-9	466
	A	Gas(86%)	2	0%	OFF	241	214	5	247	-	-9	457
	B	Gas(86%)	1	0%	ON	261	198	5	272	-	-11	464
	A	Gas(86%)	1	0%	OFF	287	181	5	299	-	-9	476
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	278	10	20	-	-15	293
	C	GSHP	2	40%	-	-16	261	10	22	-	-14	279
	A	GSHP	2	40%	-	-6	222	10	33	-	-13	252
	C	Gas(86%)	2	40%	-	4	197	10	39	-	-11	236
	C	Gas(86%)	2	30%	-	17	185	10	43	-	-9	228
	C	Gas(86%)	2	10%	-	42	162	10	52	-	-7	216
	C	Gas(86%)	2	0%	-	55	147	9	56	-	-6	206
	B	Gas(86%)	2	0%	-	71	122	9	71	-	-5	197
	B	Gas(86%)	1	0%	-	80	107	9	83	-	-4	194
A	Gas(86%)	1	0%	-	91*	93	9	93	-	-4	191	
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	243	449	9	250	-	-19	689
	B	GSHP+SHW	3	40%	-	246	407	9	254	-	-14	656
	A	GSHP	3	40%	-	266	354	9	273	-	-11	625
	B	GSHP	1	40%	-	284	315	9	293	-	-14	602
	A	GSHP	1	30%	-	302	286	9	310	-	-11	594
	A	GSHP	1	0%	-	321	260	8	326	-	-9	585
	A	Gas(86%)	3	0%	-	339	270	8	335	-	-9	604
	B	Gas(86%)	1	10%	-	352	239	8	351	-	-12	585
	B	Gas(86%)	1	0%	-	359	230	8	356	-	-12	582
A	Gas(86%)	1	0%	-	376*	210	8	374	-	-9	582	

Table 5.4c: Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (kWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	361	13	406	-	-17	763
	A	GSHP	3	40%	-	232	327	13	414	-	-11	743
	C	Gas(86%)	3	40%	-	239	291	13	426	-	-17	714
	B	Gas(86%)	3	40%	-	248*	268	13	443	-	-13	712
	B	Gas(86%)	3	20%	-	293	226	12	498	-	-11	726
	C	Gas(86%)	3	10%	-	306	220	11	509	-	-13	728
	B	Gas(86%)	3	0%	-	338	168	10	553	-	-7	724
	A	Gas(86%)	3	0%	-	349	157	10	573	-	-6	734

	A	Gas(86%)	2	0%	-	390	144	10	642	-	-6	790
	A	Gas(86%)	1	0%	-	420	131	10	690	-	-6	826
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	319	7	76	-	-23	379
	B	GSHP	3	40%	-	45	274	7	92	-	-17	356
	A	GSHP	3	40%	-	52*	252	7	104	-	-14	349
	A	GSHP	3	30%	-	64	237	7	119	-	-13	350
	A	GSHP	3	10%	-	88	208	6	147	-	-11	350
	A	GSHP	3	0%	-	99	194	5	161	-	-11	350
	A	GSHP	1	10%	-	106	181	6	177	-	-11	352
	A	GSHP	1	0%	-	118	166	5	191	-	-11	352
	A	Gas(86%)	3	0%	-	143	154	5	242	-	-11	390
	A	Gas(86%)	1	0%	-	177	127	5	300	-	-11	421
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	399	10	183	-	-19	573
	B	GSHP	3	40%	OFF	102	357	10	185	-	-14	538
	B	GSHP	2	30%	OFF	128*	315	7	223	-	-13	531
	B	GSHP	2	0%	OFF	164	271	5	266	-	-11	531
	A	GSHP	2	0%	OFF	179	253	5	291	-	-9	541
	B	GSHP	1	0%	ON	212	238	5	344	-	-11	576
	A	GSHP	1	0%	OFF	230	221	5	374	-	-9	591
	A	Gas(86%)	2	0%	OFF	241	214	5	403	-	-9	613
	B	Gas(86%)	1	0%	ON	261	198	5	435	-	-11	627
A	Gas(86%)	1	0%	OFF	287	181	5	479	-	-9	656	
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	278	10	32	-	-15	305
	C	GSHP	2	40%	-	-16	261	10	34	-	-14	291
	A	GSHP	2	40%	-	-6	222	10	50	-	-13	270
	C	Gas(86%)	2	40%	-	4	197	10	70	-	-11	267
	C	Gas(86%)	2	30%	-	17	185	10	76	-	-9	262
	C	Gas(86%)	2	10%	-	42	162	10	89	-	-7	253
	C	Gas(86%)	2	0%	-	55*	147	9	96	-	-6	246
	B	Gas(86%)	2	0%	-	71	122	9	124	-	-5	250
	B	Gas(86%)	1	0%	-	80	107	9	140	-	-4	252
	A	Gas(86%)	1	0%	-	91	93	9	159	-	-4	258
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	243	449	9	424	-	-19	863
	B	GSHP+SHW	3	40%	-	246	407	9	430	-	-14	832
	A	GSHP	3	40%	-	266	354	9	462	-	-11	814
	B	GSHP	1	40%	-	284	315	9	492	-	-14	801
	A	GSHP	1	30%	-	302	286	9	518	-	-11	802
	A	GSHP	1	0%	-	321*	260	8	542	-	-9	801
	A	Gas(86%)	3	0%	-	339	270	8	581	-	-9	850
	B	Gas(86%)	1	10%	-	352	239	8	605	-	-12	839
	B	Gas(86%)	1	0%	-	359	230	8	613	-	-12	839
	A	Gas(86%)	1	0%	-	376	210	8	642	-	-9	851

Table 5.4d: Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Services	Heating	PV	FC			Maintenance	Energy			
Retail – 20 year calc	C	GSHP	3	40%	-	227	361	9	211	-	-6	575
	A	GSHP	3	40%	-	232	327	9	215	-	-4	547
	C	Gas(86%)	3	40%	-	239	291	9	220	-	-6	514
	B	Gas(86%)	3	40%	-	248	268	9	227	-	-5	499
	B	Gas(86%)	3	20%	-	293	226	8	255	-	-4	486
	C	Gas(86%)	3	10%	-	306	220	8	263	-	-5	486
	B	Gas(86%)	3	0%	-	338	168	7	284	-	-3	456
	A	Gas(86%)	3	0%	-	349*	157	7	293	-	-2	455
	A	Gas(86%)	2	0%	-	390	144	7	327	-	-2	475
	A	Gas(86%)	1	0%	-	420	131	7	352	-	-2	488
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	319	5	39	-	-8	355
	B	GSHP	3	40%	-	45	274	5	48	-	-6	320
	A	GSHP	3	40%	-	52	252	5	54	-	-5	306
	A	GSHP	3	30%	-	64	237	4	62	-	-5	299
	A	GSHP	3	10%	-	88	208	4	77	-	-4	285
	A	GSHP	3	0%	-	99	194	3	84	-	-4	277
	A	GSHP	1	10%	-	106	181	4	92	-	-4	273
	A	GSHP	1	0%	-	118*	166	3	99	-	-4	265
	A	Gas(86%)	3	0%	-	143	154	3	117	-	-4	271
	A	Gas(86%)	1	0%	-	177	127	3	144	-	-4	271
Office (AC) – 20 year calc	C	GSHP	3	40%	OFF	101	399	7	95	-	-7	494
	B	GSHP	3	40%	OFF	102	357	7	96	-	-5	455
	B	GSHP	2	30%	OFF	128	315	4	116	-	-5	430
	B	GSHP	2	0%	OFF	164	271	3	138	-	-4	409
	A	GSHP	2	0%	OFF	179*	253	3	151	-	-3	405
	B	GSHP	1	0%	ON	212	238	3	179	-	-4	417
	A	GSHP	1	0%	OFF	230	221	3	194	-	-3	415
	A	Gas(86%)	2	0%	OFF	241	214	3	198	-	-3	412
	B	Gas(86%)	1	0%	ON	261	198	3	216	-	-4	414
	A	Gas(86%)	1	0%	OFF	287	181	3	238	-	-3	419
School (Primary) – 30 year calc	C	GSHP	3	40%	-	-17	254	6	16	-	-3	273
	C	GSHP	2	40%	-	-16	240	6	17	-	-3	260
	A	GSHP	2	40%	-	-6	200	6	26	-	-3	230
	C	Gas(86%)	2	40%	-	4	184	6	32	-	-2	220
	C	Gas(86%)	2	30%	-	17	173	6	35	-	-2	213
	C	Gas(86%)	2	10%	-	42	153	6	42	-	-1	199
	C	Gas(86%)	2	0%	-	55	140	6	46	-	-1	190

	B	Gas(86%)	2	0%	-	71	114	6	58	-	-1	177
	B	Gas(86%)	1	0%	-	80	102	6	67	-	-1	173
	A	Gas(86%)	1	0%	-	91*	88	6	76	-	-1	168
Hotel – 20 year calc	C	GSHP+SHW	3	40%	-	243	449	6	203	-	-7	651
	B	GSHP+SHW	3	40%	-	246	407	6	206	-	-5	614
	A	GSHP	3	40%	-	266	354	6	222	-	-4	578
	B	GSHP	1	40%	-	284	315	6	237	-	-5	552
	A	GSHP	1	30%	-	302	286	6	251	-	-4	538
	A	GSHP	1	0%	-	321	260	5	263	-	-3	525
	A	Gas(86%)	3	0%	-	339	270	5	274	-	-3	546
	B	Gas(86%)	1	10%	-	352	239	5	286	-	-4	526
	B	Gas(86%)	1	0%	-	359	230	5	290	-	-4	521
	A	Gas(86%)	1	0%	-	376*	210	5	304	-	-3	516

## 5.2 Existing Buildings

As with the new buildings analysis, we have assumed various underpinning costs for the existing building analysis.

- Where appropriate we have used the cost of new build measures for the equivalent renovation or replacement measures. We have followed the allowance in the regulation to omit disposal costs; hence there is often no cost difference between applying the measures to new or existing buildings.
- Additional costs have been included for renovating floors, walls and roofs. These measures are restricted by the existing building structure which for some fabric types limits the potential improvements. We have analysed a range of wall insulation options, including permutations incorporating cavity in-fill (where appropriate), external and internal insulation. These costs are recorded in Table 5.5a.
- In a similar manner to the new buildings analysis, we applied sensitivity analysis to the energy and discount rates. We did not include analysis of the variation in primary energy factor and the cost of carbon.

Due to the large number of permutations, it is not possible to include all the results tables in the body of this report. The full set of tables is included in Annex A. However, Tables 5.6a-e details the results of the macroeconomic analysis using the central discount rate and energy cost.

The sensitivity analysis showed that lower energy prices improved the relative cost-effectiveness of less energy efficient products and higher energy prices improved the relative cost-effectiveness of more energy efficient products. Higher discount rates devalued (and thus effectively lowered) the price of energy over the calculation period and thus tended to favour less energy efficient products.

Table 5.5a: Elemental Capital Costs per m<sup>2</sup> of Fabric (£/m<sup>2</sup>)

Construction	Value (W/m <sup>2</sup> K)	Cost (£/m <sup>2</sup> )
Roof: Tiled Pitched	0.25	26.7
	0.2	33.2
	0.15	39.4
	0.1	53.2
Roof: Profiled Metal	0.29	11.4
	0.18	19.2
	0.14	26.8
Roof: Flat	0.25	16.9
	0.2	20.7
	0.15	26.8
Wall: Masonry Cavity	0.3	4.7
	0.19	24.1
	0.14	39.7
	0.16	35.5
	0.1	44.8
	0.39	9.5
	0.21	16.3
Wall: Lightweight Metal Frame (LMF)	0.47	25.4
	0.36	30.7
	0.27	35.4
	0.21	40.1
	0.2	28.7
	0.15 (b)	36.6
	0.15	44.1
0.11	51.8	
Floor: Solid	0.25	19.5
	0.2	23.5
	0.15	28.0
	0.1	37.8

Table 5.6a: Retail (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	1062	57	-21	1164
Wall U-Value	0.15 (b)	647	55	0	1063	58	-17	1158
Wall U-Value	0.15	647	59	0	1063	58	-19	1161
Wall U-Value	0.2	648	50	0	1064	58	-16	1156
Wall U-Value	0.21	648	57	0	1065	58	-18	1161
Wall U-Value	0.27	649	54	0	1066	58	-17	1161
Wall U-Value	0.36	651	51	0	1069	58	-16	1162
Wall U-Value	0.47	653	48	0	1072	58	-15	1163
Roof U-value	0.14	648	0	0	1064	58	0	1122
Roof U-value	0.18	649	0	0	1067	58	0	1125
Roof U-value	0.29	654	0	0	1075	58	0	1133
Heating Source	ASHP	558	41	13	913	48	0	1015
Heating Source	Gas CHP	620	132	99	1049	56	0	1335
Heating Source	Gas (91%)	646	11	15	1062	57	0	1145
Heating Source	Gas (91%) + SHW	646	104	15	1062	57	0	1237
Heating Source	Gas (86%)	653	11	15	1074	58	0	1158
Floor U-value	0.25	652	12	0	1071	58	-4	1137
Floor U-value	0.2	652	14	0	1071	58	-5	1139
Floor U-value	0.15	653	18	0	1072	58	-6	1142
Floor U-value	0.1	653	26	0	1072	58	-8	1148
Window U-value	1.4	644	15	0	1058	57	-2	1128
Window U-value	1.1	644	19	0	1058	57	-3	1132
Window U-value	0.9	647	20	0	1064	58	-3	1138
Window U-value	1.8	653	13	0	1073	58	-2	1142
Chiller Efficiency	5.5	533	30	0	877	48	0	955
Chiller Efficiency	4.5	545	27	0	897	49	0	972
Chiller Efficiency	3.5	564	25	0	928	50	0	1003
AHU SFP	1.8	641	19	0	1053	57	0	1129
AHU SFP	2	646	17	0	1062	58	0	1137
AHU SFP	2.2	652	16	0	1072	58	0	1146
Lighting Efficacy	65	490	6	0	807	44	0	858
Lighting Efficacy	60	498	5	0	821	45	0	871
Lighting Efficacy	55	508	5	0	837	46	0	888

Table 5.6a: Retail (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	824	45	-21	914
Wall U-Value	0.15 (b)	502	55	0	826	45	-17	909
Wall U-Value	0.15	502	59	0	826	45	-19	911
Wall U-Value	0.2	503	50	0	828	45	-16	907
Wall U-Value	0.21	503	57	0	828	45	-18	912
Wall U-Value	0.27	504	54	0	830	45	-17	913
Wall U-Value	0.36	506	51	0	834	46	-16	914
Wall U-Value	0.47	509	48	0	838	46	-15	917
Roof U-value	0.14	503	0	0	828	45	0	873
Roof U-value	0.18	505	0	0	831	45	0	877
Roof U-value	0.29	511	0	0	841	46	0	887
Heating Source	ASHP	406	41	13	663	35	0	752
Heating Source	Gas CHP	473	132	99	812	43	0	1086
Heating Source	Gas (91%)	502	11	15	826	45	0	897
Heating Source	Gas (91%) + SHW	502	104	15	826	45	0	990
Heating Source	Gas (86%)	510	11	15	840	46	0	912
Floor U-value	0.1	496	26	0	815	44	-8	877
Floor U-value	0.15	497	18	0	817	44	-6	874
Floor U-value	0.2	498	14	0	819	45	-5	873
Floor U-value	0.25	502	12	0	827	45	-4	880
Window U-value	1.1	502	19	0	827	45	-3	888
Window U-value	1.4	502	15	0	828	45	-2	885
Window U-value	0.9	504	20	0	829	45	-3	892
Window U-value	1.8	508	13	0	837	46	-2	893
Chiller Efficiency	5.5	461	30	0	760	42	0	832
Chiller Efficiency	4.5	470	27	0	775	43	0	844
Chiller Efficiency	3.5	485	25	0	799	44	0	868
AHU SFP	1.8	497	19	0	818	45	0	882
AHU SFP	2	503	17	0	828	45	0	890
AHU SFP	2.2	508	16	0	837	46	0	900
Lighting Efficacy	65	453	6	0	747	41	0	794
Lighting Efficacy	60	460	5	0	759	42	0	806
Lighting Efficacy	55	469	5	0	773	42	0	820

Table 5.6b: Office (NV) (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	567	33	-22	646
Wall U-Value	0.14	341	32	0	569	33	-10	624
Wall U-Value	0.16	342	62	0	570	33	-20	645
Wall U-Value	0.19	343	16	0	572	33	-5	616
Wall U-Value	0.21	343	28	0	573	33	-9	625
Wall U-Value	0.3	346	4	0	577	33	-1	613
Wall U-Value	0.39	348	12	0	581	33	-4	623
Roof U-value	0.15	334	17	0	557	32	-5	601
Roof U-value	0.2	336	16	0	561	32	-5	604
Roof U-value	0.25	338	13	0	564	32	-4	605
Heating Source	ASHP	160	26	7	261	14	0	307
Heating Source	Gas CHP	284	101	41	537	29	0	708
Heating Source	Gas (91%) + SHW	316	56	8	527	30	0	621
Heating Source	Gas (91%)	316	9	8	527	30	0	574
Heating Source	Gas (86%)	330	9	8	549	31	0	598
Floor U-value	0.1	337	13	0	563	32	-4	604
Floor U-value	0.15	340	9	0	566	33	-3	605
Floor U-value	0.2	342	7	0	570	33	-2	608
Floor U-value	0.25	344	6	0	574	33	-2	611
Window U-value	0.9	303	92	0	505	29	-15	611
Window U-value	1.1	312	87	0	519	30	-14	622
Window U-value	1.8	315	57	0	524	30	-9	602
Window U-value	1.4	319	67	0	531	30	-11	618
Lighting Efficacy	65	288	28	0	485	29	0	542
Lighting Efficacy	60	292	23	0	491	29	0	542
Lighting Efficacy	55	295	23	0	496	29	0	547

Table 5.6b: Office (NV) (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	452	26	-22	525
Wall U-Value	0.14	272	32	0	454	26	-10	502
Wall U-Value	0.16	273	62	0	455	26	-20	523
Wall U-Value	0.19	274	16	0	457	26	-5	494
Wall U-Value	0.21	275	28	0	458	26	-9	503
Wall U-Value	0.3	277	4	0	462	26	-1	491
Wall U-Value	0.39	279	12	0	466	27	-4	501
Roof U-value	0.15	277	17	0	462	26	-5	500
Roof U-value	0.2	279	16	0	465	27	-5	502
Roof U-value	0.25	281	13	0	468	27	-4	504
Heating Source	ASHP	136	26	7	222	12	0	266
Heating Source	Gas CHP	242	101	41	458	25	0	624
Heating Source	Gas (91%) + SHW	270	56	8	449	26	0	539
Heating Source	Gas (91%)	270	9	8	449	26	0	492
Heating Source	Gas (86%)	281	9	8	468	27	0	512
Floor U-value	0.1	267	13	0	445	25	-4	479
Floor U-value	0.15	269	9	0	449	26	-3	481
Floor U-value	0.2	271	7	0	452	26	-2	483
Floor U-value	0.25	273	6	0	455	26	-2	486
Window U-value	0.9	252	92	0	419	24	-15	521
Window U-value	1.1	259	87	0	432	25	-14	529
Window U-value	1.8	262	57	0	437	25	-9	510
Window U-value	1.4	266	67	0	442	25	-11	524
Lighting Efficacy	65	231	28	0	388	23	0	439
Lighting Efficacy	60	235	23	0	394	23	0	440
Lighting Efficacy	55	239	23	0	401	23	0	447

Table 5.6c: Office (AC) (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	665	37	-24	753
Wall U-Value	0.15 (b)	402	63	0	666	37	-20	746
Wall U-Value	0.15	402	67	0	666	37	-21	749
Wall U-Value	0.2	403	57	0	667	37	-18	744
Wall U-Value	0.21	403	65	0	668	37	-21	749
Wall U-Value	0.27	404	61	0	669	37	-19	749
Wall U-Value	0.36	406	58	0	672	38	-18	749
Wall U-Value	0.47	408	54	0	675	38	-17	750
Roof U-value	0.14	404	0	0	669	37	0	707
Roof U-value	0.18	405	0	0	671	38	0	709
Roof U-value	0.29	409	0	0	677	38	0	715
Heating Source	ASHP	263	26	7	430	23	0	485
Heating Source	Gas CHP	362	101	41	649	35	0	826
Heating Source	Gas (91%)	406	9	8	673	38	0	728
Heating Source	Gas (91%) + SHW	406	56	8	673	38	0	775
Heating Source	Gas (86%)	418	9	8	693	39	0	749
Floor U-value	0.1	395	13	0	654	36	-4	699
Floor U-value	0.15	397	9	0	657	37	-3	700
Floor U-value	0.2	398	7	0	660	37	-2	701
Floor U-value	0.25	400	6	0	662	37	-2	704
Window U-value	1.1	377	87	0	625	35	-14	733
Window U-value	1.4	380	67	0	631	35	-11	723
Window U-value	0.9	383	92	0	633	35	-15	747
Window U-value	1.8	405	57	0	670	37	-9	755
Chiller Efficiency	5.5	342	26	0	568	32	0	626
Chiller Efficiency	4.5	349	23	0	580	33	0	636
Chiller Efficiency	3.5	361	21	0	599	34	0	654
AHU SFP	1.8	391	12	0	647	36	0	695
AHU SFP	2	395	11	0	655	37	0	703
AHU SFP	2.2	400	10	0	663	37	0	710
Lighting Efficacy	65	366	28	0	608	34	0	670
Lighting Efficacy	60	371	23	0	616	35	0	674
Lighting Efficacy	55	378	23	0	627	35	0	684

Table 5.6c: Office (AC) (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	504	28	-24	583
Wall U-Value	0.15 (b)	306	63	0	506	28	-20	577
Wall U-Value	0.15	306	67	0	506	28	-21	580
Wall U-Value	0.2	307	57	0	507	28	-18	574
Wall U-Value	0.21	307	65	0	508	28	-21	580
Wall U-Value	0.27	309	61	0	510	28	-19	580
Wall U-Value	0.36	311	58	0	513	28	-18	581
Wall U-Value	0.47	313	54	0	517	29	-17	582
Roof U-value	0.14	307	0	0	506	28	0	534
Roof U-value	0.18	308	0	0	509	28	0	537
Roof U-value	0.29	312	0	0	515	29	0	543
Heating Source	ASHP	225	26	7	367	19	0	419
Heating Source	Gas CHP	290	101	41	512	27	0	681
Heating Source	Gas (91%)	319	9	8	528	29	0	574
Heating Source	Gas (91%) + SHW	319	56	8	528	29	0	621
Heating Source	Gas (86%)	327	9	8	541	30	0	589
Floor U-value	0.1	305	13	0	503	28	-4	540
Floor U-value	0.15	306	9	0	506	28	-3	540
Floor U-value	0.2	308	7	0	509	28	-2	542
Floor U-value	0.25	310	6	0	513	28	-2	545
Window U-value	1.1	276	87	0	456	25	-14	554
Window U-value	1.4	280	67	0	463	26	-11	545
Window U-value	0.9	282	92	0	464	25	-15	567
Window U-value	1.8	307	57	0	506	28	-9	583
Chiller Efficiency	5.5	250	26	0	415	23	0	464
Chiller Efficiency	4.5	257	23	0	426	24	0	472
Chiller Efficiency	3.5	268	21	0	444	25	0	490
AHU SFP	1.8	301	12	0	497	28	0	536
AHU SFP	2	306	11	0	505	28	0	543
AHU SFP	2.2	310	10	0	513	28	0	551
Lighting Efficacy	65	298	28	0	492	27	0	547
Lighting Efficacy	60	303	23	0	501	28	0	552
Lighting Efficacy	55	310	23	0	513	28	0	564

Table 5.6d: Primary (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	277	16	-9	341
Wall U-Value	0.14	164	27	0	280	16	-4	319
Wall U-Value	0.16	164	51	0	281	16	-8	341
Wall U-Value	0.19	166	13	0	283	17	-2	311
Wall U-Value	0.21	166	24	0	285	17	-4	321
Wall U-Value	0.3	170	3	0	291	17	-1	311
Wall U-Value	0.39	174	10	0	297	17	-2	323
Roof U-value	0.15	172	15	0	295	17	-2	324
Roof U-value	0.2	173	13	0	296	17	-2	324
Roof U-value	0.25	173	11	0	297	17	-2	323
Heating Source	ASHP	62	30	13	107	6	0	155
Heating Source	Gas CHP	140	62	56	331	15	0	464
Heating Source	Gas (91%) + SHW	155	47	14	265	15	0	341
Heating Source	Gas (91%)	155	8	14	265	15	0	302
Heating Source	Gas (86%)	163	8	14	278	16	0	316
Floor U-value	0.1	158	11	0	271	16	-2	295
Floor U-value	0.15	161	8	0	275	16	-1	298
Floor U-value	0.2	163	6	0	279	16	-1	301
Floor U-value	0.25	166	5	0	284	17	-1	304
Window U-value	0.9	142	47	0	243	14	0	304
Window U-value	1.1	147	44	0	252	15	0	311
Window U-value	1.8	150	29	0	257	15	0	301
Window U-value	1.4	152	34	0	260	15	0	309
Lighting Efficacy	65	157	23	0	267	16	0	306
Lighting Efficacy	60	158	21	0	270	16	0	306
Lighting Efficacy	55	160	20	0	272	16	0	308

Table 5.6d: Primary (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	144	8	-9	201
Wall U-Value	0.14	86	27	0	147	9	-4	178
Wall U-Value	0.16	87	51	0	148	9	-8	200
Wall U-Value	0.19	88	13	0	150	9	-2	170
Wall U-Value	0.21	89	24	0	152	9	-4	180
Wall U-Value	0.3	92	3	0	158	9	-1	170
Wall U-Value	0.39	96	10	0	164	10	-2	182
Roof U-value	0.15	93	15	0	159	9	-2	181
Roof U-value	0.2	94	13	0	160	9	-2	181
Roof U-value	0.25	94	11	0	161	10	-2	180
Heating Source	ASHP	27	30	13	47	3	0	93
Heating Source	Gas CHP	82	62	56	203	9	0	330
Heating Source	Gas (91%) + SHW	92	47	14	157	9	0	227
Heating Source	Gas (91%)	92	8	14	157	9	0	188
Heating Source	Gas (86%)	97	8	14	166	10	0	198
Floor U-value	0.1	87	11	0	149	9	-2	167
Floor U-value	0.15	89	8	0	153	9	-1	168
Floor U-value	0.2	92	6	0	157	9	-1	171
Floor U-value	0.25	94	5	0	161	10	-1	175
Window U-value	0.9	81	47	0	138	8	0	193
Window U-value	1.1	86	44	0	147	9	0	199
Window U-value	1.8	89	29	0	152	9	0	190
Window U-value	1.4	90	34	0	154	9	0	197
Lighting Efficacy	65	91	23	0	155	9	0	187
Lighting Efficacy	60	92	21	0	157	9	0	187
Lighting Efficacy	55	93	20	0	159	9	0	188

Table 5.6e: Hotel (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	944	54	-30	1063
Wall U-Value	0.14	568	44	0	947	54	-14	1031
Wall U-Value	0.16	568	84	0	948	54	-27	1060
Wall U-Value	0.19	569	22	0	949	55	-7	1019
Wall U-Value	0.21	570	39	0	951	55	-12	1032
Wall U-Value	0.3	573	5	0	956	55	-2	1014
Wall U-Value	0.39	576	17	0	961	55	-5	1028
Roof U-value	0.15	576	10	0	960	55	-3	1022
Roof U-value	0.2	577	9	0	962	55	-3	1024
Roof U-value	0.25	578	7	0	965	55	-2	1025
Heating Source	ASHP	457	29	10	759	43	0	841
Heating Source	Gas CHP	542	74	48	948	53	0	1122
Heating Source	Gas (91%) + SHW	563	35	10	939	54	0	1039
Heating Source	Gas (91%)	576	8	10	961	55	0	1035
Heating Source	Gas (86%)	586	8	10	978	56	0	1053
Floor U-value	0.1	570	7	0	951	55	-2	1010
Floor U-value	0.15	571	5	0	953	55	-2	1011
Floor U-value	0.2	572	4	0	955	55	-1	1012
Floor U-value	0.25	573	3	0	957	55	-1	1014
Window U-value	1.1	547	87	0	911	52	-14	1037
Window U-value	0.9	548	93	0	913	52	-15	1043
Window U-value	1.4	550	68	0	918	53	-11	1028
Window U-value	1.8	563	58	0	938	54	-9	1041
Chiller Efficiency	5.5	546	31	0	912	53	0	995
Chiller Efficiency	4.5	549	27	0	917	53	0	997
Chiller Efficiency	3.5	554	25	0	925	53	0	1004
AHU SFP	1.8	558	10	0	931	54	0	995
AHU SFP	2	564	10	0	941	54	0	1005
AHU SFP	2.2	569	9	0	950	55	0	1014
Lighting Efficacy	65	489	51	0	821	48	0	920
Lighting Efficacy	60	491	46	0	824	49	0	918
Lighting Efficacy	55	493	39	0	828	49	0	915

Table 5.6e: Hotel (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	741	43	-30	848
Wall U-Value	0.14	444	44	0	743	43	-14	817
Wall U-Value	0.16	445	84	0	744	43	-27	845
Wall U-Value	0.19	446	22	0	746	44	-7	805
Wall U-Value	0.21	446	39	0	747	44	-12	818
Wall U-Value	0.3	450	5	0	753	44	-2	801
Wall U-Value	0.39	453	17	0	759	44	-5	815
Roof U-value	0.15	453	10	0	758	44	-3	810
Roof U-value	0.2	454	9	0	761	44	-3	811
Roof U-value	0.25	455	7	0	763	45	-2	812
Heating Source	ASHP	325	29	10	541	31	0	611
Heating Source	Gas CHP	420	74	48	752	43	0	916
Heating Source	Gas (91%) + SHW	446	35	10	748	44	0	837
Heating Source	Gas (91%)	458	8	10	767	45	0	830
Heating Source	Gas (86%)	469	8	10	786	46	0	850
Floor U-value	0.1	446	7	0	747	44	-2	796
Floor U-value	0.15	448	5	0	749	44	-2	797
Floor U-value	0.2	449	4	0	752	44	-1	798
Floor U-value	0.25	450	3	0	754	44	-1	800
Window U-value	0.9	431	93	0	721	42	-15	841
Window U-value	1.1	434	87	0	727	42	-14	842
Window U-value	1.4	439	68	0	735	43	-11	835
Window U-value	1.8	445	58	0	745	43	-9	837
Chiller Efficiency	5.5	437	31	0	732	43	0	806
Chiller Efficiency	4.5	439	27	0	736	43	0	806
Chiller Efficiency	3.5	442	25	0	741	43	0	810
AHU SFP	1.8	444	10	0	744	44	0	798
AHU SFP	2	450	10	0	753	44	0	807
AHU SFP	2.2	455	9	0	763	45	0	816
Lighting Efficacy	65	434	51	0	729	43	0	823
Lighting Efficacy	60	436	46	0	732	43	0	821
Lighting Efficacy	55	439	39	0	736	43	0	818

## 6. Cost Optimal Level for Reference Buildings

### 6.1 New Buildings

We have elected to undertake the gap analysis based on the macro-economic calculations. Macro-economic analysis is used by the Government for the purpose of evaluating different options for technical standards for Building Regulations. Furthermore, we have elected to use the discount rate of 4% to mirror that used by the Government policy analysis.

For completeness, the macro-economic cost optimal curves for each of the reference buildings are shown in Figures 6.1a – 6.1e. The costs are based on the central energy price and 4% discount rate.

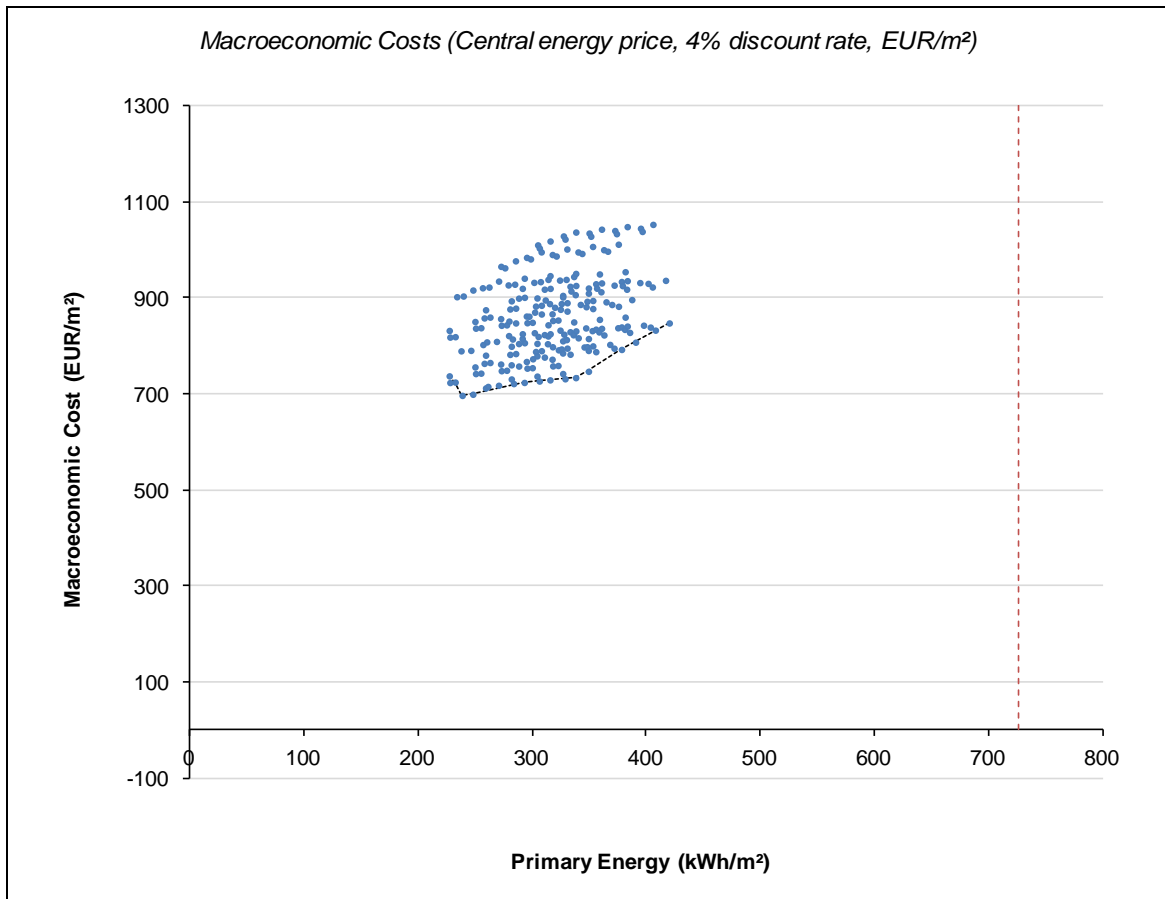


Figure 6.1a: Results of the cost-optimal analysis (Retail, Macroeconomic costs, 4% discount rate)

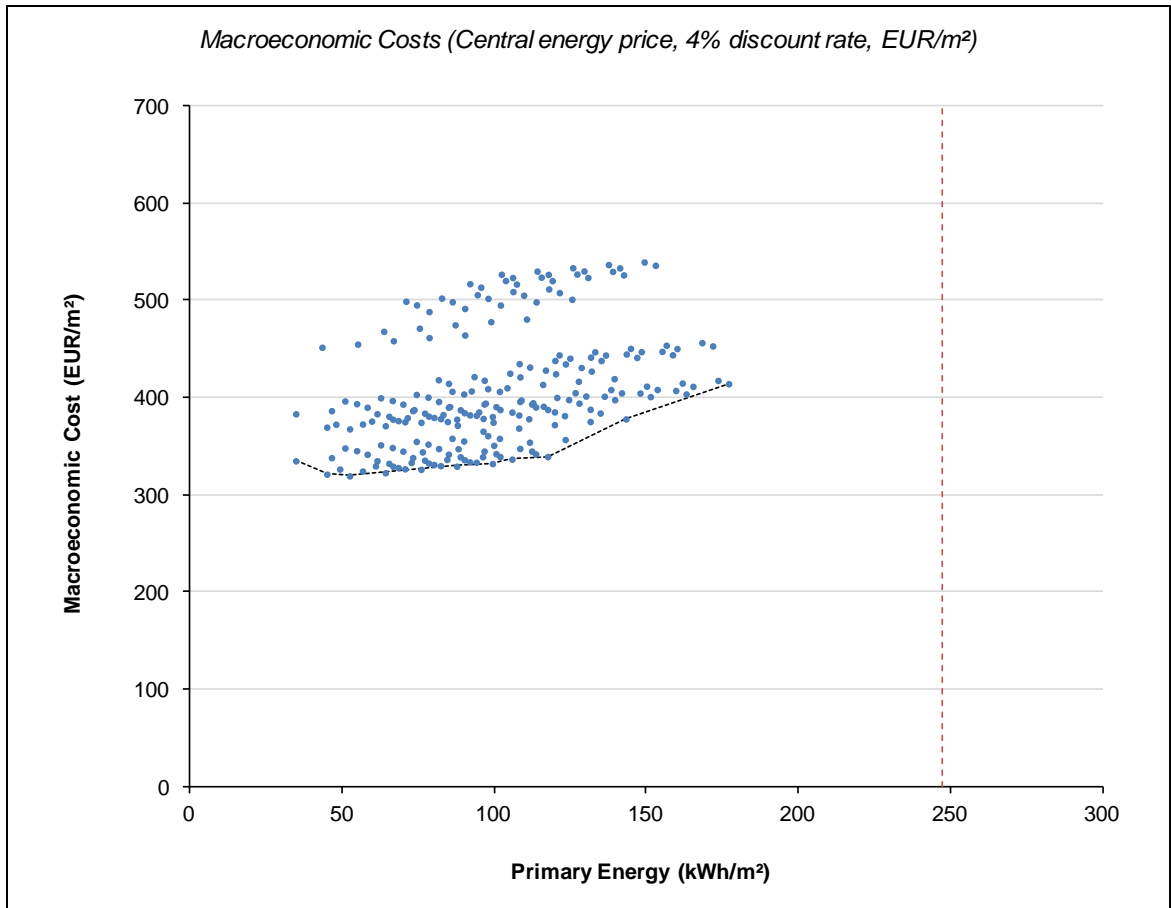


Figure 6.1b: Results of the cost-optimal analysis (Office (NV), Macroeconomic costs, 4% discount rate)

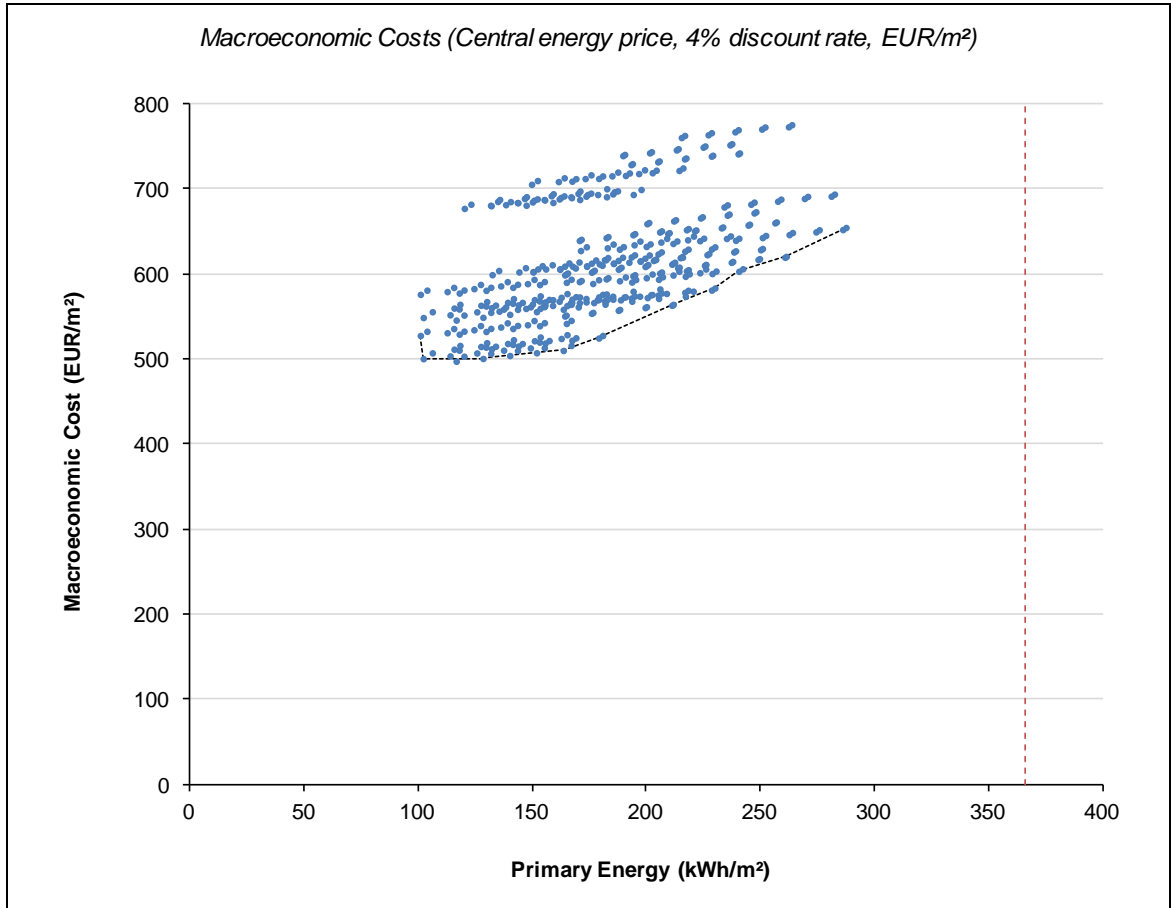


Figure 6.1c: Results of the cost-optimal analysis (Office (AC), Macroeconomic costs, 4% discount rate)

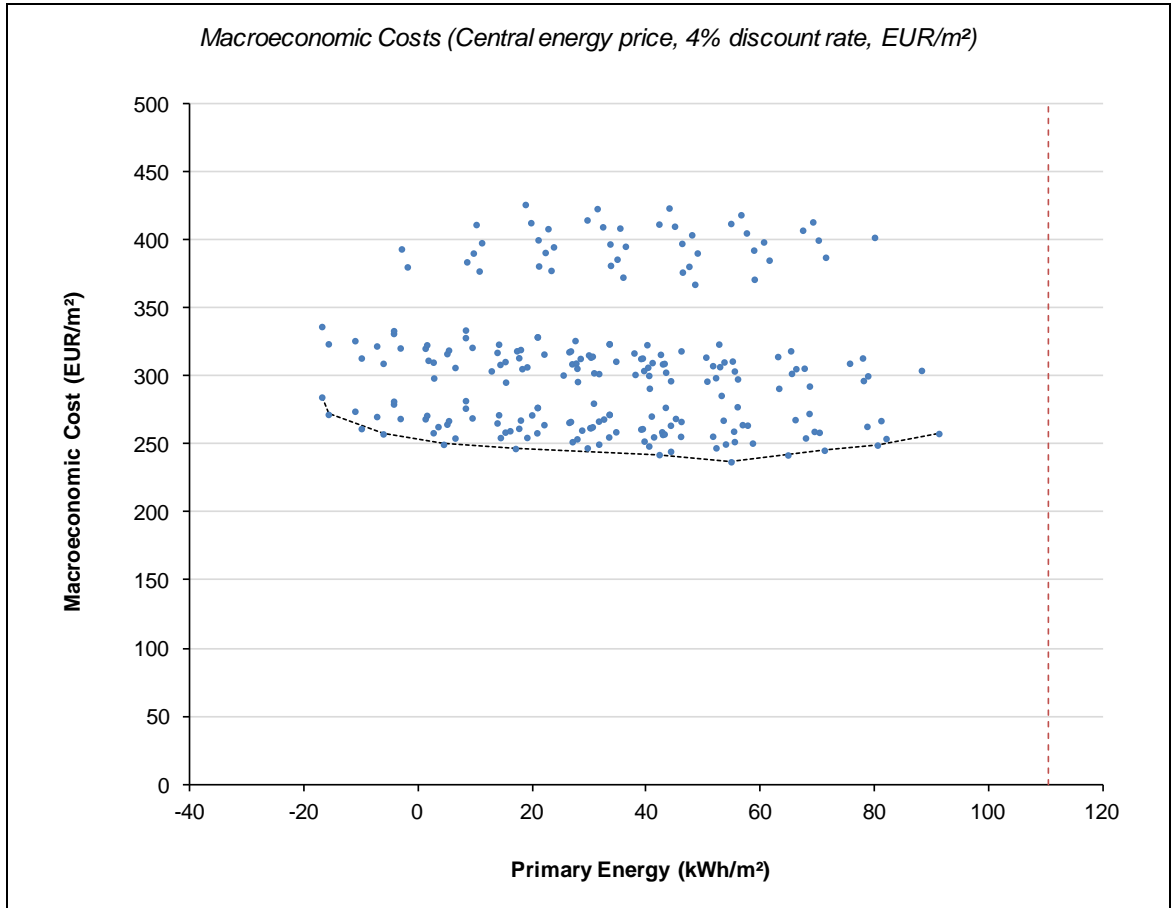


Figure 6.1d: Results of the cost-optimal analysis (School (Primary), Macroeconomic costs, 4% discount rate)

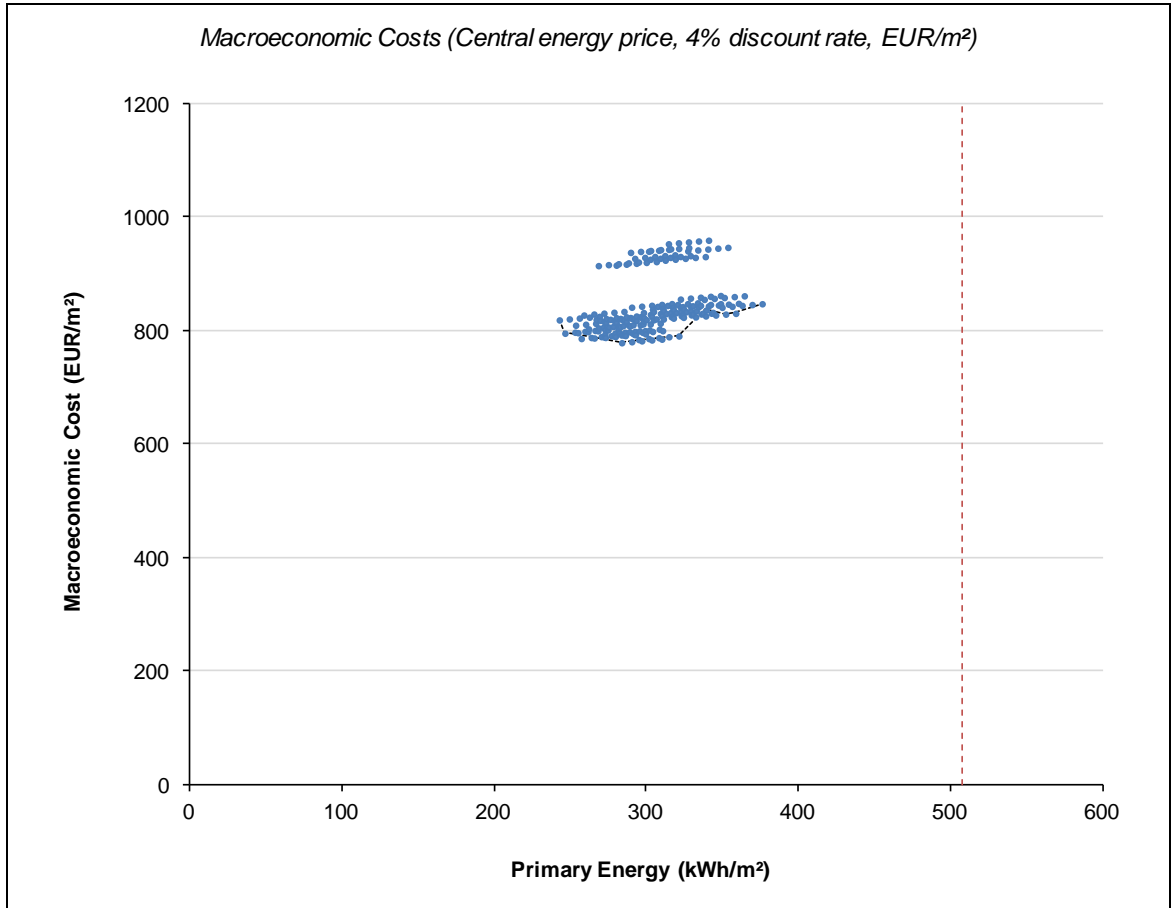


Figure 6.1e: Results of the cost-optimal analysis (Hotel, Macroeconomic costs, 4% discount rate)

From these curves, the economic optimal energy performance level in primary energy ( $\text{kWh/m}^2/\text{yr}$ ) is shown in Table 6.1. We have also included a range to cover the sensitivity cases investigated in Section 5. Furthermore, to allow for sensitivity in the price of the fabric/services/LZC measures, we have included those primary energies within 5% of the lowest macro-economic cost. This approximately allows for a +/-20% change in the building component prices.

