sEEnergies

QUANTIFICATION OF SYNERGIES BETWEEN ENERGY EFFICIENCY FIRST
PRINCIPLE AND RENEWABLE ENERGY SYSTEMS

D1.1
Data set on energy efficiency potentials, describing the cost curves for building envelope refurbishment measures on single building level (revised)

Project

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Deliverable

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Document history

Version	Date	Comments
0.1	30.09.2020	The dataset itself was reviewed, not the current document
0.2	10.11.2020	The document was updated with additional cost aspects
0.3	29.01.2021	The document was updated, including cost aspects of heating systems

Executive Summary

According to the EU targets on decarbonizing the heating sector as well as improving energy efficiency in the build environment, the economics of energy efficiency improvements and the respective measures are of high importance to understand the scenario outcomes and analyses in this work package.

The aim of this deliverable is to provide an overview of efficiency potentials for the build environment and at which costs these potentials can be achieved. To do so, we analyse on the single building level different building types (e.g., single-family houses or multi-family houses) with different building age and building status (e.g., refurbished or non-refurbished) and the potential measures to improve energy efficiency. In the build environment, insulating the building envelope or improving the energetic quality of windows are the most common measures to improve the energy efficiency and reduce heat losses. For each set of building typologies, the measures can vary in terms of refurbishment depth and quality.

Based on the potential technical solutions of improving the building envelope, the related costs for such measures have an impact on investors decision if they are implemented or not. To improve on the quality of the results also gathered within the HRE4 project, we have conducted an extensive literature review on published cost data on building refurbishment measures. Based on these costs, one can calculate the overall cost curves for the respective measures.

By integrating different sources for refurbishment costs in the analysis, one must keep in mind the often-diverging cost parameters for different countries which are considered in the referenced publications.

With our dataset we are integrating these differences into one platform and are providing an extensive overview of assumed costs for different refurbishment measures in the build environment. More details on the results and a more detailed description of the work will be published in the following deliverable D1.2 on aggregated cost curves for building related efficiency measures on country level.

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Acronyms & Abbreviations

Term	Description
GDPR	General Data Protection Regulation
SFH	Single-family house
MFH	Multi-family house
NPV	Net present value

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1 Introduction

This document introduces and describes deliverable 1.1 of the sEEnergies project: Data set on envelope refurbishment measures for single-building analysis and for the generation of aggregated cost-curves for building envelope refurbishment measures. The full data set is provided as an excel file that can be requested from the project coordinator.

The document at hand is providing a principal overview of the considered data sources as well as derived results. However, the document is only intended as explanatory to the full dataset which is available at the project coordinator.

The data set currently covers 16 combinations of energy efficiency measures applied to 4 different building-envelope components. The building typologies belong to the residential sector, separated in EU28 countries for 2 building types and 5 building periods. Although heating systems are not considered in the deliverable to other work packages, the cost of refurbishing the heating system has an impact on the investors' decision given the circumstances that investors tend to have fixed budgets for building related investments. Additionally, reducing the useful energy demand by refurbishing the envelope also allows for decreasing the size of a new heating system, therefore providing additional savings on the investment side. The cost curves for heating systems in combination with the refurbishment of the building envelope will be provided.

Therefore, this dataset includes building typologies in combination with renewable energy sources for the report to be handled as the deliverable D1.2. For completeness, the different energy carriers and respective heating technologies are included in the description at hand.

The presented dataset on the level of single buildings will be used to calculate aggregated cost curves on country level which are used as input for work package 6. Additional information on remaining heat energy demand after refurbishing the building stock will be used as input to work package 3.

2 Data set content

2.1 Scope

2.1.1 Geographic Coverage

The data set covers the 28 countries part of the European Union at the beginning of this project (including UK). The following table shows the countries with their correspondent code and acronym.

