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IEE EHP Stratego

Quantifying the Cost of Heat Savings in EU Member States

Background Report 3a

- Confidential –

IEE EHP Stratego

Report

- Confidential –

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1 Introduction

Euroheat & Power, through the DHC+ Technology Platform, is the coordinator of the STRATEGO project. The STRATEGO project is a European co-funding project developed in the framework of the Intelligent Energy Europe Programme, having the contract n°. IEE/13/650/SI2.675851.
The purpose of the project "Multi level actions for enhanced Heating and Cooling plans – STRATEGO" is to bridge the gap between EU policy, national objectives and effective actions taken at regional and local levels.
Ecofys contributed already, led by the University of Aalborg and in cooperation with Halmstad University and PlanEnergi, to the pre-study of the STRATEGO project, called "Heat Roadmap Europe 2050 – second pre-study for the EU-27" commissioned by Euroheat & Power.
After finalisation of the study and its publication in 2013, Ecofys was contracted in this STRATEGO project to calculate building stock energy demand paths for the countries Czech Republic, Italy, Romania and Croatia. Based on input from country experts we developed a reference path and an efficiency path for each of the countries.

1.1 Introduction to BEAM²

For the scenario calculation the **Built Environment Analysis Model BEAM²** is been used. Ecofys developed this model over the last years as model for international building stocks. Results of the model are energy demand, CO2-emissions and energy costs for space heating in the built environment, which then can be presented for different types of buildings, building ages, climate zones etc. Input to the model calculation is a database containing international building stock data distinguished by climatic regions, building type/size, building age, insulation level, energy supply, energy carrier, energy costs and emission factors. This can be applied in a scenario tool used for calculating the development over time of the building stock as a function of demolition rate, new building activity, refurbishments and energy-efficiency measures in retrofits. The tool is thereby fully flexible to be applied to any country world-wide, once the relevant input data are assessed and incorporated. The model was used so far in various projects (e.g. the European Commission, Eurima etc.) and contributed to the perception and reputation of Ecofys in Europe.
For more information on the BEAM² model also see *www.beam2.info*.

2 Overview of inputs

In the following paragraphs the input into BEAM² is shown per topic.

2.1 Age groups

For each country the experts have provided different building statistics per age group. These age groups differ per country also resulting in a different number of age groups per country. Table 1 shows the age groups used for each country.

Table 1 Age groups used for each country

Age Groups	Croatia	Czech Republic	Italy	Romania
Age group I	before 1945	before 1946	before 1946	before 1970
Age group II	1946 - 1969	1946 - 1980	1946-1990	1971-1990
Age group III	1970 - 1989	1981 - 2000	1991-2006	1991-2014
Age group IV	1990 - 1999	2001 - 2011	2007-2012	since 2015
Age group V	2000 - 2008	since 2012	since 2012	
Age group VI	since 2008			

2.2 Reference building geometries

Because of missing data from the country experts the dimensions of the reference buildings for the non-residential buildings are taken from an average European building and the same for each country. This counts as well for attached single family homes and small and large multifamily homes. For detached single family homes the dimensions for a Romanian or Czech Republic home are equal to each other as are the dimensions for an Hungarian and Italian dwelling. Values are again taken from a European average.

2.3 Thermal quality of building envelopes

In the following paragraphs the u-values for the different reference buildings per age group are shown per country. These values are taken from the country experts. The u-values used in the simulations for the reference efficiency scenario and the high efficiency scenario are shown in Table 2. These u-values are taken from *Renovation tracks for Europe up to 2050.*

Table 2 U-values for different envelope parts

	Croatia [W/m2.K]		Czech Republic [W/m2.K]		Italy [W/m2.K]		Romania [W/m2.K]	
	Ref	High Eff	Ref	High Eff	Ref	High Eff	Ref	High Eff
Wall	0.30	0.15	0.30	0.12	0.30	0.15	0.30	0.12
Roof	0.39	0.15	0.43	0.12	0.43	0.15	0.43	0.12
Floor	0.35	0.15	0.35	0.12	0.35	0.15	0.35	0.12
Windows	1.3	0.85	1.3	0.85	1.3	0.85	1.3	0.85

In order to connect the technical specifications to *real actions*, this paragraph gives a brief overview on retrofit and new building measures.

For *insulation* a u-values of 0,43 W/(m²K) is equivalent to approx. 9cm in standard insulation, while a u-value of 0,30 W/(m²K) means 12cm insulation and 0,15 W/(m²k) is equivalent to approx. 26cm of standard insulation (mineral wool or EPS/XPS).

Windows are either used in "standard" quality with an u-value of 1,3 W/(m²K), which is a standard triple-glazing with a simple wooden frame, or as "high performance" window with 0,85 W/(m²K), which is equivalent to a very good triple-glazing with a passive-house frame.

Concerning the assumed *ventilation* strategies a share of buildings in new buildings and renovations are assumed with ventilation systems and heat recovery. As starting point we assume that 90% of new buildings and 95% of all renovations are done without ventilations systems (and hence without heat recovery). The share of ventilations systems and heat recovery increases then in all countries and scenarios up to 25% in 2020 and remains constant. For the heat recovery systems a heat recovery rate of 85% is used.

2.3.1 Croatia

Building	Age	Wall [W/m2K]	Roof [W/m2K]	Floor [W/m2K]	Window [W/m2K]
SFH Detached	I	1.28	1.14	0.93	4.4
SFH Detached	II	1.46	1.14	0.93	4.4
SFH Detached	III	1.28	1.16	0.93	3
SFH Detached	IV	0.83	0.69	0.65	2.4
SFH Detached	V	0.34	0.29	0.65	1.8
SFH Attached	I	1.28	1.14	0.93	4.4
SFH Attached	II	1.46	1.14	0.93	4.4
SFH Attached	III	1.28	1.16	0.93	3
SFH Attached	IV	0.83	0.69	0.65	2.4
SFH Attached	V	0.34	0.29	0.65	1.8
MFH Small	I	1.28	1.14	0.93	4.4
MFH Small	II	1.46	1.14	0.93	4.4
MFH Small	III	1.28	1.16	0.93	3
MFH Small	IV	0.83	0.69	0.65	2.4