As noted earlier, we also undertook some sensitivity analyses, assessing the impact of introducing biomass within the naturally ventilated office building (see Appendix B). Key outcomes from the analysis of the results were as follows.

- The biomass options tend to have a higher primary energy than those of gas. Biomass has approximately the same primary energy factor as that of gas, but the boilers are less efficient.
- The optimum point moved from a primary energy of  $52 \text{ kWh/m}^2$  to  $102 \text{ kWh/m}^2$ . This corresponds to the same technology solution, with the exception of the heating technology, which in this case is changed from a GSHP to a biomass boiler. This reflects the significantly lower fuel cost compared to other technologies.

Table 6.1: Economic Optimal Energy Performance Level in Primary Energy

<i>Reference building</i>	<i>Primary Energy (<math>\text{kWh/m}^2/\text{yr}</math>)</i>	<i>Sensitivity Range(<math>\text{kWh/m}^2/\text{yr}</math>)</i>
Retail (Air Conditioned)	239	227-338
Office (Natural Ventilation)	52	35-103
Office (Air Conditioned)	102	101-179
School (Primary – Natural Ventilation)	55	8-80
Hotel (Air Conditioned)	284	243-330

## 6.2 Existing Buildings

Again, we have elected to undertake the gap analysis based on the macro-economic calculations. Macro-economic analysis is used by the Government for the purpose of evaluating different options for technical standards for Building Regulations. Furthermore, we have elected to use the discount rate of 4% to mirror that used by the Government policy analysis. There are too many cost optimum curves to be reproduced in the main report and are included in Annex B.

From these curves, the economic optimal energy performance level in units of the elemental component is shown in Tables 6.2a – 6.2e for the five building types respectively.

We have also included a range to cover the sensitivity cases investigated in Section 5. We have not undertaken a sensitivity analysis on the price of the products as, in general, it is assumed that price uncertainties would similarly affect all products in any given comparison as the products are comparable. The only possible exception to this is the analysis the heating systems which includes comparison of different products.

Table 6.2a: Economic Optimal Energy Performance Level (Retail (AC))

<i>Reference Building</i>	<i>Energy efficiency</i>	<i>Element</i>	<i>Optimal option</i>	<i>Sensitivity Range</i>
Retail (AC)	EE1	Wall	U=0.20 W/m <sup>2</sup> K	-
	EE1	Roof	U=0.14 W/m <sup>2</sup> K	-
	EE1	Heating	ASHP	-
	EE1	Floor	U=0.25 W/m <sup>2</sup> K	-
	EE1	Window	U=1.4 W/m <sup>2</sup> K	-
	EE1	Chiller	SEER=5.5	-
	EE1	AHU	SFP=1.8 W/l/s	-
	EE1	Lighting	65 lm/W	-
	EE2	Wall	U=0.20 W/m <sup>2</sup> K	-
	EE2	Roof	U=0.14 W/m <sup>2</sup> K	-
	EE2	Heating	ASHP	-
	EE2	Floor	U=0.20 W/m <sup>2</sup> K	-
	EE2	Window	U=1.4 W/m <sup>2</sup> K	-
	EE2	Chiller	SEER=5.5	-
	EE2	AHU	SFP=1.8 W/l/s	-
	EE2	Lighting	65 lm/W	-

Table 6.2b: Economic Optimal Energy Performance Level (Office (NV))

<i>Reference building</i>	<i>Energy efficiency</i>	<i>Element</i>	<i>Optimal option</i>	<i>Sensitivity Range</i>
Office (NV)	EE1	Wall	U=0.30 W/m <sup>2</sup> K	-
	EE1	Roof	U=0.15 W/m <sup>2</sup> K	-
	EE1	Heating	ASHP	-
	EE1	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE1	Window	U=1.8 W/m <sup>2</sup> K	-
	EE1	Lighting	65 lm/W	-
	EE2	Wall	U=0.30 W/m <sup>2</sup> K	-
	EE2	Roof	U=0.15 W/m <sup>2</sup> K	-
	EE2	Heating	ASHP	-
	EE2	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE2	Window	U=1.8 W/m <sup>2</sup> K	-
	EE2	Lighting	65 lm/W	-

Table 6.2c: Economic Optimal Energy Performance Level (Office (AC))

<i>Reference building</i>	<i>Energy efficiency</i>	<i>Element</i>	<i>Optimal option</i>	<i>Sensitivity Range</i>
Office (AC)	EE1	Wall	U=0.20 W/m <sup>2</sup> K	-
	EE1	Roof	U=0.14 W/m <sup>2</sup> K	-
	EE1	Heating	ASHP	-
	EE1	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE1	Window	U=1.4 W/m <sup>2</sup> K	-
	EE1	Chiller	SEER=5.5	-
	EE1	AHU	SFP=1.8 W/l/s	-
	EE1	Lighting	65 lm/W	-
	EE2	Wall	U=0.20 W/m <sup>2</sup> K	-
	EE2	Roof	U=0.14 W/m <sup>2</sup> K	-
	EE2	Heating	ASHP	-
	EE2	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE2	Window	U=1.4 W/m <sup>2</sup> K	-
	EE2	Chiller	SEER=5.5	-
	EE2	AHU	SFP=1.8 W/l/s	-
	EE2	Lighting	65 lm/W	-

Table 6.2d: Economic Optimal Energy Performance Level (School (Primary))

<i>Reference building</i>	<i>Energy efficiency</i>	<i>Element</i>	<i>Optimal option</i>	<i>Sensitivity Range</i>
School (Primary)	EE1	Wall	U=0.30 W/m <sup>2</sup> K	0.19 – 0.30 W/m <sup>2</sup> K
	EE1	Roof	U=0.25 W/m <sup>2</sup> K	-
	EE1	Heating	ASHP	-
	EE1	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE1	Window	U=1.8 W/m <sup>2</sup> K	0.9-1.8 W/m <sup>2</sup> K
	EE1	Lighting	65 lm/W	-
	EE2	Wall	U=0.30 W/m <sup>2</sup> K	0.19 – 0.30 W/m <sup>2</sup> K
	EE2	Roof	U=0.25 W/m <sup>2</sup> K	-
	EE2	Heating	ASHP	-
	EE2	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE2	Window	U=1.8 W/m <sup>2</sup> K	0.9-1.8 W/m <sup>2</sup> K
	EE2	Lighting	60 lm/W	-

Table 6.2e: Economic Optimal Energy Performance Level (Hotel (AC))

<i>Reference building</i>	<i>Energy efficiency</i>	<i>Element</i>	<i>Optimal option</i>	<i>Sensitivity Range</i>
Hotel (AC)	EE1	Wall	U=0.30 W/m <sup>2</sup> K	-
	EE1	Roof	U=0.15 W/m <sup>2</sup> K	-
	EE1	Heating	ASHP	-
	EE1	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE1	Window	U=1.4 W/m <sup>2</sup> K	-
	EE1	Chiller	SEER=5.5	-
	EE1	AHU	SFP=1.8 W/l/s	-
	EE1	Lighting	55 lm/W	-
	EE2	Wall	U=0.30 W/m <sup>2</sup> K	-
	EE2	Roof	U=0.15 W/m <sup>2</sup> K	-
	EE2	Heating	ASHP	-
	EE2	Floor	U=0.10 W/m <sup>2</sup> K	-
	EE2	Window	U=1.4 W/m <sup>2</sup> K	-
	EE2	Chiller	SEER=5.5	-
	EE2	AHU	SFP=1.8 W/l/s	-
	EE2	Lighting	55 lm/W	-

## 7. Comparison of Current Regulations and Cost Optimal Level

### 7.1 New Buildings

For each reference building, Table 7.1 shows the current national regulations compared to the cost optimal level. In calculating the overall gap, we have assumed the same weighting for all reference buildings.

Table 7.1: Comparison Table

<i>Reference building</i>	<i>Cost Optimal Level (kWh/m<sup>2</sup>/yr)</i>	<i>Current Requirements(kWh/m<sup>2</sup>/yr)</i>	<i>Ratio of current requirements and cost optimal level</i>
Retail (Air Conditioned)	239	726	The current requirements are more than 15% greater than cost optimal
Office (Natural Ventilation)	52	247	
Office (Air Conditioned)	102	366	
School (Primary – Natural Ventilation)	55	111	
Hotel (Air Conditioned)	284	507	
<b>Average</b>	146	391	

It is worth reviewing the uncertainty shown in the sensitivity results. If the maximum in the range for each reference building was taken, the current technical standards are 90% above the cost optimal level. This provides confidence that the current standards are more than 15% above cost optimal which the cost optimal Regulations define as a significant difference.

The results would be modified if we included the actual build mix rather than assuming a similar weighting for all reference buildings. However, apart from the school building, the current requirements are significantly greater than the cost optimal level across all building categories. Hence, the results would not significantly change if the actual build mix was applied.

#### **Plan to address gap between requirements and cost optimal level**

Energy performance levels for new buildings are calculated using NEAP as described in Part I of the Building Regulations TGD L Conservation of Fuel and Energy-Buildings other than Dwellings.

This regulation and guidance was last revised in 2008 to include maximum permitted whole building energy performance coefficient and carbon dioxide performance coefficient when compared to a reference building.

The regulation and guidance is currently undergoing a review process to complete in early 2014. The Department of Environment Community and Local Government are committed to the new regulation and guidance achieving cost optimal levels. This will be the Recast EPBD 2015 target and the first milestone on the roadmap for non residential buildings to Nearly Zero Energy Buildings by 2020 for all buildings and 2018 for public buildings.

It is intended as part of the Technical Guidance Document L –Conservation of Fuel and Energy –Buildings other than Dwellings that further analysis of the sensitivities produced for these calculations will be taken into account including low and high energy prices and the investor perspective discount rates. Buildability, spread of technologies to achieve cost optimal performance and robustness of technologies across all sectors of the non residential building stock will also be taken into account. The difference between naturally ventilated buildings and air

conditioned buildings will also be considered. The significance of the effect of services on the energy performance of new buildings and the retrofit of existing buildings will also be a consideration.

As part of the review of Part L – Buildings other than Dwellings a review of the Non-domestic Energy Assessment Procedure will also take place. In particular a review of the performance parameters for the reference buildings will also take place.

## 7.2 Existing Buildings

For each reference building and improvement measure, Table 7.2 shows the current national regulations compared to the cost optimal solution. Due to the different energy efficiency, we have calculated EE1 and EE2 separately to assess any significant difference. In calculating the overall gap, we have assumed the same weighting for all reference buildings.

Table 7.2a: Comparison Table (Cavity Walls)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	-	-	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE1	0.3 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE1	-	-	
School (Primary – Natural Ventilation)	EE1	0.3 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE1	0.3 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
<b>Average</b>		<b>0.3 W/m<sup>2</sup>K</b>	<b>0.6 W/m<sup>2</sup>K</b>	
Retail (Air Conditioned)	EE2	-	-	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE2	0.3 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE2	-	-	
School (Primary – Natural Ventilation)	EE2	0.3 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE2	0.3 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
<b>Average</b>		<b>0.3 W/m<sup>2</sup>K</b>	<b>0.6 W/m<sup>2</sup>K</b>	

Table 7.2b: Comparison Table (Other Walls)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	0.2 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE1	-	-	
Office (Air Conditioned)	EE1	0.2 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE1	-	-	
Hotel (Air Conditioned)	EE1	-	-	
<b>Average</b>		<b>0.2 W/m<sup>2</sup>K</b>	<b>0.6 W/m<sup>2</sup>K</b>	
Retail (Air Conditioned)	EE2	0.2 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE2	-	-	
Office (Air Conditioned)	EE2	0.2 W/m <sup>2</sup> K	0.6 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE2	-	-	
Hotel (Air Conditioned)	EE2	-	-	
<b>Average</b>		<b>0.2 W/m<sup>2</sup>K</b>	<b>0.6 W/m<sup>2</sup>K</b>	

Table 7.2c: Comparison Table (Roof)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	0.14 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE1	0.15 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE1	0.14 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE1	0.25 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE1	0.15 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
<b>Average</b>		<b>0.17 W/m<sup>2</sup>K</b>	<b>0.35 W/m<sup>2</sup>K</b>	
Retail (Air Conditioned)	EE2	0.14 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE2	0.15 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE2	0.14 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE2	0.25 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE2	0.15 W/m <sup>2</sup> K	0.35 W/m <sup>2</sup> K	
<b>Average</b>		<b>0.17 W/m<sup>2</sup>K</b>	<b>0.35 W/m<sup>2</sup>K</b>	

Table 7.2d: Comparison Table (Heating)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	ASHP	For replacement boilers (84+ 2 Log P <sub>n</sub> )% as per SI 260 of 1994 <sup>2</sup>	There are no requirements for renewables in current Building Regulations for non-residential
Office (Natural Ventilation)	EE1	ASHP/Biomass		
Office (Air Conditioned)	EE1	ASHP		
School (Primary – Natural Ventilation)	EE1	ASHP		
Hotel (Air Conditioned)	EE1	ASHP		
<b>Average</b>		<b>ASHP</b>		
Retail (Air Conditioned)	EE2	ASHP	For replacement boilers (84+ 2 Log P <sub>n</sub> )% as per SI 260 of 1994 <sup>2</sup>	There are no requirements for renewables in current Building Regulations for non-residential
Office (Natural Ventilation)	EE2	ASHP/Biomass		
Office (Air Conditioned)	EE2	ASHP		
School (Primary – Natural Ventilation)	EE2	ASHP		
Hotel (Air Conditioned)	EE2	ASHP		
<b>Average</b>		<b>ASHP</b>		

<sup>2</sup> <http://www.irishstatutebook.ie/1994/en/si/0260.html>



Table 7.2e: Comparison Table (Floor)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	0.25 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE1	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE1	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE1	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE1	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
<b>Average</b>		<b>0.13 W/m<sup>2</sup>K</b>	<b>0.60 W/m<sup>2</sup>K</b>	
Retail (Air Conditioned)	EE2	0.20 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE2	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE2	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE2	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE2	0.10 W/m <sup>2</sup> K	0.60 W/m <sup>2</sup> K	
<b>Average</b>		<b>0.12 W/m<sup>2</sup>K</b>	<b>0.60 W/m<sup>2</sup>K</b>	

Table 7.2f: Comparison Table (Windows)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	1.4 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE1	1.8 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE1	1.4 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE1	1.8 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE1	1.4 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
<b>Average</b>		<b>1.56 W/m<sup>2</sup>K</b>	<b>2.2 W/m<sup>2</sup>K</b>	
Retail (Air Conditioned)	EE2	1.4 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE2	1.8 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
Office (Air Conditioned)	EE2	1.4 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
School (Primary – Natural Ventilation)	EE2	1.8 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
Hotel (Air Conditioned)	EE2	1.4 W/m <sup>2</sup> K	2.2 W/m <sup>2</sup> K	
<b>Average</b>		<b>1.56 W/m<sup>2</sup>K</b>	<b>2.2 W/m<sup>2</sup>K</b>	

Table 7.2g: Comparison Table (Lighting)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	65 lm/W	55 lm/W	The gap is 13% between requirements and cost optimal
Office (Natural Ventilation)	EE1	65 lm/W	55 lm/W	
Office (Air Conditioned)	EE1	65 lm/W	55 lm/W	
School (Primary – Natural Ventilation)	EE1	65 lm/W	55 lm/W	
Hotel (Air Conditioned)	EE1	55 lm/W	55 lm/W	
<b>Average</b>		<b>63 lm/W</b>	<b>55 lm/W</b>	
<hr/>				
Retail (Air Conditioned)	EE2	65 lm/W	55 lm/W	The gap is 13% between requirements and cost optimal
Office (Natural Ventilation)	EE2	65 lm/W	55 lm/W	
Office (Air Conditioned)	EE2	65 lm/W	55 lm/W	
School (Primary – Natural Ventilation)	EE2	60 lm/W	55 lm/W	
Hotel (Air Conditioned)	EE2	55 lm/W	55 lm/W	
<b>Average</b>		<b>62 lm/W</b>	<b>55 lm/W</b>	

Table 7.2h: Comparison Table (Chiller)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	5.5	1.67	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE1	-	-	
Office (Air Conditioned)	EE1	5.5	1.67	
School (Primary – Natural Ventilation)	EE1	-	-	
Hotel (Air Conditioned)	EE1	5.5	1.67	
<b>Average</b>		<b>5.5</b>	<b>1.67</b>	
<hr/>				
Retail (Air Conditioned)	EE2	5.5	1.67	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE2	-	-	
Office (Air Conditioned)	EE2	5.5	1.67	
School (Primary – Natural Ventilation)	EE2	-	-	
Hotel (Air Conditioned)	EE2	5.5	1.67	
<b>Average</b>		<b>5.5</b>	<b>1.67</b>	

Table 7.2i: Comparison Table (AHU)

<i>Reference building</i>	<i>Energy Efficiency</i>	<i>Cost Optimal</i>	<i>Current Requirements</i>	<i>Gap</i>
Retail (Air Conditioned)	EE1	1.8 W/l/s	3.0 W/l/s	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE1	-	-	
Office (Air Conditioned)	EE1	1.8 W/l/s	3.0 W/l/s	
School (Primary – Natural Ventilation)	EE1	-	-	
Hotel (Air Conditioned)	EE1	1.8 W/l/s	3.0 W/l/s	
<b>Average</b>		<b>1.8 W/l/s</b>	<b>3.0 W/l/s</b>	
Retail (Air Conditioned)	EE2	1.8 W/l/s	3.0 W/l/s	The gap is greater than 15% between requirements and cost optimal
Office (Natural Ventilation)	EE2	-	-	
Office (Air Conditioned)	EE2	1.8 W/l/s	3.0 W/l/s	
School (Primary – Natural Ventilation)	EE2	-	-	
Hotel (Air Conditioned)	EE2	1.8 W/l/s	3.0 W/l/s	
<b>Average</b>		<b>1.8 W/l/s</b>	<b>3.0 W/l/s</b>	

We discuss further those cases where the gap between current requirements and cost optimal was greater than 15%.

- The current standard for walls is  $U=0.60\text{W/m}^2\text{K}$ . By comparison, the cost optimum solution for cavity walls was  $U=0.30\text{W/m}^2\text{K}$  (fully filled cavity) and for other walls was  $U=0.2\text{W/m}^2\text{K}$  (150 external insulation - EPS).
- The current standard for roofs is  $U=0.35\text{W/m}^2\text{K}$ . By comparison, the cost optimum solution for pitched roofs and metal roofs both ranged from  $U=0.14\text{W/m}^2\text{K}$  to  $0.25\text{W/m}^2\text{K}$ . In practice, any technical requirement would need to take account of the impact on the available space in flat roof voids and parapet heights. From a buildability perspective this may restrict the depth of insulation that may be practically installed.
- The current standard for floors is  $U=0.6\text{W/m}^2\text{K}$ . By comparison, the cost optimum solution ranged from  $U=0.1\text{W/m}^2\text{K}$  to  $0.25\text{W/m}^2\text{K}$ . In practice, any technical requirement would need to take account of the impact on usable room volume and available foundation depth. From a buildability perspective this may restrict the depth of insulation that may be practically installed.
- The current standard for windows is  $U=2.2\text{W/m}^2\text{K}$ . By comparison, the cost optimum solution ranged from  $U=1.4\text{W/m}^2\text{K}$  to  $1.8\text{W/m}^2\text{K}$ .
- The current standard for chillers is a SEER of 1.67. By comparison, the cost optimum solution was 5.5 for all air conditioned buildings modelled.
- The current standard for air handling units (AHU) is 3.0 W/l/s. By comparison, the cost optimum solution was 1.8 W/l/s for all mechanically ventilated buildings.
- The current standard for replacement boilers for non residential buildings is 84% as per S.I. No. 260 of 1994: European Communities (Efficiency requirements for new hot water boilers fired with liquid or gaseous fuels) Regulations, 1994.. The cost optimal study has identified renewables as being a cost optimal solution for heating of buildings. Currently SI 243 of 2012 European Union (Energy Performance of Buildings) Regulations 2012 encourages feasibility studies for alternative energies for existing buildings undergoing major renovation.

### **Plan to address gap between requirements and cost optimal level**

Energy performance levels for existing buildings are set on a component basis as set out in Part L of the Building Regulations TGD L Conservation of Fuel and Energy-Buildings other than Dwellings.

The component level performance standards in this regulation were last reviewed in 2002.

The Regulation and Technical Guidance Document is currently undergoing a review process to complete in early 2014. It is intended that the new Regulation and Guidance for components will be reviewed in light of cost optimal levels for components.

It is intended as part of the Technical Guidance Document L –Conservation of Fuel and Energy –Buildings other than Dwellings that further analysis of the sensitivities produced for these calculations will be taken into account including low and high energy prices and the investor perspective discount rates. Other influencing parameters such as buildability, available spread of technologies to achieve cost optimal performance and robustness of technologies across all sectors of the non residential building stock will also be taken into account. The difference between naturally ventilated buildings and air conditioned buildings will also be considered. The significance of the effect of

services on the energy performance of new buildings and the retrofit of existing buildings will also be a consideration.

## Appendix A: Irish standards

The following calculation methods from Section 1.2 of TGD L Conservation of Fuel and Energy –Buildings other than Dwellings<sup>3</sup> sets out the maximum performance levels for fabric for new and existing buildings. Whilst these are the maximum values permitted it is likely that actual values will need to be significantly better than these “backstop” values

### 1.2.2 OVERALL HEAT LOSS METHOD

**1.2.2.1** This method sets a maximum acceptable level of transmission heat loss through the fabric of a building, in terms of the maximum average U-value ( $U_m$ ) of all fabric elements contributing to heat loss. The level depends on the ratio of the total area of these elements ( $A_t$ ) to the building volume ( $V$ ), and is specified in Table 1. The acceptable level of heat loss is expressed graphically in Diagram 1.

**1.2.2.2** In addition to not exceeding the maximum average value set, average elemental U-values should not exceed the following:

- roofs 0.25 W/m<sup>2</sup>K
- walls 0.37 W/m<sup>2</sup>K
- exposed floors 0.37 W/m<sup>2</sup>K
- ground floors 0.37 W/m<sup>2</sup>K

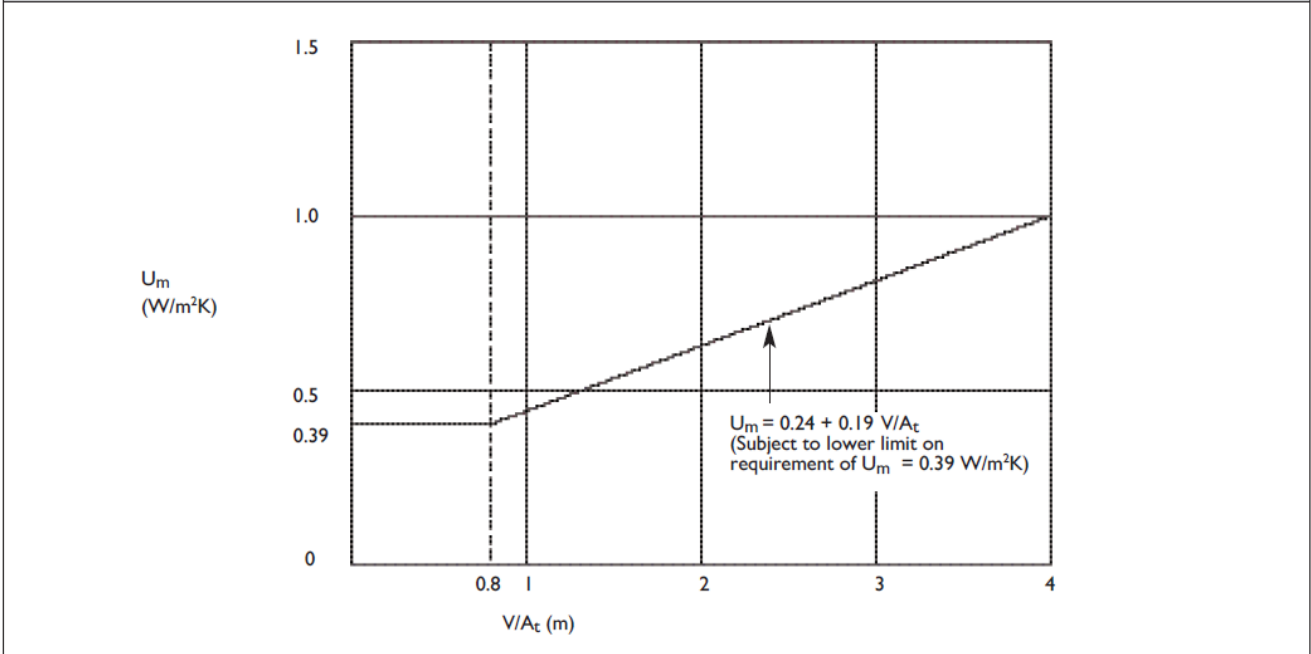
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<sup>3</sup> <http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownload,20322,en.pdf>

<b>Table 1 Maximum average U-value (<math>U_m</math>) as a function of building volume (<math>V</math>) and fabric heat-loss area (<math>A_f</math>)</b>	
Area of Heat Loss Elements/ Building Volume ( $A_f/V$ ) ( $m^{-1}$ )	Maximum Average U-Value ( $U_m$ ) ( $W/m^2K$ )
1.3	0.39
1.2	0.40
1.1	0.41
1.0	0.43
0.9	0.45
0.8	0.48
0.7	0.51
0.6	0.56
0.5	0.62
0.4	0.72
0.3	0.87

NOTE 1: The expression  $U_m = 0.24 + 0.19 V/A_f$  can be used to establish  $U_m$  for intermediate values of  $A_f/V$  and for values below  $0.3 m^{-1}$ .

*Diagram 1* *Para 1.2.2.1*  
**Maximum average U-value ( $U_m$ ) in relation to building volume ( $V$ ) and total area of heat loss elements ( $A_t$ )**



## Elemental heat loss method for existing buildings

The following table sets out Maximum average elemental U-Value Material Alterations to, or Material Changes of Use of, Existing Buildings

<b>Table 2 ELEMENTAL HEAT LOSS METHOD: Maximum average elemental U-value (W/m<sup>2</sup>K)</b>		
Fabric Elements	New Buildings & Extensions to Existing Buildings	Material Alterations to, or Material Changes of Use of, Existing Buildings
Pitched roof, insulation horizontal at ceiling level	0.16	0.35
Pitched roof, insulation on slope	0.20	0.35
Flat roof	0.22	0.35
Walls	0.27	0.60
Ground Floors	0.25	-
Other Exposed Floors	0.25	0.60
External personnel doors, windows and rooflights	2.20 <sup>1</sup>	2.20
Vehicle access and similar large doors	1.5	-

NOTE 1: Permitted average U-value of external personnel doors, windows and rooflights in buildings other than dwellings may vary as described in Paragraph 1.2.3.2.

## Appendix B: Biomass Boiler Sensitivity

This appendix outlines the sensitivity analysis undertaken on the Office (NV) building to assess the macro-economic costs associated with the use of biomass boilers. We modelled a biomass boiler of 80% efficiency. The technology costs assumed are recorded in Table B1.

Table B1: Biomass capital costs

	Building Type	Biomass Boiler
Capital	Office (NV)	43,921
Maintenance	Office (NV)	818

The energy costs assumed for the analysis were provided by SEAI and are recorded in Table B2.

Table B2: Biomass energy costs

			2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Low</b>	<b>Biomass</b>	<i>c/kWh</i>	4.3	3.9	3.6	3.4	3.2	3.1	2.9	2.8	2.7	2.6
<b>Central</b>	<b>Biomass</b>	<i>c/kWh</i>	4.6	4.4	4.1	3.9	3.8	3.6	3.5	3.3	3.2	3.1
<b>High</b>	<b>Biomass</b>	<i>c/kWh</i>	5.1	5.0	4.9	4.8	4.6	4.5	4.3	4.2	4.1	4.0

			2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
<b>Low</b>	<b>Biomass</b>	<i>c/kWh</i>	2.5	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1
<b>Central</b>	<b>Biomass</b>	<i>c/kWh</i>	3.0	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7
<b>High</b>	<b>Biomass</b>	<i>c/kWh</i>	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9

			2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
<b>Low</b>	<b>Biomass</b>	<i>c/kWh</i>	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
<b>Central</b>	<b>Biomass</b>	<i>c/kWh</i>	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
<b>High</b>	<b>Biomass</b>	<i>c/kWh</i>	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9

The detailed breakdown for the macroeconomic cost (central energy price and 4% discount rate) is shown in Table B3. This shows the original points from the previous analysis, plus key additional points from the inclusion of a biomass boiler for comparison.

Key outcomes from the analysis of the results were as follows.

- The biomass options tend to have a higher primary energy than those of gas. Biomass has approximately the same primary energy factor as that of gas, but the boilers are less efficient.
- The optimum point has now moved from a primary energy of 52 kWh/m<sup>2</sup> to 102 kWh/m<sup>2</sup>. This corresponds to the same technology solution, with the exception of the heating technology, which in this case is changed from a GSHP to a biomass boiler. This reflects the significantly lower fuel cost compared to other technologies.

Table B3: Comparing macroeconomic costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Building	Package					PE (KWh/ m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
	Fabric	Heating	Services	PV	FC			Maintenance	Energy			
Office (NV) – 20 year calc	C	GSHP	3	40%	-	35	281	9	76	3	-34	335
	B	GSHP	3	40%	-	45	241	9	93	4	-25	321
	C	Biomass (80%)	3	40%	-	51	266	10	75	2	-34	319
	A	GSHP	3	40%	-	52*	222	9	105	5	-21	319
	A	GSHP	3	30%	-	64	209	8	119	6	-20	323
	B	Biomass (80%)	3	40%	-	80	226	10	90	2	-25	303
	A	GSHP	3	10%	-	88	183	8	148	8	-17	329
	A	GSHP	3	0%	-	99	171	6	162	9	-16	332
	A	Biomass (80%)	3	40%	-	102*	207	10	102	2	-21	300
	A	GSHP	1	10%	-	106	160	8	178	9	-17	337
	A	Biomass (80%)	3	30%	-	113	194	9	116	3	-20	303
	A	GSHP	1	0%	-	118	147	6	192	10	-16	339
	A	Biomass (80%)	1	40%	-	137	183	10	130	3	-21	305
	A	Gas(86%)	3	0%	-	143	135	6	239	14	-16	378
	A	Biomass (80%)	1	30%	-	149	170	9	145	4	-20	308
	A	Biomass (80%)	1	20%	-	161	157	9	159	5	-19	312
	A	Gas(86%)	1	0%	-	177	111	6	295	17	-16	414
A	Biomass (80%)	1	0%	-	184	131	7	188	7	-16	318	

Capabilities on project:  
Building Engineering

# Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-Residential Buildings: Annex A

Capabilities on project:  
Building Engineering

# **Table A:**

## **Macroeconomic Costs**

### **Central energy price**

### **4% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	1062	57	-21	1164
Wall U-Value	0.15 (b)	647	55	0	1063	58	-17	1158
Wall U-Value	0.15	647	59	0	1063	58	-19	1161
Wall U-Value	0.2	648	50	0	1064	58	-16	1156
Wall U-Value	0.21	648	57	0	1065	58	-18	1161
Wall U-Value	0.27	649	54	0	1066	58	-17	1161
Wall U-Value	0.36	651	51	0	1069	58	-16	1162
Wall U-Value	0.47	653	48	0	1072	58	-15	1163
Roof U-value	0.14	648	0	0	1064	58	0	1122
Roof U-value	0.18	649	0	0	1067	58	0	1125
Roof U-value	0.29	654	0	0	1075	58	0	1133
Heating Source	ASHP	558	41	13	913	48	0	1015
Heating Source	Gas CHP	620	132	99	1049	56	0	1335
Heating Source	Gas (91%)	646	11	15	1062	57	0	1145
Heating Source	Gas (91%) + SHW	646	104	15	1062	57	0	1237
Heating Source	Gas (86%)	653	11	15	1074	58	0	1158
Floor U-value	0.25	652	12	0	1071	58	-4	1137
Floor U-value	0.2	652	14	0	1071	58	-5	1139
Floor U-value	0.15	653	18	0	1072	58	-6	1142
Floor U-value	0.1	653	26	0	1072	58	-8	1148
Window U-value	1.4	644	15	0	1058	57	-2	1128
Window U-value	1.1	644	19	0	1058	57	-3	1132
Window U-value	0.9	647	20	0	1064	58	-3	1138
Window U-value	1.8	653	13	0	1073	58	-2	1142
Chiller Efficiency	5.5	533	30	0	877	48	0	955
Chiller Efficiency	4.5	545	27	0	897	49	0	972
Chiller Efficiency	3.5	564	25	0	928	50	0	1003
AHU SFP	1.8	641	19	0	1053	57	0	1129
AHU SFP	2	646	17	0	1062	58	0	1137
AHU SFP	2.2	652	16	0	1072	58	0	1146
Lighting Efficacy	65	490	6	0	807	44	0	858
Lighting Efficacy	60	498	5	0	821	45	0	871
Lighting Efficacy	55	508	5	0	837	46	0	888

Capabilities on project:  
Building Engineering

Retail (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	824	45	-21	914
Wall U-Value	0.15 (b)	502	55	0	826	45	-17	909
Wall U-Value	0.15	502	59	0	826	45	-19	911
Wall U-Value	0.2	503	50	0	828	45	-16	907
Wall U-Value	0.21	503	57	0	828	45	-18	912
Wall U-Value	0.27	504	54	0	830	45	-17	913
Wall U-Value	0.36	506	51	0	834	46	-16	914
Wall U-Value	0.47	509	48	0	838	46	-15	917
Roof U-value	0.14	503	0	0	828	45	0	873
Roof U-value	0.18	505	0	0	831	45	0	877
Roof U-value	0.29	511	0	0	841	46	0	887
Heating Source	ASHP	406	41	13	663	35	0	752
Heating Source	Gas CHP	473	132	99	812	43	0	1086
Heating Source	Gas (91%)	502	11	15	826	45	0	897
Heating Source	Gas (91%) + SHW	502	104	15	826	45	0	990
Heating Source	Gas (86%)	510	11	15	840	46	0	912
Floor U-value	0.1	496	26	0	815	44	-8	877
Floor U-value	0.15	497	18	0	817	44	-6	874
Floor U-value	0.2	498	14	0	819	45	-5	873
Floor U-value	0.25	502	12	0	827	45	-4	880
Window U-value	1.1	502	19	0	827	45	-3	888
Window U-value	1.4	502	15	0	828	45	-2	885
Window U-value	0.9	504	20	0	829	45	-3	892
Window U-value	1.8	508	13	0	837	46	-2	893
Chiller Efficiency	5.5	461	30	0	760	42	0	832
Chiller Efficiency	4.5	470	27	0	775	43	0	844
Chiller Efficiency	3.5	485	25	0	799	44	0	868
AHU SFP	1.8	497	19	0	818	45	0	882
AHU SFP	2	503	17	0	828	45	0	890
AHU SFP	2.2	508	16	0	837	46	0	900
Lighting Efficacy	65	453	6	0	747	41	0	794
Lighting Efficacy	60	460	5	0	759	42	0	806
Lighting Efficacy	55	469	5	0	773	42	0	820

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	567	33	-22	646
Wall U-Value	0.14	341	32	0	569	33	-10	624
Wall U-Value	0.16	342	62	0	570	33	-20	645
Wall U-Value	0.19	343	16	0	572	33	-5	616
Wall U-Value	0.21	343	28	0	573	33	-9	625
Wall U-Value	0.3	346	4	0	577	33	-1	613
Wall U-Value	0.39	348	12	0	581	33	-4	623
Roof U-value	0.15	334	17	0	557	32	-5	601
Roof U-value	0.2	336	16	0	561	32	-5	604
Roof U-value	0.25	338	13	0	564	32	-4	605
Heating Source	GSHP	160	26	7	261	14	0	307
Heating Source	Gas CHP	284	101	41	537	29	0	708
Heating Source	Gas (91%) + SHW	316	56	8	527	30	0	621
Heating Source	Gas (91%)	316	9	8	527	30	0	574
Heating Source	Gas (86%)	330	9	8	549	31	0	598
Floor U-value	0.1	337	13	0	563	32	-4	604
Floor U-value	0.15	340	9	0	566	33	-3	605
Floor U-value	0.2	342	7	0	570	33	-2	608
Floor U-value	0.25	344	6	0	574	33	-2	611
Window U-value	0.9	303	92	0	505	29	-15	611
Window U-value	1.1	312	87	0	519	30	-14	622
Window U-value	1.8	315	57	0	524	30	-9	602
Window U-value	1.4	319	67	0	531	30	-11	618
Lighting Efficacy	65	288	28	0	485	29	0	542
Lighting Efficacy	60	292	23	0	491	29	0	542
Lighting Efficacy	55	295	23	0	496	29	0	547

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	452	26	-22	525
Wall U-Value	0.14	272	32	0	454	26	-10	502
Wall U-Value	0.16	273	62	0	455	26	-20	523
Wall U-Value	0.19	274	16	0	457	26	-5	494
Wall U-Value	0.21	275	28	0	458	26	-9	503
Wall U-Value	0.3	277	4	0	462	26	-1	491
Wall U-Value	0.39	279	12	0	466	27	-4	501
Roof U-value	0.15	277	17	0	462	26	-5	500
Roof U-value	0.2	279	16	0	465	27	-5	502
Roof U-value	0.25	281	13	0	468	27	-4	504
Heating Source	GSHP	136	26	7	222	12	0	266
Heating Source	Gas CHP	242	101	41	458	25	0	624
Heating Source	Gas (91%) + SHW	270	56	8	449	26	0	539
Heating Source	Gas (91%)	270	9	8	449	26	0	492
Heating Source	Gas (86%)	281	9	8	468	27	0	512
Floor U-value	0.1	267	13	0	445	25	-4	479
Floor U-value	0.15	269	9	0	449	26	-3	481
Floor U-value	0.2	271	7	0	452	26	-2	483
Floor U-value	0.25	273	6	0	455	26	-2	486
Window U-value	0.9	252	92	0	419	24	-15	521
Window U-value	1.1	259	87	0	432	25	-14	529
Window U-value	1.8	262	57	0	437	25	-9	510
Window U-value	1.4	266	67	0	442	25	-11	524
Lighting Efficacy	65	231	28	0	388	23	0	439
Lighting Efficacy	60	235	23	0	394	23	0	440
Lighting Efficacy	55	239	23	0	401	23	0	447

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	665	37	-24	753
Wall U-Value	0.15 (b)	402	63	0	666	37	-20	746
Wall U-Value	0.15	402	67	0	666	37	-21	749
Wall U-Value	0.2	403	57	0	667	37	-18	744
Wall U-Value	0.21	403	65	0	668	37	-21	749
Wall U-Value	0.27	404	61	0	669	37	-19	749
Wall U-Value	0.36	406	58	0	672	38	-18	749
Wall U-Value	0.47	408	54	0	675	38	-17	750
Roof U-value	0.14	404	0	0	669	37	0	707
Roof U-value	0.18	405	0	0	671	38	0	709
Roof U-value	0.29	409	0	0	677	38	0	715
Heating Source	GSHP	263	26	7	430	23	0	485
Heating Source	Gas CHP	362	101	41	649	35	0	826
Heating Source	Gas (91%)	406	9	8	673	38	0	728
Heating Source	Gas (91%) + SHW	406	56	8	673	38	0	775
Heating Source	Gas (86%)	418	9	8	693	39	0	749
Floor U-value	0.1	395	13	0	654	36	-4	699
Floor U-value	0.15	397	9	0	657	37	-3	700
Floor U-value	0.2	398	7	0	660	37	-2	701
Floor U-value	0.25	400	6	0	662	37	-2	704
Window U-value	1.1	377	87	0	625	35	-14	733
Window U-value	1.4	380	67	0	631	35	-11	723
Window U-value	0.9	383	92	0	633	35	-15	747
Window U-value	1.8	405	57	0	670	37	-9	755
Chiller Efficiency	5.5	342	26	0	568	32	0	626
Chiller Efficiency	4.5	349	23	0	580	33	0	636
Chiller Efficiency	3.5	361	21	0	599	34	0	654
AHU SFP	1.8	391	12	0	647	36	0	695
AHU SFP	2	395	11	0	655	37	0	703
AHU SFP	2.2	400	10	0	663	37	0	710
Lighting Efficacy	65	366	28	0	608	34	0	670
Lighting Efficacy	60	371	23	0	616	35	0	674
Lighting Efficacy	55	378	23	0	627	35	0	684

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	504	28	-24	583
Wall U-Value	0.15 (b)	306	63	0	506	28	-20	577
Wall U-Value	0.15	306	67	0	506	28	-21	580
Wall U-Value	0.2	307	57	0	507	28	-18	574
Wall U-Value	0.21	307	65	0	508	28	-21	580
Wall U-Value	0.27	309	61	0	510	28	-19	580
Wall U-Value	0.36	311	58	0	513	28	-18	581
Wall U-Value	0.47	313	54	0	517	29	-17	582
Roof U-value	0.14	307	0	0	506	28	0	534
Roof U-value	0.18	308	0	0	509	28	0	537
Roof U-value	0.29	312	0	0	515	29	0	543
Heating Source	GSHP	225	26	7	367	19	0	419
Heating Source	Gas CHP	290	101	41	512	27	0	681
Heating Source	Gas (91%)	319	9	8	528	29	0	574
Heating Source	Gas (91%) + SHW	319	56	8	528	29	0	621
Heating Source	Gas (86%)	327	9	8	541	30	0	589
Floor U-value	0.1	305	13	0	503	28	-4	540
Floor U-value	0.15	306	9	0	506	28	-3	540
Floor U-value	0.2	308	7	0	509	28	-2	542
Floor U-value	0.25	310	6	0	513	28	-2	545
Window U-value	1.1	276	87	0	456	25	-14	554
Window U-value	1.4	280	67	0	463	26	-11	545
Window U-value	0.9	282	92	0	464	25	-15	567
Window U-value	1.8	307	57	0	506	28	-9	583
Chiller Efficiency	5.5	250	26	0	415	23	0	464
Chiller Efficiency	4.5	257	23	0	426	24	0	472
Chiller Efficiency	3.5	268	21	0	444	25	0	490
AHU SFP	1.8	301	12	0	497	28	0	536
AHU SFP	2	306	11	0	505	28	0	543
AHU SFP	2.2	310	10	0	513	28	0	551
Lighting Efficacy	65	298	28	0	492	27	0	547
Lighting Efficacy	60	303	23	0	501	28	0	552
Lighting Efficacy	55	310	23	0	513	28	0	564

Capabilities on project:  
Building Engineering

Primary (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	277	16	-9	341
Wall U-Value	0.14	164	27	0	280	16	-4	319
Wall U-Value	0.16	164	51	0	281	16	-8	341
Wall U-Value	0.19	166	13	0	283	17	-2	311
Wall U-Value	0.21	166	24	0	285	17	-4	321
Wall U-Value	0.3	170	3	0	291	17	-1	311
Wall U-Value	0.39	174	10	0	297	17	-2	323
Roof U-value	0.15	172	15	0	295	17	-2	324
Roof U-value	0.2	173	13	0	296	17	-2	324
Roof U-value	0.25	173	11	0	297	17	-2	323
Heating Source	GSHP	62	30	13	107	6	0	155
Heating Source	Gas CHP	140	62	56	331	15	0	464
Heating Source	Gas (91%) + SHW	155	47	14	265	15	0	341
Heating Source	Gas (91%)	155	8	14	265	15	0	302
Heating Source	Gas (86%)	163	8	14	278	16	0	316
Floor U-value	0.1	158	11	0	271	16	-2	295
Floor U-value	0.15	161	8	0	275	16	-1	298
Floor U-value	0.2	163	6	0	279	16	-1	301
Floor U-value	0.25	166	5	0	284	17	-1	304
Window U-value	0.9	142	47	0	243	14	0	304
Window U-value	1.1	147	44	0	252	15	0	311
Window U-value	1.8	150	29	0	257	15	0	301
Window U-value	1.4	152	34	0	260	15	0	309
Lighting Efficacy	65	157	23	0	267	16	0	306
Lighting Efficacy	60	158	21	0	270	16	0	306
Lighting Efficacy	55	160	20	0	272	16	0	308

Capabilities on project:  
Building Engineering

Primary (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	144	8	-9	201
Wall U-Value	0.14	86	27	0	147	9	-4	178
Wall U-Value	0.16	87	51	0	148	9	-8	200
Wall U-Value	0.19	88	13	0	150	9	-2	170
Wall U-Value	0.21	89	24	0	152	9	-4	180
Wall U-Value	0.3	92	3	0	158	9	-1	170
Wall U-Value	0.39	96	10	0	164	10	-2	182
Roof U-value	0.15	93	15	0	159	9	-2	181
Roof U-value	0.2	94	13	0	160	9	-2	181
Roof U-value	0.25	94	11	0	161	10	-2	180
Heating Source	GSHP	27	30	13	47	3	0	93
Heating Source	Gas CHP	82	62	56	203	9	0	330
Heating Source	Gas (91%) + SHW	92	47	14	157	9	0	227
Heating Source	Gas (91%)	92	8	14	157	9	0	188
Heating Source	Gas (86%)	97	8	14	166	10	0	198
Floor U-value	0.1	87	11	0	149	9	-2	167
Floor U-value	0.15	89	8	0	153	9	-1	168
Floor U-value	0.2	92	6	0	157	9	-1	171
Floor U-value	0.25	94	5	0	161	10	-1	175
Window U-value	0.9	81	47	0	138	8	0	193
Window U-value	1.1	86	44	0	147	9	0	199
Window U-value	1.8	89	29	0	152	9	0	190
Window U-value	1.4	90	34	0	154	9	0	197
Lighting Efficacy	65	91	23	0	155	9	0	187
Lighting Efficacy	60	92	21	0	157	9	0	187
Lighting Efficacy	55	93	20	0	159	9	0	188

Capabilities on project:  
Building Engineering

Hotel (EE1): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	944	54	-30	1063
Wall U-Value	0.14	568	44	0	947	54	-14	1031
Wall U-Value	0.16	568	84	0	948	54	-27	1060
Wall U-Value	0.19	569	22	0	949	55	-7	1019
Wall U-Value	0.21	570	39	0	951	55	-12	1032
Wall U-Value	0.3	573	5	0	956	55	-2	1014
Wall U-Value	0.39	576	17	0	961	55	-5	1028
Roof U-value	0.15	576	10	0	960	55	-3	1022
Roof U-value	0.2	577	9	0	962	55	-3	1024
Roof U-value	0.25	578	7	0	965	55	-2	1025
Heating Source	GSHP	457	29	10	759	43	0	841
Heating Source	Gas CHP	542	74	48	948	53	0	1122
Heating Source	Gas (91%) + SHW	563	35	10	939	54	0	1039
Heating Source	Gas (91%)	576	8	10	961	55	0	1035
Heating Source	Gas (86%)	586	8	10	978	56	0	1053
Floor U-value	0.1	570	7	0	951	55	-2	1010
Floor U-value	0.15	571	5	0	953	55	-2	1011
Floor U-value	0.2	572	4	0	955	55	-1	1012
Floor U-value	0.25	573	3	0	957	55	-1	1014
Window U-value	1.1	547	87	0	911	52	-14	1037
Window U-value	0.9	548	93	0	913	52	-15	1043
Window U-value	1.4	550	68	0	918	53	-11	1028
Window U-value	1.8	563	58	0	938	54	-9	1041
Chiller Efficiency	5.5	546	31	0	912	53	0	995
Chiller Efficiency	4.5	549	27	0	917	53	0	997
Chiller Efficiency	3.5	554	25	0	925	53	0	1004
AHU SFP	1.8	558	10	0	931	54	0	995
AHU SFP	2	564	10	0	941	54	0	1005
AHU SFP	2.2	569	9	0	950	55	0	1014
Lighting Efficacy	65	489	51	0	821	48	0	920
Lighting Efficacy	60	491	46	0	824	49	0	918
Lighting Efficacy	55	493	39	0	828	49	0	915

Capabilities on project:  
Building Engineering

Hotel (EE2): Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	741	43	-30	848
Wall U-Value	0.14	444	44	0	743	43	-14	817
Wall U-Value	0.16	445	84	0	744	43	-27	845
Wall U-Value	0.19	446	22	0	746	44	-7	805
Wall U-Value	0.21	446	39	0	747	44	-12	818
Wall U-Value	0.3	450	5	0	753	44	-2	801
Wall U-Value	0.39	453	17	0	759	44	-5	815
Roof U-value	0.15	453	10	0	758	44	-3	810
Roof U-value	0.2	454	9	0	761	44	-3	811
Roof U-value	0.25	455	7	0	763	45	-2	812
Heating Source	GSHP	325	29	10	541	31	0	611
Heating Source	Gas CHP	420	74	48	752	43	0	916
Heating Source	Gas (91%) + SHW	446	35	10	748	44	0	837
Heating Source	Gas (91%)	458	8	10	767	45	0	830
Heating Source	Gas (86%)	469	8	10	786	46	0	850
Floor U-value	0.1	446	7	0	747	44	-2	796
Floor U-value	0.15	448	5	0	749	44	-2	797
Floor U-value	0.2	449	4	0	752	44	-1	798
Floor U-value	0.25	450	3	0	754	44	-1	800
Window U-value	0.9	431	93	0	721	42	-15	841
Window U-value	1.1	434	87	0	727	42	-14	842
Window U-value	1.4	439	68	0	735	43	-11	835
Window U-value	1.8	445	58	0	745	43	-9	837
Chiller Efficiency	5.5	437	31	0	732	43	0	806
Chiller Efficiency	4.5	439	27	0	736	43	0	806
Chiller Efficiency	3.5	442	25	0	741	43	0	810
AHU SFP	1.8	444	10	0	744	44	0	798
AHU SFP	2	450	10	0	753	44	0	807
AHU SFP	2.2	455	9	0	763	45	0	816
Lighting Efficacy	65	434	51	0	729	43	0	823
Lighting Efficacy	60	436	46	0	732	43	0	821
Lighting Efficacy	55	439	39	0	736	43	0	818

Capabilities on project:  
Building Engineering

# **Table B:**

## **Macroeconomic Costs**

### **Low energy price**

### **4% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	835	57	-21	937
Wall U-Value	0.15 (b)	647	55	0	836	58	-17	931
Wall U-Value	0.15	647	59	0	836	58	-19	934
Wall U-Value	0.2	648	50	0	837	58	-16	929
Wall U-Value	0.21	648	57	0	837	58	-18	933
Wall U-Value	0.27	649	54	0	838	58	-17	933
Wall U-Value	0.36	651	51	0	840	58	-16	932
Wall U-Value	0.47	653	48	0	842	58	-15	933
Roof U-value	0.14	648	0	0	836	58	0	894
Roof U-value	0.18	649	0	0	838	58	0	896
Roof U-value	0.29	654	0	0	844	58	0	902
Heating Source	ASHP	558	41	13	730	48	0	833
Heating Source	Gas CHP	620	132	99	817	56	0	1103
Heating Source	Gas (91%)	646	11	15	834	57	0	918
Heating Source	Gas (91%) + SHW	646	104	15	834	57	0	1010
Heating Source	Gas (86%)	653	11	15	843	58	0	927
Floor U-value	0.25	652	12	0	843	58	-4	909
Floor U-value	0.2	652	14	0	843	58	-5	911
Floor U-value	0.15	653	18	0	844	58	-6	915
Floor U-value	0.1	653	26	0	845	58	-8	921
Window U-value	1.4	644	15	0	831	57	-2	901
Window U-value	1.1	644	19	0	831	57	-3	905
Window U-value	0.9	647	20	0	836	58	-3	910
Window U-value	1.8	653	13	0	843	58	-2	912
Chiller Efficiency	5.5	533	30	0	686	48	0	764
Chiller Efficiency	4.5	545	27	0	702	49	0	777
Chiller Efficiency	3.5	564	25	0	726	50	0	802
AHU SFP	1.8	641	19	0	826	57	0	902
AHU SFP	2	646	17	0	834	58	0	909
AHU SFP	2.2	652	16	0	842	58	0	916
Lighting Efficacy	65	490	6	0	627	44	0	678
Lighting Efficacy	60	498	5	0	638	45	0	689
Lighting Efficacy	55	508	5	0	651	46	0	702

Capabilities on project:  
Building Engineering

Retail (EE2): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	644	45	-21	734
Wall U-Value	0.15 (b)	502	55	0	645	45	-17	727
Wall U-Value	0.15	502	59	0	645	45	-19	730
Wall U-Value	0.2	503	50	0	646	45	-16	725
Wall U-Value	0.21	503	57	0	646	45	-18	730
Wall U-Value	0.27	504	54	0	648	45	-17	730
Wall U-Value	0.36	506	51	0	650	46	-16	730
Wall U-Value	0.47	509	48	0	653	46	-15	731
Roof U-value	0.14	503	0	0	646	45	0	691
Roof U-value	0.18	505	0	0	648	45	0	694
Roof U-value	0.29	511	0	0	655	46	0	701
Heating Source	ASHP	406	41	13	530	35	0	620
Heating Source	Gas CHP	473	132	99	626	43	0	899
Heating Source	Gas (91%)	502	11	15	645	45	0	716
Heating Source	Gas (91%) + SHW	502	104	15	645	45	0	808
Heating Source	Gas (86%)	510	11	15	654	46	0	726
Floor U-value	0.1	496	26	0	639	44	-8	701
Floor U-value	0.15	497	18	0	640	44	-6	697
Floor U-value	0.2	498	14	0	641	45	-5	695
Floor U-value	0.25	502	12	0	646	45	-4	699
Window U-value	1.1	502	19	0	644	45	-3	706
Window U-value	1.4	502	15	0	645	45	-2	703
Window U-value	0.9	504	20	0	647	45	-3	709
Window U-value	1.8	508	13	0	652	46	-2	709
Chiller Efficiency	5.5	461	30	0	590	42	0	662
Chiller Efficiency	4.5	470	27	0	603	43	0	672
Chiller Efficiency	3.5	485	25	0	622	44	0	690
AHU SFP	1.8	497	19	0	637	45	0	701
AHU SFP	2	503	17	0	645	45	0	707
AHU SFP	2.2	508	16	0	653	46	0	715
Lighting Efficacy	65	453	6	0	579	41	0	626
Lighting Efficacy	60	460	5	0	589	42	0	636
Lighting Efficacy	55	469	5	0	600	42	0	648

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	423	33	-22	502
Wall U-Value	0.14	341	32	0	425	33	-10	479
Wall U-Value	0.16	342	62	0	425	33	-20	500
Wall U-Value	0.19	343	16	0	426	33	-5	470
Wall U-Value	0.21	343	28	0	427	33	-9	479
Wall U-Value	0.3	346	4	0	430	33	-1	466
Wall U-Value	0.39	348	12	0	433	33	-4	475
Roof U-value	0.15	334	17	0	416	32	-5	460
Roof U-value	0.2	336	16	0	419	32	-5	462
Roof U-value	0.25	338	13	0	421	32	-4	462
Heating Source	GSHP	160	26	7	209	14	0	255
Heating Source	Gas CHP	284	101	41	385	29	0	556
Heating Source	Gas (91%) + SHW	316	56	8	395	30	0	489
Heating Source	Gas (91%)	316	9	8	395	30	0	442
Heating Source	Gas (86%)	330	9	8	411	31	0	459
Floor U-value	0.1	337	13	0	420	32	-4	461
Floor U-value	0.15	340	9	0	423	33	-3	461
Floor U-value	0.2	342	7	0	425	33	-2	463
Floor U-value	0.25	344	6	0	428	33	-2	465
Window U-value	0.9	303	92	0	379	29	-15	486
Window U-value	1.1	312	87	0	390	30	-14	492
Window U-value	1.8	315	57	0	393	30	-9	471
Window U-value	1.4	319	67	0	398	30	-11	485
Lighting Efficacy	65	288	28	0	351	29	0	408
Lighting Efficacy	60	292	23	0	356	29	0	408
Lighting Efficacy	55	295	23	0	360	29	0	412

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	339	26	-22	412
Wall U-Value	0.14	272	32	0	340	26	-10	388
Wall U-Value	0.16	273	62	0	341	26	-20	409
Wall U-Value	0.19	274	16	0	342	26	-5	379
Wall U-Value	0.21	275	28	0	343	26	-9	388
Wall U-Value	0.3	277	4	0	346	26	-1	375
Wall U-Value	0.39	279	12	0	348	27	-4	383
Roof U-value	0.15	277	17	0	346	26	-5	384
Roof U-value	0.2	279	16	0	348	27	-5	385
Roof U-value	0.25	281	13	0	350	27	-4	386
Heating Source	GSHP	136	26	7	178	12	0	222
Heating Source	Gas CHP	242	101	41	328	25	0	495
Heating Source	Gas (91%) + SHW	270	56	8	337	26	0	426
Heating Source	Gas (91%)	270	9	8	337	26	0	380
Heating Source	Gas (86%)	281	9	8	350	27	0	394
Floor U-value	0.1	267	13	0	334	25	-4	368
Floor U-value	0.15	269	9	0	336	26	-3	368
Floor U-value	0.2	271	7	0	339	26	-2	369
Floor U-value	0.25	273	6	0	341	26	-2	371
Window U-value	0.9	252	92	0	315	24	-15	417
Window U-value	1.1	259	87	0	325	25	-14	422
Window U-value	1.8	262	57	0	328	25	-9	401
Window U-value	1.4	266	67	0	332	25	-11	414
Lighting Efficacy	65	231	28	0	283	23	0	334
Lighting Efficacy	60	235	23	0	288	23	0	334
Lighting Efficacy	55	239	23	0	294	23	0	340

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	509	37	-24	597
Wall U-Value	0.15 (b)	402	63	0	509	37	-20	590
Wall U-Value	0.15	402	67	0	509	37	-21	593
Wall U-Value	0.2	403	57	0	510	37	-18	587
Wall U-Value	0.21	403	65	0	511	37	-21	592
Wall U-Value	0.27	404	61	0	512	37	-19	591
Wall U-Value	0.36	406	58	0	514	38	-18	591
Wall U-Value	0.47	408	54	0	516	38	-17	591
Roof U-value	0.14	404	0	0	511	37	0	549
Roof U-value	0.18	405	0	0	513	38	0	550
Roof U-value	0.29	409	0	0	517	38	0	555
Heating Source	GSHP	263	26	7	344	23	0	399
Heating Source	Gas CHP	362	101	41	484	35	0	661
Heating Source	Gas (91%)	406	9	8	514	38	0	569
Heating Source	Gas (91%) + SHW	406	56	8	514	38	0	616
Heating Source	Gas (86%)	418	9	8	528	39	0	584
Floor U-value	0.1	395	13	0	501	36	-4	546
Floor U-value	0.15	397	9	0	503	37	-3	546
Floor U-value	0.2	398	7	0	505	37	-2	547
Floor U-value	0.25	400	6	0	507	37	-2	548
Window U-value	1.1	377	87	0	477	35	-14	585
Window U-value	1.4	380	67	0	481	35	-11	573
Window U-value	0.9	383	92	0	485	35	-15	598
Window U-value	1.8	405	57	0	513	37	-9	598
Chiller Efficiency	5.5	342	26	0	430	32	0	488
Chiller Efficiency	4.5	349	23	0	440	33	0	495
Chiller Efficiency	3.5	361	21	0	455	34	0	510
AHU SFP	1.8	391	12	0	493	36	0	541
AHU SFP	2	395	11	0	500	37	0	547
AHU SFP	2.2	400	10	0	506	37	0	553
Lighting Efficacy	65	366	28	0	460	34	0	523
Lighting Efficacy	60	371	23	0	467	35	0	525
Lighting Efficacy	55	378	23	0	476	35	0	534

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	390	28	-24	469
Wall U-Value	0.15 (b)	306	63	0	391	28	-20	462
Wall U-Value	0.15	306	67	0	391	28	-21	465
Wall U-Value	0.2	307	57	0	392	28	-18	459
Wall U-Value	0.21	307	65	0	392	28	-21	465
Wall U-Value	0.27	309	61	0	394	28	-19	464
Wall U-Value	0.36	311	58	0	396	28	-18	464
Wall U-Value	0.47	313	54	0	398	29	-17	464
Roof U-value	0.14	307	0	0	391	28	0	419
Roof U-value	0.18	308	0	0	393	28	0	421
Roof U-value	0.29	312	0	0	397	29	0	426
Heating Source	GSHP	225	26	7	294	19	0	346
Heating Source	Gas CHP	290	101	41	386	27	0	556
Heating Source	Gas (91%)	319	9	8	406	29	0	453
Heating Source	Gas (91%) + SHW	319	56	8	406	29	0	500
Heating Source	Gas (86%)	327	9	8	416	30	0	463
Floor U-value	0.1	305	13	0	389	28	-4	426
Floor U-value	0.15	306	9	0	391	28	-3	425
Floor U-value	0.2	308	7	0	393	28	-2	426
Floor U-value	0.25	310	6	0	396	28	-2	428
Window U-value	1.1	276	87	0	352	25	-14	451
Window U-value	1.4	280	67	0	357	26	-11	439
Window U-value	0.9	282	92	0	361	25	-15	464
Window U-value	1.8	307	57	0	392	28	-9	468
Chiller Efficiency	5.5	250	26	0	317	23	0	366
Chiller Efficiency	4.5	257	23	0	326	24	0	373
Chiller Efficiency	3.5	268	21	0	341	25	0	386
AHU SFP	1.8	301	12	0	383	28	0	422
AHU SFP	2	306	11	0	389	28	0	428
AHU SFP	2.2	310	10	0	396	28	0	434
Lighting Efficacy	65	298	28	0	379	27	0	434
Lighting Efficacy	60	303	23	0	386	28	0	437
Lighting Efficacy	55	310	23	0	396	28	0	447

Capabilities on project:  
Building Engineering

Primary (EE1): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	204	16	-9	268
Wall U-Value	0.14	164	27	0	206	16	-4	245
Wall U-Value	0.16	164	51	0	207	16	-8	266
Wall U-Value	0.19	166	13	0	208	17	-2	236
Wall U-Value	0.21	166	24	0	209	17	-4	246
Wall U-Value	0.3	170	3	0	214	17	-1	233
Wall U-Value	0.39	174	10	0	218	17	-2	244
Roof U-value	0.15	172	15	0	216	17	-2	246
Roof U-value	0.2	173	13	0	217	17	-2	245
Roof U-value	0.25	173	11	0	218	17	-2	244
Heating Source	GSHP	62	30	13	85	6	0	133
Heating Source	Gas CHP	140	62	56	238	15	0	371
Heating Source	Gas (91%) + SHW	155	47	14	195	15	0	271
Heating Source	Gas (91%)	155	8	14	195	15	0	232
Heating Source	Gas (86%)	163	8	14	205	16	0	242
Floor U-value	0.1	158	11	0	199	16	-2	224
Floor U-value	0.15	161	8	0	202	16	-1	225
Floor U-value	0.2	163	6	0	205	16	-1	227
Floor U-value	0.25	166	5	0	208	17	-1	229
Window U-value	0.9	142	47	0	180	14	0	241
Window U-value	1.1	147	44	0	187	15	0	245
Window U-value	1.8	150	29	0	190	15	0	234
Window U-value	1.4	152	34	0	192	15	0	241
Lighting Efficacy	65	157	23	0	192	16	0	231
Lighting Efficacy	60	158	21	0	194	16	0	231
Lighting Efficacy	55	160	20	0	196	16	0	232

Capabilities on project:  
Building Engineering

Primary (EE2): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	105	8	-9	162
Wall U-Value	0.14	86	27	0	107	9	-4	138
Wall U-Value	0.16	87	51	0	108	9	-8	160
Wall U-Value	0.19	88	13	0	109	9	-2	130
Wall U-Value	0.21	89	24	0	110	9	-4	139
Wall U-Value	0.3	92	3	0	115	9	-1	127
Wall U-Value	0.39	96	10	0	119	10	-2	137
Roof U-value	0.15	93	15	0	116	9	-2	137
Roof U-value	0.2	94	13	0	116	9	-2	137
Roof U-value	0.25	94	11	0	117	10	-2	136
Heating Source	GSHP	27	30	13	37	3	0	82
Heating Source	Gas CHP	82	62	56	144	9	0	271
Heating Source	Gas (91%) + SHW	92	47	14	114	9	0	184
Heating Source	Gas (91%)	92	8	14	114	9	0	145
Heating Source	Gas (86%)	97	8	14	121	10	0	152
Floor U-value	0.1	87	11	0	108	9	-2	126
Floor U-value	0.15	89	8	0	111	9	-1	127
Floor U-value	0.2	92	6	0	114	9	-1	128
Floor U-value	0.25	94	5	0	117	10	-1	131
Window U-value	0.9	81	47	0	101	8	0	156
Window U-value	1.1	86	44	0	107	9	0	159
Window U-value	1.8	89	29	0	110	9	0	148
Window U-value	1.4	90	34	0	112	9	0	155
Lighting Efficacy	65	91	23	0	112	9	0	144
Lighting Efficacy	60	92	21	0	113	9	0	143
Lighting Efficacy	55	93	20	0	115	9	0	144

Capabilities on project:  
Building Engineering

Hotel (EE1): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	705	54	-30	824
Wall U-Value	0.14	568	44	0	707	54	-14	791
Wall U-Value	0.16	568	84	0	707	54	-27	819
Wall U-Value	0.19	569	22	0	709	55	-7	778
Wall U-Value	0.21	570	39	0	709	55	-12	791
Wall U-Value	0.3	573	5	0	713	55	-2	772
Wall U-Value	0.39	576	17	0	717	55	-5	783
Roof U-value	0.15	576	10	0	716	55	-3	778
Roof U-value	0.2	577	9	0	717	55	-3	779
Roof U-value	0.25	578	7	0	719	55	-2	780
Heating Source	GSHP	457	29	10	575	43	0	657
Heating Source	Gas CHP	542	74	48	695	53	0	870
Heating Source	Gas (91%) + SHW	563	35	10	701	54	0	801
Heating Source	Gas (91%)	576	8	10	717	55	0	790
Heating Source	Gas (86%)	586	8	10	729	56	0	803
Floor U-value	0.1	570	7	0	709	55	-2	769
Floor U-value	0.15	571	5	0	711	55	-2	769
Floor U-value	0.2	572	4	0	712	55	-1	770
Floor U-value	0.25	573	3	0	713	55	-1	771
Window U-value	1.1	547	87	0	681	52	-14	807
Window U-value	0.9	548	93	0	683	52	-15	814
Window U-value	1.4	550	68	0	685	53	-11	795
Window U-value	1.8	563	58	0	702	54	-9	805
Chiller Efficiency	5.5	546	31	0	677	53	0	760
Chiller Efficiency	4.5	549	27	0	681	53	0	761
Chiller Efficiency	3.5	554	25	0	687	53	0	766
AHU SFP	1.8	558	10	0	692	54	0	757
AHU SFP	2	564	10	0	700	54	0	764
AHU SFP	2.2	569	9	0	708	55	0	771
Lighting Efficacy	65	489	51	0	598	48	0	697
Lighting Efficacy	60	491	46	0	600	49	0	694
Lighting Efficacy	55	493	39	0	603	49	0	691

Capabilities on project:  
Building Engineering

Hotel (EE2): Macroeconomic Costs (Low energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	545	43	-30	653
Wall U-Value	0.14	444	44	0	547	43	-14	620
Wall U-Value	0.16	445	84	0	548	43	-27	649
Wall U-Value	0.19	446	22	0	549	44	-7	608
Wall U-Value	0.21	446	39	0	550	44	-12	620
Wall U-Value	0.3	450	5	0	554	44	-2	601
Wall U-Value	0.39	453	17	0	558	44	-5	614
Roof U-value	0.15	453	10	0	557	44	-3	609
Roof U-value	0.2	454	9	0	559	44	-3	610
Roof U-value	0.25	455	7	0	560	45	-2	610
Heating Source	GSHP	325	29	10	405	31	0	475
Heating Source	Gas CHP	420	74	48	540	43	0	704
Heating Source	Gas (91%) + SHW	446	35	10	550	44	0	639
Heating Source	Gas (91%)	458	8	10	563	45	0	626
Heating Source	Gas (86%)	469	8	10	577	46	0	641
Floor U-value	0.1	446	7	0	550	44	-2	598
Floor U-value	0.15	448	5	0	551	44	-2	599
Floor U-value	0.2	449	4	0	553	44	-1	599
Floor U-value	0.25	450	3	0	554	44	-1	601
Window U-value	0.9	431	93	0	531	42	-15	651
Window U-value	1.1	434	87	0	534	42	-14	650
Window U-value	1.4	439	68	0	540	43	-11	640
Window U-value	1.8	445	58	0	549	43	-9	641
Chiller Efficiency	5.5	437	31	0	536	43	0	610
Chiller Efficiency	4.5	439	27	0	539	43	0	609
Chiller Efficiency	3.5	442	25	0	543	43	0	612
AHU SFP	1.8	444	10	0	545	44	0	599
AHU SFP	2	450	10	0	553	44	0	606
AHU SFP	2.2	455	9	0	560	45	0	614
Lighting Efficacy	65	434	51	0	532	43	0	626
Lighting Efficacy	60	436	46	0	535	43	0	623
Lighting Efficacy	55	439	39	0	538	43	0	620

Capabilities on project:  
Building Engineering

# **Table C:**

## **Macroeconomic Costs**

### **High energy price**

### **4% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	1288	57	-21	1391
Wall U-Value	0.15 (b)	647	55	0	1290	58	-17	1385
Wall U-Value	0.15	647	59	0	1290	58	-19	1388
Wall U-Value	0.2	648	50	0	1292	58	-16	1384
Wall U-Value	0.21	648	57	0	1293	58	-18	1389
Wall U-Value	0.27	649	54	0	1295	58	-17	1389
Wall U-Value	0.36	651	51	0	1298	58	-16	1391
Wall U-Value	0.47	653	48	0	1303	58	-15	1394
Roof U-value	0.14	648	0	0	1292	58	0	1350
Roof U-value	0.18	649	0	0	1296	58	0	1353
Roof U-value	0.29	654	0	0	1306	58	0	1364
Heating Source	ASHP	558	41	13	1095	48	0	1198
Heating Source	Gas CHP	620	132	99	1280	56	0	1567
Heating Source	Gas (91%)	646	11	15	1289	57	0	1372
Heating Source	Gas (91%) + SHW	646	104	15	1289	57	0	1465
Heating Source	Gas (86%)	653	11	15	1305	58	0	1389
Floor U-value	0.25	652	12	0	1299	58	-4	1365
Floor U-value	0.2	652	14	0	1299	58	-5	1367
Floor U-value	0.15	653	18	0	1299	58	-6	1370
Floor U-value	0.1	653	26	0	1299	58	-8	1375
Window U-value	1.4	644	15	0	1285	57	-2	1355
Window U-value	1.1	644	19	0	1285	57	-3	1359
Window U-value	0.9	647	20	0	1291	58	-3	1366
Window U-value	1.8	653	13	0	1303	58	-2	1372
Chiller Efficiency	5.5	533	30	0	1069	48	0	1147
Chiller Efficiency	4.5	545	27	0	1092	49	0	1168
Chiller Efficiency	3.5	564	25	0	1129	50	0	1205
AHU SFP	1.8	641	19	0	1279	57	0	1355
AHU SFP	2	646	17	0	1291	58	0	1365
AHU SFP	2.2	652	16	0	1302	58	0	1376
Lighting Efficacy	65	490	6	0	987	44	0	1038
Lighting Efficacy	60	498	5	0	1004	45	0	1054
Lighting Efficacy	55	508	5	0	1023	46	0	1074

Capabilities on project:  
Building Engineering

Retail (EE2): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	1005	45	-21	1095
Wall U-Value	0.15 (b)	502	55	0	1007	45	-17	1090
Wall U-Value	0.15	502	59	0	1007	45	-19	1093
Wall U-Value	0.2	503	50	0	1010	45	-16	1089
Wall U-Value	0.21	503	57	0	1010	45	-18	1094
Wall U-Value	0.27	504	54	0	1013	45	-17	1095
Wall U-Value	0.36	506	51	0	1018	46	-16	1098
Wall U-Value	0.47	509	48	0	1023	46	-15	1102
Roof U-value	0.14	503	0	0	1010	45	0	1055
Roof U-value	0.18	505	0	0	1014	45	0	1060
Roof U-value	0.29	511	0	0	1027	46	0	1073
Heating Source	ASHP	406	41	13	795	35	0	885
Heating Source	Gas CHP	473	132	99	998	43	0	1272
Heating Source	Gas (91%)	502	11	15	1008	45	0	1079
Heating Source	Gas (91%) + SHW	502	104	15	1008	45	0	1171
Heating Source	Gas (86%)	510	11	15	1025	46	0	1097
Floor U-value	0.1	496	26	0	992	44	-8	1054
Floor U-value	0.15	497	18	0	994	44	-6	1052
Floor U-value	0.2	498	14	0	997	45	-5	1052
Floor U-value	0.25	502	12	0	1007	45	-4	1061
Window U-value	1.1	502	19	0	1010	45	-3	1071
Window U-value	1.4	502	15	0	1010	45	-2	1068
Window U-value	0.9	504	20	0	1012	45	-3	1075
Window U-value	1.8	508	13	0	1021	46	-2	1078
Chiller Efficiency	5.5	461	30	0	929	42	0	1001
Chiller Efficiency	4.5	470	27	0	948	43	0	1017
Chiller Efficiency	3.5	485	25	0	976	44	0	1045
AHU SFP	1.8	497	19	0	1000	45	0	1063
AHU SFP	2	503	17	0	1011	45	0	1073
AHU SFP	2.2	508	16	0	1022	46	0	1084
Lighting Efficacy	65	453	6	0	915	41	0	962
Lighting Efficacy	60	460	5	0	929	42	0	976
Lighting Efficacy	55	469	5	0	946	42	0	993

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	711	33	-22	790
Wall U-Value	0.14	341	32	0	714	33	-10	769
Wall U-Value	0.16	342	62	0	715	33	-20	790
Wall U-Value	0.19	343	16	0	717	33	-5	761
Wall U-Value	0.21	343	28	0	718	33	-9	771
Wall U-Value	0.3	346	4	0	724	33	-1	759
Wall U-Value	0.39	348	12	0	729	33	-4	771
Roof U-value	0.15	334	17	0	698	32	-5	742
Roof U-value	0.2	336	16	0	703	32	-5	746
Roof U-value	0.25	338	13	0	707	32	-4	748
Heating Source	GSHP	160	26	7	313	14	0	359
Heating Source	Gas CHP	284	101	41	689	29	0	860
Heating Source	Gas (91%) + SHW	316	56	8	659	30	0	753
Heating Source	Gas (91%)	316	9	8	659	30	0	706
Heating Source	Gas (86%)	330	9	8	688	31	0	737
Floor U-value	0.1	337	13	0	706	32	-4	747
Floor U-value	0.15	340	9	0	710	33	-3	749
Floor U-value	0.2	342	7	0	715	33	-2	753
Floor U-value	0.25	344	6	0	720	33	-2	757
Window U-value	0.9	303	92	0	630	29	-15	736
Window U-value	1.1	312	87	0	649	30	-14	752
Window U-value	1.8	315	57	0	655	30	-9	733
Window U-value	1.4	319	67	0	664	30	-11	751
Lighting Efficacy	65	288	28	0	619	29	0	676
Lighting Efficacy	60	292	23	0	625	29	0	677
Lighting Efficacy	55	295	23	0	631	29	0	683

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	565	26	-22	638
Wall U-Value	0.14	272	32	0	568	26	-10	616
Wall U-Value	0.16	273	62	0	570	26	-20	638
Wall U-Value	0.19	274	16	0	572	26	-5	609
Wall U-Value	0.21	275	28	0	573	26	-9	619
Wall U-Value	0.3	277	4	0	579	26	-1	608
Wall U-Value	0.39	279	12	0	583	27	-4	618
Roof U-value	0.15	277	17	0	578	26	-5	617
Roof U-value	0.2	279	16	0	582	27	-5	620
Roof U-value	0.25	281	13	0	587	27	-4	622
Heating Source	GSHP	136	26	7	266	12	0	311
Heating Source	Gas CHP	242	101	41	587	25	0	754
Heating Source	Gas (91%) + SHW	270	56	8	562	26	0	652
Heating Source	Gas (91%)	270	9	8	562	26	0	605
Heating Source	Gas (86%)	281	9	8	587	27	0	631
Floor U-value	0.1	267	13	0	556	25	-4	590
Floor U-value	0.15	269	9	0	561	26	-3	593
Floor U-value	0.2	271	7	0	566	26	-2	596
Floor U-value	0.25	273	6	0	570	26	-2	600
Window U-value	0.9	252	92	0	522	24	-15	624
Window U-value	1.1	259	87	0	539	25	-14	637
Window U-value	1.8	262	57	0	546	25	-9	619
Window U-value	1.4	266	67	0	553	25	-11	635
Lighting Efficacy	65	231	28	0	493	23	0	544
Lighting Efficacy	60	235	23	0	499	23	0	545
Lighting Efficacy	55	239	23	0	507	23	0	553

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	821	37	-24	909
Wall U-Value	0.15 (b)	402	63	0	822	37	-20	902
Wall U-Value	0.15	402	67	0	822	37	-21	905
Wall U-Value	0.2	403	57	0	824	37	-18	901
Wall U-Value	0.21	403	65	0	825	37	-21	906
Wall U-Value	0.27	404	61	0	827	37	-19	906
Wall U-Value	0.36	406	58	0	831	38	-18	908
Wall U-Value	0.47	408	54	0	835	38	-17	910
Roof U-value	0.14	404	0	0	827	37	0	864
Roof U-value	0.18	405	0	0	829	38	0	867
Roof U-value	0.29	409	0	0	837	38	0	875
Heating Source	GSHP	263	26	7	516	23	0	571
Heating Source	Gas CHP	362	101	41	815	35	0	992
Heating Source	Gas (91%)	406	9	8	832	38	0	887
Heating Source	Gas (91%) + SHW	406	56	8	832	38	0	934
Heating Source	Gas (86%)	418	9	8	858	39	0	915
Floor U-value	0.1	395	13	0	807	36	-4	852
Floor U-value	0.15	397	9	0	810	37	-3	853
Floor U-value	0.2	398	7	0	814	37	-2	856
Floor U-value	0.25	400	6	0	818	37	-2	859
Window U-value	1.1	377	87	0	773	35	-14	881
Window U-value	1.4	380	67	0	781	35	-11	873
Window U-value	0.9	383	92	0	782	35	-15	895
Window U-value	1.8	405	57	0	827	37	-9	913
Chiller Efficiency	5.5	342	26	0	706	32	0	764
Chiller Efficiency	4.5	349	23	0	721	33	0	776
Chiller Efficiency	3.5	361	21	0	743	34	0	798
AHU SFP	1.8	391	12	0	801	36	0	849
AHU SFP	2	395	11	0	811	37	0	858
AHU SFP	2.2	400	10	0	820	37	0	868
Lighting Efficacy	65	366	28	0	755	34	0	817
Lighting Efficacy	60	371	23	0	765	35	0	823
Lighting Efficacy	55	378	23	0	777	35	0	835

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	618	28	-24	697
Wall U-Value	0.15 (b)	306	63	0	620	28	-20	691
Wall U-Value	0.15	306	67	0	620	28	-21	694
Wall U-Value	0.2	307	57	0	623	28	-18	690
Wall U-Value	0.21	307	65	0	623	28	-21	695
Wall U-Value	0.27	309	61	0	626	28	-19	696
Wall U-Value	0.36	311	58	0	630	28	-18	698
Wall U-Value	0.47	313	54	0	635	29	-17	701
Roof U-value	0.14	307	0	0	621	28	0	649
Roof U-value	0.18	308	0	0	625	28	0	653
Roof U-value	0.29	312	0	0	633	29	0	661
Heating Source	GSHP	225	26	7	440	19	0	493
Heating Source	Gas CHP	290	101	41	638	27	0	807
Heating Source	Gas (91%)	319	9	8	650	29	0	696
Heating Source	Gas (91%) + SHW	319	56	8	650	29	0	743
Heating Source	Gas (86%)	327	9	8	667	30	0	714
Floor U-value	0.1	305	13	0	617	28	-4	654
Floor U-value	0.15	306	9	0	621	28	-3	655
Floor U-value	0.2	308	7	0	625	28	-2	658
Floor U-value	0.25	310	6	0	630	28	-2	662
Window U-value	1.1	276	87	0	559	25	-14	657
Window U-value	1.4	280	67	0	569	26	-11	651
Window U-value	0.9	282	92	0	567	25	-15	671
Window U-value	1.8	307	57	0	621	28	-9	697
Chiller Efficiency	5.5	250	26	0	512	23	0	561
Chiller Efficiency	4.5	257	23	0	526	24	0	572
Chiller Efficiency	3.5	268	21	0	547	25	0	593
AHU SFP	1.8	301	12	0	611	28	0	650
AHU SFP	2	306	11	0	620	28	0	659
AHU SFP	2.2	310	10	0	630	28	0	668
Lighting Efficacy	65	298	28	0	605	27	0	660
Lighting Efficacy	60	303	23	0	616	28	0	667
Lighting Efficacy	55	310	23	0	630	28	0	681

Capabilities on project:  
Building Engineering

Primary (EE1): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	350	16	-9	414
Wall U-Value	0.14	164	27	0	354	16	-4	393
Wall U-Value	0.16	164	51	0	356	16	-8	415
Wall U-Value	0.19	166	13	0	358	17	-2	386
Wall U-Value	0.21	166	24	0	360	17	-4	397
Wall U-Value	0.3	170	3	0	368	17	-1	388
Wall U-Value	0.39	174	10	0	376	17	-2	402
Roof U-value	0.15	172	15	0	373	17	-2	403
Roof U-value	0.2	173	13	0	375	17	-2	403
Roof U-value	0.25	173	11	0	376	17	-2	402
Heating Source	GSHP	62	30	13	129	6	0	178
Heating Source	Gas CHP	140	62	56	425	15	0	558
Heating Source	Gas (91%) + SHW	155	47	14	335	15	0	411
Heating Source	Gas (91%)	155	8	14	335	15	0	371
Heating Source	Gas (86%)	163	8	14	352	16	0	389
Floor U-value	0.1	158	11	0	342	16	-2	367
Floor U-value	0.15	161	8	0	348	16	-1	370
Floor U-value	0.2	163	6	0	353	16	-1	375
Floor U-value	0.25	166	5	0	359	17	-1	380
Window U-value	0.9	142	47	0	306	14	0	367
Window U-value	1.1	147	44	0	318	15	0	376
Window U-value	1.8	150	29	0	324	15	0	368
Window U-value	1.4	152	34	0	328	15	0	377
Lighting Efficacy	65	157	23	0	343	16	0	382
Lighting Efficacy	60	158	21	0	345	16	0	382
Lighting Efficacy	55	160	20	0	349	16	0	384

Capabilities on project:  
Building Engineering

Primary (EE2): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	183	8	-9	240
Wall U-Value	0.14	86	27	0	187	9	-4	218
Wall U-Value	0.16	87	51	0	189	9	-8	240
Wall U-Value	0.19	88	13	0	191	9	-2	211
Wall U-Value	0.21	89	24	0	193	9	-4	222
Wall U-Value	0.3	92	3	0	201	9	-1	213
Wall U-Value	0.39	96	10	0	209	10	-2	227
Roof U-value	0.15	93	15	0	203	9	-2	225
Roof U-value	0.2	94	13	0	204	9	-2	225
Roof U-value	0.25	94	11	0	205	10	-2	224
Heating Source	GSHP	27	30	13	58	3	0	103
Heating Source	Gas CHP	82	62	56	263	9	0	390
Heating Source	Gas (91%) + SHW	92	47	14	200	9	0	270
Heating Source	Gas (91%)	92	8	14	200	9	0	231
Heating Source	Gas (86%)	97	8	14	212	10	0	243
Floor U-value	0.1	87	11	0	189	9	-2	207
Floor U-value	0.15	89	8	0	194	9	-1	210
Floor U-value	0.2	92	6	0	200	9	-1	214
Floor U-value	0.25	94	5	0	205	10	-1	219
Window U-value	0.9	81	47	0	176	8	0	230
Window U-value	1.1	86	44	0	187	9	0	239
Window U-value	1.8	89	29	0	193	9	0	231
Window U-value	1.4	90	34	0	196	9	0	239
Lighting Efficacy	65	91	23	0	199	9	0	231
Lighting Efficacy	60	92	21	0	200	9	0	230
Lighting Efficacy	55	93	20	0	203	9	0	232

Capabilities on project:  
Building Engineering

Hotel (EE1): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	1183	54	-30	1302
Wall U-Value	0.14	568	44	0	1186	54	-14	1271
Wall U-Value	0.16	568	84	0	1188	54	-27	1300
Wall U-Value	0.19	569	22	0	1190	55	-7	1260
Wall U-Value	0.21	570	39	0	1192	55	-12	1273
Wall U-Value	0.3	573	5	0	1199	55	-2	1257
Wall U-Value	0.39	576	17	0	1206	55	-5	1272
Roof U-value	0.15	576	10	0	1205	55	-3	1267
Roof U-value	0.2	577	9	0	1208	55	-3	1269
Roof U-value	0.25	578	7	0	1210	55	-2	1271
Heating Source	GSHP	457	29	10	943	43	0	1025
Heating Source	Gas CHP	542	74	48	1200	53	0	1375
Heating Source	Gas (91%) + SHW	563	35	10	1177	54	0	1276
Heating Source	Gas (91%)	576	8	10	1206	55	0	1279
Heating Source	Gas (86%)	586	8	10	1228	56	0	1302
Floor U-value	0.1	570	7	0	1192	55	-2	1252
Floor U-value	0.15	571	5	0	1194	55	-2	1253
Floor U-value	0.2	572	4	0	1197	55	-1	1255
Floor U-value	0.25	573	3	0	1200	55	-1	1257
Window U-value	1.1	547	87	0	1142	52	-14	1268
Window U-value	0.9	548	93	0	1142	52	-15	1272
Window U-value	1.4	550	68	0	1151	53	-11	1260
Window U-value	1.8	563	58	0	1174	54	-9	1277
Chiller Efficiency	5.5	546	31	0	1147	53	0	1230
Chiller Efficiency	4.5	549	27	0	1153	53	0	1233
Chiller Efficiency	3.5	554	25	0	1163	53	0	1241
AHU SFP	1.8	558	10	0	1170	54	0	1234
AHU SFP	2	564	10	0	1182	54	0	1245
AHU SFP	2.2	569	9	0	1193	55	0	1257
Lighting Efficacy	65	489	51	0	1044	48	0	1144
Lighting Efficacy	60	491	46	0	1048	49	0	1142
Lighting Efficacy	55	493	39	0	1052	49	0	1140