Building	Age	Wall [W/m2K]	Roof [W/m2K]	Floor [W/m2K]	Window [W/m2K]
MFH Small	V	0.34	0.29	0.65	1.8
MFH Large	I	1.28	1.14	0.93	4.4
MFH Large	II	1.46	1.14	0.93	4.4
MFH Large	III	1.28	1.16	0.93	3
MFH Large	IV	0.83	0.69	0.65	2.4
MFH Large	V	0.34	0.29	0.65	1.8
Office	I	1.28	1.14	0.93	4.4
Office	II	1.46	1.14	0.93	4.4
Office	III	1.28	1.16	0.93	3
Office	IV	0.83	0.69	0.65	2.4
Office	V	0.34	0.29	0.65	1.8
Wholesale and retail trade	I	1.28	1.14	0.93	4.4
Wholesale and retail trade	II	1.46	1.14	0.93	4.4
Wholesale and retail trade	III	1.28	1.16	0.93	3
Wholesale and retail trade	IV	0.83	0.69	0.65	2.4
Wholesale and retail trade	V	0.34	0.29	0.65	1.8
Education	I	1.28	1.14	0.93	4.4
Education	II	1.46	1.14	0.93	4.4
Education	III	1.28	1.16	0.93	3
Education	IV	0.83	0.69	0.65	2.4
Education	V	0.34	0.29	0.65	1.8
Hotels and restaurants	I	1.28	1.14	0.93	4.4
Hotels and restaurants	II	1.46	1.14	0.93	4.4
Hotels and restaurants	III	1.28	1.16	0.93	3
Hotels and restaurants	IV	0.83	0.69	0.65	2.4
Hotels and restaurants	V	0.34	0.29	0.65	1.8
Healthcare	I	1.28	1.14	0.93	4.4
Healthcare	II	1.46	1.14	0.93	4.4
Healthcare	III	1.28	1.16	0.93	3
Healthcare	IV	0.83	0.69	0.65	2.4
Healthcare	V	0.34	0.29	0.65	1.8
Other NonRes	I	1.28	1.14	0.93	4.4
Other NonRes	II	1.46	1.14	0.93	4.4
Other NonRes	III	1.28	1.16	0.93	3
Other NonRes	IV	0.83	0.69	0.65	2.4
Other NonRes	V	0.34	0.29	0.65	1.8

2.3.2 Czech Republic

Building	Age	Wall [W/m2K]		Roof [W/m2K]		Floor [W/m2K]		Window [W/m2K]	
Building		Not retrofitted	Already retrofitted	Not retrofitted	Already retrofitted	Not retrofitted	Already retrofitted	Not retrofitted	Already retrofitted
SFH Detached	I	1.47	0.93	1.39	0.95	2.35	1.43	2.85	1.8
SFH Detached	II	1.68	0.96	1.37	0.99	1.3	0.69	3.33	1.92
SFH Detached	III	0.59	0.38	0.57	0.38	1.2	0.37	2.9	1.5
SFH Detached	IV	0.3	0.19	0.43	0.19	0.59	0.33	1.54	0.83
SFH Attached	I	1.47	0.93	1.39	0.95	2.35	1.43	2.85	1.8
SFH Attached	II	1.68	0.96	1.37	0.99	1.3	0.69	3.33	3.33
SFH Attached	III	0.59	0.38	0.57	0.38	1.2	0.37	2.9	1.5
SFH Attached	IV	0.3	0.19	0.43	0.19	0.59	0.33	1.54	0.83
MFH Small	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
MFH Small	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01
MFH Small	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
MFH Small	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2
MFH Large	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
MFH Large	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01
MFH Large	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
MFH Large	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2
Office	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
Office	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01
Office	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
Office	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2
Wholesale and retail trade	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
Wholesale and retail trade	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01
Wholesale and retail trade	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
Wholesale and retail trade	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2
Education	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
Education	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01
Education	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
Education	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2
Hotels and restaurants	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
Hotels and restaurants	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01
Hotels and restaurants	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
Hotels and restaurants	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2
Healthcare	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
Healthcare	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01
Healthcare	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
Healthcare	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2
Other NonRes	I	1.47	0.83	2.94	0.85	1.38	0.8	2.85	1.8
Other NonRes	II	1.56	0.88	1.51	0.91	1.47	0.85	3.33	2.01

Building	Age	Wall [W/m2K]		Roof [W/m2K]		Floor [W/m2K]		Window [W/m2K]	
Building		Not retrofitted	Already retrofitted	Not retrofitted	Already retrofitted	Not retrofitted	Already retrofitted	Not retrofitted	Already retrofitted
Other NonRes	III	0.9	0.55	0.57	0.56	0.87	0.54	3.44	2.03
Other NonRes	IV	0.59	0.19	0.39	0.19	0.58	0.19	1.9	1.2

2.3.3 Italy

Building	Age	Wall [W/m2K]	Roof [W/m2K]	Floor [W/m2K]	Window [W/m2K]
SFH Detached	I	1.3	1.1	1.1	1.1
SFH Detached	II	1.2	1.2	1.2	1.2
SFH Detached	III	1	1	1	1.1
SFH Detached	IV	0.7	0.7	0.7	0.8
SFH Attached	I	1.3	1.1	1.1	1.1
SFH Attached	II	1.2	1.2	1.2	1.2
SFH Attached	III	1	1	1	1.1
SFH Attached	IV	0.7	0.7	0.7	0.8
MFH Small	I	1.3	1.1	1.1	1.1
MFH Small	II	1.2	1.2	1.2	1.2
MFH Small	III	1	1	1	1.1
MFH Small	IV	0.7	0.7	0.7	0.8
MFH Large	I	1.3	1.1	1.1	1.1
MFH Large	II	1.2	1.2	1.2	1.2
MFH Large	III	1	1	1	1.1
MFH Large	IV	0.7	0.7	0.7	0.8
Office	I	1.3	1.1	1.1	1.1
Office	II	1.2	1.2	1.2	1.2
Office	III	1	1	1	1.1
Office	IV	0.7	0.7	0.7	0.8
Wholesale and retail trade	I	1.3	1.1	1.1	1.1
Wholesale and retail trade	II	1.2	1.2	1.2	1.2
Wholesale and retail trade	III	1	1	1	1.1
Wholesale and retail trade	IV	0.7	0.7	0.7	0.8
Education	I	1.3	1.1	1.1	1.1
Education	II	1.2	1.2	1.2	1.2
Education	III	1	1	1	1.1
Education	IV	0.7	0.7	0.7	0.8
Hotels and restaurants	I	1.3	1.1	1.1	1.1
Hotels and restaurants	II	1.2	1.2	1.2	1.2
Hotels and restaurants	III	1	1	1	1.1
Hotels and restaurants	IV	0.7	0.7	0.7	0.8