Capabilities on project:  
Building Engineering

Hotel (EE2): Macroeconomic Costs (High energy price, 4% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	936	43	-30	1043
Wall U-Value	0.14	444	44	0	939	43	-14	1013
Wall U-Value	0.16	445	84	0	941	43	-27	1042
Wall U-Value	0.19	446	22	0	943	44	-7	1002
Wall U-Value	0.21	446	39	0	945	44	-12	1015
Wall U-Value	0.3	450	5	0	952	44	-2	1000
Wall U-Value	0.39	453	17	0	960	44	-5	1016
Roof U-value	0.15	453	10	0	959	44	-3	1011
Roof U-value	0.2	454	9	0	962	44	-3	1013
Roof U-value	0.25	455	7	0	965	45	-2	1015
Heating Source	GSHP	325	29	10	677	31	0	747
Heating Source	Gas CHP	420	74	48	964	43	0	1128
Heating Source	Gas (91%) + SHW	446	35	10	945	44	0	1035
Heating Source	Gas (91%)	458	8	10	971	45	0	1033
Heating Source	Gas (86%)	469	8	10	995	46	0	1059
Floor U-value	0.1	446	7	0	945	44	-2	994
Floor U-value	0.15	448	5	0	948	44	-2	995
Floor U-value	0.2	449	4	0	950	44	-1	997
Floor U-value	0.25	450	3	0	953	44	-1	1000
Window U-value	0.9	431	93	0	911	42	-15	1031
Window U-value	1.1	434	87	0	919	42	-14	1035
Window U-value	1.4	439	68	0	931	43	-11	1031
Window U-value	1.8	445	58	0	941	43	-9	1034
Chiller Efficiency	5.5	437	31	0	929	43	0	1003
Chiller Efficiency	4.5	439	27	0	933	43	0	1003
Chiller Efficiency	3.5	442	25	0	939	43	0	1008
AHU SFP	1.8	444	10	0	942	44	0	996
AHU SFP	2	450	10	0	953	44	0	1007
AHU SFP	2.2	455	9	0	965	45	0	1019
Lighting Efficacy	65	434	51	0	927	43	0	1020
Lighting Efficacy	60	436	46	0	930	43	0	1019
Lighting Efficacy	55	439	39	0	934	43	0	1017

Capabilities on project:  
Building Engineering

# **Table D:**

## **Macroeconomic Costs**

### **Central energy price**

### **3% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	1199	66	-25	1305
Wall U-Value	0.15 (b)	647	55	0	1200	66	-21	1300
Wall U-Value	0.15	647	59	0	1200	66	-22	1303
Wall U-Value	0.2	648	50	0	1202	66	-19	1299
Wall U-Value	0.21	648	57	0	1202	66	-22	1304
Wall U-Value	0.27	649	54	0	1204	66	-20	1304
Wall U-Value	0.36	651	51	0	1207	66	-19	1305
Wall U-Value	0.47	653	48	0	1211	67	-18	1307
Roof U-value	0.14	648	0	0	1202	66	0	1268
Roof U-value	0.18	649	0	0	1205	66	0	1271
Roof U-value	0.29	654	0	0	1214	67	0	1281
Heating Source	ASHP	558	41	14	1028	55	0	1139
Heating Source	Gas CHP	620	132	108	1185	64	0	1489
Heating Source	Gas (91%)	646	11	16	1199	66	0	1292
Heating Source	Gas (91%) + SHW	646	104	16	1199	66	0	1384
Heating Source	Gas (86%)	653	11	16	1213	67	0	1307
Floor U-value	0.25	652	12	0	1209	66	-5	1283
Floor U-value	0.2	652	14	0	1209	66	-5	1285
Floor U-value	0.15	653	18	0	1210	66	-7	1288
Floor U-value	0.1	653	26	0	1211	66	-10	1293
Window U-value	1.4	644	15	0	1195	66	-3	1273
Window U-value	1.1	644	19	0	1195	66	-4	1276
Window U-value	0.9	647	20	0	1201	66	-4	1284
Window U-value	1.8	653	13	0	1212	67	-2	1288
Chiller Efficiency	5.5	533	30	0	991	55	0	1076
Chiller Efficiency	4.5	545	27	0	1013	56	0	1096
Chiller Efficiency	3.5	564	25	0	1048	58	0	1131
AHU SFP	1.8	641	19	0	1189	65	0	1273
AHU SFP	2	646	17	0	1200	66	0	1283
AHU SFP	2.2	652	16	0	1211	67	0	1293
Lighting Efficacy	65	490	6	0	913	51	0	970
Lighting Efficacy	60	498	5	0	928	52	0	985
Lighting Efficacy	55	508	5	0	946	53	0	1004

Capabilities on project:  
Building Engineering

Retail (EE2): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	932	52	-25	1024
Wall U-Value	0.15 (b)	502	55	0	933	52	-21	1019
Wall U-Value	0.15	502	59	0	933	52	-22	1022
Wall U-Value	0.2	503	50	0	936	52	-19	1019
Wall U-Value	0.21	503	57	0	936	52	-22	1023
Wall U-Value	0.27	504	54	0	939	52	-20	1024
Wall U-Value	0.36	506	51	0	943	52	-19	1026
Wall U-Value	0.47	509	48	0	948	53	-18	1030
Roof U-value	0.14	503	0	0	936	52	0	987
Roof U-value	0.18	505	0	0	940	52	0	992
Roof U-value	0.29	511	0	0	951	53	0	1004
Heating Source	ASHP	406	41	14	747	40	0	843
Heating Source	Gas CHP	473	132	108	919	50	0	1208
Heating Source	Gas (91%)	502	11	16	934	52	0	1013
Heating Source	Gas (91%) + SHW	502	104	16	934	52	0	1105
Heating Source	Gas (86%)	510	11	16	949	53	0	1029
Floor U-value	0.1	496	26	0	921	51	-10	988
Floor U-value	0.15	497	18	0	923	51	-7	986
Floor U-value	0.2	498	14	0	925	51	-5	985
Floor U-value	0.25	502	12	0	934	52	-5	993
Window U-value	1.1	502	19	0	935	52	-4	1002
Window U-value	1.4	502	15	0	936	52	-3	1000
Window U-value	0.9	504	20	0	938	52	-4	1006
Window U-value	1.8	508	13	0	946	52	-2	1009
Chiller Efficiency	5.5	461	30	0	859	48	0	937
Chiller Efficiency	4.5	470	27	0	876	49	0	952
Chiller Efficiency	3.5	485	25	0	903	50	0	978
AHU SFP	1.8	497	19	0	925	51	0	995
AHU SFP	2	503	17	0	936	52	0	1005
AHU SFP	2.2	508	16	0	947	53	0	1015
Lighting Efficacy	65	453	6	0	845	47	0	898
Lighting Efficacy	60	460	5	0	858	48	0	912
Lighting Efficacy	55	469	5	0	874	49	0	928

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	644	38	-26	724
Wall U-Value	0.14	341	32	0	647	38	-12	705
Wall U-Value	0.16	342	62	0	648	38	-23	724
Wall U-Value	0.19	343	16	0	649	38	-6	697
Wall U-Value	0.21	343	28	0	651	38	-11	706
Wall U-Value	0.3	346	4	0	655	38	-1	696
Wall U-Value	0.39	348	12	0	660	39	-5	706
Roof U-value	0.15	334	17	0	633	37	-7	681
Roof U-value	0.2	336	16	0	637	37	-6	684
Roof U-value	0.25	338	13	0	641	37	-5	686
Heating Source	GSHP	160	26	7	294	16	0	343
Heating Source	Gas CHP	284	101	45	612	34	0	792
Heating Source	Gas (91%) + SHW	316	56	9	599	35	0	698
Heating Source	Gas (91%)	316	9	9	599	35	0	651
Heating Source	Gas (86%)	330	9	9	624	36	0	678
Floor U-value	0.1	337	13	0	639	37	-5	685
Floor U-value	0.15	340	9	0	643	38	-4	687
Floor U-value	0.2	342	7	0	648	38	-3	690
Floor U-value	0.25	344	6	0	652	38	-2	694
Window U-value	0.9	303	92	0	573	33	-18	681
Window U-value	1.1	312	87	0	590	34	-16	694
Window U-value	1.8	315	57	0	595	35	-11	676
Window U-value	1.4	319	67	0	603	35	-13	693
Lighting Efficacy	65	288	28	0	553	33	0	614
Lighting Efficacy	60	292	23	0	559	34	0	615
Lighting Efficacy	55	295	23	0	565	34	0	621

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	513	30	-26	586
Wall U-Value	0.14	272	32	0	515	30	-12	565
Wall U-Value	0.16	273	62	0	517	30	-23	585
Wall U-Value	0.19	274	16	0	519	30	-6	559
Wall U-Value	0.21	275	28	0	520	30	-11	568
Wall U-Value	0.3	277	4	0	525	31	-1	558
Wall U-Value	0.39	279	12	0	529	31	-5	568
Roof U-value	0.15	277	17	0	525	31	-7	566
Roof U-value	0.2	279	16	0	528	31	-6	569
Roof U-value	0.25	281	13	0	532	31	-5	571
Heating Source	GSHP	136	26	7	250	13	0	297
Heating Source	Gas CHP	242	101	45	522	29	0	697
Heating Source	Gas (91%) + SHW	270	56	9	510	30	0	605
Heating Source	Gas (91%)	270	9	9	510	30	0	558
Heating Source	Gas (86%)	281	9	9	532	31	0	581
Floor U-value	0.1	267	13	0	505	29	-5	543
Floor U-value	0.15	269	9	0	510	30	-4	545
Floor U-value	0.2	271	7	0	513	30	-3	548
Floor U-value	0.25	273	6	0	517	30	-2	551
Window U-value	0.9	252	92	0	475	27	-18	578
Window U-value	1.1	259	87	0	490	28	-16	589
Window U-value	1.8	262	57	0	496	29	-11	571
Window U-value	1.4	266	67	0	502	29	-13	586
Lighting Efficacy	65	231	28	0	442	26	0	496
Lighting Efficacy	60	235	23	0	448	27	0	498
Lighting Efficacy	55	239	23	0	456	27	0	506

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	753	43	-29	842
Wall U-Value	0.15 (b)	402	63	0	754	43	-24	836
Wall U-Value	0.15	402	67	0	754	43	-26	839
Wall U-Value	0.2	403	57	0	756	43	-22	834
Wall U-Value	0.21	403	65	0	756	43	-25	839
Wall U-Value	0.27	404	61	0	758	43	-23	839
Wall U-Value	0.36	406	58	0	761	43	-22	841
Wall U-Value	0.47	408	54	0	765	44	-21	843
Roof U-value	0.14	404	0	0	758	43	0	801
Roof U-value	0.18	405	0	0	760	43	0	804
Roof U-value	0.29	409	0	0	767	44	0	811
Heating Source	GSHP	263	26	7	484	26	0	544
Heating Source	Gas CHP	362	101	45	738	40	0	924
Heating Source	Gas (91%)	406	9	9	763	43	0	824
Heating Source	Gas (91%) + SHW	406	56	9	763	43	0	871
Heating Source	Gas (86%)	418	9	9	786	45	0	849
Floor U-value	0.1	395	13	0	741	42	-5	790
Floor U-value	0.15	397	9	0	744	42	-4	792
Floor U-value	0.2	398	7	0	747	42	-3	794
Floor U-value	0.25	400	6	0	751	43	-2	797
Window U-value	1.1	377	87	0	709	40	-16	819
Window U-value	1.4	380	67	0	715	41	-13	810
Window U-value	0.9	383	92	0	717	41	-18	833
Window U-value	1.8	405	57	0	759	43	-11	848
Chiller Efficiency	5.5	342	26	0	644	37	0	707
Chiller Efficiency	4.5	349	23	0	658	38	0	718
Chiller Efficiency	3.5	361	21	0	679	39	0	739
AHU SFP	1.8	391	12	0	734	42	0	787
AHU SFP	2	395	11	0	743	42	0	796
AHU SFP	2.2	400	10	0	751	43	0	804
Lighting Efficacy	65	366	28	0	689	40	0	757
Lighting Efficacy	60	371	23	0	699	40	0	762
Lighting Efficacy	55	378	23	0	710	41	0	774

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	570	32	-29	649
Wall U-Value	0.15 (b)	306	63	0	572	32	-24	643
Wall U-Value	0.15	306	67	0	572	32	-26	646
Wall U-Value	0.2	307	57	0	574	32	-22	642
Wall U-Value	0.21	307	65	0	574	32	-25	647
Wall U-Value	0.27	309	61	0	577	32	-23	647
Wall U-Value	0.36	311	58	0	581	33	-22	649
Wall U-Value	0.47	313	54	0	585	33	-21	651
Roof U-value	0.14	307	0	0	573	32	0	605
Roof U-value	0.18	308	0	0	576	32	0	608
Roof U-value	0.29	312	0	0	583	33	0	615
Heating Source	GSHP	225	26	7	414	22	0	469
Heating Source	Gas CHP	290	101	45	581	32	0	758
Heating Source	Gas (91%)	319	9	9	598	34	0	649
Heating Source	Gas (91%) + SHW	319	56	9	598	34	0	696
Heating Source	Gas (86%)	327	9	9	613	35	0	665
Floor U-value	0.1	305	13	0	569	32	-5	609
Floor U-value	0.15	306	9	0	573	32	-4	610
Floor U-value	0.2	308	7	0	576	32	-3	613
Floor U-value	0.25	310	6	0	580	33	-2	616
Window U-value	1.1	276	87	0	516	29	-16	615
Window U-value	1.4	280	67	0	524	29	-13	608
Window U-value	0.9	282	92	0	525	29	-18	629
Window U-value	1.8	307	57	0	573	32	-11	651
Chiller Efficiency	5.5	250	26	0	470	27	0	522
Chiller Efficiency	4.5	257	23	0	482	27	0	533
Chiller Efficiency	3.5	268	21	0	503	28	0	552
AHU SFP	1.8	301	12	0	562	32	0	606
AHU SFP	2	306	11	0	571	32	0	614
AHU SFP	2.2	310	10	0	580	33	0	623
Lighting Efficacy	65	298	28	0	557	31	0	616
Lighting Efficacy	60	303	23	0	567	32	0	622
Lighting Efficacy	55	310	23	0	580	33	0	635

Capabilities on project:  
Building Engineering

Primary (EE1): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	315	19	-12	379
Wall U-Value	0.14	164	27	0	318	19	-6	358
Wall U-Value	0.16	164	51	0	320	19	-11	379
Wall U-Value	0.19	166	13	0	322	19	-3	352
Wall U-Value	0.21	166	24	0	324	19	-5	362
Wall U-Value	0.3	170	3	0	331	20	-1	354
Wall U-Value	0.39	174	10	0	338	20	-2	367
Roof U-value	0.15	172	15	0	336	20	-3	367
Roof U-value	0.2	173	13	0	337	20	-3	367
Roof U-value	0.25	173	11	0	338	20	-2	366
Heating Source	GSHP	62	30	14	121	7	0	172
Heating Source	Gas CHP	140	62	64	378	17	0	521
Heating Source	Gas (91%) + SHW	155	47	15	301	18	0	382
Heating Source	Gas (91%)	155	8	15	301	18	0	342
Heating Source	Gas (86%)	163	8	15	317	19	0	358
Floor U-value	0.1	158	11	0	308	18	-2	335
Floor U-value	0.15	161	8	0	313	19	-2	338
Floor U-value	0.2	163	6	0	318	19	-1	342
Floor U-value	0.25	166	5	0	323	19	-1	346
Window U-value	0.9	142	47	0	276	16	0	339
Window U-value	1.1	147	44	0	287	17	0	348
Window U-value	1.8	150	29	0	293	17	0	339
Window U-value	1.4	152	34	0	296	17	0	347
Lighting Efficacy	65	157	23	0	305	19	0	346
Lighting Efficacy	60	158	21	0	308	19	0	347
Lighting Efficacy	55	160	20	0	311	19	0	349

Capabilities on project:  
Building Engineering

Primary (EE2): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	164	10	-12	219
Wall U-Value	0.14	86	27	0	167	10	-6	199
Wall U-Value	0.16	87	51	0	169	10	-11	219
Wall U-Value	0.19	88	13	0	171	10	-3	192
Wall U-Value	0.21	89	24	0	173	10	-5	202
Wall U-Value	0.3	92	3	0	180	11	-1	193
Wall U-Value	0.39	96	10	0	187	11	-2	206
Roof U-value	0.15	93	15	0	182	11	-3	204
Roof U-value	0.2	94	13	0	183	11	-3	204
Roof U-value	0.25	94	11	0	184	11	-2	203
Heating Source	GSHP	27	30	14	54	3	0	101
Heating Source	Gas CHP	82	62	64	232	10	0	368
Heating Source	Gas (91%) + SHW	92	47	15	179	11	0	252
Heating Source	Gas (91%)	92	8	15	179	11	0	213
Heating Source	Gas (86%)	97	8	15	190	11	0	224
Floor U-value	0.1	87	11	0	170	10	-2	188
Floor U-value	0.15	89	8	0	174	10	-2	191
Floor U-value	0.2	92	6	0	179	11	-1	194
Floor U-value	0.25	94	5	0	184	11	-1	199
Window U-value	0.9	81	47	0	158	9	0	214
Window U-value	1.1	86	44	0	167	10	0	221
Window U-value	1.8	89	29	0	173	10	0	212
Window U-value	1.4	90	34	0	176	11	0	220
Lighting Efficacy	65	91	23	0	177	11	0	211
Lighting Efficacy	60	92	21	0	179	11	0	210
Lighting Efficacy	55	93	20	0	181	11	0	212

Capabilities on project:  
Building Engineering

Hotel (EE1): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	1073	63	-36	1194
Wall U-Value	0.14	568	44	0	1075	63	-17	1165
Wall U-Value	0.16	568	84	0	1077	63	-32	1192
Wall U-Value	0.19	569	22	0	1079	63	-8	1155
Wall U-Value	0.21	570	39	0	1080	63	-15	1167
Wall U-Value	0.3	573	5	0	1086	63	-2	1153
Wall U-Value	0.39	576	17	0	1092	64	-6	1166
Roof U-value	0.15	576	10	0	1091	64	-4	1161
Roof U-value	0.2	577	9	0	1094	64	-3	1163
Roof U-value	0.25	578	7	0	1096	64	-3	1165
Heating Source	GSHP	457	29	11	861	49	0	950
Heating Source	Gas CHP	542	74	52	1079	62	0	1266
Heating Source	Gas (91%) + SHW	563	35	11	1066	62	0	1176
Heating Source	Gas (91%)	576	8	11	1092	64	0	1175
Heating Source	Gas (86%)	586	8	11	1112	65	0	1196
Floor U-value	0.1	570	7	0	1080	63	-3	1148
Floor U-value	0.15	571	5	0	1082	63	-2	1149
Floor U-value	0.2	572	4	0	1084	63	-2	1150
Floor U-value	0.25	573	3	0	1087	64	-1	1152
Window U-value	1.1	547	87	0	1035	60	-17	1166
Window U-value	0.9	548	93	0	1036	60	-18	1172
Window U-value	1.4	550	68	0	1043	61	-13	1159
Window U-value	1.8	563	58	0	1066	62	-11	1175
Chiller Efficiency	5.5	546	31	0	1036	61	0	1128
Chiller Efficiency	4.5	549	27	0	1042	61	0	1131
Chiller Efficiency	3.5	554	25	0	1051	62	0	1138
AHU SFP	1.8	558	10	0	1058	62	0	1131
AHU SFP	2	564	10	0	1069	63	0	1141
AHU SFP	2.2	569	9	0	1080	63	0	1152
Lighting Efficacy	65	489	51	0	935	56	0	1042
Lighting Efficacy	60	491	46	0	939	56	0	1040
Lighting Efficacy	55	493	39	0	943	56	0	1038

Capabilities on project:  
Building Engineering

Hotel (EE2): Macroeconomic Costs (Central energy price, 3% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	843	50	-36	951
Wall U-Value	0.14	444	44	0	846	50	-17	923
Wall U-Value	0.16	445	84	0	847	50	-32	949
Wall U-Value	0.19	446	22	0	849	50	-8	913
Wall U-Value	0.21	446	39	0	851	50	-15	925
Wall U-Value	0.3	450	5	0	857	51	-2	911
Wall U-Value	0.39	453	17	0	864	51	-6	925
Roof U-value	0.15	453	10	0	863	51	-4	921
Roof U-value	0.2	454	9	0	866	51	-3	923
Roof U-value	0.25	455	7	0	868	52	-3	924
Heating Source	GSHP	325	29	11	614	36	0	690
Heating Source	Gas CHP	420	74	52	858	50	0	1033
Heating Source	Gas (91%) + SHW	446	35	11	851	50	0	948
Heating Source	Gas (91%)	458	8	11	873	52	0	944
Heating Source	Gas (86%)	469	8	11	894	53	0	967
Floor U-value	0.1	446	7	0	850	50	-3	905
Floor U-value	0.15	448	5	0	853	51	-2	907
Floor U-value	0.2	449	4	0	855	51	-2	909
Floor U-value	0.25	450	3	0	858	51	-1	911
Window U-value	0.9	431	93	0	820	49	-18	944
Window U-value	1.1	434	87	0	827	49	-17	947
Window U-value	1.4	439	68	0	837	50	-13	942
Window U-value	1.8	445	58	0	848	50	-11	945
Chiller Efficiency	5.5	437	31	0	834	50	0	915
Chiller Efficiency	4.5	439	27	0	838	50	0	915
Chiller Efficiency	3.5	442	25	0	844	50	0	920
AHU SFP	1.8	444	10	0	846	50	0	907
AHU SFP	2	450	10	0	857	51	0	918
AHU SFP	2.2	455	9	0	868	52	0	929
Lighting Efficacy	65	434	51	0	831	50	0	931
Lighting Efficacy	60	436	46	0	834	50	0	930
Lighting Efficacy	55	439	39	0	838	50	0	927

Capabilities on project:  
Building Engineering

# **Table E:**

## **Macroeconomic Costs**

### **Central energy price**

### **6% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	851	45	-15	948
Wall U-Value	0.15 (b)	647	55	0	852	45	-12	940
Wall U-Value	0.15	647	59	0	852	45	-13	943
Wall U-Value	0.2	648	50	0	854	45	-11	938
Wall U-Value	0.21	648	57	0	854	45	-13	943
Wall U-Value	0.27	649	54	0	855	45	-12	942
Wall U-Value	0.36	651	51	0	857	45	-11	942
Wall U-Value	0.47	653	48	0	860	45	-10	942
Roof U-value	0.14	648	0	0	853	45	0	898
Roof U-value	0.18	649	0	0	855	45	0	901
Roof U-value	0.29	654	0	0	862	46	0	907
Heating Source	ASHP	558	41	11	735	38	0	825
Heating Source	Gas CHP	620	132	84	839	44	0	1098
Heating Source	Gas (91%)	646	11	13	851	45	0	920
Heating Source	Gas (91%) + SHW	646	104	13	851	45	0	1012
Heating Source	Gas (86%)	653	11	13	861	46	0	930
Floor U-value	0.25	652	12	0	859	45	-3	914
Floor U-value	0.2	652	14	0	859	45	-3	916
Floor U-value	0.15	653	18	0	860	45	-4	920
Floor U-value	0.1	653	26	0	860	45	-6	926
Window U-value	1.4	644	15	0	848	45	-2	906
Window U-value	1.1	644	19	0	848	45	-2	910
Window U-value	0.9	647	20	0	853	45	-2	916
Window U-value	1.8	653	13	0	860	45	-1	917
Chiller Efficiency	5.5	533	30	0	703	37	0	770
Chiller Efficiency	4.5	545	27	0	718	38	0	783
Chiller Efficiency	3.5	564	25	0	743	39	0	808
AHU SFP	1.8	641	19	0	844	45	0	907
AHU SFP	2	646	17	0	852	45	0	914
AHU SFP	2.2	652	16	0	859	45	0	921
Lighting Efficacy	65	490	6	0	646	35	0	686
Lighting Efficacy	60	498	5	0	657	35	0	697
Lighting Efficacy	55	508	5	0	670	36	0	710

Capabilities on project:  
Building Engineering

Retail (EE2): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	660	35	-15	747
Wall U-Value	0.15 (b)	502	55	0	661	35	-12	739
Wall U-Value	0.15	502	59	0	661	35	-13	743
Wall U-Value	0.2	503	50	0	663	35	-11	737
Wall U-Value	0.21	503	57	0	663	35	-13	743
Wall U-Value	0.27	504	54	0	665	35	-12	742
Wall U-Value	0.36	506	51	0	668	36	-11	743
Wall U-Value	0.47	509	48	0	671	36	-10	744
Roof U-value	0.14	503	0	0	663	35	0	698
Roof U-value	0.18	505	0	0	665	35	0	701
Roof U-value	0.29	511	0	0	673	36	0	709
Heating Source	ASHP	406	41	11	534	28	0	614
Heating Source	Gas CHP	473	132	84	648	34	0	898
Heating Source	Gas (91%)	502	11	13	661	35	0	720
Heating Source	Gas (91%) + SHW	502	104	13	661	35	0	813
Heating Source	Gas (86%)	510	11	13	672	36	0	732
Floor U-value	0.1	496	26	0	653	35	-6	708
Floor U-value	0.15	497	18	0	655	35	-4	704
Floor U-value	0.2	498	14	0	656	35	-3	702
Floor U-value	0.25	502	12	0	662	35	-3	707
Window U-value	1.1	502	19	0	662	35	-2	714
Window U-value	1.4	502	15	0	662	35	-2	711
Window U-value	0.9	504	20	0	664	35	-2	718
Window U-value	1.8	508	13	0	670	36	-1	717
Chiller Efficiency	5.5	461	30	0	608	33	0	671
Chiller Efficiency	4.5	470	27	0	620	33	0	680
Chiller Efficiency	3.5	485	25	0	639	34	0	698
AHU SFP	1.8	497	19	0	655	35	0	709
AHU SFP	2	503	17	0	663	35	0	715
AHU SFP	2.2	508	16	0	670	36	0	722
Lighting Efficacy	65	453	6	0	597	32	0	635
Lighting Efficacy	60	460	5	0	607	32	0	645
Lighting Efficacy	55	469	5	0	618	33	0	656

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	449	25	-15	528
Wall U-Value	0.14	341	32	0	451	25	-7	502
Wall U-Value	0.16	342	62	0	452	25	-14	525
Wall U-Value	0.19	343	16	0	453	25	-4	491
Wall U-Value	0.21	343	28	0	454	25	-6	501
Wall U-Value	0.3	346	4	0	457	25	-1	486
Wall U-Value	0.39	348	12	0	460	26	-3	496
Roof U-value	0.15	334	17	0	442	25	-4	480
Roof U-value	0.2	336	16	0	445	25	-3	482
Roof U-value	0.25	338	13	0	447	25	-3	482
Heating Source	GSHP	160	26	6	210	11	0	253
Heating Source	Gas CHP	284	101	35	422	22	0	580
Heating Source	Gas (91%) + SHW	316	56	7	418	23	0	504
Heating Source	Gas (91%)	316	9	7	418	23	0	458
Heating Source	Gas (86%)	330	9	7	436	24	0	476
Floor U-value	0.1	337	13	0	446	25	-3	481
Floor U-value	0.15	340	9	0	449	25	-2	481
Floor U-value	0.2	342	7	0	452	25	-2	483
Floor U-value	0.25	344	6	0	455	25	-1	485
Window U-value	0.9	303	92	0	401	22	-10	505
Window U-value	1.1	312	87	0	412	23	-10	512
Window U-value	1.8	315	57	0	416	23	-6	490
Window U-value	1.4	319	67	0	421	23	-7	505
Lighting Efficacy	65	288	28	0	382	22	0	432
Lighting Efficacy	60	292	23	0	387	22	0	432
Lighting Efficacy	55	295	23	0	391	22	0	436

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	359	20	-15	432
Wall U-Value	0.14	272	32	0	360	20	-7	405
Wall U-Value	0.16	273	62	0	361	20	-14	429
Wall U-Value	0.19	274	16	0	363	20	-4	395
Wall U-Value	0.21	275	28	0	363	20	-6	406
Wall U-Value	0.3	277	4	0	367	20	-1	390
Wall U-Value	0.39	279	12	0	369	21	-3	400
Roof U-value	0.15	277	17	0	367	20	-4	400
Roof U-value	0.2	279	16	0	369	20	-3	402
Roof U-value	0.25	281	13	0	371	21	-3	402
Heating Source	GSHP	136	26	6	179	9	0	220
Heating Source	Gas CHP	242	101	35	360	19	0	514
Heating Source	Gas (91%) + SHW	270	56	7	357	20	0	439
Heating Source	Gas (91%)	270	9	7	357	20	0	392
Heating Source	Gas (86%)	281	9	7	371	21	0	408
Floor U-value	0.1	267	13	0	353	20	-3	383
Floor U-value	0.15	269	9	0	356	20	-2	383
Floor U-value	0.2	271	7	0	359	20	-2	384
Floor U-value	0.25	273	6	0	361	20	-1	386
Window U-value	0.9	252	92	0	333	18	-10	433
Window U-value	1.1	259	87	0	343	19	-10	439
Window U-value	1.8	262	57	0	347	19	-6	417
Window U-value	1.4	266	67	0	351	19	-7	430
Lighting Efficacy	65	231	28	0	306	17	0	352
Lighting Efficacy	60	235	23	0	311	18	0	351
Lighting Efficacy	55	239	23	0	316	18	0	357

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	530	29	-17	617
Wall U-Value	0.15 (b)	402	63	0	531	29	-14	609
Wall U-Value	0.15	402	67	0	531	29	-15	612
Wall U-Value	0.2	403	57	0	532	29	-13	605
Wall U-Value	0.21	403	65	0	532	29	-14	612
Wall U-Value	0.27	404	61	0	533	29	-14	610
Wall U-Value	0.36	406	58	0	536	29	-13	610
Wall U-Value	0.47	408	54	0	538	29	-12	610
Roof U-value	0.14	404	0	0	533	29	0	562
Roof U-value	0.18	405	0	0	535	29	0	564
Roof U-value	0.29	409	0	0	539	29	0	569
Heating Source	GSHP	263	26	6	346	18	0	396
Heating Source	Gas CHP	362	101	35	515	27	0	677
Heating Source	Gas (91%)	406	9	7	536	29	0	582
Heating Source	Gas (91%) + SHW	406	56	7	536	29	0	628
Heating Source	Gas (86%)	418	9	7	552	30	0	598
Floor U-value	0.1	395	13	0	521	28	-3	560
Floor U-value	0.15	397	9	0	524	28	-2	559
Floor U-value	0.2	398	7	0	526	29	-2	560
Floor U-value	0.25	400	6	0	528	29	-1	561
Window U-value	1.1	377	87	0	498	27	-10	603
Window U-value	1.4	380	67	0	502	27	-7	589
Window U-value	0.9	383	92	0	505	27	-10	615
Window U-value	1.8	405	57	0	534	29	-6	614
Chiller Efficiency	5.5	342	26	0	452	25	0	503
Chiller Efficiency	4.5	349	23	0	462	25	0	510
Chiller Efficiency	3.5	361	21	0	477	26	0	524
AHU SFP	1.8	391	12	0	516	28	0	555
AHU SFP	2	395	11	0	522	28	0	561
AHU SFP	2.2	400	10	0	528	29	0	567
Lighting Efficacy	65	366	28	0	483	27	0	538
Lighting Efficacy	60	371	23	0	491	27	0	540
Lighting Efficacy	55	378	23	0	499	27	0	549

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	403	22	-17	483
Wall U-Value	0.15 (b)	306	63	0	404	22	-14	475
Wall U-Value	0.15	306	67	0	404	22	-15	478
Wall U-Value	0.2	307	57	0	405	22	-13	472
Wall U-Value	0.21	307	65	0	406	22	-14	478
Wall U-Value	0.27	309	61	0	407	22	-14	477
Wall U-Value	0.36	311	58	0	410	22	-13	477
Wall U-Value	0.47	313	54	0	412	22	-12	477
Roof U-value	0.14	307	0	0	405	22	0	426
Roof U-value	0.18	308	0	0	407	22	0	428
Roof U-value	0.29	312	0	0	411	22	0	433
Heating Source	GSHP	225	26	6	295	15	0	343
Heating Source	Gas CHP	290	101	35	407	21	0	564
Heating Source	Gas (91%)	319	9	7	421	23	0	460
Heating Source	Gas (91%) + SHW	319	56	7	421	23	0	507
Heating Source	Gas (86%)	327	9	7	432	23	0	471
Floor U-value	0.1	305	13	0	402	22	-3	434
Floor U-value	0.15	306	9	0	404	22	-2	433
Floor U-value	0.2	308	7	0	407	22	-2	434
Floor U-value	0.25	310	6	0	409	22	-1	436
Window U-value	1.1	276	87	0	364	20	-10	461
Window U-value	1.4	280	67	0	370	20	-7	449
Window U-value	0.9	282	92	0	371	20	-10	473
Window U-value	1.8	307	57	0	405	22	-6	478
Chiller Efficiency	5.5	250	26	0	330	18	0	374
Chiller Efficiency	4.5	257	23	0	340	18	0	381
Chiller Efficiency	3.5	268	21	0	354	19	0	394
AHU SFP	1.8	301	12	0	397	21	0	430
AHU SFP	2	306	11	0	403	22	0	435
AHU SFP	2.2	310	10	0	409	22	0	442
Lighting Efficacy	65	298	28	0	393	21	0	442
Lighting Efficacy	60	303	23	0	400	22	0	445
Lighting Efficacy	55	310	23	0	409	22	0	454

Capabilities on project:  
Building Engineering

Primary (EE1): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	219	12	-5	283
Wall U-Value	0.14	164	27	0	221	12	-2	258
Wall U-Value	0.16	164	51	0	222	13	-5	281
Wall U-Value	0.19	166	13	0	224	13	-1	249
Wall U-Value	0.21	166	24	0	225	13	-2	259
Wall U-Value	0.3	170	3	0	230	13	0	246
Wall U-Value	0.39	174	10	0	235	13	-1	257
Roof U-value	0.15	172	15	0	233	13	-1	259
Roof U-value	0.2	173	13	0	234	13	-1	259
Roof U-value	0.25	173	11	0	234	13	-1	258
Heating Source	GSHP	62	30	10	86	5	0	130
Heating Source	Gas CHP	140	62	45	260	11	0	379
Heating Source	Gas (91%) + SHW	155	47	11	210	12	0	279
Heating Source	Gas (91%)	155	8	11	210	12	0	240
Heating Source	Gas (86%)	163	8	11	220	12	0	251
Floor U-value	0.1	158	11	0	214	12	-1	236
Floor U-value	0.15	161	8	0	217	12	-1	237
Floor U-value	0.2	163	6	0	221	12	-1	239
Floor U-value	0.25	166	5	0	224	13	0	241
Window U-value	0.9	142	47	0	192	11	0	250
Window U-value	1.1	147	44	0	200	11	0	255
Window U-value	1.8	150	29	0	204	11	0	244
Window U-value	1.4	152	34	0	206	12	0	251
Lighting Efficacy	65	157	23	0	210	12	0	245
Lighting Efficacy	60	158	21	0	212	12	0	245
Lighting Efficacy	55	160	20	0	214	12	0	247

Capabilities on project:  
Building Engineering

Primary (EE2): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	114	6	-5	172
Wall U-Value	0.14	86	27	0	116	7	-2	147
Wall U-Value	0.16	87	51	0	117	7	-5	170
Wall U-Value	0.19	88	13	0	119	7	-1	138
Wall U-Value	0.21	89	24	0	120	7	-2	148
Wall U-Value	0.3	92	3	0	124	7	0	134
Wall U-Value	0.39	96	10	0	129	7	-1	146
Roof U-value	0.15	93	15	0	126	7	-1	146
Roof U-value	0.2	94	13	0	126	7	-1	146
Roof U-value	0.25	94	11	0	127	7	-1	144
Heating Source	GSHP	27	30	10	38	2	0	80
Heating Source	Gas CHP	82	62	45	159	7	0	273
Heating Source	Gas (91%) + SHW	92	47	11	124	7	0	189
Heating Source	Gas (91%)	92	8	11	124	7	0	150
Heating Source	Gas (86%)	97	8	11	131	8	0	157
Floor U-value	0.1	87	11	0	117	7	-1	134
Floor U-value	0.15	89	8	0	121	7	-1	135
Floor U-value	0.2	92	6	0	124	7	-1	136
Floor U-value	0.25	94	5	0	127	7	0	139
Window U-value	0.9	81	47	0	109	6	0	162
Window U-value	1.1	86	44	0	116	7	0	166
Window U-value	1.8	89	29	0	120	7	0	156
Window U-value	1.4	90	34	0	122	7	0	162
Lighting Efficacy	65	91	23	0	122	7	0	152
Lighting Efficacy	60	92	21	0	124	7	0	151
Lighting Efficacy	55	93	20	0	125	7	0	152

Capabilities on project:  
Building Engineering

Hotel (EE1): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	749	42	-21	864
Wall U-Value	0.14	568	44	0	751	42	-10	827
Wall U-Value	0.16	568	84	0	752	42	-19	859
Wall U-Value	0.19	569	22	0	753	42	-5	812
Wall U-Value	0.21	570	39	0	754	42	-9	826
Wall U-Value	0.3	573	5	0	758	42	-1	804
Wall U-Value	0.39	576	17	0	762	42	-4	818
Roof U-value	0.15	576	10	0	761	42	-2	812
Roof U-value	0.2	577	9	0	763	43	-2	813
Roof U-value	0.25	578	7	0	765	43	-2	813
Heating Source	GSHP	457	29	8	604	33	0	674
Heating Source	Gas CHP	542	74	41	749	41	0	904
Heating Source	Gas (91%) + SHW	563	35	9	744	41	0	830
Heating Source	Gas (91%)	576	8	9	762	42	0	821
Heating Source	Gas (86%)	586	8	9	775	43	0	835
Floor U-value	0.1	570	7	0	754	42	-2	802
Floor U-value	0.15	571	5	0	755	42	-1	802
Floor U-value	0.2	572	4	0	757	42	-1	802
Floor U-value	0.25	573	3	0	758	42	-1	803
Window U-value	1.1	547	87	0	723	40	-10	841
Window U-value	0.9	548	93	0	724	40	-10	847
Window U-value	1.4	550	68	0	728	41	-7	829
Window U-value	1.8	563	58	0	745	41	-6	837
Chiller Efficiency	5.5	546	31	0	722	40	0	794
Chiller Efficiency	4.5	549	27	0	726	41	0	794
Chiller Efficiency	3.5	554	25	0	733	41	0	799
AHU SFP	1.8	558	10	0	738	41	0	790
AHU SFP	2	564	10	0	746	42	0	797
AHU SFP	2.2	569	9	0	753	42	0	804
Lighting Efficacy	65	489	51	0	648	37	0	736
Lighting Efficacy	60	491	46	0	650	37	0	733
Lighting Efficacy	55	493	39	0	653	37	0	729

Capabilities on project:  
Building Engineering

Hotel (EE2): Macroeconomic Costs (Central energy price, 6% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	586	33	-21	692
Wall U-Value	0.14	444	44	0	588	33	-10	655
Wall U-Value	0.16	445	84	0	589	33	-19	687
Wall U-Value	0.19	446	22	0	590	33	-5	640
Wall U-Value	0.21	446	39	0	591	33	-9	655
Wall U-Value	0.3	450	5	0	595	34	-1	633
Wall U-Value	0.39	453	17	0	600	34	-4	647
Roof U-value	0.15	453	10	0	599	34	-2	641
Roof U-value	0.2	454	9	0	601	34	-2	642
Roof U-value	0.25	455	7	0	603	34	-2	643
Heating Source	GSHP	325	29	8	429	24	0	491
Heating Source	Gas CHP	420	74	41	591	32	0	738
Heating Source	Gas (91%) + SHW	446	35	9	591	33	0	669
Heating Source	Gas (91%)	458	8	9	606	34	0	657
Heating Source	Gas (86%)	469	8	9	621	35	0	672
Floor U-value	0.1	446	7	0	591	33	-2	630
Floor U-value	0.15	448	5	0	592	33	-1	630
Floor U-value	0.2	449	4	0	594	34	-1	631
Floor U-value	0.25	450	3	0	596	34	-1	632
Window U-value	0.9	431	93	0	570	32	-10	685
Window U-value	1.1	434	87	0	574	32	-10	684
Window U-value	1.4	439	68	0	581	33	-7	674
Window U-value	1.8	445	58	0	589	33	-6	674
Chiller Efficiency	5.5	437	31	0	578	33	0	642
Chiller Efficiency	4.5	439	27	0	581	33	0	641
Chiller Efficiency	3.5	442	25	0	586	33	0	644
AHU SFP	1.8	444	10	0	587	33	0	631
AHU SFP	2	450	10	0	595	34	0	638
AHU SFP	2.2	455	9	0	603	34	0	646
Lighting Efficacy	65	434	51	0	576	33	0	659
Lighting Efficacy	60	436	46	0	578	33	0	657
Lighting Efficacy	55	439	39	0	581	33	0	653

Capabilities on project:  
Building Engineering

# **Table F:**

## **Financial Costs**

### **Central energy price**

### **7% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	874	-	-12	928
Wall U-Value	0.15 (b)	647	55	0	875	-	-10	920
Wall U-Value	0.15	647	59	0	875	-	-11	924
Wall U-Value	0.2	648	50	0	877	-	-9	918
Wall U-Value	0.21	648	57	0	877	-	-11	923
Wall U-Value	0.27	649	54	0	878	-	-10	922
Wall U-Value	0.36	651	51	0	880	-	-9	922
Wall U-Value	0.47	653	48	0	883	-	-9	922
Roof U-value	0.14	648	0	0	876	-	0	876
Roof U-value	0.18	649	0	0	879	-	0	879
Roof U-value	0.29	654	0	0	885	-	0	885
Heating Source	ASHP	558	41	10	756	-	0	807
Heating Source	Gas CHP	620	132	78	861	-	0	1071
Heating Source	Gas (91%)	646	11	12	874	-	0	897
Heating Source	Gas (91%) + SHW	646	104	12	874	-	0	990
Heating Source	Gas (86%)	653	11	12	884	-	0	907
Floor U-value	0.25	652	12	0	882	-	-2	892
Floor U-value	0.2	652	14	0	883	-	-3	894
Floor U-value	0.15	653	18	0	883	-	-3	898
Floor U-value	0.1	653	26	0	884	-	-5	905
Window U-value	1.4	644	15	0	871	-	-1	885
Window U-value	1.1	644	19	0	871	-	-2	889
Window U-value	0.9	647	20	0	876	-	-2	894
Window U-value	1.8	653	13	0	883	-	-1	895
Chiller Efficiency	5.5	533	30	0	721	-	0	752
Chiller Efficiency	4.5	545	27	0	737	-	0	764
Chiller Efficiency	3.5	564	25	0	763	-	0	788
AHU SFP	1.8	641	19	0	867	-	0	885
AHU SFP	2	646	17	0	875	-	0	892
AHU SFP	2.2	652	16	0	882	-	0	899
Lighting Efficacy	65	490	6	0	662	-	0	668
Lighting Efficacy	60	498	5	0	674	-	0	679
Lighting Efficacy	55	508	5	0	687	-	0	692

Capabilities on project:  
Building Engineering

Retail (EE2): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	677	-	-12	731
Wall U-Value	0.15 (b)	502	55	0	679	-	-10	724
Wall U-Value	0.15	502	59	0	679	-	-11	727
Wall U-Value	0.2	503	50	0	680	-	-9	721
Wall U-Value	0.21	503	57	0	680	-	-11	727
Wall U-Value	0.27	504	54	0	682	-	-10	726
Wall U-Value	0.36	506	51	0	685	-	-9	726
Wall U-Value	0.47	509	48	0	688	-	-9	727
Roof U-value	0.14	503	0	0	680	-	0	680
Roof U-value	0.18	505	0	0	683	-	0	683
Roof U-value	0.29	511	0	0	691	-	0	691
Heating Source	ASHP	406	41	10	549	-	0	601
Heating Source	Gas CHP	473	132	78	664	-	0	874
Heating Source	Gas (91%)	502	11	12	679	-	0	702
Heating Source	Gas (91%) + SHW	502	104	12	679	-	0	794
Heating Source	Gas (86%)	510	11	12	690	-	0	712
Floor U-value	0.1	496	26	0	671	-	-5	692
Floor U-value	0.15	497	18	0	672	-	-3	687
Floor U-value	0.2	498	14	0	674	-	-3	685
Floor U-value	0.25	502	12	0	680	-	-2	689
Window U-value	1.1	502	19	0	679	-	-2	697
Window U-value	1.4	502	15	0	680	-	-1	693
Window U-value	0.9	504	20	0	681	-	-2	700
Window U-value	1.8	508	13	0	687	-	-1	699
Chiller Efficiency	5.5	461	30	0	623	-	0	654
Chiller Efficiency	4.5	470	27	0	636	-	0	663
Chiller Efficiency	3.5	485	25	0	656	-	0	681
AHU SFP	1.8	497	19	0	672	-	0	691
AHU SFP	2	503	17	0	680	-	0	697
AHU SFP	2.2	508	16	0	688	-	0	704
Lighting Efficacy	65	453	6	0	612	-	0	619
Lighting Efficacy	60	460	5	0	622	-	0	628
Lighting Efficacy	55	469	5	0	634	-	0	639

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	459	-	-13	515
Wall U-Value	0.14	341	32	0	461	-	-6	488
Wall U-Value	0.16	342	62	0	462	-	-11	512
Wall U-Value	0.19	343	16	0	463	-	-3	476
Wall U-Value	0.21	343	28	0	464	-	-5	487
Wall U-Value	0.3	346	4	0	467	-	-1	470
Wall U-Value	0.39	348	12	0	470	-	-2	480
Roof U-value	0.15	334	17	0	452	-	-3	466
Roof U-value	0.2	336	16	0	454	-	-3	467
Roof U-value	0.25	338	13	0	457	-	-2	468
Heating Source	GSHP	160	26	5	216	-	0	247
Heating Source	Gas CHP	284	101	32	430	-	0	563
Heating Source	Gas (91%) + SHW	316	56	6	428	-	0	490
Heating Source	Gas (91%)	316	9	6	428	-	0	443
Heating Source	Gas (86%)	330	9	6	445	-	0	461
Floor U-value	0.1	337	13	0	456	-	-2	466
Floor U-value	0.15	340	9	0	459	-	-2	466
Floor U-value	0.2	342	7	0	462	-	-1	468
Floor U-value	0.25	344	6	0	465	-	-1	470
Window U-value	0.9	303	92	0	410	-	-9	494
Window U-value	1.1	312	87	0	422	-	-8	500
Window U-value	1.8	315	57	0	425	-	-5	477
Window U-value	1.4	319	67	0	431	-	-6	492
Lighting Efficacy	65	288	28	0	389	-	0	418
Lighting Efficacy	60	292	23	0	394	-	0	417
Lighting Efficacy	55	295	23	0	398	-	0	421

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	367	-	-13	423
Wall U-Value	0.14	272	32	0	368	-	-6	394
Wall U-Value	0.16	273	62	0	369	-	-11	419
Wall U-Value	0.19	274	16	0	371	-	-3	384
Wall U-Value	0.21	275	28	0	371	-	-5	394
Wall U-Value	0.3	277	4	0	375	-	-1	378
Wall U-Value	0.39	279	12	0	378	-	-2	388
Roof U-value	0.15	277	17	0	375	-	-3	389
Roof U-value	0.2	279	16	0	377	-	-3	390
Roof U-value	0.25	281	13	0	380	-	-2	390
Heating Source	GSHP	136	26	5	184	-	0	215
Heating Source	Gas CHP	242	101	32	366	-	0	499
Heating Source	Gas (91%) + SHW	270	56	6	365	-	0	427
Heating Source	Gas (91%)	270	9	6	365	-	0	380
Heating Source	Gas (86%)	281	9	6	380	-	0	395
Floor U-value	0.1	267	13	0	361	-	-2	372
Floor U-value	0.15	269	9	0	364	-	-2	372
Floor U-value	0.2	271	7	0	367	-	-1	373
Floor U-value	0.25	273	6	0	369	-	-1	374
Window U-value	0.9	252	92	0	340	-	-9	424
Window U-value	1.1	259	87	0	351	-	-8	429
Window U-value	1.8	262	57	0	355	-	-5	407
Window U-value	1.4	266	67	0	359	-	-6	420
Lighting Efficacy	65	231	28	0	312	-	0	340
Lighting Efficacy	60	235	23	0	317	-	0	340
Lighting Efficacy	55	239	23	0	323	-	0	345

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	543	-	-14	604
Wall U-Value	0.15 (b)	402	63	0	544	-	-12	595
Wall U-Value	0.15	402	67	0	544	-	-12	599
Wall U-Value	0.2	403	57	0	545	-	-11	591
Wall U-Value	0.21	403	65	0	545	-	-12	598
Wall U-Value	0.27	404	61	0	546	-	-11	596
Wall U-Value	0.36	406	58	0	549	-	-11	596
Wall U-Value	0.47	408	54	0	551	-	-10	595
Roof U-value	0.14	404	0	0	546	-	0	546
Roof U-value	0.18	405	0	0	548	-	0	548
Roof U-value	0.29	409	0	0	552	-	0	552
Heating Source	GSHP	263	26	5	356	-	0	387
Heating Source	Gas CHP	362	101	32	526	-	0	659
Heating Source	Gas (91%)	406	9	6	549	-	0	565
Heating Source	Gas (91%) + SHW	406	56	6	549	-	0	612
Heating Source	Gas (86%)	418	9	6	565	-	0	581
Floor U-value	0.1	395	13	0	534	-	-2	545
Floor U-value	0.15	397	9	0	536	-	-2	544
Floor U-value	0.2	398	7	0	539	-	-1	544
Floor U-value	0.25	400	6	0	541	-	-1	546
Window U-value	1.1	377	87	0	510	-	-8	589
Window U-value	1.4	380	67	0	514	-	-6	575
Window U-value	0.9	383	92	0	517	-	-9	601
Window U-value	1.8	405	57	0	547	-	-5	599
Chiller Efficiency	5.5	342	26	0	462	-	0	488
Chiller Efficiency	4.5	349	23	0	472	-	0	495
Chiller Efficiency	3.5	361	21	0	488	-	0	509
AHU SFP	1.8	391	12	0	528	-	0	540
AHU SFP	2	395	11	0	534	-	0	545
AHU SFP	2.2	400	10	0	541	-	0	551
Lighting Efficacy	65	366	28	0	495	-	0	523
Lighting Efficacy	60	371	23	0	502	-	0	525
Lighting Efficacy	55	378	23	0	510	-	0	533

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	413	-	-14	474
Wall U-Value	0.15 (b)	306	63	0	414	-	-12	466
Wall U-Value	0.15	306	67	0	414	-	-12	469
Wall U-Value	0.2	307	57	0	416	-	-11	462
Wall U-Value	0.21	307	65	0	416	-	-12	469
Wall U-Value	0.27	309	61	0	417	-	-11	467
Wall U-Value	0.36	311	58	0	420	-	-11	467
Wall U-Value	0.47	313	54	0	423	-	-10	467
Roof U-value	0.14	307	0	0	415	-	0	415
Roof U-value	0.18	308	0	0	417	-	0	417
Roof U-value	0.29	312	0	0	421	-	0	421
Heating Source	GSHP	225	26	5	304	-	0	335
Heating Source	Gas CHP	290	101	32	416	-	0	549
Heating Source	Gas (91%)	319	9	6	432	-	0	447
Heating Source	Gas (91%) + SHW	319	56	6	432	-	0	494
Heating Source	Gas (86%)	327	9	6	442	-	0	458
Floor U-value	0.1	305	13	0	412	-	-2	423
Floor U-value	0.15	306	9	0	414	-	-2	422
Floor U-value	0.2	308	7	0	417	-	-1	423
Floor U-value	0.25	310	6	0	420	-	-1	425
Window U-value	1.1	276	87	0	373	-	-8	452
Window U-value	1.4	280	67	0	379	-	-6	440
Window U-value	0.9	282	92	0	381	-	-9	465
Window U-value	1.8	307	57	0	415	-	-5	467
Chiller Efficiency	5.5	250	26	0	338	-	0	364
Chiller Efficiency	4.5	257	23	0	348	-	0	371
Chiller Efficiency	3.5	268	21	0	363	-	0	384
AHU SFP	1.8	301	12	0	407	-	0	418
AHU SFP	2	306	11	0	413	-	0	424
AHU SFP	2.2	310	10	0	420	-	0	430
Lighting Efficacy	65	298	28	0	402	-	0	430
Lighting Efficacy	60	303	23	0	410	-	0	433
Lighting Efficacy	55	310	23	0	420	-	0	442

Capabilities on project:  
Building Engineering

Primary (EE1): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	223	-	-4	277
Wall U-Value	0.14	164	27	0	226	-	-2	251
Wall U-Value	0.16	164	51	0	227	-	-4	274
Wall U-Value	0.19	166	13	0	228	-	-1	241
Wall U-Value	0.21	166	24	0	230	-	-2	252
Wall U-Value	0.3	170	3	0	235	-	0	238
Wall U-Value	0.39	174	10	0	240	-	-1	249
Roof U-value	0.15	172	15	0	238	-	-1	251
Roof U-value	0.2	173	13	0	238	-	-1	251
Roof U-value	0.25	173	11	0	239	-	-1	249
Heating Source	GSHP	62	30	9	88	-	0	127
Heating Source	Gas CHP	140	62	41	265	-	0	368
Heating Source	Gas (91%) + SHW	155	47	10	214	-	0	271
Heating Source	Gas (91%)	155	8	10	214	-	0	232
Heating Source	Gas (86%)	163	8	10	224	-	0	242
Floor U-value	0.1	158	11	0	218	-	-1	228
Floor U-value	0.15	161	8	0	222	-	-1	229
Floor U-value	0.2	163	6	0	225	-	0	231
Floor U-value	0.25	166	5	0	229	-	0	233
Window U-value	0.9	142	47	0	196	-	0	243
Window U-value	1.1	147	44	0	204	-	0	247
Window U-value	1.8	150	29	0	208	-	0	237
Window U-value	1.4	152	34	0	210	-	0	244
Lighting Efficacy	65	157	23	0	214	-	0	237
Lighting Efficacy	60	158	21	0	216	-	0	237
Lighting Efficacy	55	160	20	0	218	-	0	238

Capabilities on project:  
Building Engineering

Primary (EE2): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	116	-	-4	169
Wall U-Value	0.14	86	27	0	118	-	-2	143
Wall U-Value	0.16	87	51	0	119	-	-4	167
Wall U-Value	0.19	88	13	0	121	-	-1	133
Wall U-Value	0.21	89	24	0	122	-	-2	144
Wall U-Value	0.3	92	3	0	127	-	0	130
Wall U-Value	0.39	96	10	0	131	-	-1	141
Roof U-value	0.15	93	15	0	128	-	-1	142
Roof U-value	0.2	94	13	0	129	-	-1	141
Roof U-value	0.25	94	11	0	129	-	-1	139
Heating Source	GSHP	27	30	9	39	-	0	78
Heating Source	Gas CHP	82	62	41	162	-	0	265
Heating Source	Gas (91%) + SHW	92	47	10	126	-	0	183
Heating Source	Gas (91%)	92	8	10	126	-	0	144
Heating Source	Gas (86%)	97	8	10	134	-	0	151
Floor U-value	0.1	87	11	0	120	-	-1	130
Floor U-value	0.15	89	8	0	123	-	-1	130
Floor U-value	0.2	92	6	0	126	-	0	132
Floor U-value	0.25	94	5	0	129	-	0	134
Window U-value	0.9	81	47	0	111	-	0	158
Window U-value	1.1	86	44	0	118	-	0	162
Window U-value	1.8	89	29	0	122	-	0	151
Window U-value	1.4	90	34	0	124	-	0	158
Lighting Efficacy	65	91	23	0	125	-	0	147
Lighting Efficacy	60	92	21	0	126	-	0	147
Lighting Efficacy	55	93	20	0	127	-	0	147

Capabilities on project:  
Building Engineering

Hotel (EE1): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	765	-	-17	842
Wall U-Value	0.14	568	44	0	767	-	-8	803
Wall U-Value	0.16	568	84	0	768	-	-16	837
Wall U-Value	0.19	569	22	0	769	-	-4	787
Wall U-Value	0.21	570	39	0	770	-	-7	802
Wall U-Value	0.3	573	5	0	774	-	-1	779
Wall U-Value	0.39	576	17	0	778	-	-3	792
Roof U-value	0.15	576	10	0	778	-	-2	786
Roof U-value	0.2	577	9	0	780	-	-2	787
Roof U-value	0.25	578	7	0	781	-	-1	787
Heating Source	GSHP	457	29	8	618	-	0	655
Heating Source	Gas CHP	542	74	38	764	-	0	875
Heating Source	Gas (91%) + SHW	563	35	8	761	-	0	804
Heating Source	Gas (91%)	576	8	8	779	-	0	794
Heating Source	Gas (86%)	586	8	8	792	-	0	808
Floor U-value	0.1	570	7	0	770	-	-1	776
Floor U-value	0.15	571	5	0	772	-	-1	776
Floor U-value	0.2	572	4	0	773	-	-1	777
Floor U-value	0.25	573	3	0	775	-	-1	778
Window U-value	1.1	547	87	0	739	-	-8	818
Window U-value	0.9	548	93	0	740	-	-9	824
Window U-value	1.4	550	68	0	744	-	-6	805
Window U-value	1.8	563	58	0	761	-	-5	813
Chiller Efficiency	5.5	546	31	0	737	-	0	768
Chiller Efficiency	4.5	549	27	0	742	-	0	769
Chiller Efficiency	3.5	554	25	0	748	-	0	774
AHU SFP	1.8	558	10	0	754	-	0	764
AHU SFP	2	564	10	0	762	-	0	771
AHU SFP	2.2	569	9	0	769	-	0	779
Lighting Efficacy	65	489	51	0	660	-	0	711
Lighting Efficacy	60	491	46	0	663	-	0	708
Lighting Efficacy	55	493	39	0	666	-	0	705

Capabilities on project:  
Building Engineering

Hotel (EE2): Financial Costs (Central energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	598	-	-17	674
Wall U-Value	0.14	444	44	0	600	-	-8	636
Wall U-Value	0.16	445	84	0	601	-	-16	669
Wall U-Value	0.19	446	22	0	602	-	-4	620
Wall U-Value	0.21	446	39	0	603	-	-7	635
Wall U-Value	0.3	450	5	0	607	-	-1	612
Wall U-Value	0.39	453	17	0	612	-	-3	626
Roof U-value	0.15	453	10	0	612	-	-2	620
Roof U-value	0.2	454	9	0	613	-	-2	621
Roof U-value	0.25	455	7	0	615	-	-1	621
Heating Source	GSHP	325	29	8	439	-	0	476
Heating Source	Gas CHP	420	74	38	602	-	0	713
Heating Source	Gas (91%) + SHW	446	35	8	603	-	0	647
Heating Source	Gas (91%)	458	8	8	618	-	0	634
Heating Source	Gas (86%)	469	8	8	633	-	0	649
Floor U-value	0.1	446	7	0	603	-	-1	609
Floor U-value	0.15	448	5	0	604	-	-1	609
Floor U-value	0.2	449	4	0	606	-	-1	610
Floor U-value	0.25	450	3	0	608	-	-1	611
Window U-value	0.9	431	93	0	582	-	-9	666
Window U-value	1.1	434	87	0	586	-	-8	665
Window U-value	1.4	439	68	0	593	-	-6	654
Window U-value	1.8	445	58	0	601	-	-5	654
Chiller Efficiency	5.5	437	31	0	590	-	0	621
Chiller Efficiency	4.5	439	27	0	593	-	0	620
Chiller Efficiency	3.5	442	25	0	597	-	0	623
AHU SFP	1.8	444	10	0	599	-	0	610
AHU SFP	2	450	10	0	607	-	0	617
AHU SFP	2.2	455	9	0	615	-	0	624
Lighting Efficacy	65	434	51	0	587	-	0	638
Lighting Efficacy	60	436	46	0	589	-	0	635
Lighting Efficacy	55	439	39	0	593	-	0	632

Capabilities on project:  
Building Engineering

# **Table G:**

## **Financial Costs**

### **Low energy price**

### **7% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	688	-	-12	742
Wall U-Value	0.15 (b)	647	55	0	689	-	-10	734
Wall U-Value	0.15	647	59	0	689	-	-11	737
Wall U-Value	0.2	648	50	0	689	-	-9	730
Wall U-Value	0.21	648	57	0	690	-	-11	736
Wall U-Value	0.27	649	54	0	691	-	-10	734
Wall U-Value	0.36	651	51	0	692	-	-9	733
Wall U-Value	0.47	653	48	0	694	-	-9	732
Roof U-value	0.14	648	0	0	689	-	0	689
Roof U-value	0.18	649	0	0	691	-	0	691
Roof U-value	0.29	654	0	0	695	-	0	695
Heating Source	ASHP	558	41	10	605	-	0	656
Heating Source	Gas CHP	620	132	78	671	-	0	881
Heating Source	Gas (91%)	646	11	12	688	-	0	710
Heating Source	Gas (91%) + SHW	646	104	12	688	-	0	803
Heating Source	Gas (86%)	653	11	12	694	-	0	717
Floor U-value	0.25	652	12	0	695	-	-2	705
Floor U-value	0.2	652	14	0	695	-	-3	707
Floor U-value	0.15	653	18	0	696	-	-3	711
Floor U-value	0.1	653	26	0	697	-	-5	718
Window U-value	1.4	644	15	0	685	-	-1	698
Window U-value	1.1	644	19	0	685	-	-2	702
Window U-value	0.9	647	20	0	688	-	-2	707
Window U-value	1.8	653	13	0	694	-	-1	706
Chiller Efficiency	5.5	533	30	0	564	-	0	595
Chiller Efficiency	4.5	545	27	0	577	-	0	604
Chiller Efficiency	3.5	564	25	0	598	-	0	623
AHU SFP	1.8	641	19	0	681	-	0	699
AHU SFP	2	646	17	0	687	-	0	704
AHU SFP	2.2	652	16	0	693	-	0	710
Lighting Efficacy	65	490	6	0	515	-	0	521
Lighting Efficacy	60	498	5	0	524	-	0	530
Lighting Efficacy	55	508	5	0	535	-	0	540

Capabilities on project:  
Building Engineering

Retail (EE2): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	529	-	-12	583
Wall U-Value	0.15 (b)	502	55	0	530	-	-10	575
Wall U-Value	0.15	502	59	0	530	-	-11	578
Wall U-Value	0.2	503	50	0	531	-	-9	572
Wall U-Value	0.21	503	57	0	531	-	-11	578
Wall U-Value	0.27	504	54	0	533	-	-10	577
Wall U-Value	0.36	506	51	0	534	-	-9	576
Wall U-Value	0.47	509	48	0	537	-	-9	576
Roof U-value	0.14	503	0	0	531	-	0	531
Roof U-value	0.18	505	0	0	533	-	0	533
Roof U-value	0.29	511	0	0	538	-	0	538
Heating Source	ASHP	406	41	10	439	-	0	491
Heating Source	Gas CHP	473	132	78	512	-	0	722
Heating Source	Gas (91%)	502	11	12	530	-	0	553
Heating Source	Gas (91%) + SHW	502	104	12	530	-	0	645
Heating Source	Gas (86%)	510	11	12	538	-	0	560
Floor U-value	0.1	496	26	0	526	-	-5	547
Floor U-value	0.15	497	18	0	527	-	-3	542
Floor U-value	0.2	498	14	0	528	-	-3	539
Floor U-value	0.25	502	12	0	531	-	-2	541
Window U-value	1.1	502	19	0	530	-	-2	547
Window U-value	1.4	502	15	0	530	-	-1	543
Window U-value	0.9	504	20	0	532	-	-2	550
Window U-value	1.8	508	13	0	536	-	-1	548
Chiller Efficiency	5.5	461	30	0	485	-	0	515
Chiller Efficiency	4.5	470	27	0	495	-	0	522
Chiller Efficiency	3.5	485	25	0	511	-	0	536
AHU SFP	1.8	497	19	0	524	-	0	542
AHU SFP	2	503	17	0	530	-	0	547
AHU SFP	2.2	508	16	0	536	-	0	553
Lighting Efficacy	65	453	6	0	475	-	0	481
Lighting Efficacy	60	460	5	0	483	-	0	489
Lighting Efficacy	55	469	5	0	493	-	0	498

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	343	-	-13	399
Wall U-Value	0.14	341	32	0	344	-	-6	371
Wall U-Value	0.16	342	62	0	345	-	-11	395
Wall U-Value	0.19	343	16	0	346	-	-3	359
Wall U-Value	0.21	343	28	0	346	-	-5	369
Wall U-Value	0.3	346	4	0	349	-	-1	352
Wall U-Value	0.39	348	12	0	351	-	-2	361
Roof U-value	0.15	334	17	0	338	-	-3	352
Roof U-value	0.2	336	16	0	340	-	-3	352
Roof U-value	0.25	338	13	0	342	-	-2	352
Heating Source	GSHP	160	26	5	173	-	0	204
Heating Source	Gas CHP	284	101	32	308	-	0	441
Heating Source	Gas (91%) + SHW	316	56	6	321	-	0	383
Heating Source	Gas (91%)	316	9	6	321	-	0	336
Heating Source	Gas (86%)	330	9	6	333	-	0	349
Floor U-value	0.1	337	13	0	341	-	-2	351
Floor U-value	0.15	340	9	0	343	-	-2	350
Floor U-value	0.2	342	7	0	345	-	-1	351
Floor U-value	0.25	344	6	0	347	-	-1	352
Window U-value	0.9	303	92	0	308	-	-9	392
Window U-value	1.1	312	87	0	317	-	-8	395
Window U-value	1.8	315	57	0	319	-	-5	371
Window U-value	1.4	319	67	0	323	-	-6	384
Lighting Efficacy	65	288	28	0	282	-	0	310
Lighting Efficacy	60	292	23	0	286	-	0	309
Lighting Efficacy	55	295	23	0	290	-	0	312

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	275	-	-13	331
Wall U-Value	0.14	272	32	0	276	-	-6	302
Wall U-Value	0.16	273	62	0	277	-	-11	327
Wall U-Value	0.19	274	16	0	278	-	-3	291
Wall U-Value	0.21	275	28	0	278	-	-5	301
Wall U-Value	0.3	277	4	0	281	-	-1	284
Wall U-Value	0.39	279	12	0	283	-	-2	293
Roof U-value	0.15	277	17	0	281	-	-3	295
Roof U-value	0.2	279	16	0	282	-	-3	295
Roof U-value	0.25	281	13	0	284	-	-2	295
Heating Source	GSHP	136	26	5	147	-	0	178
Heating Source	Gas CHP	242	101	32	263	-	0	396
Heating Source	Gas (91%) + SHW	270	56	6	274	-	0	336
Heating Source	Gas (91%)	270	9	6	274	-	0	289
Heating Source	Gas (86%)	281	9	6	284	-	0	300
Floor U-value	0.1	267	13	0	271	-	-2	282
Floor U-value	0.15	269	9	0	273	-	-2	281
Floor U-value	0.2	271	7	0	275	-	-1	281
Floor U-value	0.25	273	6	0	277	-	-1	282
Window U-value	0.9	252	92	0	257	-	-9	341
Window U-value	1.1	259	87	0	264	-	-8	343
Window U-value	1.8	262	57	0	267	-	-5	319
Window U-value	1.4	266	67	0	270	-	-6	331
Lighting Efficacy	65	231	28	0	228	-	0	256
Lighting Efficacy	60	235	23	0	232	-	0	255
Lighting Efficacy	55	239	23	0	237	-	0	260

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	416	-	-14	477
Wall U-Value	0.15 (b)	402	63	0	416	-	-12	468
Wall U-Value	0.15	402	67	0	416	-	-12	471
Wall U-Value	0.2	403	57	0	417	-	-11	464
Wall U-Value	0.21	403	65	0	417	-	-12	470
Wall U-Value	0.27	404	61	0	418	-	-11	468
Wall U-Value	0.36	406	58	0	420	-	-11	467
Wall U-Value	0.47	408	54	0	421	-	-10	466
Roof U-value	0.14	404	0	0	418	-	0	418
Roof U-value	0.18	405	0	0	419	-	0	419
Roof U-value	0.29	409	0	0	422	-	0	422
Heating Source	GSHP	263	26	5	285	-	0	316
Heating Source	Gas CHP	362	101	32	393	-	0	526
Heating Source	Gas (91%)	406	9	6	420	-	0	436
Heating Source	Gas (91%) + SHW	406	56	6	420	-	0	483
Heating Source	Gas (86%)	418	9	6	431	-	0	447
Floor U-value	0.1	395	13	0	410	-	-2	420
Floor U-value	0.15	397	9	0	411	-	-2	419
Floor U-value	0.2	398	7	0	413	-	-1	419
Floor U-value	0.25	400	6	0	414	-	-1	419
Window U-value	1.1	377	87	0	390	-	-8	469
Window U-value	1.4	380	67	0	392	-	-6	453
Window U-value	0.9	383	92	0	397	-	-9	481
Window U-value	1.8	405	57	0	419	-	-5	471
Chiller Efficiency	5.5	342	26	0	350	-	0	376
Chiller Efficiency	4.5	349	23	0	358	-	0	381
Chiller Efficiency	3.5	361	21	0	371	-	0	392
AHU SFP	1.8	391	12	0	403	-	0	415
AHU SFP	2	395	11	0	408	-	0	419
AHU SFP	2.2	400	10	0	413	-	0	423
Lighting Efficacy	65	366	28	0	375	-	0	403
Lighting Efficacy	60	371	23	0	381	-	0	404
Lighting Efficacy	55	378	23	0	388	-	0	411

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	320	-	-14	381
Wall U-Value	0.15 (b)	306	63	0	321	-	-12	372
Wall U-Value	0.15	306	67	0	321	-	-12	376
Wall U-Value	0.2	307	57	0	321	-	-11	368
Wall U-Value	0.21	307	65	0	322	-	-12	375
Wall U-Value	0.27	309	61	0	323	-	-11	373
Wall U-Value	0.36	311	58	0	324	-	-11	371
Wall U-Value	0.47	313	54	0	326	-	-10	370
Roof U-value	0.14	307	0	0	321	-	0	321
Roof U-value	0.18	308	0	0	322	-	0	322
Roof U-value	0.29	312	0	0	325	-	0	325
Heating Source	GSHP	225	26	5	243	-	0	275
Heating Source	Gas CHP	290	101	32	314	-	0	447
Heating Source	Gas (91%)	319	9	6	333	-	0	348
Heating Source	Gas (91%) + SHW	319	56	6	333	-	0	395
Heating Source	Gas (86%)	327	9	6	340	-	0	356
Floor U-value	0.1	305	13	0	319	-	-2	329
Floor U-value	0.15	306	9	0	321	-	-2	328
Floor U-value	0.2	308	7	0	322	-	-1	328
Floor U-value	0.25	310	6	0	324	-	-1	329
Window U-value	1.1	276	87	0	289	-	-8	368
Window U-value	1.4	280	67	0	292	-	-6	353
Window U-value	0.9	282	92	0	296	-	-9	380
Window U-value	1.8	307	57	0	322	-	-5	374
Chiller Efficiency	5.5	250	26	0	259	-	0	285
Chiller Efficiency	4.5	257	23	0	267	-	0	289
Chiller Efficiency	3.5	268	21	0	279	-	0	300
AHU SFP	1.8	301	12	0	314	-	0	325
AHU SFP	2	306	11	0	319	-	0	330
AHU SFP	2.2	310	10	0	324	-	0	334
Lighting Efficacy	65	298	28	0	310	-	0	338
Lighting Efficacy	60	303	23	0	316	-	0	339
Lighting Efficacy	55	310	23	0	324	-	0	347

Capabilities on project:  
Building Engineering

Primary (EE1): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	164	-	-4	218
Wall U-Value	0.14	164	27	0	166	-	-2	191
Wall U-Value	0.16	164	51	0	167	-	-4	215
Wall U-Value	0.19	166	13	0	168	-	-1	181
Wall U-Value	0.21	166	24	0	169	-	-2	191
Wall U-Value	0.3	170	3	0	172	-	0	175
Wall U-Value	0.39	174	10	0	176	-	-1	185
Roof U-value	0.15	172	15	0	175	-	-1	188
Roof U-value	0.2	173	13	0	175	-	-1	187
Roof U-value	0.25	173	11	0	176	-	-1	186
Heating Source	GSHP	62	30	9	70	-	0	109
Heating Source	Gas CHP	140	62	41	190	-	0	293
Heating Source	Gas (91%) + SHW	155	47	10	158	-	0	215
Heating Source	Gas (91%)	155	8	10	158	-	0	176
Heating Source	Gas (86%)	163	8	10	165	-	0	183
Floor U-value	0.1	158	11	0	161	-	-1	171
Floor U-value	0.15	161	8	0	163	-	-1	171
Floor U-value	0.2	163	6	0	166	-	0	172
Floor U-value	0.25	166	5	0	168	-	0	173
Window U-value	0.9	142	47	0	146	-	0	192
Window U-value	1.1	147	44	0	151	-	0	195
Window U-value	1.8	150	29	0	154	-	0	182
Window U-value	1.4	152	34	0	155	-	0	189
Lighting Efficacy	65	157	23	0	154	-	0	177
Lighting Efficacy	60	158	21	0	156	-	0	176
Lighting Efficacy	55	160	20	0	158	-	0	177

Capabilities on project:  
Building Engineering

Primary (EE2): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	85	-	-4	138
Wall U-Value	0.14	86	27	0	86	-	-2	111
Wall U-Value	0.16	87	51	0	87	-	-4	135
Wall U-Value	0.19	88	13	0	88	-	-1	101
Wall U-Value	0.21	89	24	0	89	-	-2	111
Wall U-Value	0.3	92	3	0	92	-	0	95
Wall U-Value	0.39	96	10	0	95	-	-1	105
Roof U-value	0.15	93	15	0	93	-	-1	107
Roof U-value	0.2	94	13	0	94	-	-1	106
Roof U-value	0.25	94	11	0	94	-	-1	104
Heating Source	GSHP	27	30	9	31	-	0	70
Heating Source	Gas CHP	82	62	41	115	-	0	217
Heating Source	Gas (91%) + SHW	92	47	10	92	-	0	149
Heating Source	Gas (91%)	92	8	10	92	-	0	110
Heating Source	Gas (86%)	97	8	10	97	-	0	115
Floor U-value	0.1	87	11	0	87	-	-1	97
Floor U-value	0.15	89	8	0	89	-	-1	97
Floor U-value	0.2	92	6	0	92	-	0	97
Floor U-value	0.25	94	5	0	94	-	0	99
Window U-value	0.9	81	47	0	81	-	0	128
Window U-value	1.1	86	44	0	86	-	0	130
Window U-value	1.8	89	29	0	89	-	0	118
Window U-value	1.4	90	34	0	90	-	0	124
Lighting Efficacy	65	91	23	0	90	-	0	113
Lighting Efficacy	60	92	21	0	91	-	0	112
Lighting Efficacy	55	93	20	0	92	-	0	112

Capabilities on project:  
Building Engineering

Hotel (EE1): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	572	-	-17	649
Wall U-Value	0.14	568	44	0	573	-	-8	609
Wall U-Value	0.16	568	84	0	574	-	-16	643
Wall U-Value	0.19	569	22	0	575	-	-4	593
Wall U-Value	0.21	570	39	0	576	-	-7	607
Wall U-Value	0.3	573	5	0	578	-	-1	583
Wall U-Value	0.39	576	17	0	581	-	-3	595
Roof U-value	0.15	576	10	0	581	-	-2	589
Roof U-value	0.2	577	9	0	582	-	-2	589
Roof U-value	0.25	578	7	0	583	-	-1	589
Heating Source	GSHP	457	29	8	469	-	0	506
Heating Source	Gas CHP	542	74	38	561	-	0	673
Heating Source	Gas (91%) + SHW	563	35	8	569	-	0	612
Heating Source	Gas (91%)	576	8	8	581	-	0	597
Heating Source	Gas (86%)	586	8	8	591	-	0	606
Floor U-value	0.1	570	7	0	575	-	-1	582
Floor U-value	0.15	571	5	0	577	-	-1	581
Floor U-value	0.2	572	4	0	578	-	-1	581
Floor U-value	0.25	573	3	0	579	-	-1	582
Window U-value	1.1	547	87	0	553	-	-8	632
Window U-value	0.9	548	93	0	555	-	-9	639
Window U-value	1.4	550	68	0	556	-	-6	617
Window U-value	1.8	563	58	0	570	-	-5	623
Chiller Efficiency	5.5	546	31	0	548	-	0	579
Chiller Efficiency	4.5	549	27	0	551	-	0	579
Chiller Efficiency	3.5	554	25	0	557	-	0	582
AHU SFP	1.8	558	10	0	561	-	0	572
AHU SFP	2	564	10	0	567	-	0	577
AHU SFP	2.2	569	9	0	574	-	0	583
Lighting Efficacy	65	489	51	0	481	-	0	532
Lighting Efficacy	60	491	46	0	483	-	0	529
Lighting Efficacy	55	493	39	0	486	-	0	525

Capabilities on project:  
Building Engineering

Hotel (EE2): Financial Costs (Low energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	441	-	-17	517
Wall U-Value	0.14	444	44	0	442	-	-8	478
Wall U-Value	0.16	445	84	0	443	-	-16	511
Wall U-Value	0.19	446	22	0	444	-	-4	462
Wall U-Value	0.21	446	39	0	444	-	-7	476
Wall U-Value	0.3	450	5	0	447	-	-1	452
Wall U-Value	0.39	453	17	0	450	-	-3	464
Roof U-value	0.15	453	10	0	450	-	-2	458
Roof U-value	0.2	454	9	0	451	-	-2	459
Roof U-value	0.25	455	7	0	452	-	-1	459
Heating Source	GSHP	325	29	8	329	-	0	366
Heating Source	Gas CHP	420	74	38	433	-	0	544
Heating Source	Gas (91%) + SHW	446	35	8	444	-	0	488
Heating Source	Gas (91%)	458	8	8	455	-	0	471
Heating Source	Gas (86%)	469	8	8	465	-	0	481
Floor U-value	0.1	446	7	0	444	-	-1	450
Floor U-value	0.15	448	5	0	445	-	-1	450
Floor U-value	0.2	449	4	0	446	-	-1	450
Floor U-value	0.25	450	3	0	448	-	-1	450
Window U-value	0.9	431	93	0	429	-	-9	513
Window U-value	1.1	434	87	0	431	-	-8	510
Window U-value	1.4	439	68	0	436	-	-6	497
Window U-value	1.8	445	58	0	443	-	-5	496
Chiller Efficiency	5.5	437	31	0	432	-	0	463
Chiller Efficiency	4.5	439	27	0	435	-	0	462
Chiller Efficiency	3.5	442	25	0	438	-	0	464
AHU SFP	1.8	444	10	0	440	-	0	450
AHU SFP	2	450	10	0	446	-	0	456
AHU SFP	2.2	455	9	0	452	-	0	462
Lighting Efficacy	65	434	51	0	428	-	0	479
Lighting Efficacy	60	436	46	0	431	-	0	476
Lighting Efficacy	55	439	39	0	433	-	0	473

Capabilities on project:  
Building Engineering

# **Table H:**

## **Financial Costs**

### **High energy price**

### **7% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	1061	-	-12	1115
Wall U-Value	0.15 (b)	647	55	0	1062	-	-10	1107
Wall U-Value	0.15	647	59	0	1062	-	-11	1110
Wall U-Value	0.2	648	50	0	1064	-	-9	1105
Wall U-Value	0.21	648	57	0	1064	-	-11	1111
Wall U-Value	0.27	649	54	0	1066	-	-10	1110
Wall U-Value	0.36	651	51	0	1069	-	-9	1110
Wall U-Value	0.47	653	48	0	1072	-	-9	1111
Roof U-value	0.14	648	0	0	1064	-	0	1064
Roof U-value	0.18	649	0	0	1066	-	0	1066
Roof U-value	0.29	654	0	0	1075	-	0	1075
Heating Source	ASHP	558	41	10	907	-	0	959
Heating Source	Gas CHP	620	132	78	1051	-	0	1260
Heating Source	Gas (91%)	646	11	12	1061	-	0	1084
Heating Source	Gas (91%) + SHW	646	104	12	1061	-	0	1176
Heating Source	Gas (86%)	653	11	12	1074	-	0	1097
Floor U-value	0.25	652	12	0	1070	-	-2	1080
Floor U-value	0.2	652	14	0	1070	-	-3	1082
Floor U-value	0.15	653	18	0	1070	-	-3	1085
Floor U-value	0.1	653	26	0	1071	-	-5	1092
Window U-value	1.4	644	15	0	1058	-	-1	1071
Window U-value	1.1	644	19	0	1058	-	-2	1075
Window U-value	0.9	647	20	0	1063	-	-2	1082
Window U-value	1.8	653	13	0	1072	-	-1	1084
Chiller Efficiency	5.5	533	30	0	878	-	0	908
Chiller Efficiency	4.5	545	27	0	898	-	0	924
Chiller Efficiency	3.5	564	25	0	928	-	0	953
AHU SFP	1.8	641	19	0	1053	-	0	1071
AHU SFP	2	646	17	0	1062	-	0	1079
AHU SFP	2.2	652	16	0	1072	-	0	1088
Lighting Efficacy	65	490	6	0	810	-	0	816
Lighting Efficacy	60	498	5	0	823	-	0	829
Lighting Efficacy	55	508	5	0	839	-	0	844

Capabilities on project:  
Building Engineering

Retail (EE2): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	826	-	-12	879
Wall U-Value	0.15 (b)	502	55	0	827	-	-10	872
Wall U-Value	0.15	502	59	0	827	-	-11	875
Wall U-Value	0.2	503	50	0	829	-	-9	870
Wall U-Value	0.21	503	57	0	830	-	-11	876
Wall U-Value	0.27	504	54	0	832	-	-10	876
Wall U-Value	0.36	506	51	0	836	-	-9	877
Wall U-Value	0.47	509	48	0	840	-	-9	879
Roof U-value	0.14	503	0	0	829	-	0	829
Roof U-value	0.18	505	0	0	833	-	0	833
Roof U-value	0.29	511	0	0	843	-	0	843
Heating Source	ASHP	406	41	10	659	-	0	710
Heating Source	Gas CHP	473	132	78	816	-	0	1026
Heating Source	Gas (91%)	502	11	12	828	-	0	850
Heating Source	Gas (91%) + SHW	502	104	12	828	-	0	943
Heating Source	Gas (86%)	510	11	12	842	-	0	864
Floor U-value	0.1	496	26	0	816	-	-5	837
Floor U-value	0.15	497	18	0	818	-	-3	833
Floor U-value	0.2	498	14	0	820	-	-3	831
Floor U-value	0.25	502	12	0	828	-	-2	837
Window U-value	1.1	502	19	0	829	-	-2	846
Window U-value	1.4	502	15	0	829	-	-1	843
Window U-value	0.9	504	20	0	831	-	-2	850
Window U-value	1.8	508	13	0	838	-	-1	850
Chiller Efficiency	5.5	461	30	0	762	-	0	792
Chiller Efficiency	4.5	470	27	0	777	-	0	804
Chiller Efficiency	3.5	485	25	0	801	-	0	826
AHU SFP	1.8	497	19	0	820	-	0	839
AHU SFP	2	503	17	0	830	-	0	847
AHU SFP	2.2	508	16	0	839	-	0	855
Lighting Efficacy	65	453	6	0	750	-	0	756
Lighting Efficacy	60	460	5	0	761	-	0	767
Lighting Efficacy	55	469	5	0	775	-	0	780

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	575	-	-13	632
Wall U-Value	0.14	341	32	0	578	-	-6	604
Wall U-Value	0.16	342	62	0	579	-	-11	629
Wall U-Value	0.19	343	16	0	580	-	-3	594
Wall U-Value	0.21	343	28	0	581	-	-5	604
Wall U-Value	0.3	346	4	0	586	-	-1	589
Wall U-Value	0.39	348	12	0	590	-	-2	600
Roof U-value	0.15	334	17	0	566	-	-3	580
Roof U-value	0.2	336	16	0	569	-	-3	582
Roof U-value	0.25	338	13	0	573	-	-2	583
Heating Source	GSHP	160	26	5	259	-	0	290
Heating Source	Gas CHP	284	101	32	551	-	0	684
Heating Source	Gas (91%) + SHW	316	56	6	534	-	0	597
Heating Source	Gas (91%)	316	9	6	534	-	0	550
Heating Source	Gas (86%)	330	9	6	557	-	0	573
Floor U-value	0.1	337	13	0	571	-	-2	582
Floor U-value	0.15	340	9	0	575	-	-2	582
Floor U-value	0.2	342	7	0	579	-	-1	585
Floor U-value	0.25	344	6	0	582	-	-1	587
Window U-value	0.9	303	92	0	511	-	-9	595
Window U-value	1.1	312	87	0	526	-	-8	605
Window U-value	1.8	315	57	0	531	-	-5	583
Window U-value	1.4	319	67	0	538	-	-6	599
Lighting Efficacy	65	288	28	0	497	-	0	525
Lighting Efficacy	60	292	23	0	502	-	0	525
Lighting Efficacy	55	295	23	0	507	-	0	529

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	458	-	-13	514
Wall U-Value	0.14	272	32	0	460	-	-6	486
Wall U-Value	0.16	273	62	0	462	-	-11	512
Wall U-Value	0.19	274	16	0	463	-	-3	477
Wall U-Value	0.21	275	28	0	464	-	-5	487
Wall U-Value	0.3	277	4	0	469	-	-1	472
Wall U-Value	0.39	279	12	0	473	-	-2	483
Roof U-value	0.15	277	17	0	469	-	-3	483
Roof U-value	0.2	279	16	0	472	-	-3	485
Roof U-value	0.25	281	13	0	475	-	-2	486
Heating Source	GSHP	136	26	5	221	-	0	252
Heating Source	Gas CHP	242	101	32	470	-	0	603
Heating Source	Gas (91%) + SHW	270	56	6	455	-	0	518
Heating Source	Gas (91%)	270	9	6	455	-	0	471
Heating Source	Gas (86%)	281	9	6	475	-	0	491
Floor U-value	0.1	267	13	0	451	-	-2	461
Floor U-value	0.15	269	9	0	455	-	-2	463
Floor U-value	0.2	271	7	0	458	-	-1	464
Floor U-value	0.25	273	6	0	462	-	-1	467
Window U-value	0.9	252	92	0	424	-	-9	508
Window U-value	1.1	259	87	0	438	-	-8	516
Window U-value	1.8	262	57	0	443	-	-5	495
Window U-value	1.4	266	67	0	448	-	-6	509
Lighting Efficacy	65	231	28	0	396	-	0	424
Lighting Efficacy	60	235	23	0	402	-	0	425
Lighting Efficacy	55	239	23	0	409	-	0	431

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	670	-	-14	731
Wall U-Value	0.15 (b)	402	63	0	671	-	-12	722
Wall U-Value	0.15	402	67	0	671	-	-12	726
Wall U-Value	0.2	403	57	0	672	-	-11	719
Wall U-Value	0.21	403	65	0	673	-	-12	726
Wall U-Value	0.27	404	61	0	675	-	-11	725
Wall U-Value	0.36	406	58	0	677	-	-11	725
Wall U-Value	0.47	408	54	0	681	-	-10	725
Roof U-value	0.14	404	0	0	674	-	0	674
Roof U-value	0.18	405	0	0	676	-	0	676
Roof U-value	0.29	409	0	0	683	-	0	683
Heating Source	GSHP	263	26	5	427	-	0	458
Heating Source	Gas CHP	362	101	32	659	-	0	793
Heating Source	Gas (91%)	406	9	6	679	-	0	694
Heating Source	Gas (91%) + SHW	406	56	6	679	-	0	741
Heating Source	Gas (86%)	418	9	6	699	-	0	715
Floor U-value	0.1	395	13	0	659	-	-2	669
Floor U-value	0.15	397	9	0	661	-	-2	669
Floor U-value	0.2	398	7	0	664	-	-1	670
Floor U-value	0.25	400	6	0	668	-	-1	672
Window U-value	1.1	377	87	0	631	-	-8	709
Window U-value	1.4	380	67	0	636	-	-6	697
Window U-value	0.9	383	92	0	638	-	-9	722
Window U-value	1.8	405	57	0	675	-	-5	727
Chiller Efficiency	5.5	342	26	0	574	-	0	600
Chiller Efficiency	4.5	349	23	0	586	-	0	609
Chiller Efficiency	3.5	361	21	0	605	-	0	626
AHU SFP	1.8	391	12	0	653	-	0	665
AHU SFP	2	395	11	0	661	-	0	671
AHU SFP	2.2	400	10	0	669	-	0	679
Lighting Efficacy	65	366	28	0	614	-	0	642
Lighting Efficacy	60	371	23	0	623	-	0	646
Lighting Efficacy	55	378	23	0	633	-	0	655

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	506	-	-14	567
Wall U-Value	0.15 (b)	306	63	0	508	-	-12	559
Wall U-Value	0.15	306	67	0	508	-	-12	563
Wall U-Value	0.2	307	57	0	510	-	-11	556
Wall U-Value	0.21	307	65	0	510	-	-12	563
Wall U-Value	0.27	309	61	0	512	-	-11	562
Wall U-Value	0.36	311	58	0	516	-	-11	563
Wall U-Value	0.47	313	54	0	519	-	-10	564
Roof U-value	0.14	307	0	0	509	-	0	509
Roof U-value	0.18	308	0	0	511	-	0	511
Roof U-value	0.29	312	0	0	517	-	0	517
Heating Source	GSHP	225	26	5	365	-	0	396
Heating Source	Gas CHP	290	101	32	518	-	0	651
Heating Source	Gas (91%)	319	9	6	531	-	0	546
Heating Source	Gas (91%) + SHW	319	56	6	531	-	0	593
Heating Source	Gas (86%)	327	9	6	545	-	0	560
Floor U-value	0.1	305	13	0	505	-	-2	516
Floor U-value	0.15	306	9	0	508	-	-2	516
Floor U-value	0.2	308	7	0	511	-	-1	517
Floor U-value	0.25	310	6	0	515	-	-1	520
Window U-value	1.1	276	87	0	458	-	-8	536
Window U-value	1.4	280	67	0	465	-	-6	526
Window U-value	0.9	282	92	0	465	-	-9	549
Window U-value	1.8	307	57	0	508	-	-5	561
Chiller Efficiency	5.5	250	26	0	418	-	0	444
Chiller Efficiency	4.5	257	23	0	429	-	0	452
Chiller Efficiency	3.5	268	21	0	447	-	0	468
AHU SFP	1.8	301	12	0	500	-	0	511
AHU SFP	2	306	11	0	507	-	0	518
AHU SFP	2.2	310	10	0	515	-	0	525
Lighting Efficacy	65	298	28	0	495	-	0	523
Lighting Efficacy	60	303	23	0	504	-	0	527
Lighting Efficacy	55	310	23	0	515	-	0	538