Building	Age	Wall [W/m2K]	Roof [W/m2K]	Floor [W/m2K]	Window [W/m2K]
Healthcare	I	1.3	1.1	1.1	1.1
Healthcare	II	1.2	1.2	1.2	1.2
Healthcare	III	1	1	1	1.1
Healthcare	IV	0.7	0.7	0.7	0.8
Other NonRes	I	1.3	1.1	1.1	1.1
Other NonRes	II	1.2	1.2	1.2	1.2
Other NonRes	III	1	1	1	1.1
Other NonRes	IV	0.7	0.7	0.7	0.8

2.3.4 Romania

Building	Age	Wall [W/m2K]	Roof [W/m2K]	Floor [W/m2K]	Window [W/m2K]
SFH Detached	I	0.83	0.5	0.5	2.56
SFH Detached	II	0.83	0.5	0.5	2.56
SFH Detached	III	0.71	0.33	0.42	2
SFH Attached	I	0.83	0.5	0.5	2.56
SFH Attached	II	0.83	0.5	0.5	2.56
SFH Attached	III	0.71	0.33	0.42	2
MFH Small	I	0.83	0.5	0.5	2.56
MFH Small	II	0.83	0.5	0.5	2.56
MFH Small	III	0.71	0.33	0.42	2
MFH Large	I	0.83	0.5	0.5	2.56
MFH Large	II	0.83	0.5	0.5	2.56
MFH Large	III	0.71	0.33	0.42	2
Office	I	0.83	0.5	0.5	2.56
Office	II	0.83	0.5	0.5	2.56
Office	III	0.71	0.33	0.42	2
Wholesale and retail trade	I	0.83	0.5	0.5	2.56
Wholesale and retail trade	II	0.83	0.5	0.5	2.56
Wholesale and retail trade	III	0.71	0.33	0.42	2
Education	I	0.83	0.5	0.5	2.56
Education	II	0.83	0.5	0.5	2.56
Education	III	0.71	0.33	0.42	2
Hotels and restaurants	I	0.83	0.5	0.5	2.56
Hotels and restaurants	II	0.83	0.5	0.5	2.56
Hotels and restaurants	III	0.71	0.33	0.42	2
Healthcare	I	0.83	0.5	0.5	2.56
Healthcare	II	0.83	0.5	0.5	2.56
Healthcare	III	0.71	0.33	0.42	2
Other NonRes	I	0.83	0.5	0.5	2.56
Other NonRes	II	0.83	0.5	0.5	2.56
Other NonRes	III	0.71	0.33	0.42	2

2.4 Investment costs

Similar to the insulation values the investment costs are taken from the report *Renovation tracks for Europe up to 2050.* The investment costs are shown in Table 3. The investment costs for insulation are split into a fixed and a variable part, the latter being dependent on the thickness of the insulation.

Table 3 Investment costs

	Croatia		Czech Republic		Italy		Romania	
	Fixed costs [€/m²]	Variable costs [€/m²/cm]	Fixed costs [€/m²]	Variable costs [€/m²/cm]	Fixed costs [€/m²]	Variable costs [€/m²/cm]	Fixed costs[€/m²]	Variable costs [€/m²/cm]
Wall	16.3	1.1	17.5	1.2	18.8	1.3	17.5	1.2
Roof	14.1	1	15.1	1.1	16.3	1.2	15.1	1.1
Floor	17	1	18.2	1.1	19.3	1.2	18.2	1.1
Window Reference Efficiency	119.43	N.A.	187.5	N.A.	167.03	N.A.	187.5	N.A.
Window High Efficiency	140.5	N.A.	222	N.A.	196.5	N.A.	222	N.A.

2.5 Climate data

For each country a reference city is picked to provide the climate data used for the calculations.

Table 4 Reference city for climate data

Country	Reference city
Croatia	Zagreb
Czech Republic	Ostrava
Italy	Milan
Romania	Bucharest

2.5.1 Croatia

In its building legislation Croatia recognises two climate zones (continental and maritime). For the simulations in this model we have used Zagreb as it is quite centralized and has the largest population in the country. It also has a substantial heating and cooling demand. [1]

[1] Email Tomislav Novosel - University of Zagreb

2.5.2 Czech Republic

For the Czech Republic three cities where taken into account for the climate data; Ostrava, Plzeň or Prague. Prague is the in the warmest region of Czech Republic and was advised against. The data used is for Ostrava.

2.5.3 Italy

Milan was chosen as the reference city for Italy. In Milan energy demand is significant both for heating in winter and for cooling in summer. Other cities, located in southern regions, might have a demand for ambient heating during winter season not really significant for the scope of Stratego Project[2].

2.5.4 Romania

Romania has four climate zones of which the Stratego cities are located in two of them. Bucharest is also located in one of these two climate zones and is also part of an area with high population density. Therefor Bucharest is chosen as a reference city.[3]

2.6 Retrofit-, new building and demolition rates

Table 5 show the rates for retrofit, new construction and demolition used in the simulations. The rates are not different for the reference scenario or the high efficiency scenario and are based on information from the country experts.

Table 5 Rates per annum for retrofit, construction and demolition

Rates	Retrofit	New building	Demolition
Croatia	1,0% p.a. for all buildings	1,0% p.a. for all buildings	0,5% p.a. for all buildings
Czech Republic	For all components of the building envelope increasing from 1,0% p.a. to 1,5% p.a. (0,1% p.a. increase per year)	0,95% p.a. for SFH and 0,65% p.a. for MFH and non-residential buildings	0,2% p.a. for all buildings
Italy	3,0% p.a. for all buildings	1,0% p.a. for all buildings	0,35% p.a. for all buildings
Romania	For all components of the building envelope 1,7% p.a.	0,64% p.a. for residential buildings 2,0% p.a. for non-residential buildings	0,2% p.a. for all buildings

[2] Email Luca Bertagna - A2A Calore & Servizi S.r.L. - Gruppo A2A
[3] Email Gabriela Crisan-Badea – Tractabel Engineering

While new buildings and retrofits both have a direct positive impact on costs, energy demand is lowered by retrofitting buildings, but it increases by new builds. Therefore a high retrofit rate typically leads to increasing investments per energy saving over time (€/kWh saved), mainly due to the fact that the worst performing buildings are retrofitted at first and saving are decreasing over time, while a high new building rates increases both investments and energy use and hence influences this equation as well.