Capabilities on project:  
Building Engineering

Primary (EE1): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	282	-	-4	335
Wall U-Value	0.14	164	27	0	285	-	-2	310
Wall U-Value	0.16	164	51	0	287	-	-4	334
Wall U-Value	0.19	166	13	0	289	-	-1	301
Wall U-Value	0.21	166	24	0	290	-	-2	312
Wall U-Value	0.3	170	3	0	297	-	0	300
Wall U-Value	0.39	174	10	0	303	-	-1	313
Roof U-value	0.15	172	15	0	301	-	-1	314
Roof U-value	0.2	173	13	0	302	-	-1	314
Roof U-value	0.25	173	11	0	303	-	-1	313
Heating Source	GSHP	62	30	9	107	-	0	146
Heating Source	Gas CHP	140	62	41	340	-	0	442
Heating Source	Gas (91%) + SHW	155	47	10	270	-	0	327
Heating Source	Gas (91%)	155	8	10	270	-	0	288
Heating Source	Gas (86%)	163	8	10	284	-	0	301
Floor U-value	0.1	158	11	0	276	-	-1	286
Floor U-value	0.15	161	8	0	280	-	-1	288
Floor U-value	0.2	163	6	0	285	-	0	290
Floor U-value	0.25	166	5	0	289	-	0	294
Window U-value	0.9	142	47	0	247	-	0	294
Window U-value	1.1	147	44	0	257	-	0	300
Window U-value	1.8	150	29	0	262	-	0	291
Window U-value	1.4	152	34	0	265	-	0	299
Lighting Efficacy	65	157	23	0	274	-	0	297
Lighting Efficacy	60	158	21	0	277	-	0	297
Lighting Efficacy	55	160	20	0	279	-	0	299

Capabilities on project:  
Building Engineering

Primary (EE2): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	147	-	-4	201
Wall U-Value	0.14	86	27	0	150	-	-2	175
Wall U-Value	0.16	87	51	0	152	-	-4	199
Wall U-Value	0.19	88	13	0	154	-	-1	166
Wall U-Value	0.21	89	24	0	155	-	-2	177
Wall U-Value	0.3	92	3	0	161	-	0	164
Wall U-Value	0.39	96	10	0	167	-	-1	177
Roof U-value	0.15	93	15	0	163	-	-1	177
Roof U-value	0.2	94	13	0	164	-	-1	176
Roof U-value	0.25	94	11	0	165	-	-1	175
Heating Source	GSHP	27	30	9	47	-	0	86
Heating Source	Gas CHP	82	62	41	209	-	0	312
Heating Source	Gas (91%) + SHW	92	47	10	161	-	0	218
Heating Source	Gas (91%)	92	8	10	161	-	0	178
Heating Source	Gas (86%)	97	8	10	170	-	0	188
Floor U-value	0.1	87	11	0	152	-	-1	162
Floor U-value	0.15	89	8	0	156	-	-1	164
Floor U-value	0.2	92	6	0	161	-	0	166
Floor U-value	0.25	94	5	0	165	-	0	169
Window U-value	0.9	81	47	0	141	-	0	188
Window U-value	1.1	86	44	0	150	-	0	194
Window U-value	1.8	89	29	0	155	-	0	184
Window U-value	1.4	90	34	0	158	-	0	191
Lighting Efficacy	65	91	23	0	159	-	0	182
Lighting Efficacy	60	92	21	0	161	-	0	181
Lighting Efficacy	55	93	20	0	163	-	0	182

Capabilities on project:  
Building Engineering

Hotel (EE1): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	958	-	-17	1035
Wall U-Value	0.14	568	44	0	961	-	-8	997
Wall U-Value	0.16	568	84	0	962	-	-16	1030
Wall U-Value	0.19	569	22	0	964	-	-4	982
Wall U-Value	0.21	570	39	0	965	-	-7	996
Wall U-Value	0.3	573	5	0	970	-	-1	975
Wall U-Value	0.39	576	17	0	976	-	-3	989
Roof U-value	0.15	576	10	0	975	-	-2	983
Roof U-value	0.2	577	9	0	977	-	-2	985
Roof U-value	0.25	578	7	0	979	-	-1	986
Heating Source	GSHP	457	29	8	767	-	0	804
Heating Source	Gas CHP	542	74	38	966	-	0	1078
Heating Source	Gas (91%) + SHW	563	35	8	953	-	0	996
Heating Source	Gas (91%)	576	8	8	976	-	0	992
Heating Source	Gas (86%)	586	8	8	994	-	0	1009
Floor U-value	0.1	570	7	0	965	-	-1	971
Floor U-value	0.15	571	5	0	967	-	-1	971
Floor U-value	0.2	572	4	0	969	-	-1	972
Floor U-value	0.25	573	3	0	971	-	-1	974
Window U-value	1.1	547	87	0	925	-	-8	1004
Window U-value	0.9	548	93	0	925	-	-9	1010
Window U-value	1.4	550	68	0	932	-	-6	993
Window U-value	1.8	563	58	0	952	-	-5	1004
Chiller Efficiency	5.5	546	31	0	927	-	0	958
Chiller Efficiency	4.5	549	27	0	932	-	0	959
Chiller Efficiency	3.5	554	25	0	940	-	0	965
AHU SFP	1.8	558	10	0	946	-	0	957
AHU SFP	2	564	10	0	956	-	0	965
AHU SFP	2.2	569	9	0	965	-	0	974
Lighting Efficacy	65	489	51	0	839	-	0	890
Lighting Efficacy	60	491	46	0	842	-	0	888
Lighting Efficacy	55	493	39	0	846	-	0	885

Capabilities on project:  
Building Engineering

Hotel (EE2): Financial Costs (High energy price, 7% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	755	-	-17	831
Wall U-Value	0.14	444	44	0	757	-	-8	793
Wall U-Value	0.16	445	84	0	758	-	-16	827
Wall U-Value	0.19	446	22	0	760	-	-4	778
Wall U-Value	0.21	446	39	0	762	-	-7	793
Wall U-Value	0.3	450	5	0	768	-	-1	772
Wall U-Value	0.39	453	17	0	774	-	-3	787
Roof U-value	0.15	453	10	0	773	-	-2	781
Roof U-value	0.2	454	9	0	775	-	-2	783
Roof U-value	0.25	455	7	0	778	-	-1	784
Heating Source	GSHP	325	29	8	549	-	0	585
Heating Source	Gas CHP	420	74	38	771	-	0	883
Heating Source	Gas (91%) + SHW	446	35	8	762	-	0	806
Heating Source	Gas (91%)	458	8	8	782	-	0	798
Heating Source	Gas (86%)	469	8	8	801	-	0	817
Floor U-value	0.1	446	7	0	762	-	-1	768
Floor U-value	0.15	448	5	0	764	-	-1	768
Floor U-value	0.2	449	4	0	766	-	-1	769
Floor U-value	0.25	450	3	0	768	-	-1	771
Window U-value	0.9	431	93	0	735	-	-9	819
Window U-value	1.1	434	87	0	741	-	-8	820
Window U-value	1.4	439	68	0	750	-	-6	811
Window U-value	1.8	445	58	0	759	-	-5	812
Chiller Efficiency	5.5	437	31	0	747	-	0	778
Chiller Efficiency	4.5	439	27	0	751	-	0	778
Chiller Efficiency	3.5	442	25	0	756	-	0	782
AHU SFP	1.8	444	10	0	759	-	0	769
AHU SFP	2	450	10	0	768	-	0	778
AHU SFP	2.2	455	9	0	778	-	0	787
Lighting Efficacy	65	434	51	0	745	-	0	796
Lighting Efficacy	60	436	46	0	748	-	0	794
Lighting Efficacy	55	439	39	0	752	-	0	791

Capabilities on project:  
Building Engineering

# **Table J:**

## **Financial Costs**

### **Central energy price**

### **13% discount rate**

Capabilities on project:  
Building Engineering

Retail (EE1): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	646	66	0	541	-	-4	603
Wall U-Value	0.15 (b)	647	55	0	542	-	-4	594
Wall U-Value	0.15	647	59	0	542	-	-4	597
Wall U-Value	0.2	648	50	0	543	-	-3	590
Wall U-Value	0.21	648	57	0	543	-	-4	596
Wall U-Value	0.27	649	54	0	544	-	-4	594
Wall U-Value	0.36	651	51	0	545	-	-3	592
Wall U-Value	0.47	653	48	0	546	-	-3	591
Roof U-value	0.14	648	0	0	543	-	0	543
Roof U-value	0.18	649	0	0	544	-	0	544
Roof U-value	0.29	654	0	0	547	-	0	547
Heating Source	ASHP	558	41	7	472	-	0	520
Heating Source	Gas CHP	620	132	52	531	-	0	715
Heating Source	Gas (91%)	646	11	8	541	-	0	560
Heating Source	Gas (91%) + SHW	646	104	8	541	-	0	653
Heating Source	Gas (86%)	653	11	8	547	-	0	566
Floor U-value	0.25	652	12	0	547	-	-1	558
Floor U-value	0.2	652	14	0	547	-	-1	560
Floor U-value	0.15	653	18	0	547	-	-1	565
Floor U-value	0.1	653	26	0	548	-	-2	572
Window U-value	1.4	644	15	0	539	-	0	553
Window U-value	1.1	644	19	0	539	-	-1	558
Window U-value	0.9	647	20	0	542	-	-1	562
Window U-value	1.8	653	13	0	547	-	0	559
Chiller Efficiency	5.5	533	30	0	445	-	0	476
Chiller Efficiency	4.5	545	27	0	456	-	0	482
Chiller Efficiency	3.5	564	25	0	472	-	0	496
AHU SFP	1.8	641	19	0	536	-	0	555
AHU SFP	2	646	17	0	541	-	0	558
AHU SFP	2.2	652	16	0	546	-	0	562
Lighting Efficacy	65	490	6	0	408	-	0	414
Lighting Efficacy	60	498	5	0	415	-	0	420
Lighting Efficacy	55	508	5	0	423	-	0	428

Capabilities on project:  
Building Engineering

Retail (EE2): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	501	66	0	418	-	-4	480
Wall U-Value	0.15 (b)	502	55	0	419	-	-4	470
Wall U-Value	0.15	502	59	0	419	-	-4	474
Wall U-Value	0.2	503	50	0	420	-	-3	467
Wall U-Value	0.21	503	57	0	420	-	-4	473
Wall U-Value	0.27	504	54	0	421	-	-4	471
Wall U-Value	0.36	506	51	0	422	-	-3	470
Wall U-Value	0.47	509	48	0	424	-	-3	469
Roof U-value	0.14	503	0	0	420	-	0	420
Roof U-value	0.18	505	0	0	421	-	0	421
Roof U-value	0.29	511	0	0	426	-	0	426
Heating Source	ASHP	406	41	7	343	-	0	391
Heating Source	Gas CHP	473	132	52	407	-	0	591
Heating Source	Gas (91%)	502	11	8	419	-	0	438
Heating Source	Gas (91%) + SHW	502	104	8	419	-	0	530
Heating Source	Gas (86%)	510	11	8	425	-	0	444
Floor U-value	0.1	496	26	0	415	-	-2	439
Floor U-value	0.15	497	18	0	415	-	-1	433
Floor U-value	0.2	498	14	0	416	-	-1	430
Floor U-value	0.25	502	12	0	420	-	-1	431
Window U-value	1.1	502	19	0	419	-	-1	437
Window U-value	1.4	502	15	0	419	-	0	433
Window U-value	0.9	504	20	0	420	-	-1	440
Window U-value	1.8	508	13	0	424	-	0	436
Chiller Efficiency	5.5	461	30	0	384	-	0	414
Chiller Efficiency	4.5	470	27	0	392	-	0	418
Chiller Efficiency	3.5	485	25	0	404	-	0	429
AHU SFP	1.8	497	19	0	414	-	0	433
AHU SFP	2	503	17	0	419	-	0	436
AHU SFP	2.2	508	16	0	424	-	0	440
Lighting Efficacy	65	453	6	0	377	-	0	383
Lighting Efficacy	60	460	5	0	383	-	0	389
Lighting Efficacy	55	469	5	0	390	-	0	395

Capabilities on project:  
Building Engineering

Office (NV) (EE1): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	340	69	0	277	-	-5	342
Wall U-Value	0.14	341	32	0	278	-	-2	309
Wall U-Value	0.16	342	62	0	279	-	-4	337
Wall U-Value	0.19	343	16	0	280	-	-1	295
Wall U-Value	0.21	343	28	0	280	-	-2	307
Wall U-Value	0.3	346	4	0	282	-	0	286
Wall U-Value	0.39	348	12	0	284	-	-1	295
Roof U-value	0.15	334	17	0	273	-	-1	289
Roof U-value	0.2	336	16	0	274	-	-1	289
Roof U-value	0.25	338	13	0	276	-	-1	288
Heating Source	GSHP	160	26	3	135	-	0	164
Heating Source	Gas CHP	284	101	22	255	-	0	377
Heating Source	Gas (91%) + SHW	316	56	4	259	-	0	319
Heating Source	Gas (91%)	316	9	4	259	-	0	272
Heating Source	Gas (86%)	330	9	4	269	-	0	283
Floor U-value	0.1	337	13	0	275	-	-1	287
Floor U-value	0.15	340	9	0	277	-	-1	286
Floor U-value	0.2	342	7	0	279	-	0	286
Floor U-value	0.25	344	6	0	281	-	0	286
Window U-value	0.9	303	92	0	248	-	-3	338
Window U-value	1.1	312	87	0	255	-	-3	339
Window U-value	1.8	315	57	0	257	-	-2	313
Window U-value	1.4	319	67	0	261	-	-2	326
Lighting Efficacy	65	288	28	0	232	-	0	260
Lighting Efficacy	60	292	23	0	235	-	0	258
Lighting Efficacy	55	295	23	0	238	-	0	260

Capabilities on project:  
Building Engineering

Office (NV) (EE2): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	271	69	0	222	-	-5	286
Wall U-Value	0.14	272	32	0	223	-	-2	253
Wall U-Value	0.16	273	62	0	223	-	-4	281
Wall U-Value	0.19	274	16	0	224	-	-1	239
Wall U-Value	0.21	275	28	0	225	-	-2	251
Wall U-Value	0.3	277	4	0	227	-	0	230
Wall U-Value	0.39	279	12	0	228	-	-1	240
Roof U-value	0.15	277	17	0	227	-	-1	243
Roof U-value	0.2	279	16	0	228	-	-1	243
Roof U-value	0.25	281	13	0	229	-	-1	241
Heating Source	GSHP	136	26	3	115	-	0	144
Heating Source	Gas CHP	242	101	22	217	-	0	340
Heating Source	Gas (91%) + SHW	270	56	4	221	-	0	281
Heating Source	Gas (91%)	270	9	4	221	-	0	234
Heating Source	Gas (86%)	281	9	4	229	-	0	243
Floor U-value	0.1	267	13	0	219	-	-1	231
Floor U-value	0.15	269	9	0	220	-	-1	229
Floor U-value	0.2	271	7	0	222	-	0	229
Floor U-value	0.25	273	6	0	223	-	0	229
Window U-value	0.9	252	92	0	206	-	-3	296
Window U-value	1.1	259	87	0	213	-	-3	296
Window U-value	1.8	262	57	0	215	-	-2	270
Window U-value	1.4	266	67	0	217	-	-2	282
Lighting Efficacy	65	231	28	0	187	-	0	215
Lighting Efficacy	60	235	23	0	190	-	0	213
Lighting Efficacy	55	239	23	0	193	-	0	216

Capabilities on project:  
Building Engineering

Office (AC) (EE1): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	401	75	0	332	-	-5	402
Wall U-Value	0.15 (b)	402	63	0	332	-	-4	391
Wall U-Value	0.15	402	67	0	332	-	-4	395
Wall U-Value	0.2	403	57	0	333	-	-4	386
Wall U-Value	0.21	403	65	0	333	-	-4	394
Wall U-Value	0.27	404	61	0	334	-	-4	391
Wall U-Value	0.36	406	58	0	335	-	-4	389
Wall U-Value	0.47	408	54	0	337	-	-4	387
Roof U-value	0.14	404	0	0	334	-	0	334
Roof U-value	0.18	405	0	0	335	-	0	335
Roof U-value	0.29	409	0	0	337	-	0	337
Heating Source	GSHP	263	26	3	222	-	0	252
Heating Source	Gas CHP	362	101	22	318	-	0	440
Heating Source	Gas (91%)	406	9	4	336	-	0	349
Heating Source	Gas (91%) + SHW	406	56	4	336	-	0	396
Heating Source	Gas (86%)	418	9	4	345	-	0	358
Floor U-value	0.1	395	13	0	327	-	-1	339
Floor U-value	0.15	397	9	0	328	-	-1	337
Floor U-value	0.2	398	7	0	329	-	0	336
Floor U-value	0.25	400	6	0	331	-	0	336
Window U-value	1.1	377	87	0	312	-	-3	395
Window U-value	1.4	380	67	0	314	-	-2	379
Window U-value	0.9	383	92	0	316	-	-3	406
Window U-value	1.8	405	57	0	334	-	-2	390
Chiller Efficiency	5.5	342	26	0	281	-	0	307
Chiller Efficiency	4.5	349	23	0	287	-	0	310
Chiller Efficiency	3.5	361	21	0	297	-	0	318
AHU SFP	1.8	391	12	0	322	-	0	334
AHU SFP	2	395	11	0	326	-	0	337
AHU SFP	2.2	400	10	0	330	-	0	340
Lighting Efficacy	65	366	28	0	301	-	0	329
Lighting Efficacy	60	371	23	0	306	-	0	328
Lighting Efficacy	55	378	23	0	311	-	0	334

Capabilities on project:  
Building Engineering

Office (AC) (EE2): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.11	305	75	0	254	-	-5	324
Wall U-Value	0.15 (b)	306	63	0	254	-	-4	313
Wall U-Value	0.15	306	67	0	254	-	-4	317
Wall U-Value	0.2	307	57	0	255	-	-4	309
Wall U-Value	0.21	307	65	0	255	-	-4	316
Wall U-Value	0.27	309	61	0	256	-	-4	314
Wall U-Value	0.36	311	58	0	258	-	-4	312
Wall U-Value	0.47	313	54	0	259	-	-4	310
Roof U-value	0.14	307	0	0	255	-	0	255
Roof U-value	0.18	308	0	0	256	-	0	256
Roof U-value	0.29	312	0	0	259	-	0	259
Heating Source	GSHP	225	26	3	190	-	0	219
Heating Source	Gas CHP	290	101	22	253	-	0	375
Heating Source	Gas (91%)	319	9	4	265	-	0	278
Heating Source	Gas (91%) + SHW	319	56	4	265	-	0	325
Heating Source	Gas (86%)	327	9	4	271	-	0	284
Floor U-value	0.1	305	13	0	253	-	-1	265
Floor U-value	0.15	306	9	0	255	-	-1	263
Floor U-value	0.2	308	7	0	256	-	0	263
Floor U-value	0.25	310	6	0	258	-	0	263
Window U-value	1.1	276	87	0	229	-	-3	313
Window U-value	1.4	280	67	0	232	-	-2	297
Window U-value	0.9	282	92	0	235	-	-3	324
Window U-value	1.8	307	57	0	255	-	-2	311
Chiller Efficiency	5.5	250	26	0	207	-	0	233
Chiller Efficiency	4.5	257	23	0	213	-	0	235
Chiller Efficiency	3.5	268	21	0	222	-	0	243
AHU SFP	1.8	301	12	0	249	-	0	261
AHU SFP	2	306	11	0	254	-	0	264
AHU SFP	2.2	310	10	0	258	-	0	268
Lighting Efficacy	65	298	28	0	247	-	0	275
Lighting Efficacy	60	303	23	0	252	-	0	274
Lighting Efficacy	55	310	23	0	258	-	0	280

Capabilities on project:  
Building Engineering

Primary (EE1): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	162	57	0	134	-	-1	190
Wall U-Value	0.14	164	27	0	135	-	0	162
Wall U-Value	0.16	164	51	0	136	-	-1	187
Wall U-Value	0.19	166	13	0	137	-	0	150
Wall U-Value	0.21	166	24	0	138	-	0	161
Wall U-Value	0.3	170	3	0	141	-	0	144
Wall U-Value	0.39	174	10	0	143	-	0	154
Roof U-value	0.15	172	15	0	142	-	0	157
Roof U-value	0.2	173	13	0	143	-	0	156
Roof U-value	0.25	173	11	0	143	-	0	154
Heating Source	GSHP	62	30	6	55	-	0	90
Heating Source	Gas CHP	140	62	25	157	-	0	244
Heating Source	Gas (91%) + SHW	155	47	6	128	-	0	181
Heating Source	Gas (91%)	155	8	6	128	-	0	142
Heating Source	Gas (86%)	163	8	6	135	-	0	148
Floor U-value	0.1	158	11	0	131	-	0	142
Floor U-value	0.15	161	8	0	133	-	0	141
Floor U-value	0.2	163	6	0	135	-	0	141
Floor U-value	0.25	166	5	0	137	-	0	142
Window U-value	0.9	142	47	0	118	-	0	165
Window U-value	1.1	147	44	0	123	-	0	166
Window U-value	1.8	150	29	0	125	-	0	154
Window U-value	1.4	152	34	0	126	-	0	160
Lighting Efficacy	65	157	23	0	127	-	0	150
Lighting Efficacy	60	158	21	0	128	-	0	149
Lighting Efficacy	55	160	20	0	130	-	0	149

Capabilities on project:  
Building Engineering

Primary (EE2): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	84	57	0	69	-	-1	126
Wall U-Value	0.14	86	27	0	71	-	0	97
Wall U-Value	0.16	87	51	0	71	-	-1	122
Wall U-Value	0.19	88	13	0	72	-	0	85
Wall U-Value	0.21	89	24	0	73	-	0	96
Wall U-Value	0.3	92	3	0	76	-	0	79
Wall U-Value	0.39	96	10	0	78	-	0	88
Roof U-value	0.15	93	15	0	76	-	0	91
Roof U-value	0.2	94	13	0	77	-	0	90
Roof U-value	0.25	94	11	0	77	-	0	88
Heating Source	GSHP	27	30	6	24	-	0	60
Heating Source	Gas CHP	82	62	25	95	-	0	182
Heating Source	Gas (91%) + SHW	92	47	6	75	-	0	128
Heating Source	Gas (91%)	92	8	6	75	-	0	89
Heating Source	Gas (86%)	97	8	6	80	-	0	93
Floor U-value	0.1	87	11	0	71	-	0	82
Floor U-value	0.15	89	8	0	73	-	0	81
Floor U-value	0.2	92	6	0	75	-	0	81
Floor U-value	0.25	94	5	0	77	-	0	82
Window U-value	0.9	81	47	0	67	-	0	113
Window U-value	1.1	86	44	0	71	-	0	114
Window U-value	1.8	89	29	0	73	-	0	102
Window U-value	1.4	90	34	0	74	-	0	108
Lighting Efficacy	65	91	23	0	74	-	0	97
Lighting Efficacy	60	92	21	0	75	-	0	96
Lighting Efficacy	55	93	20	0	76	-	0	96

Capabilities on project:  
Building Engineering

Hotel (EE1): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

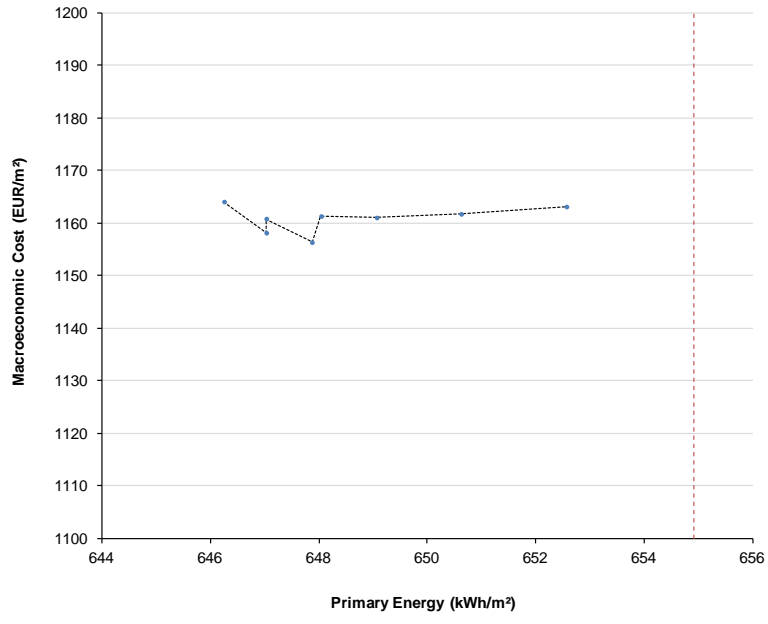
Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	566	94	0	462	-	-6	550
Wall U-Value	0.14	568	44	0	463	-	-3	505
Wall U-Value	0.16	568	84	0	464	-	-6	543
Wall U-Value	0.19	569	22	0	465	-	-1	485
Wall U-Value	0.21	570	39	0	465	-	-3	502
Wall U-Value	0.3	573	5	0	468	-	0	473
Wall U-Value	0.39	576	17	0	470	-	-1	486
Roof U-value	0.15	576	10	0	470	-	-1	479
Roof U-value	0.2	577	9	0	471	-	-1	479
Roof U-value	0.25	578	7	0	472	-	0	479
Heating Source	GSHP	457	29	5	376	-	0	410
Heating Source	Gas CHP	542	74	25	458	-	0	557
Heating Source	Gas (91%) + SHW	563	35	5	460	-	0	501
Heating Source	Gas (91%)	576	8	5	470	-	0	483
Heating Source	Gas (86%)	586	8	5	478	-	0	491
Floor U-value	0.1	570	7	0	465	-	0	472
Floor U-value	0.15	571	5	0	466	-	0	471
Floor U-value	0.2	572	4	0	467	-	0	471
Floor U-value	0.25	573	3	0	468	-	0	471
Window U-value	1.1	547	87	0	446	-	-3	531
Window U-value	0.9	548	93	0	448	-	-3	538
Window U-value	1.4	550	68	0	449	-	-2	515
Window U-value	1.8	563	58	0	460	-	-2	516
Chiller Efficiency	5.5	546	31	0	444	-	0	475
Chiller Efficiency	4.5	549	27	0	447	-	0	474
Chiller Efficiency	3.5	554	25	0	451	-	0	476
AHU SFP	1.8	558	10	0	454	-	0	465
AHU SFP	2	564	10	0	459	-	0	469
AHU SFP	2.2	569	9	0	464	-	0	473
Lighting Efficacy	65	489	51	0	394	-	0	445
Lighting Efficacy	60	491	46	0	396	-	0	441
Lighting Efficacy	55	493	39	0	398	-	0	437

Capabilities on project:  
Building Engineering

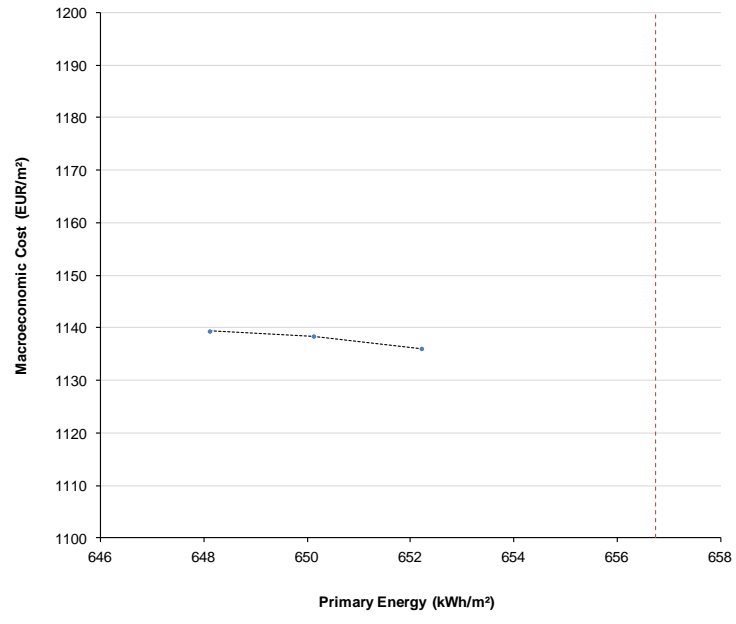
Hotel (EE2): Financial Costs (Central energy price, 13% discount rate, EUR/m<sup>2</sup>)

Package	Value	PE (KWh/m <sup>2</sup> )	Initial Investment Cost	Annual Costs		Cost of Emissions	Residual Value	Macro Cost
				Maintenance	Energy			
Wall U-Value	0.1	442	94	0	359	-	-6	447
Wall U-Value	0.14	444	44	0	360	-	-3	401
Wall U-Value	0.16	445	84	0	360	-	-6	439
Wall U-Value	0.19	446	22	0	361	-	-1	382
Wall U-Value	0.21	446	39	0	362	-	-3	398
Wall U-Value	0.3	450	5	0	364	-	0	369
Wall U-Value	0.39	453	17	0	367	-	-1	383
Roof U-value	0.15	453	10	0	367	-	-1	376
Roof U-value	0.2	454	9	0	368	-	-1	376
Roof U-value	0.25	455	7	0	369	-	0	376
Heating Source	GSHP	325	29	5	266	-	0	300
Heating Source	Gas CHP	420	74	25	357	-	0	456
Heating Source	Gas (91%) + SHW	446	35	5	362	-	0	403
Heating Source	Gas (91%)	458	8	5	371	-	0	384
Heating Source	Gas (86%)	469	8	5	380	-	0	393
Floor U-value	0.1	446	7	0	362	-	0	369
Floor U-value	0.15	448	5	0	363	-	0	368
Floor U-value	0.2	449	4	0	364	-	0	368
Floor U-value	0.25	450	3	0	365	-	0	368
Window U-value	0.9	431	93	0	349	-	-3	439
Window U-value	1.1	434	87	0	351	-	-3	436
Window U-value	1.4	439	68	0	355	-	-2	421
Window U-value	1.8	445	58	0	361	-	-2	417
Chiller Efficiency	5.5	437	31	0	353	-	0	384
Chiller Efficiency	4.5	439	27	0	355	-	0	382
Chiller Efficiency	3.5	442	25	0	358	-	0	383
AHU SFP	1.8	444	10	0	359	-	0	369
AHU SFP	2	450	10	0	364	-	0	373
AHU SFP	2.2	455	9	0	369	-	0	378
Lighting Efficacy	65	434	51	0	351	-	0	402
Lighting Efficacy	60	436	46	0	352	-	0	398
Lighting Efficacy	55	439	39	0	354	-	0	393

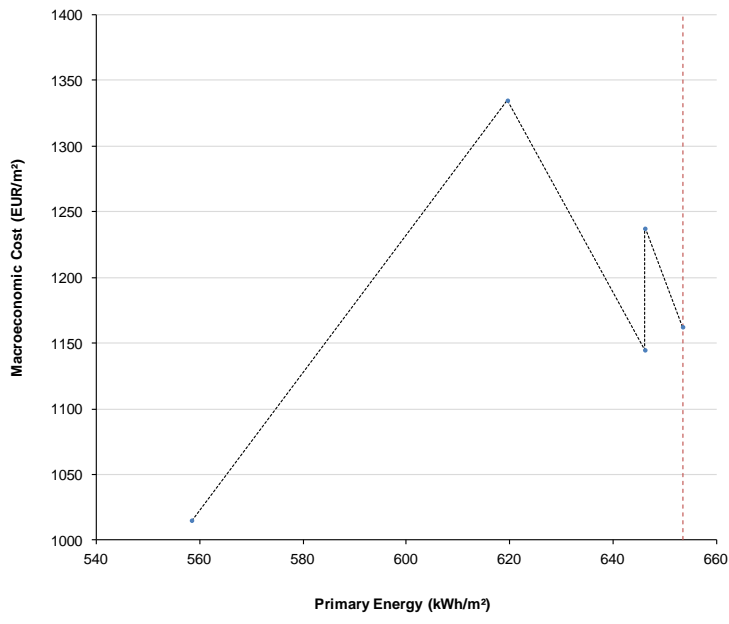
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



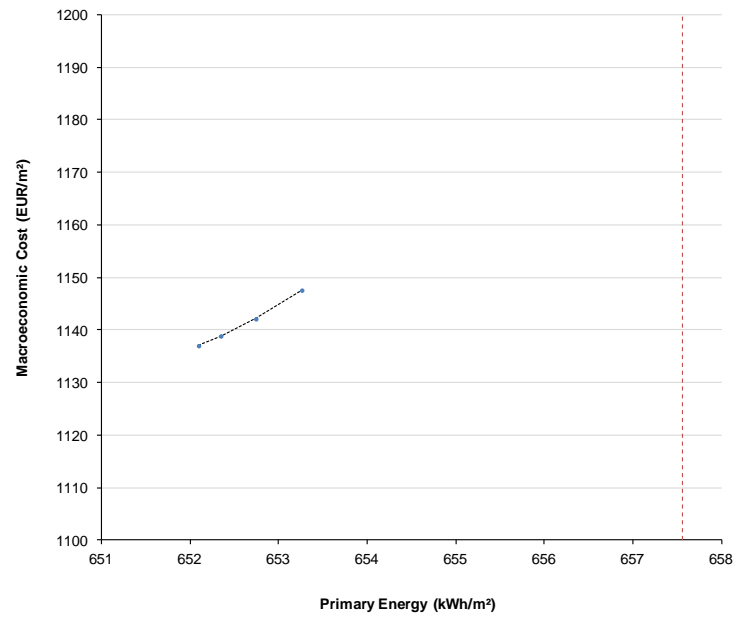
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



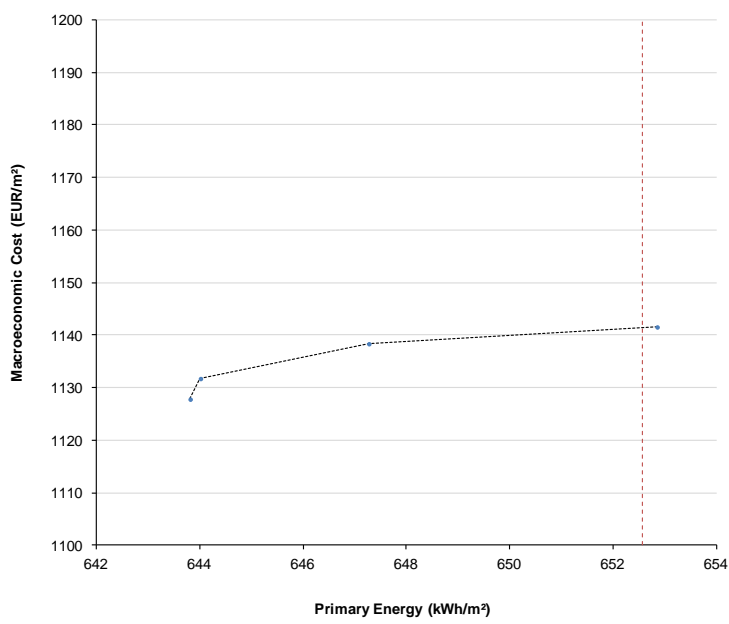
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



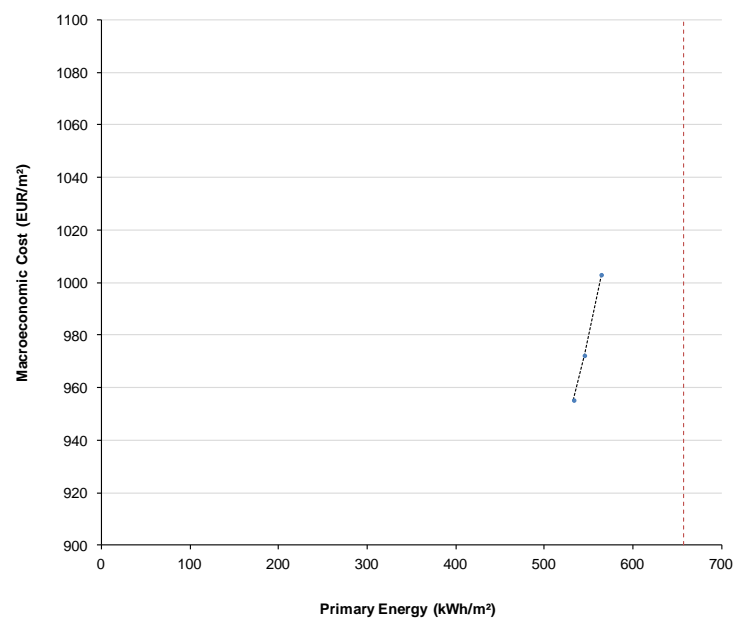
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



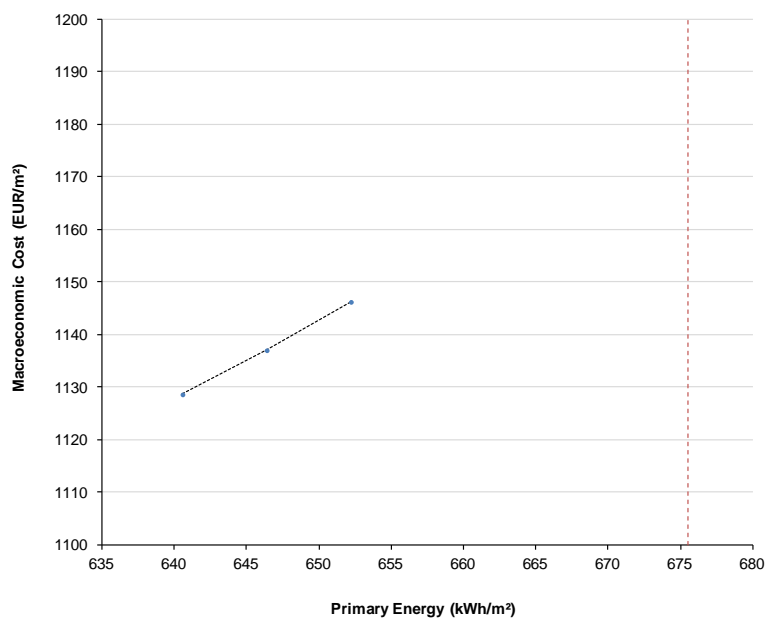
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



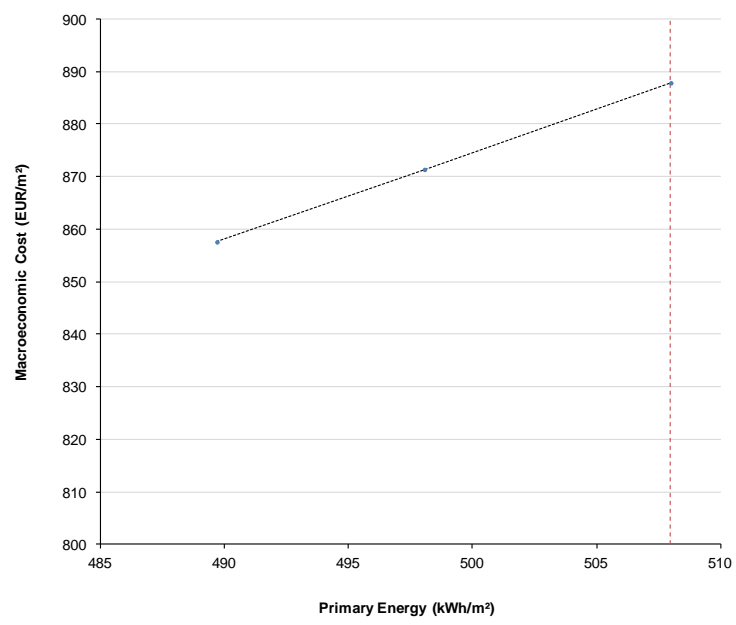
Chiller Efficiency - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



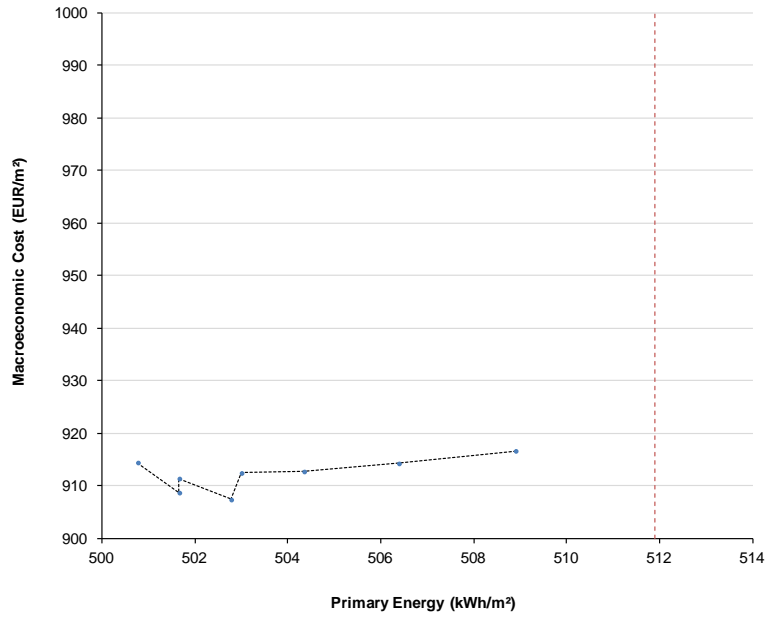
AHU SFP - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



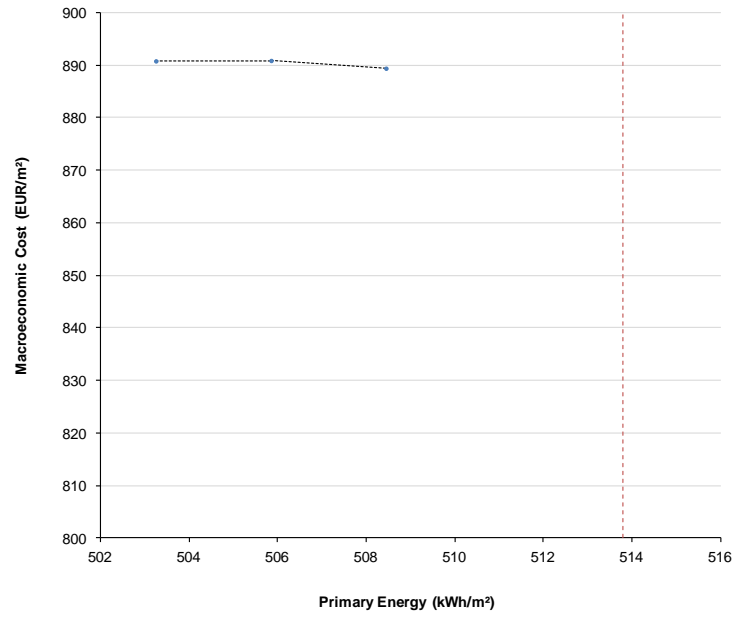
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



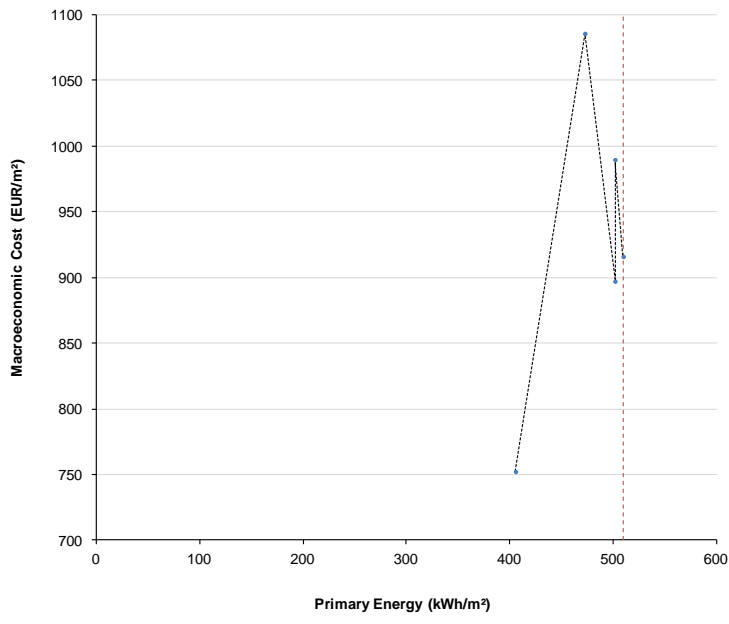
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



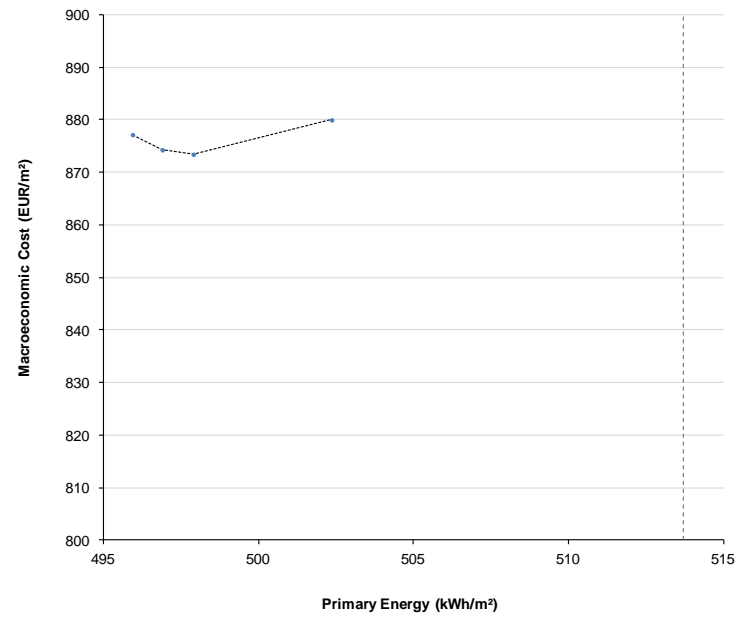
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



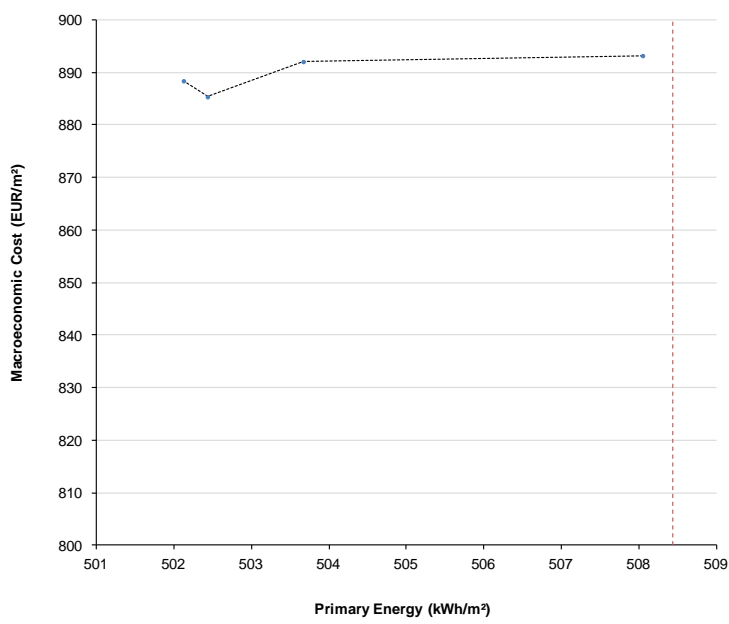
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



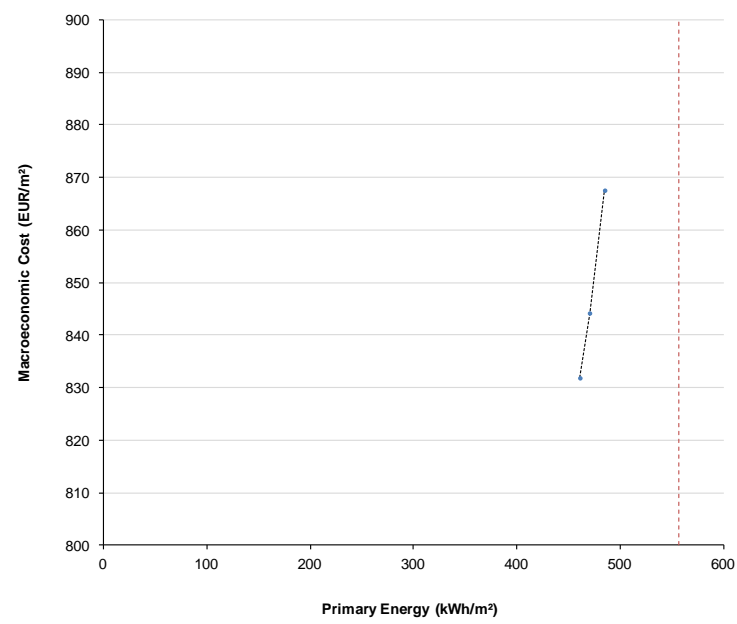
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



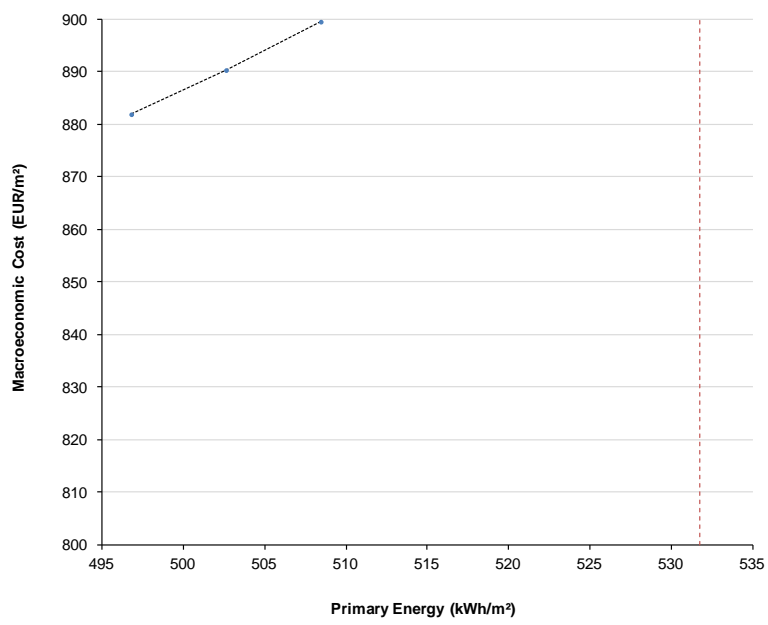
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



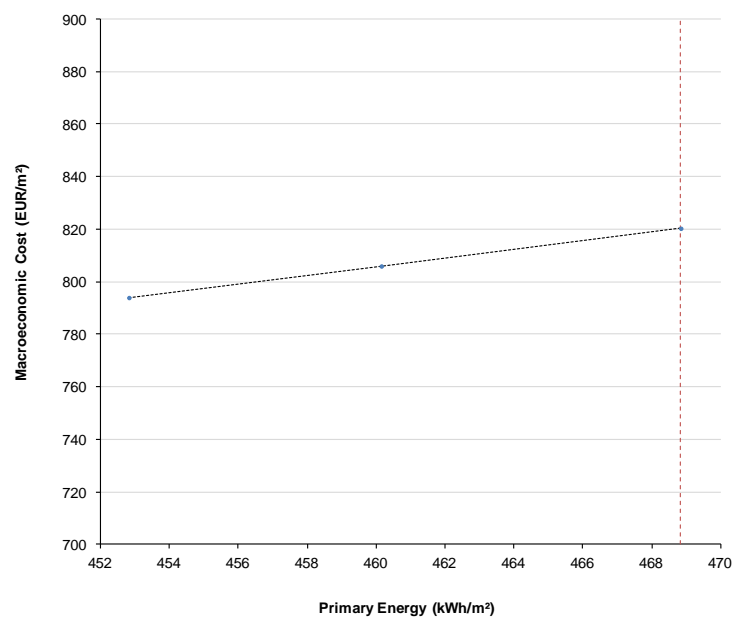
Chiller Efficiency - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



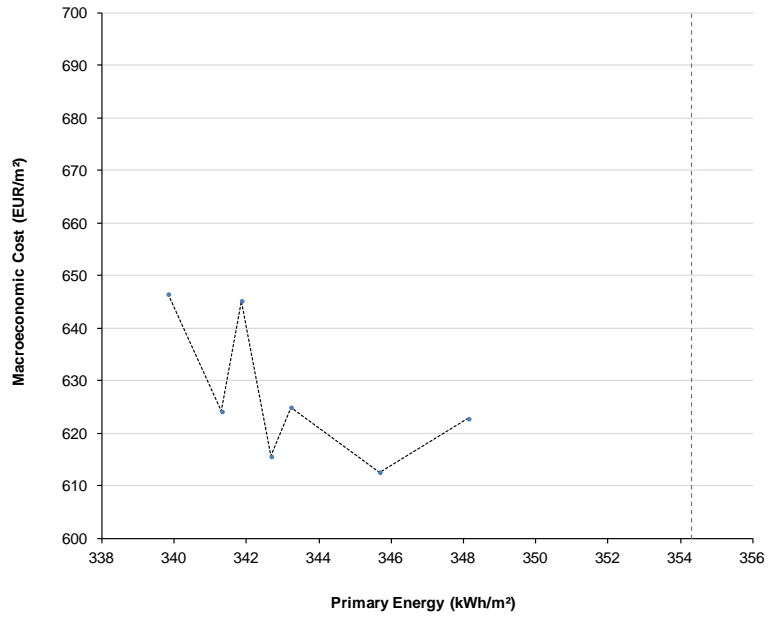
AHU SFP - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



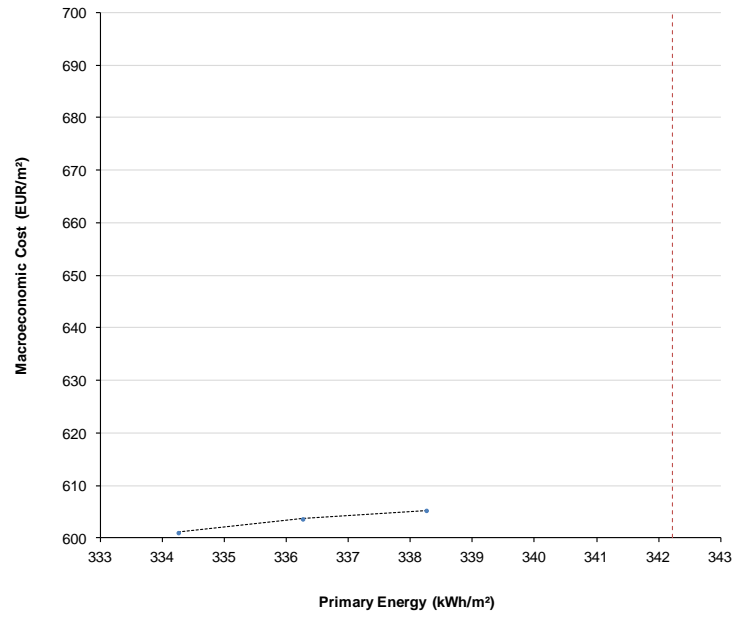
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



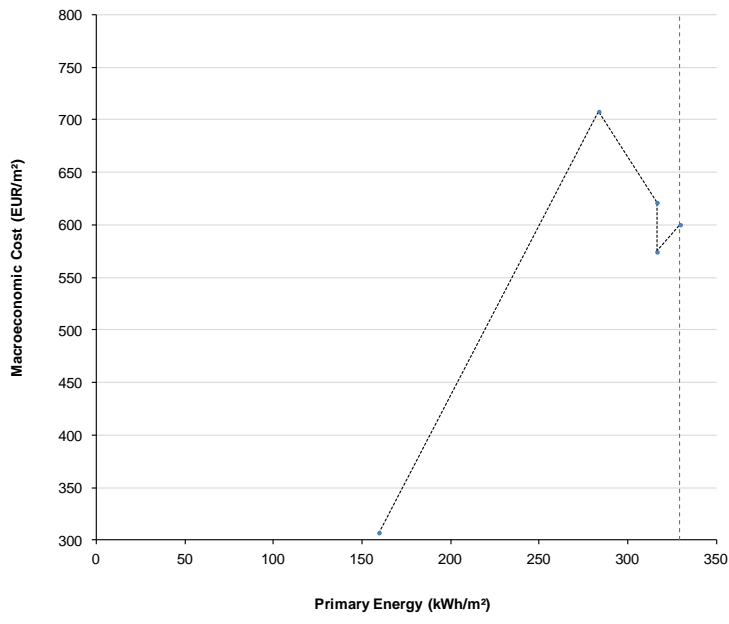
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



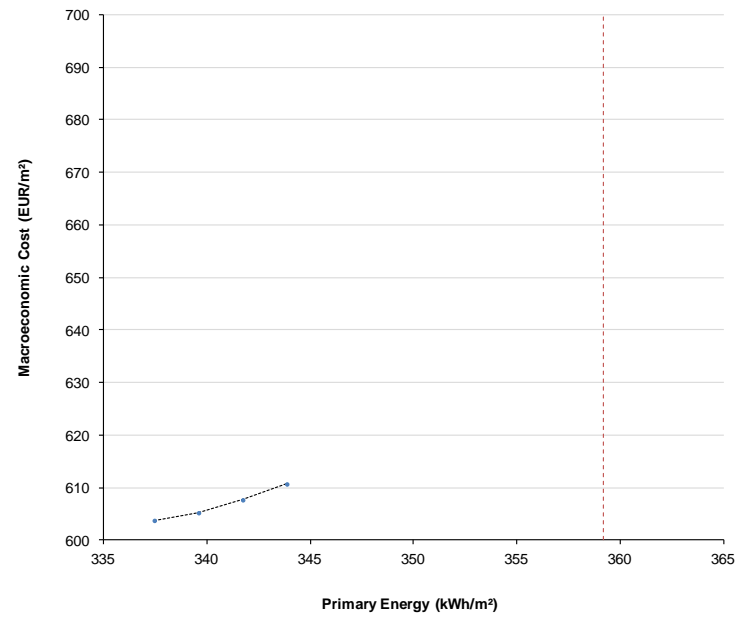
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



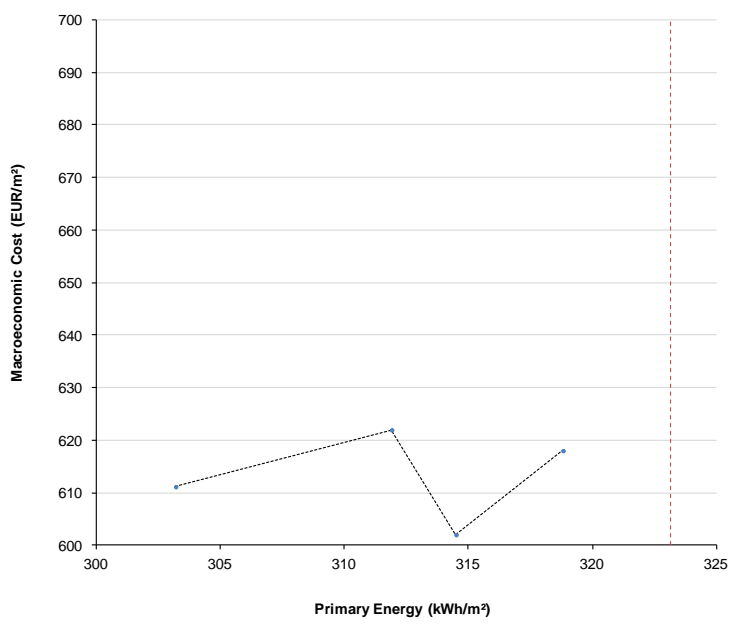
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



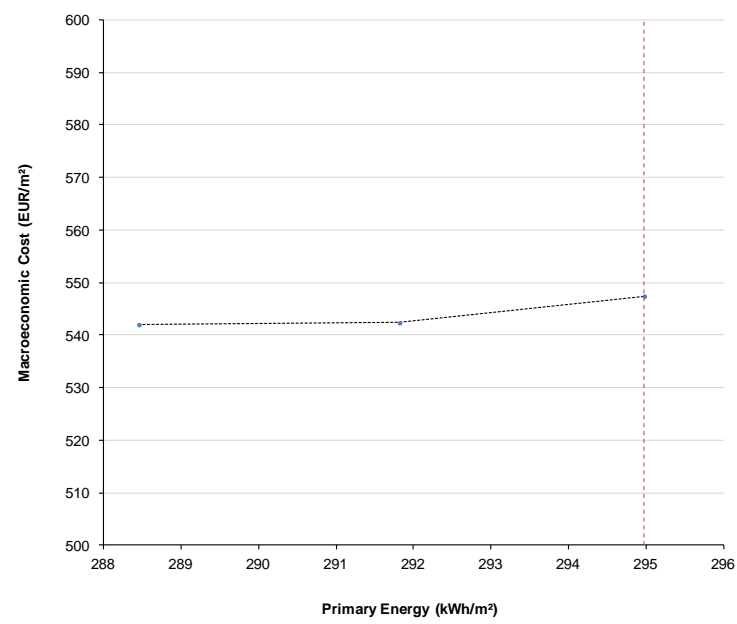
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



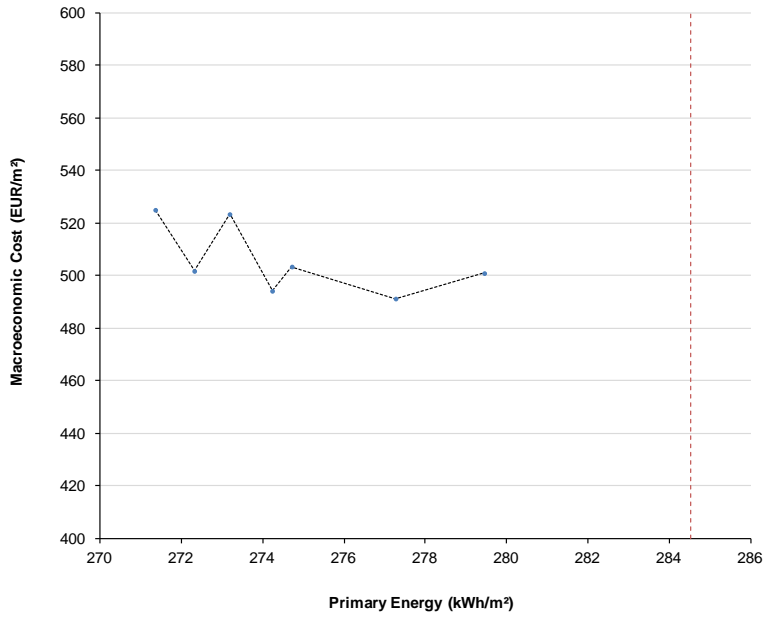
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



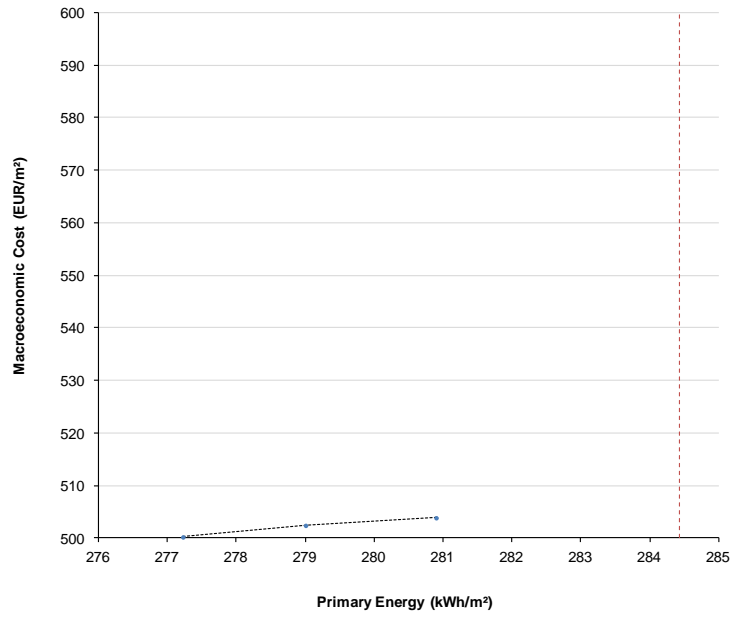
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



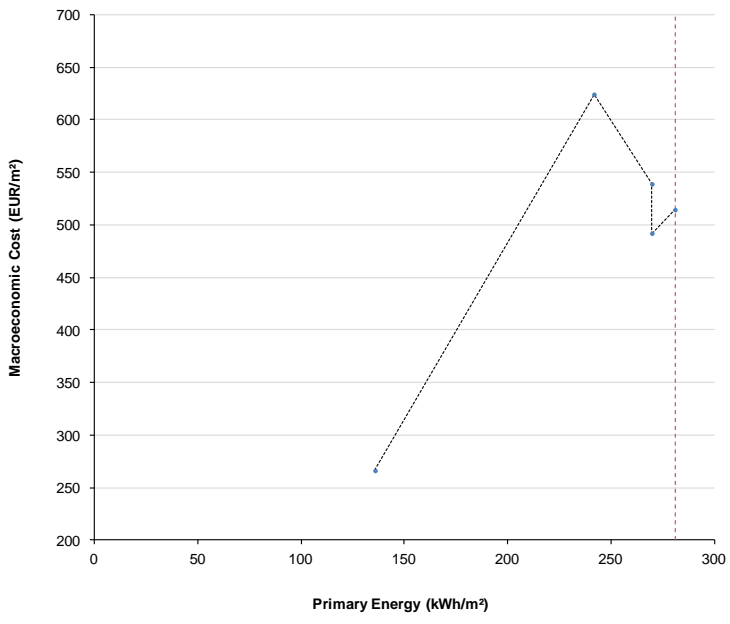
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



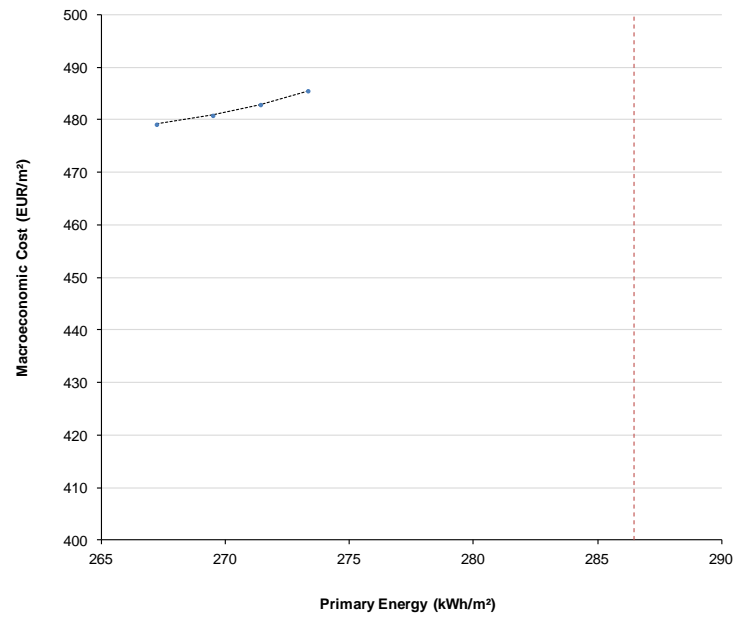
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



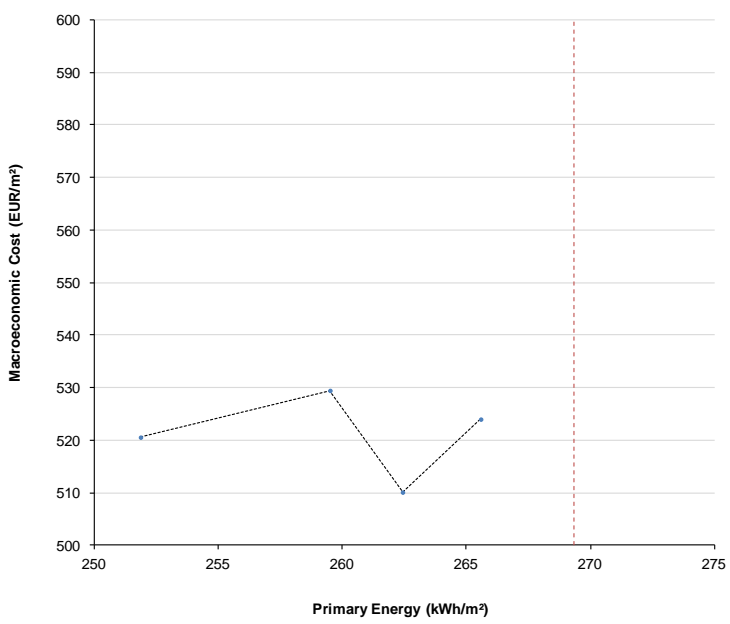
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



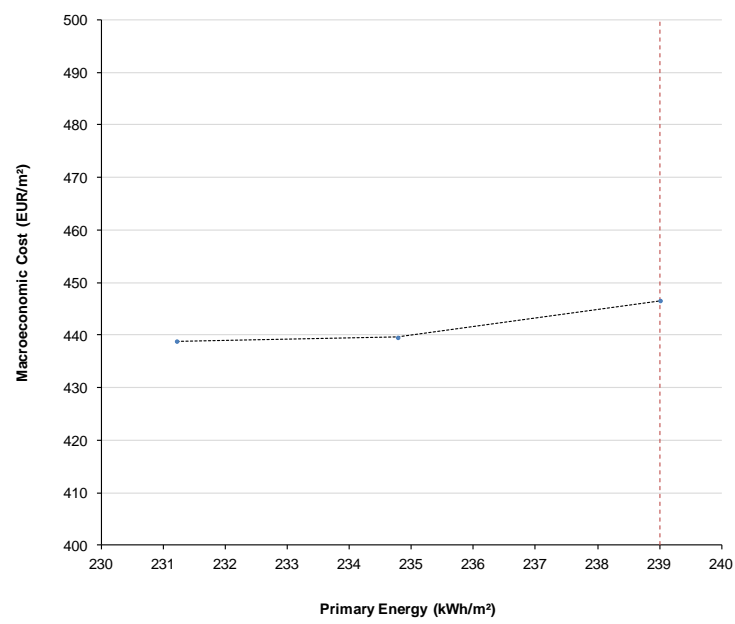
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



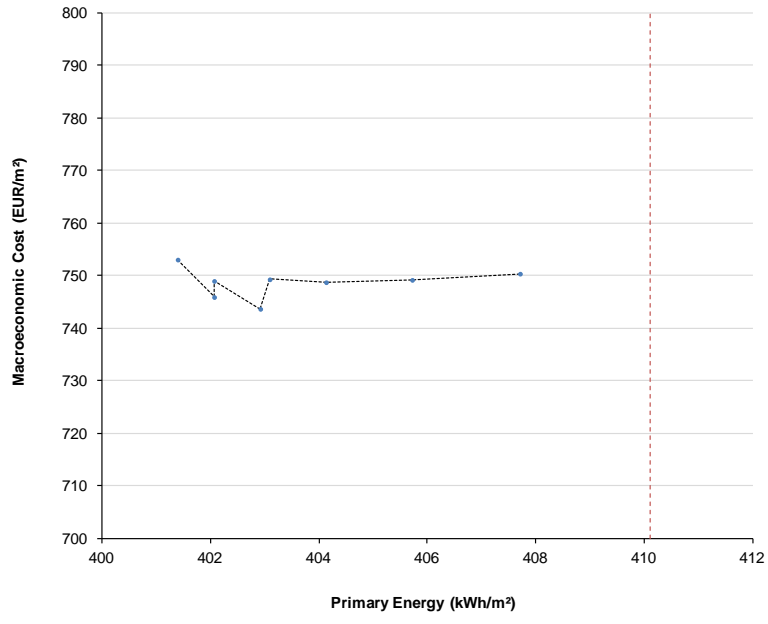
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



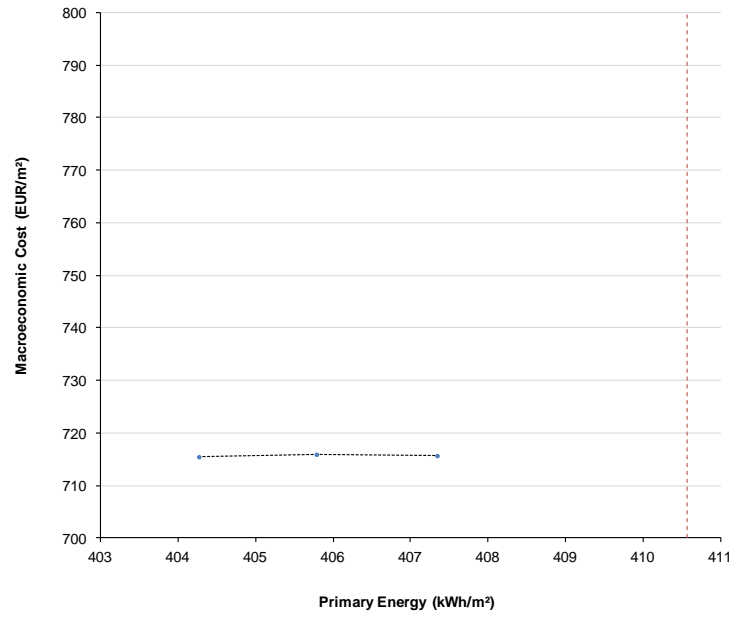
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



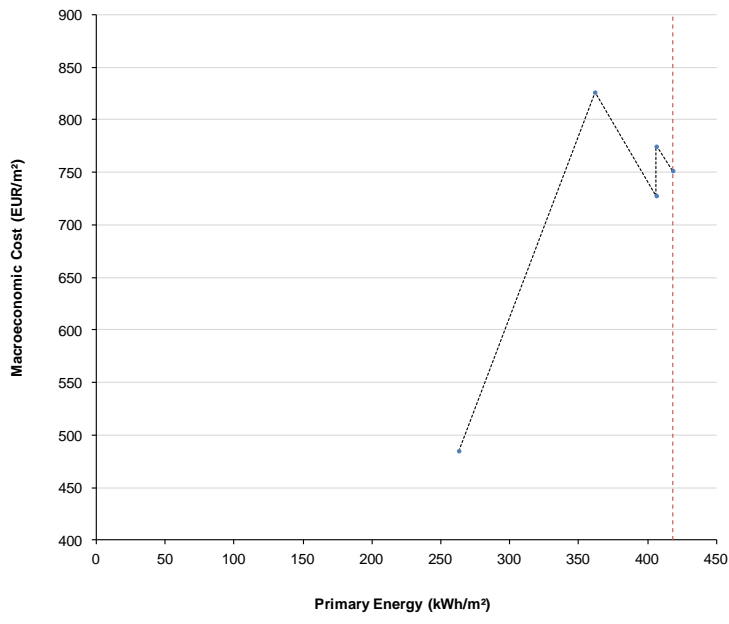
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



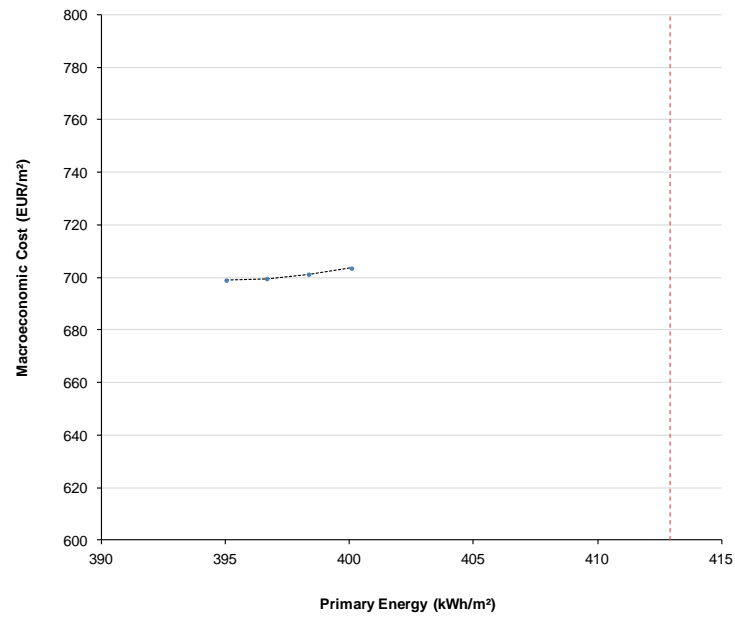
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



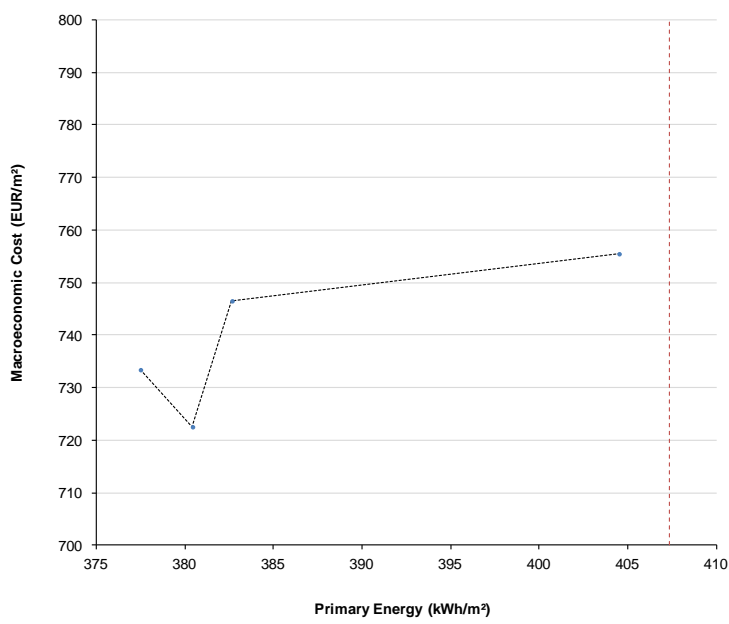
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



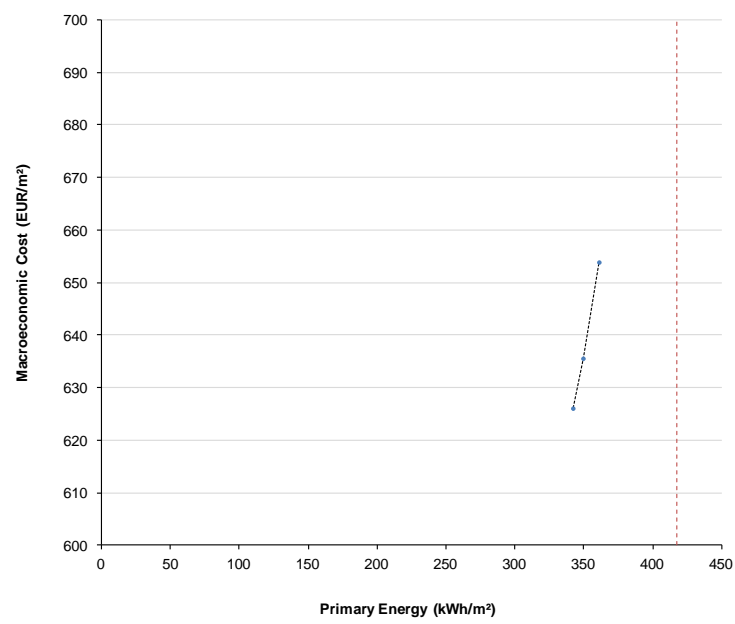
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



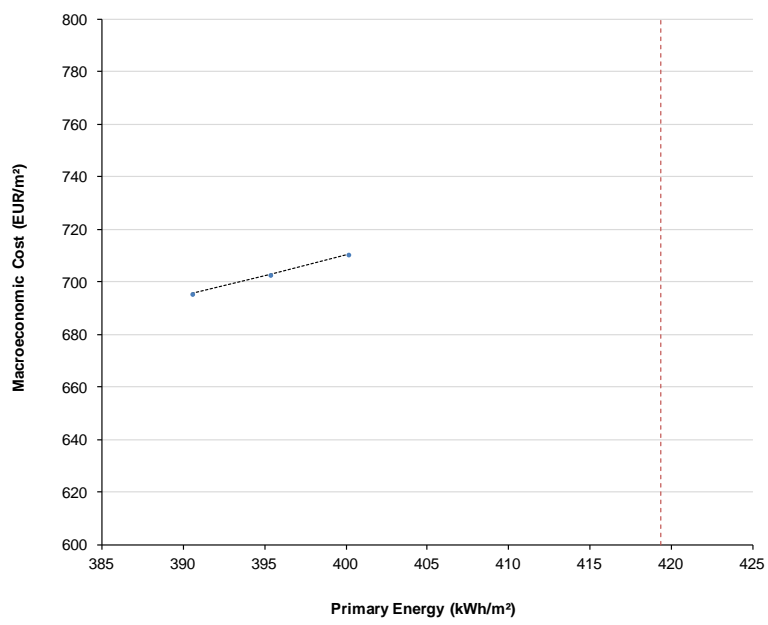
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



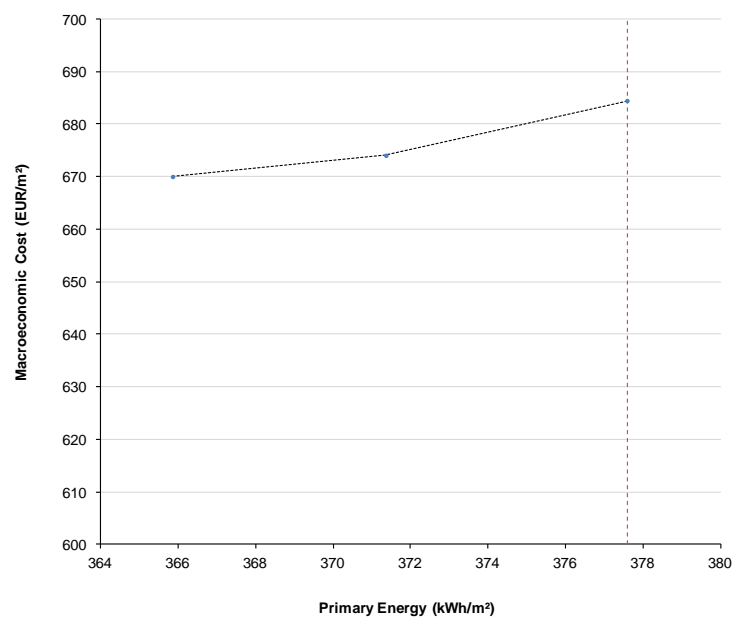
Chiller Efficiency - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



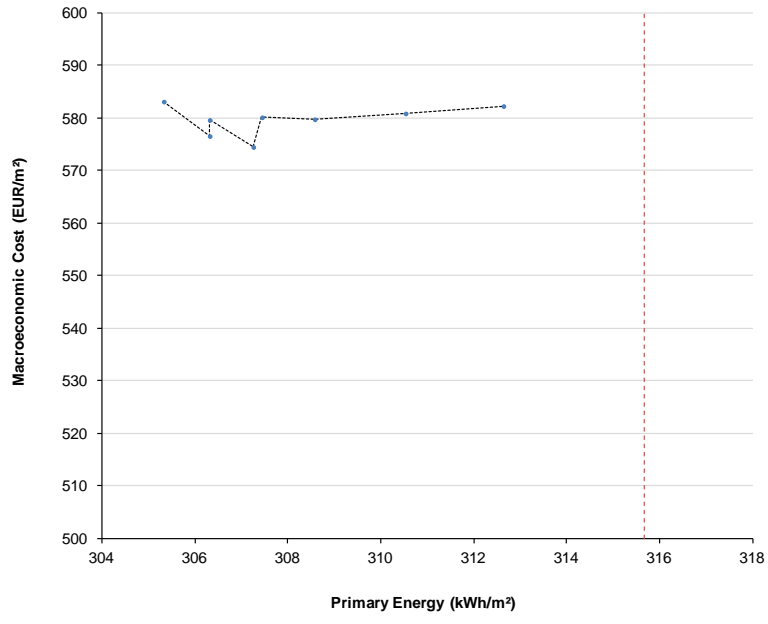
AHU SFP - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



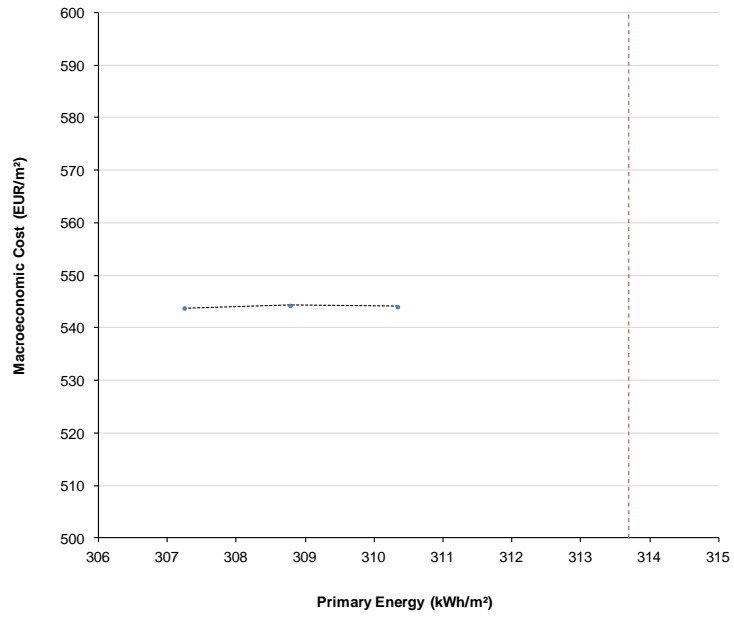
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



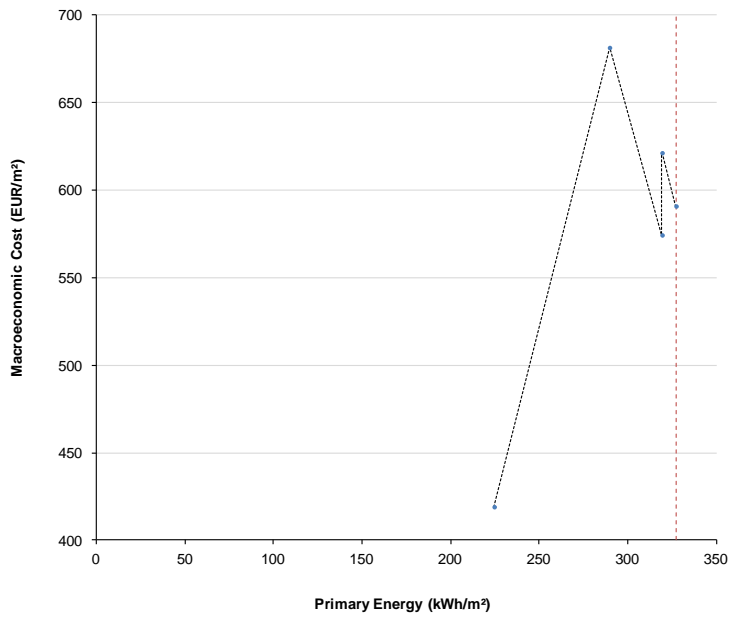
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



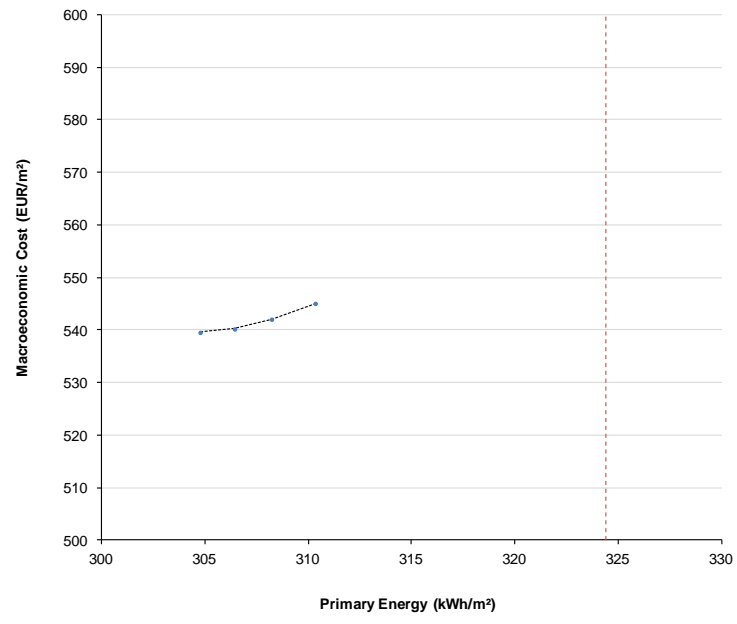
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



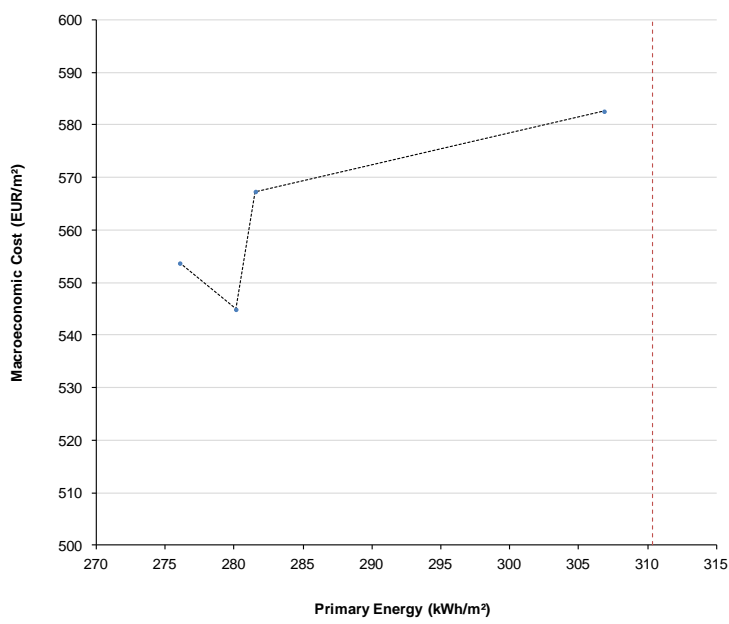
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