3 Output of the simulations

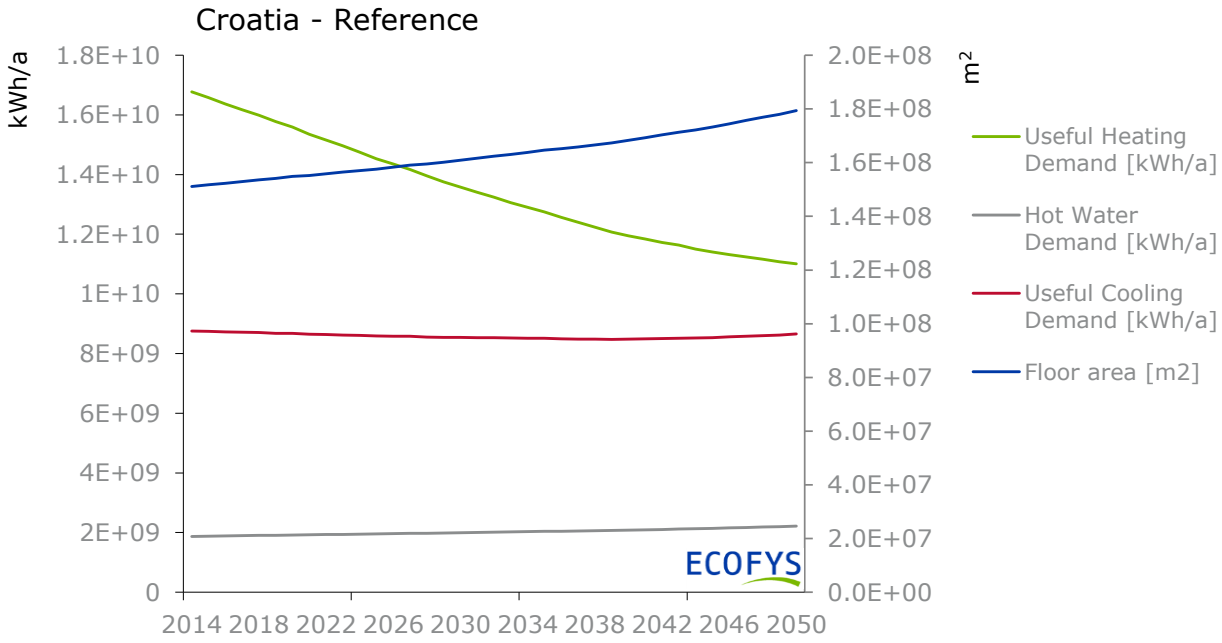
The simulations generate multiple results for each country, which are shown in the following graphs. Detailed information is given in the provided Excel output-file, this section just gives an overview over the output parameters per country:

- Floor area per building type
- Useful heating demand per building type
- Hot water demand per building type
- Useful cooing demand per building type
- Investment costs for the building envelope

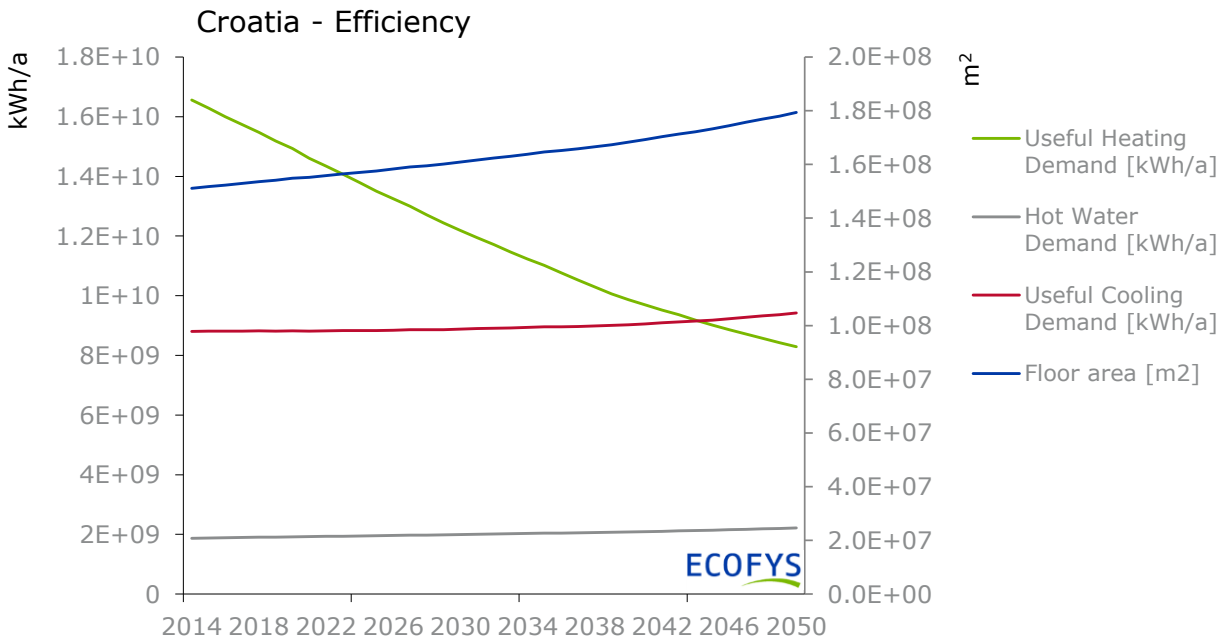
These results are provided for two scenarios, the reference path and the efficiency path, the difference coming from the different u-values and investment costs per path. For each path similar retrofit, new building and demolition rates are assumed.