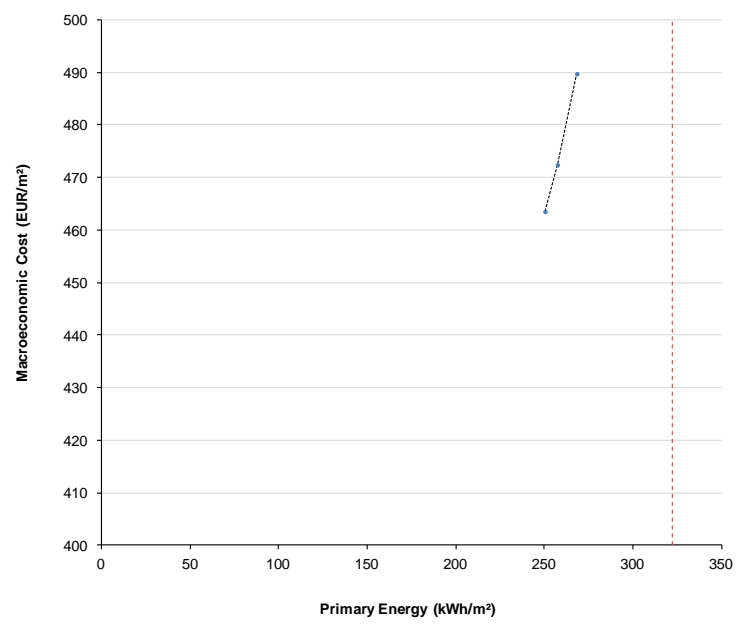
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



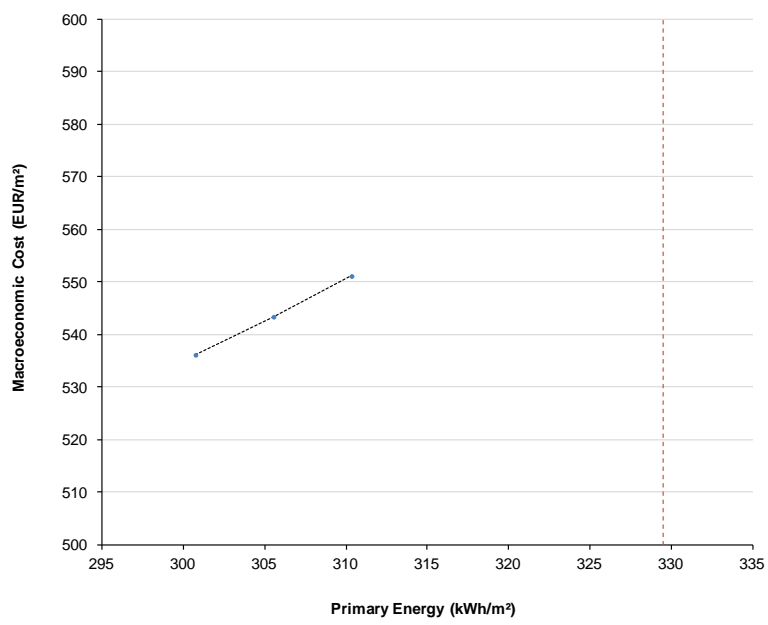
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



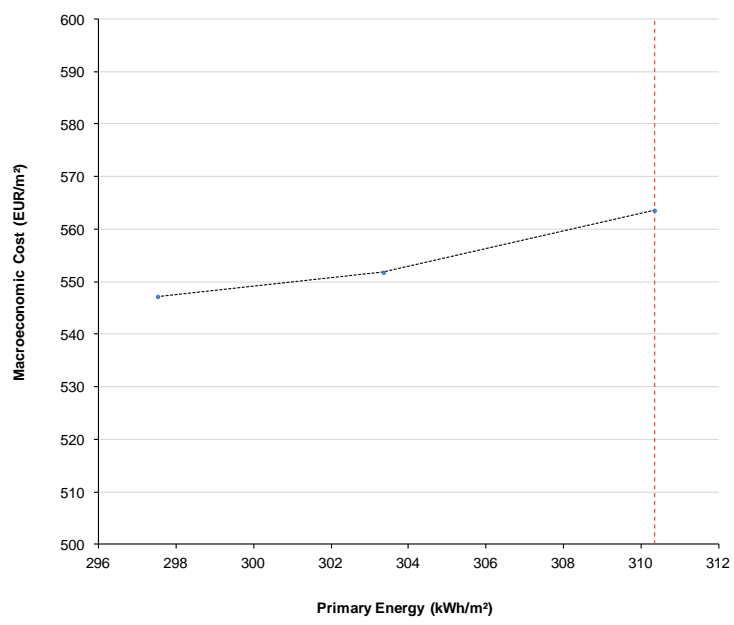
Chiller Efficiency - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



AHU SFP - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

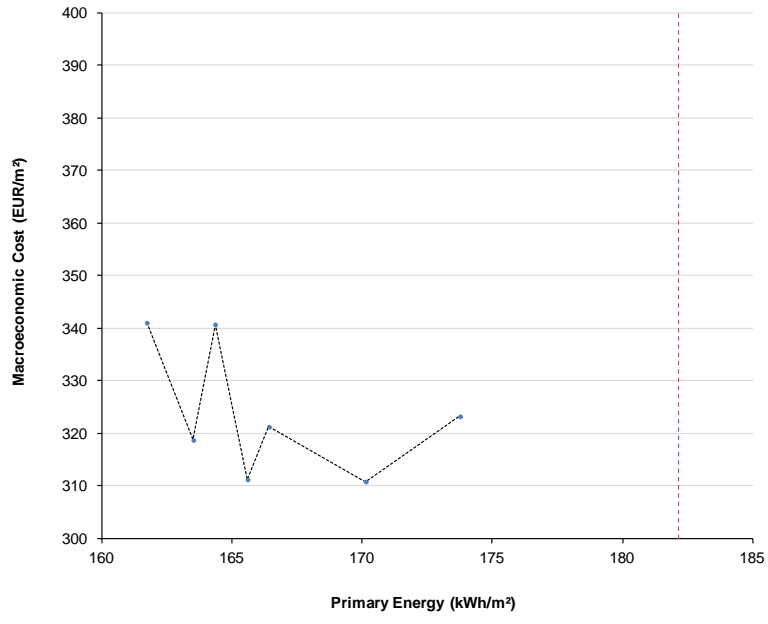


Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

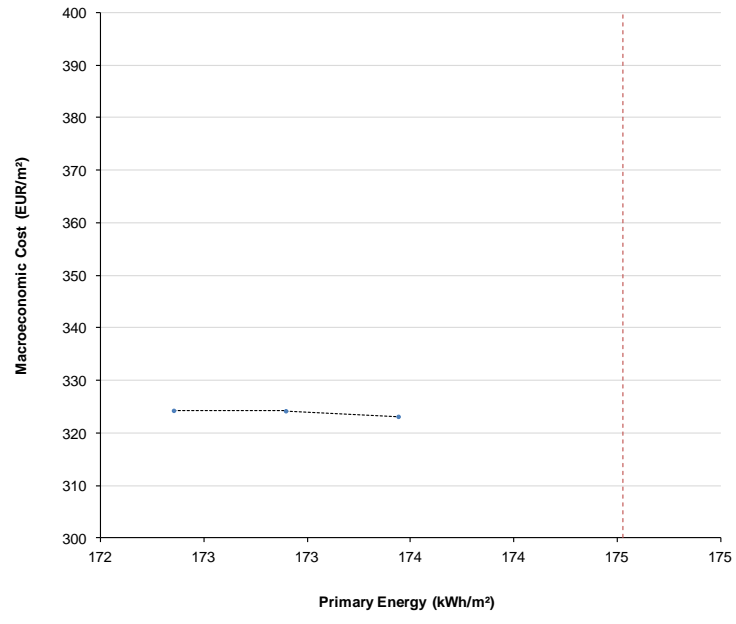


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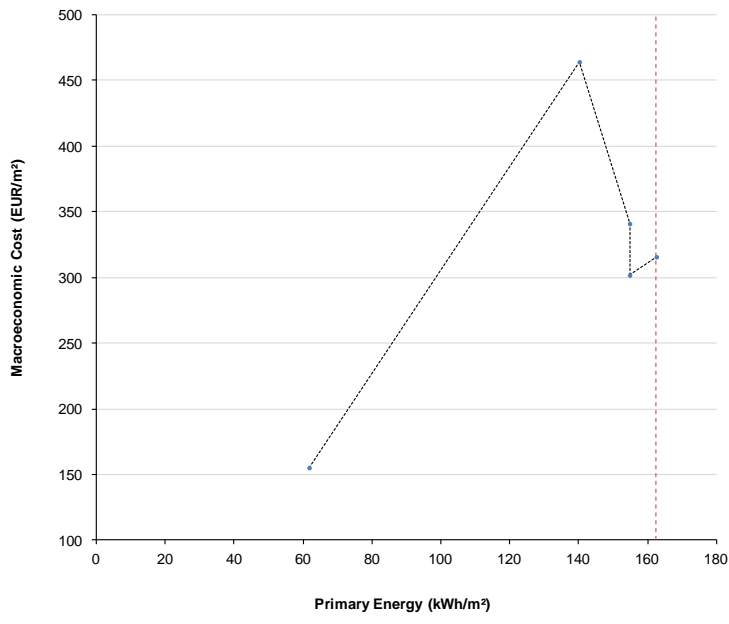
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



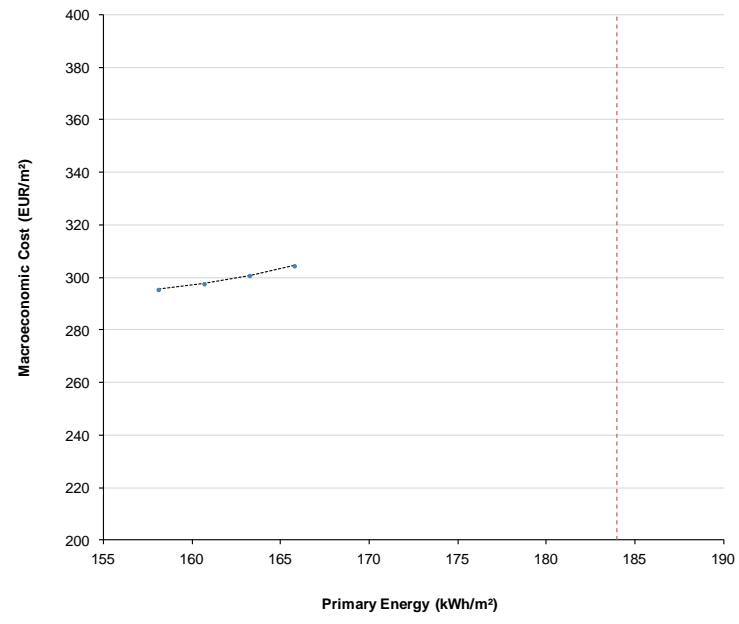
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



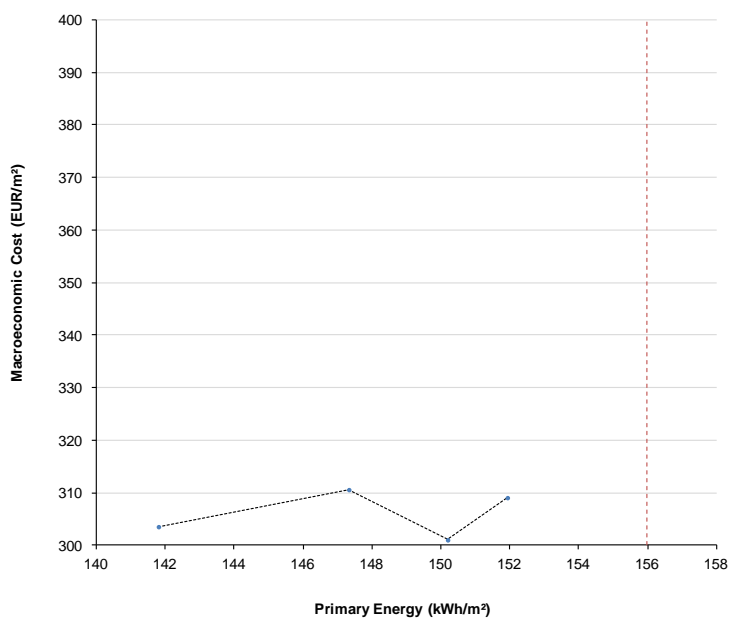
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



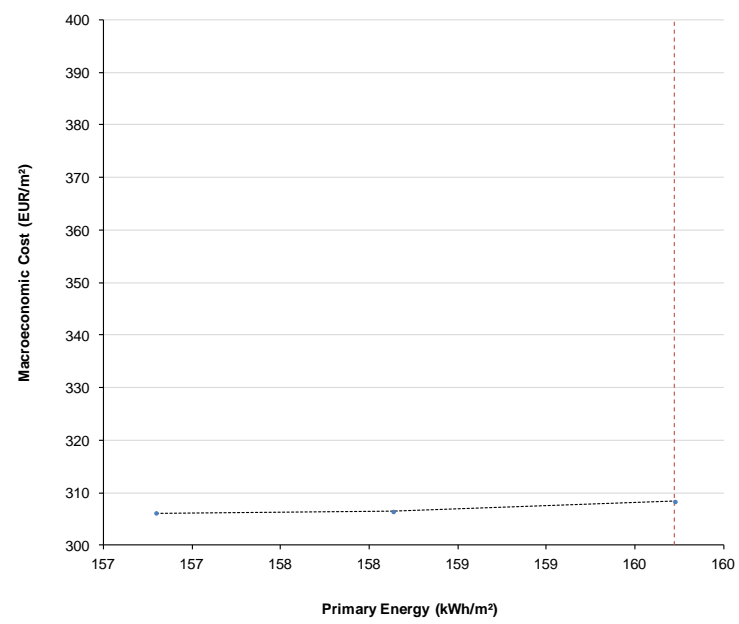
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



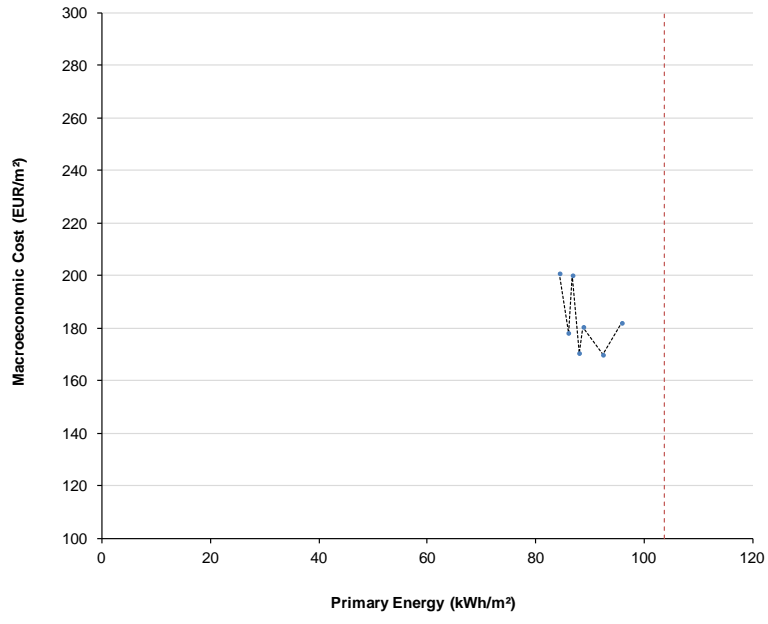
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



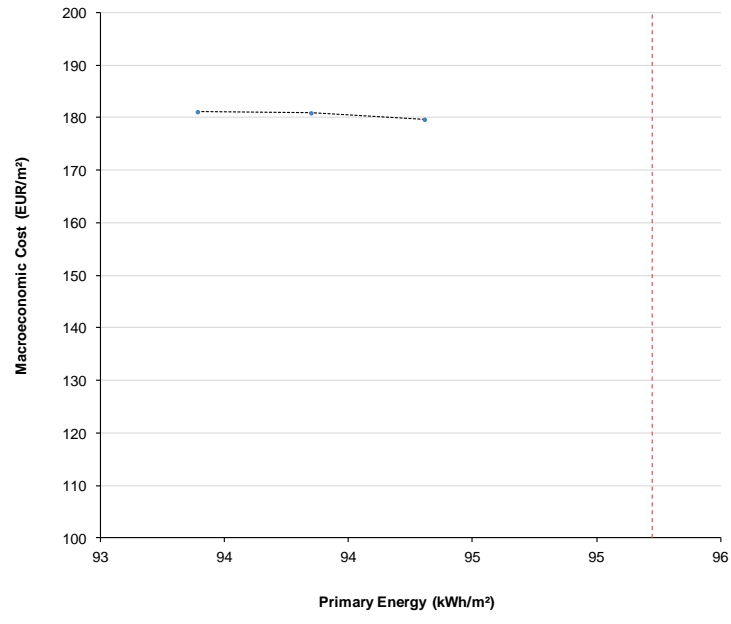
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



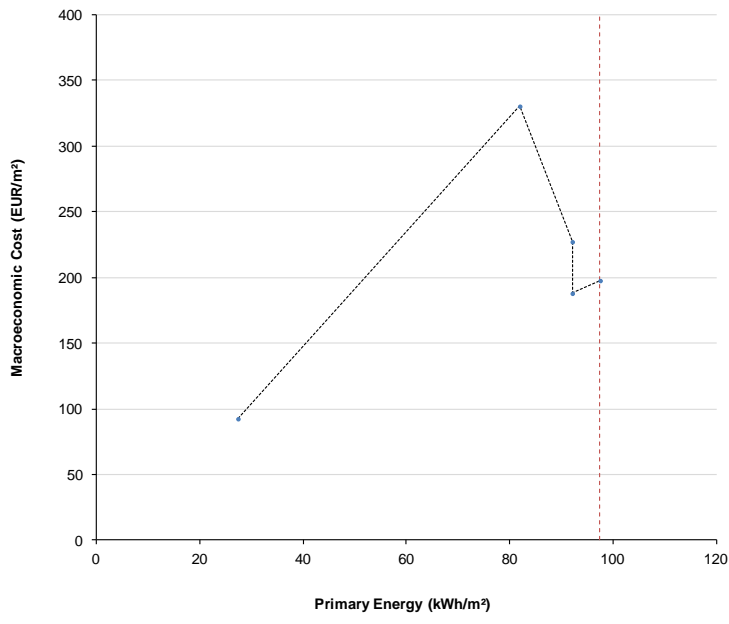
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



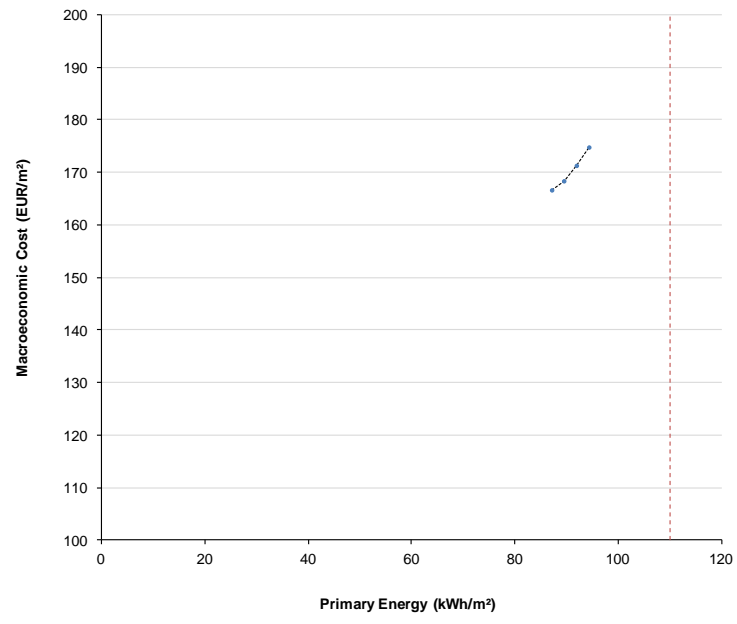
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



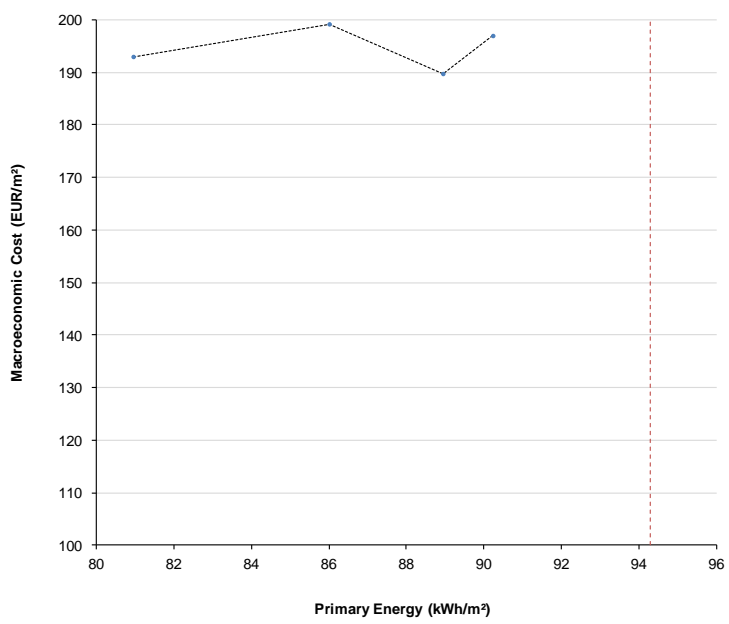
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



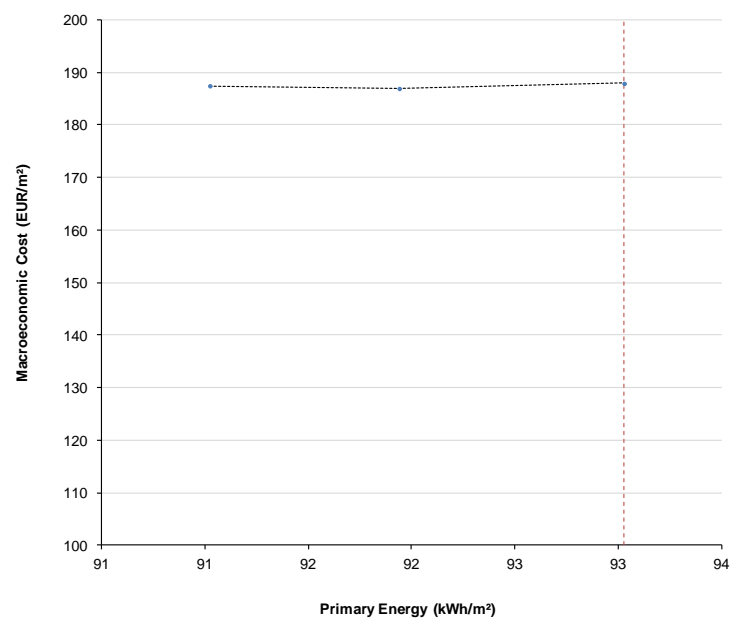
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



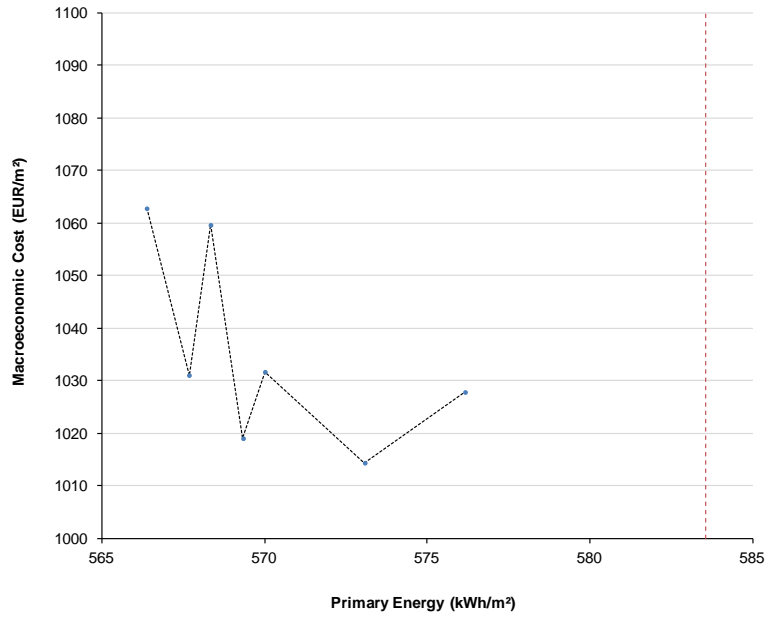
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



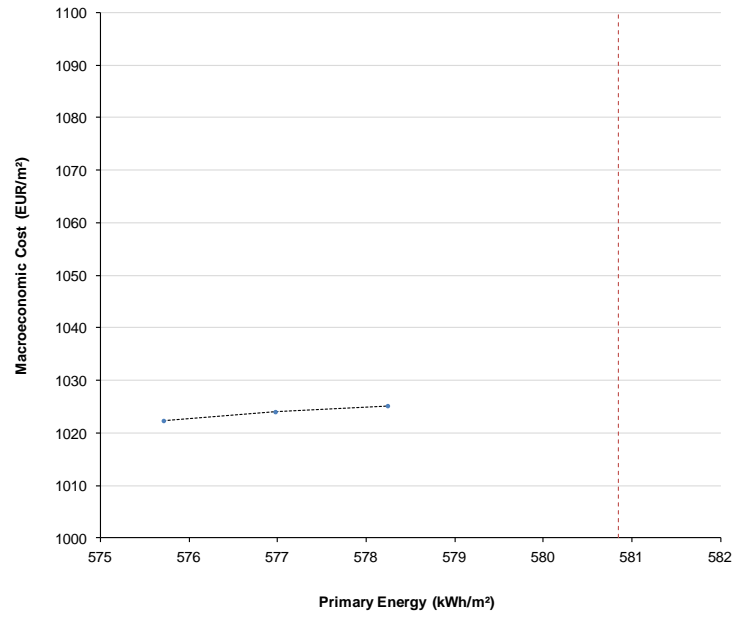
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



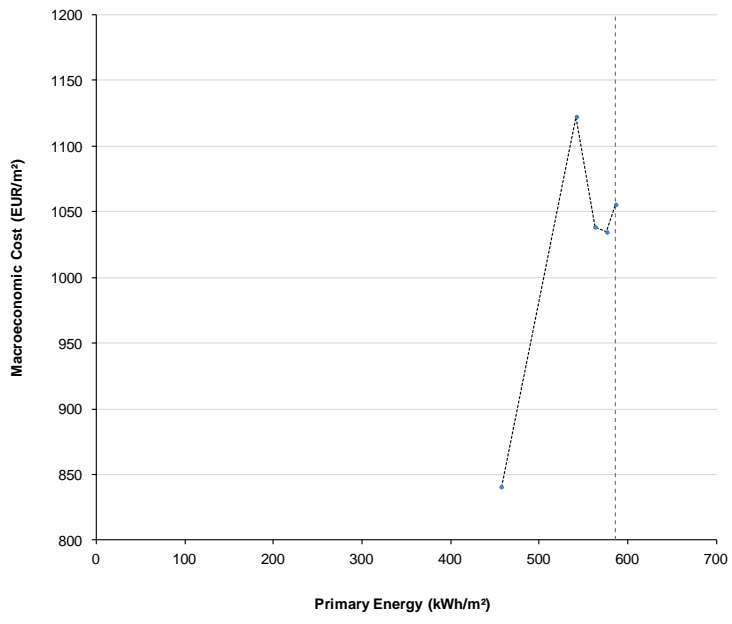
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



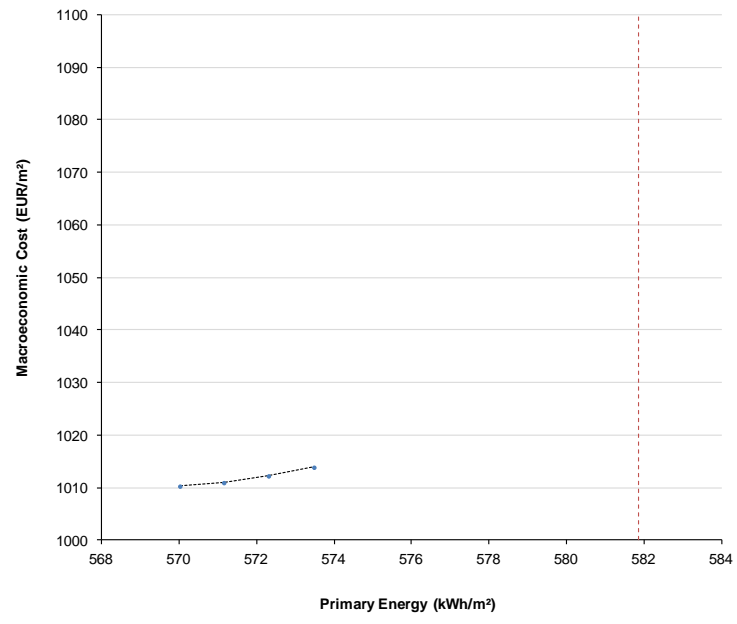
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



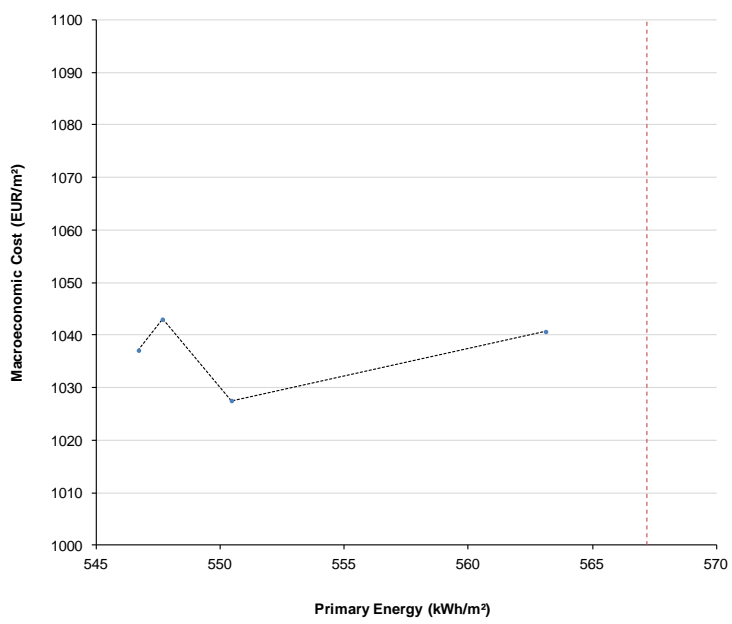
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



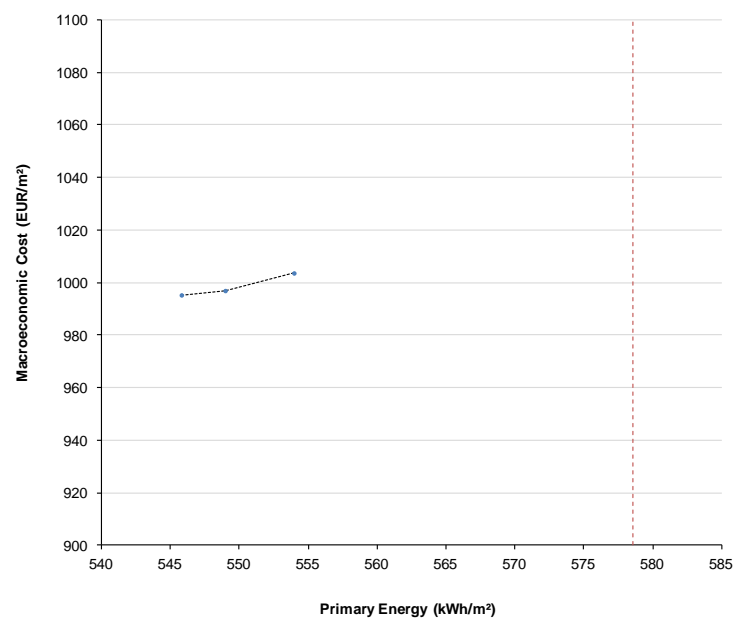
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



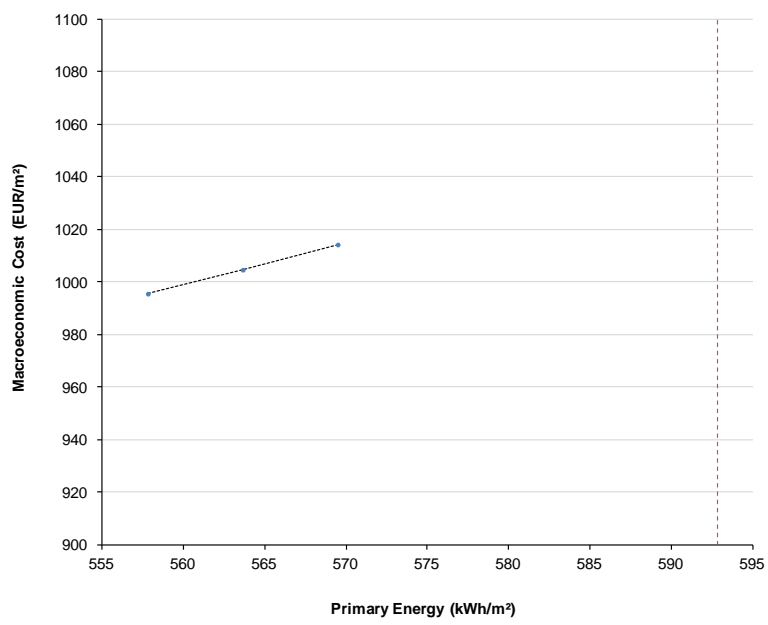
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



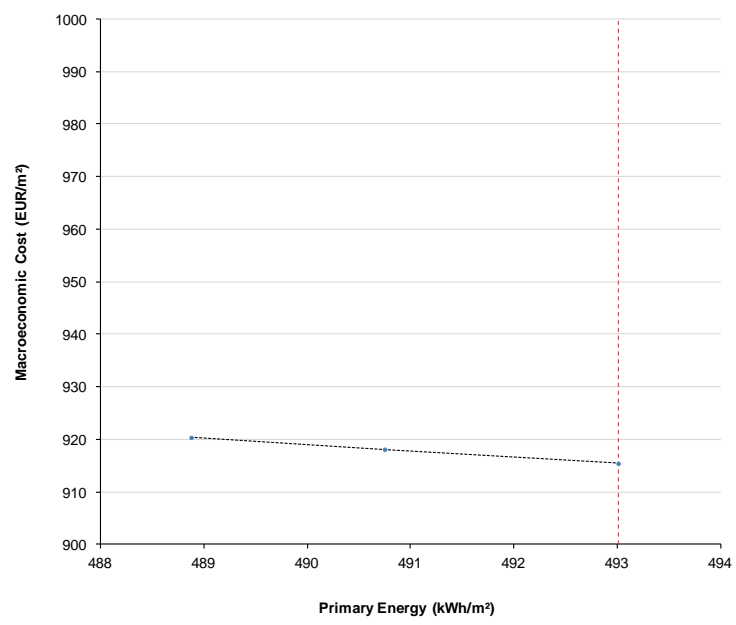
Chiller Efficiency - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



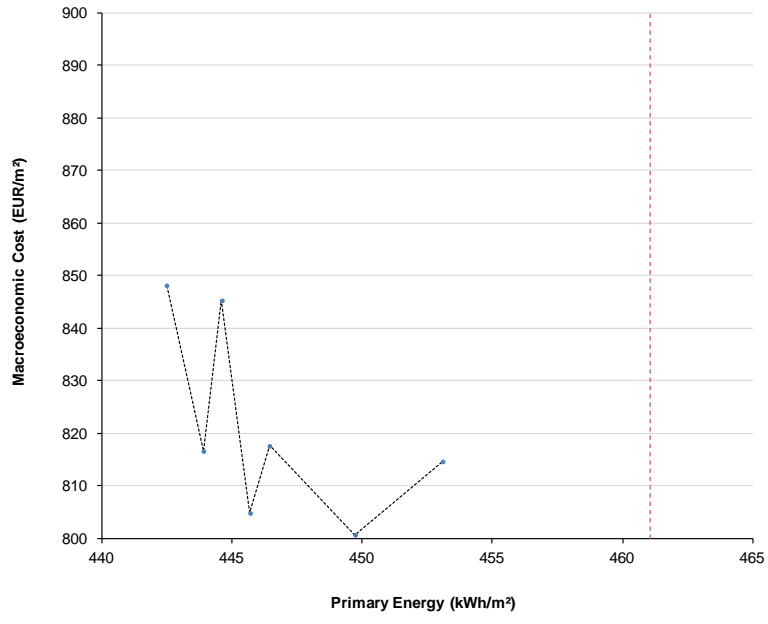
AHU SFP - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



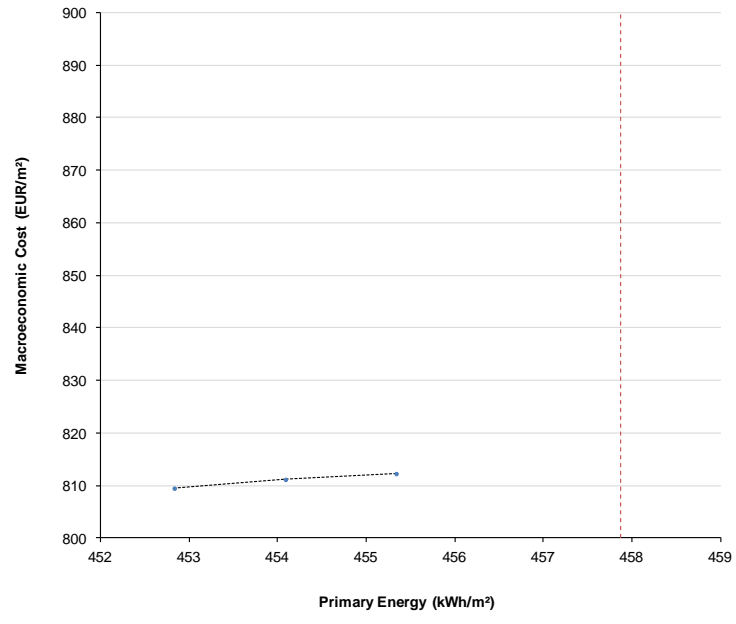
Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



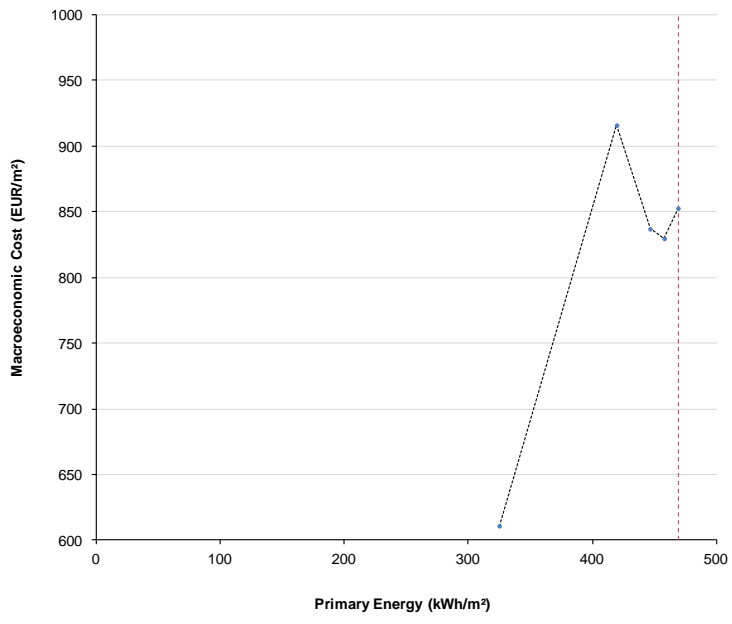
Wall U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



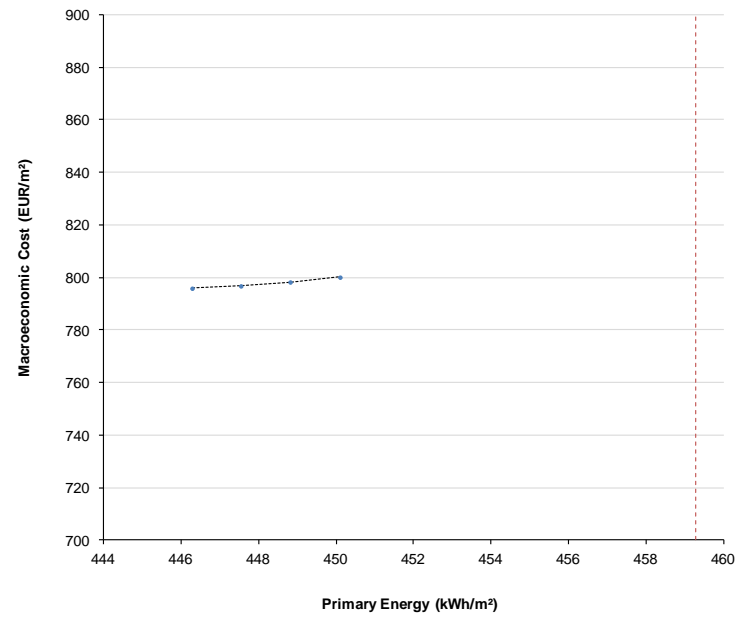
Roof U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



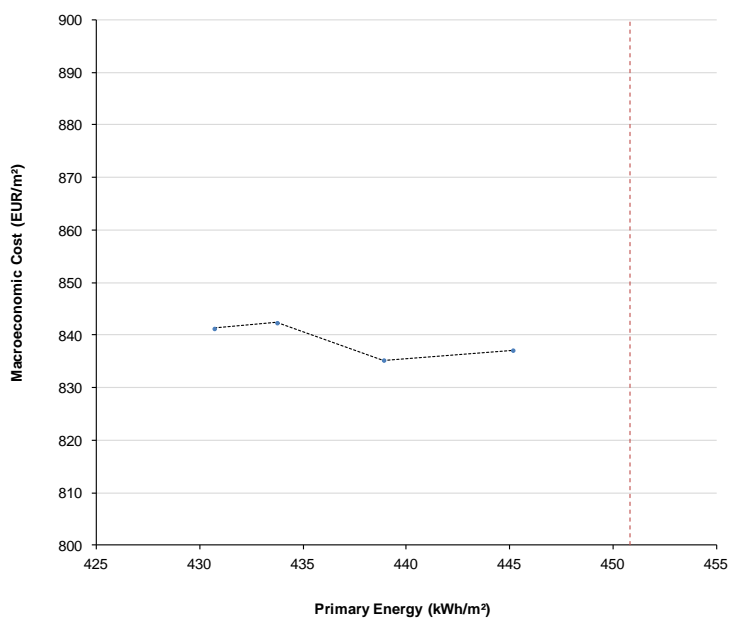
Heating Source - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



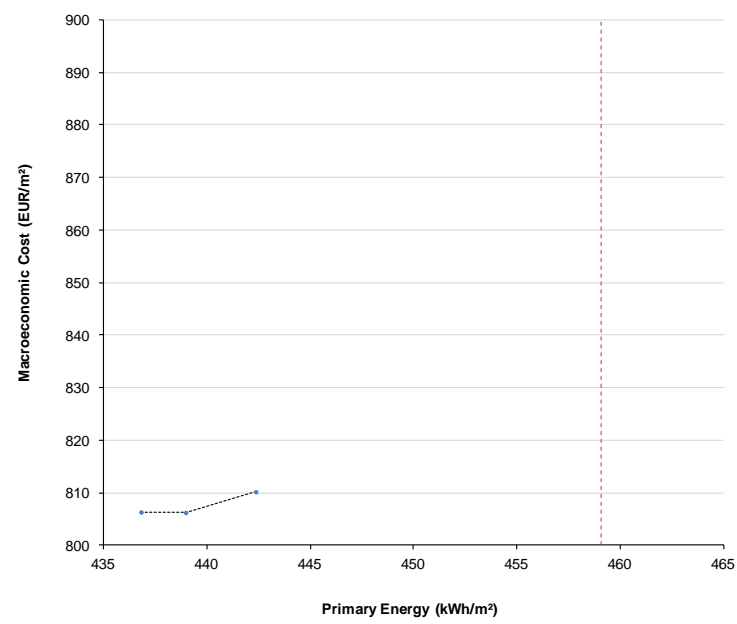
Floor U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



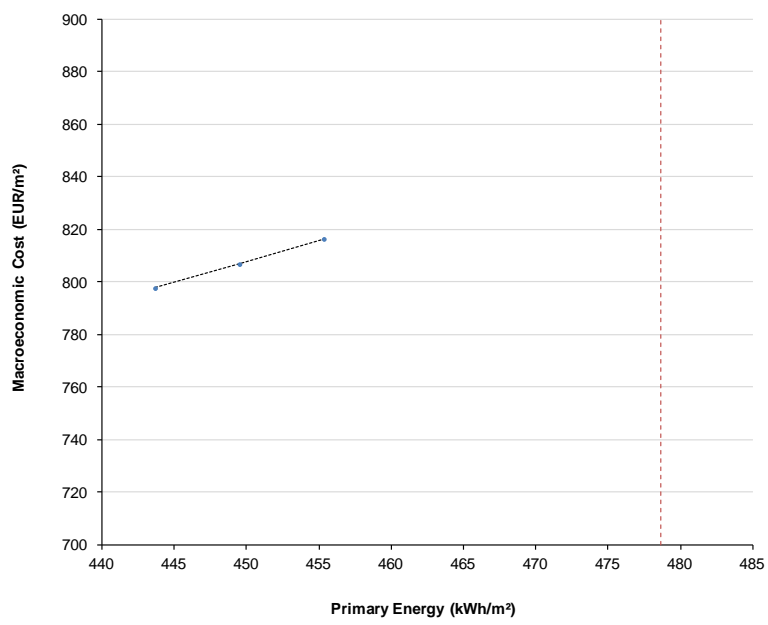
Window U-value - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



Chiller Efficiency - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



AHU SFP - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)



Lighting (lm/W) - Macroeconomic Costs (Central energy price, 4% discount rate, EUR/m<sup>2</sup>)