3.1 Croatia

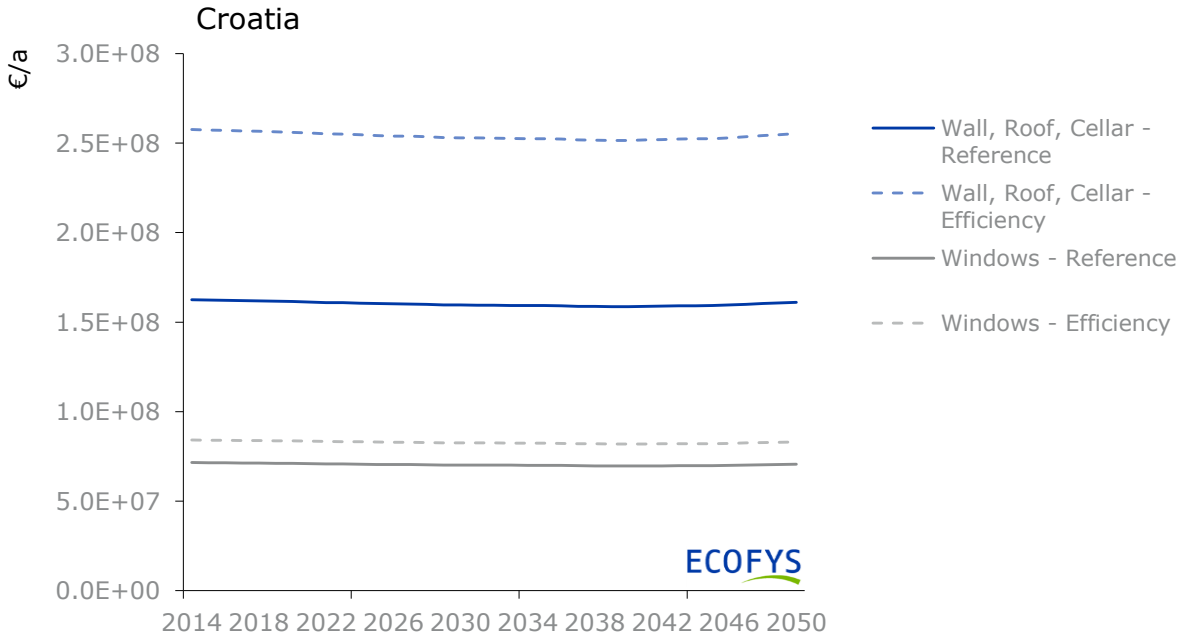
3.1.1 Reference path



3.1.2 Efficiency path

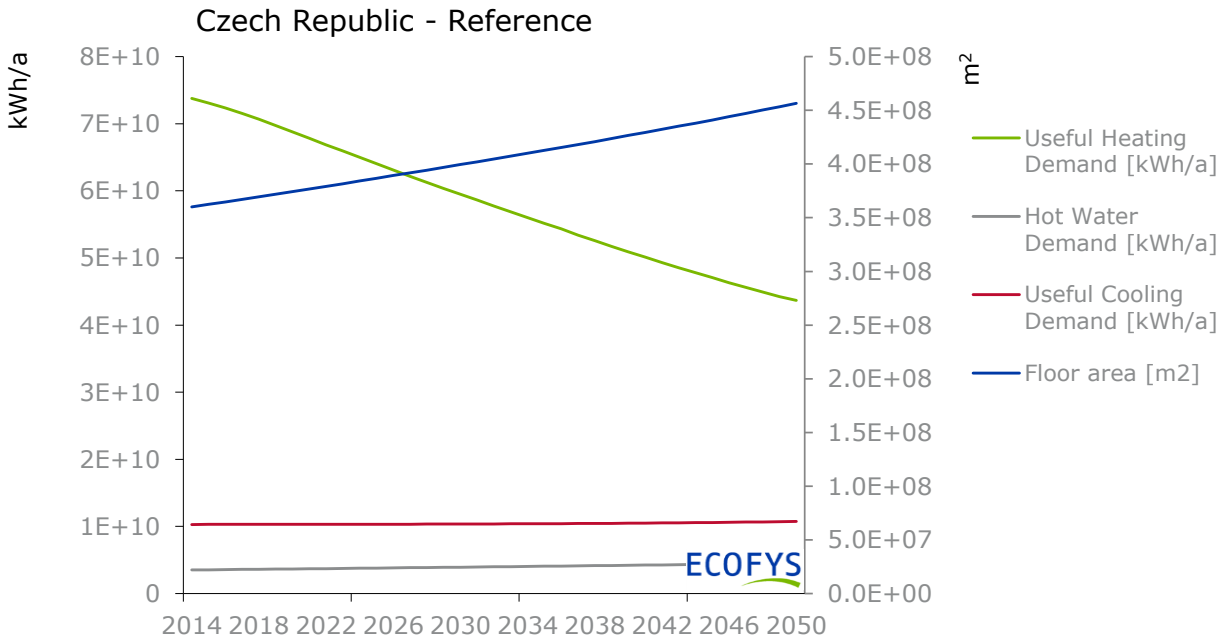


3.1.3 Investments

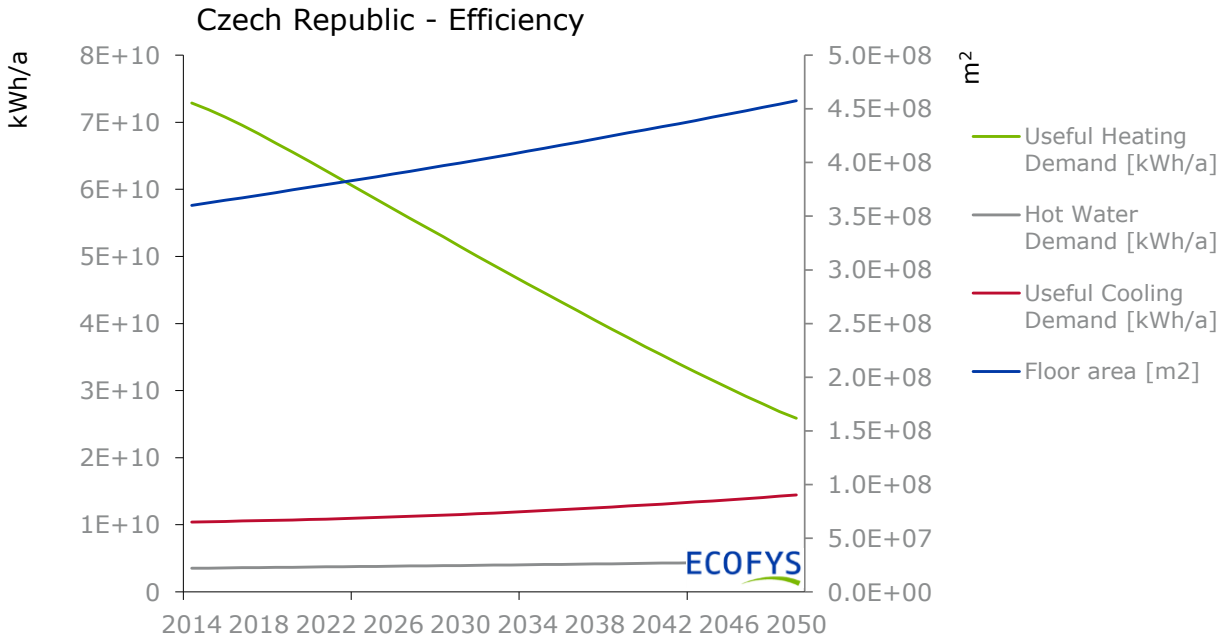


3.2 Czech Republic

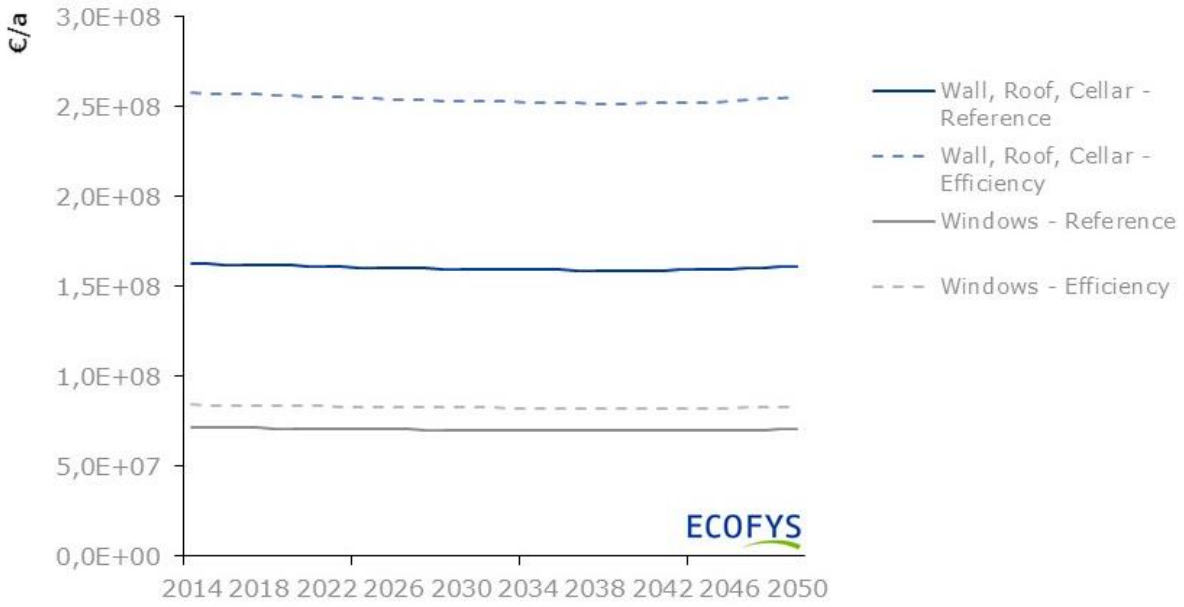
3.2.1 Reference path



3.2.2 Efficiency path

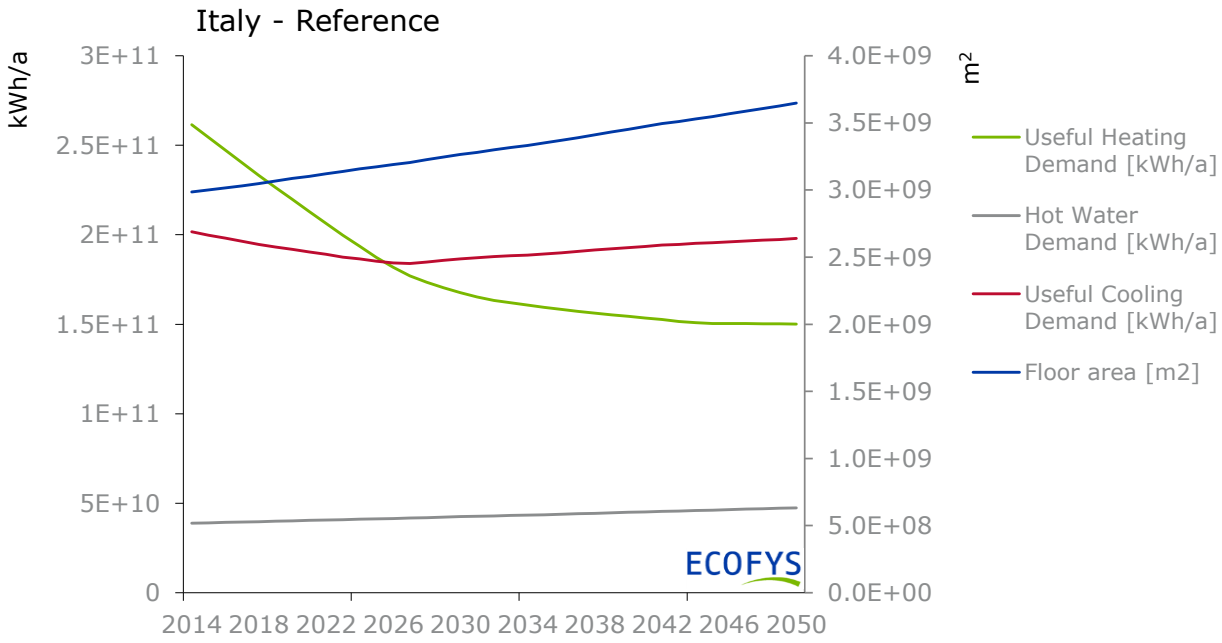


3.2.3 Investments

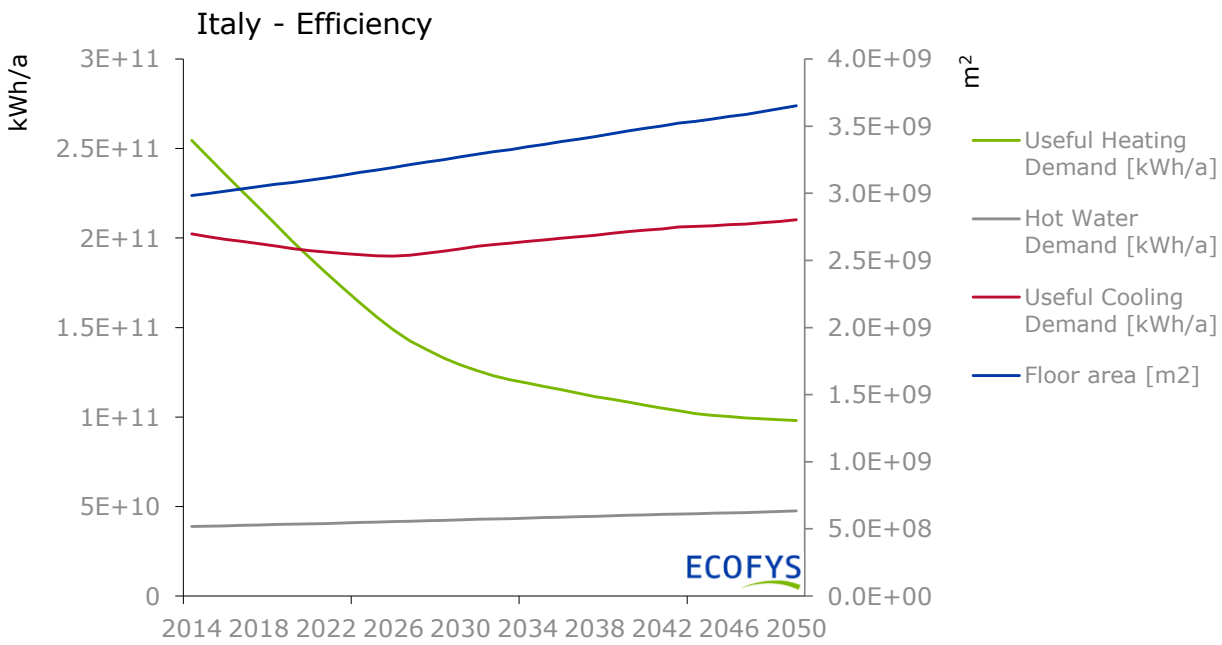


3.3 Italy

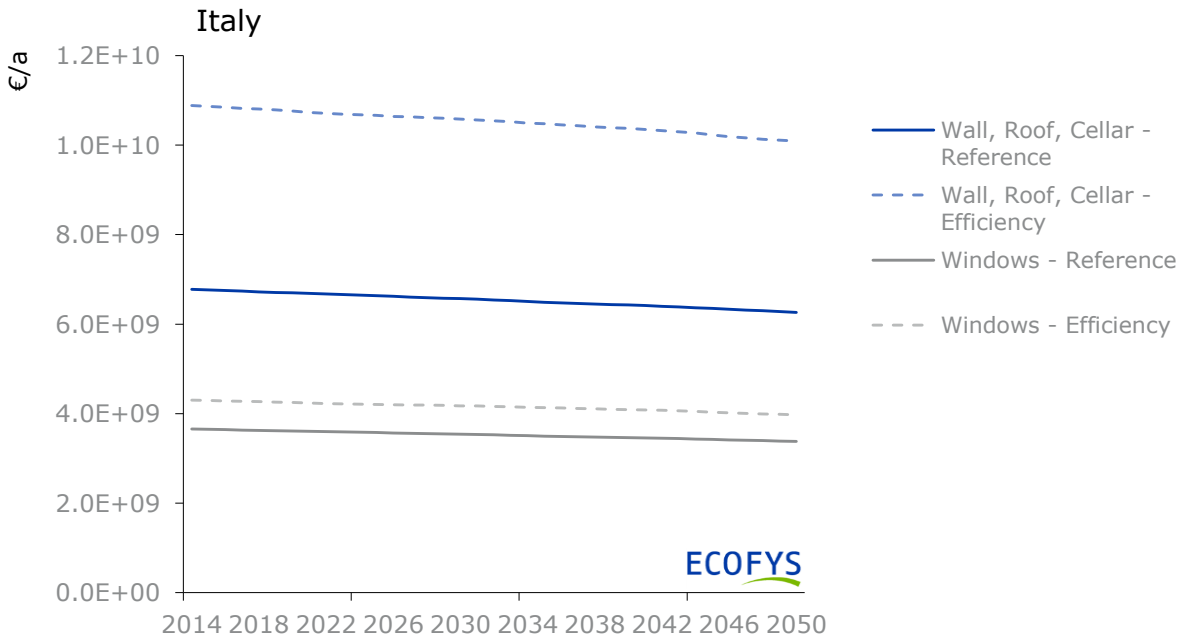
3.3.1 Reference path



3.3.2 Efficiency path

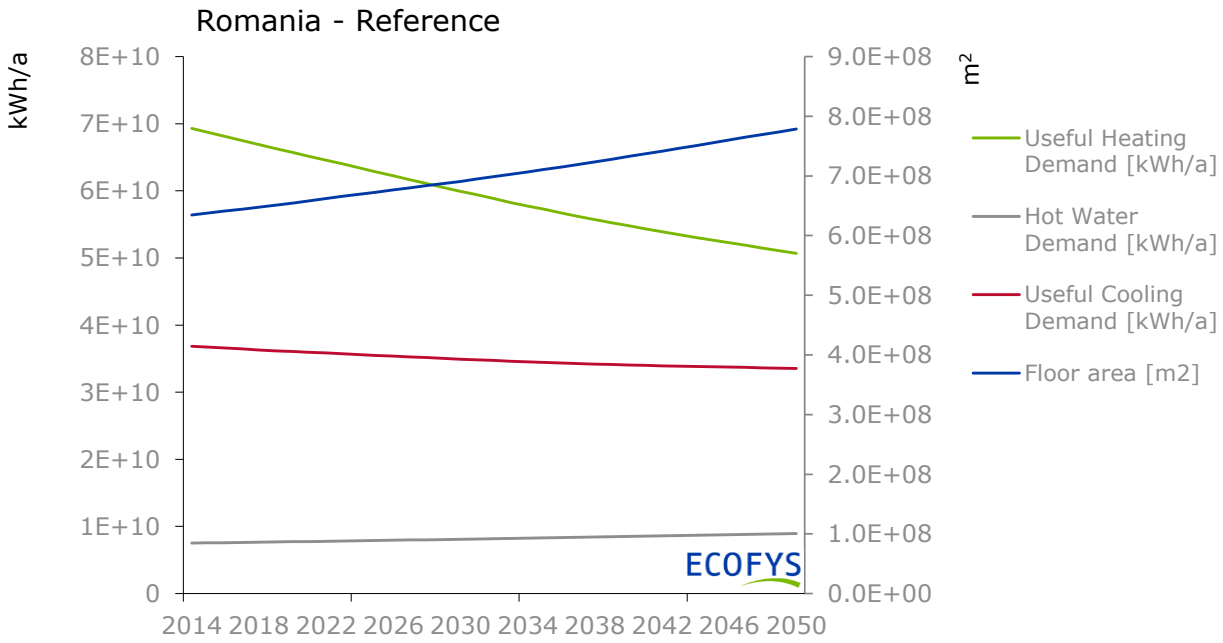


3.3.3 Investments

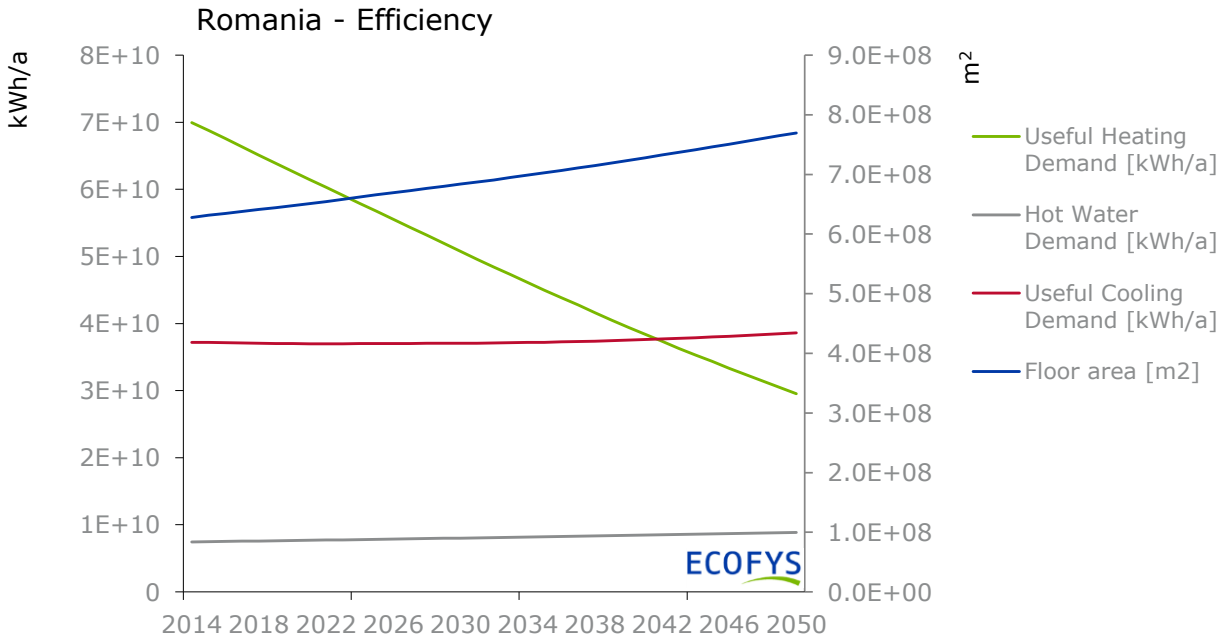


3.4 Romania

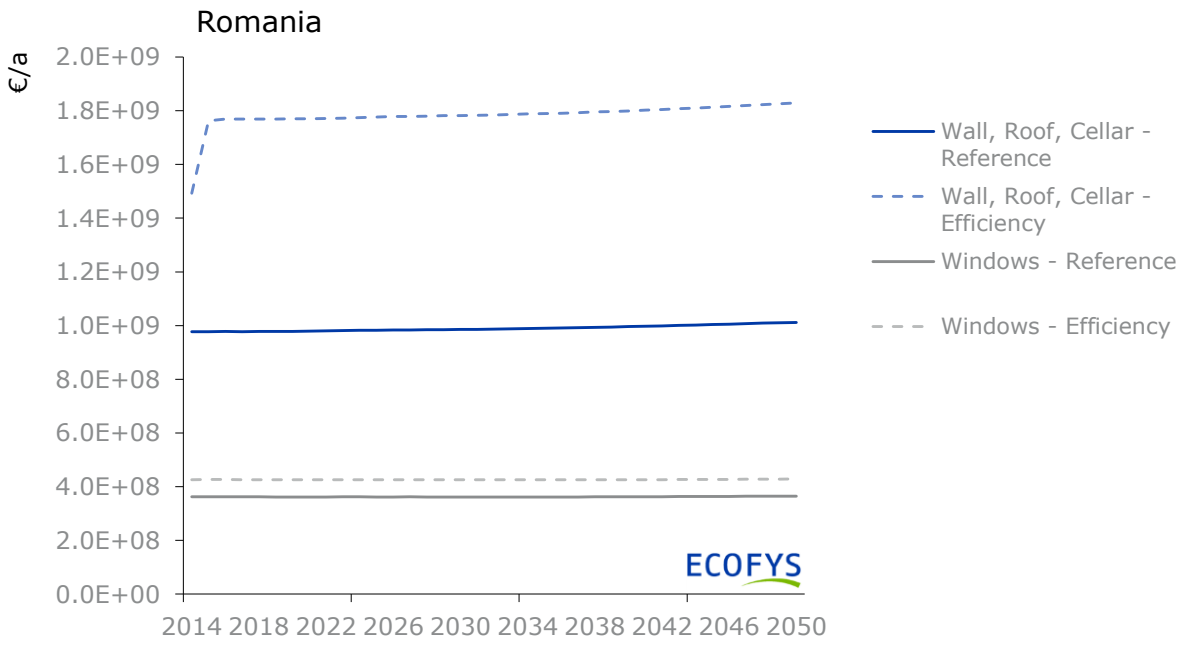
3.4.1 Reference path



3.4.2 Efficiency path



3.4.3 Investments



4 Conclusion

This sections gives a brief overview of the scenarios results.

The *floor area* development in all countries follows a linear path, since the new building and demolition rates are assumed as constant over the period until 2050. Furthermore there is no difference between the reference and the efficiency path, since the difference in retrofit depth is not visible in the total floor area development.

In contrast to this the *heating demand* is decreasing in all scenarios due to energy efficiency measures in the building stock. The additional energy demand of new buildings is overcompensated by the retrofit efficiency gains. In most countries the curve is almost linear, except for Italy. Here we see that building from the worst performing age group are fully retrofitted and then buildings form the next age group undergo renovation. Since the energy demand before renovation is lower for the second age group, the reduction in energy demand is decreasing over time. This is the effect we see here.

The *cooling demand* stays more less the same in all scenarios and sometimes is increasing a bit, especially for the efficiency paths. This is due to the fact that functions like night cooling needs to be optimized in high energy efficient buildings, otherwise the higher tightness and lower transmission leads to a situation where the buildings heats up especially during summertime and does not cool down again when it would be possible during night-time. Since this issue is not especially addressed in the scenarios the results are reasonable.

Hot water demands are increasing slowly due to new buildings being constructed.

The overall *investment costs* for the building envelope are split up by insulation and windows. In general the investments for the efficiency paths are between 50-100% higher than for the reference path due to higher efficiency standards.

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