Table 1. Geographic coverage of the data set

ID_Country	Country	Acronym
1	Austria	AT
2	Belgium	BE
3	Cyprus	CY
4	Czech Republic	CZ
5	Denmark	DK
6	Estonia	EE
7	Finland	FI
8	France	FR
9	Germany	DE
10	Greece	EL
11	Hungary	HU
12	Ireland	IE
13	Italy	IT
14	Latvia	LV
15	Lithuania	LT
16	Luxembourg	LU
17	Malta	MT
18	Netherlands	NL
19	Poland	PL
20	Portugal	PT
21	Slovakia	SK
22	Slovenia	SI
23	Spain	ES
24	Sweden	SE
25	United Kingdom	UK
26	Romania	RO
27	Bulgaria	BU
32	Croatia	HR

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2.1.2 Typologies

The data set covers 10 residential buildings typologies, separated in 2 building types and 5 building construction periods.

Table 2. Building types

ID_BuildingType	Building Type	Acronym Building Type
1	Single-family houses	SFH
2	Multi-family houses	MFH

Table 3. Building construction periods

ID_Building Age Class	Building Age Class
1	Before 1961
2	1961-1990
3	1991-2008
4	2009-2020
5	after 2020

2.1.3 Energy efficiency measures

The analysis covers 16 combinations of energy-efficiency measures applied to 4 different building-envelope components. The different levels of efficiency (low, medium, high, etc.) relate to U values for the different components. The standard values for recent new buildings (construction period between 2009-2020 with actual building code regulations) is considered a "high" standard for refurbishment measures, and it is used as the base of calculation for the rest of the standards. More information on the methodology will be given in the deliverable 1.2.

Table 4. Energy-efficiency measures packages

ID_Packages	Energy-efficiency measure
1	Façade painting
2	Refurbishing only windows (low)
3	Refurbishing window and walls (low)
4	Refurbishing windows, walls, and roof (medium)
5	Refurbishing windows, walls, roof, and floor (high)
6	Building on package 5, windows, walls, roof, and floor (higher)
7	Building on package 5, windows, walls, roof, and floor (highest)
8	Building on package 5, windows, walls, roof, and floor ("passive house")
9	Refurbishing windows (high); roof (higher)
10	Refurbishing only walls (low)
11	Refurbishing windows (higher)
12	Refurbishing windows and walls (higher)
13	Refurbishing windows (medium); roof (medium); floor (high)
14	Refurbishing windows, roof, and floor (higher)
15	Refurbishing roof (medium); floor (high)
16	Refurbishing roof and floor (highest)

2.1.4 Heating Systems

For the cost-benefit analysis, 13 heating systems were considered.

Table 5. Heating Systems

ID_Heating System	Heating System	Acronym Heating System
1	Oil	Oil
2	Gas	Gas
3	Heat pump air water	HPAW
4	Heat pump geothermal	HPG
5	Heat pump ground	HPGW
6	Wood	Wood
7	District heating	DH
8	Electricity	El
9	Coal	Coal
10	Heat pump air air	HPAA
11	Oil Solar	OilSolar
12	Gas Solar	GasSolar
13	Biogas	Biogas

2.2 Data

The data for the cost-benefit analysis consist in the associated investments and benefits of the 16 energy-efficiency "packages" (see Table 4) applied to each of the 10 typologies considered, in each country. The parameters listed in the table below are given for each of the 16 energy-refurbishment packages. This data can be found in the excel file on the tab *"Cost Efficiency"*.

Table 6. Data parameters provided in the data set on cost curves for the envelope only

Parameter	Unit	Description
Area EBF	m^2	Average energy reference area for the specific building type
Inv_*component*	[EUR/m^2EBF/year]	Annual investment costs per m^2 of energy reference area for each building component involved in the refurbishment package
Inv_Total	[EUR/m^2EBF/year]	Annual investment costs per m^2 of energy reference area for all components involved in the refurbishment package
Savings_UE_SH	[kWh/m^2EBF/year]	Total annual savings of useful energy demand for space heating per m^2 of energy reference area
Savings_SH_*energy carrier*	[EUR/m^2EBF/year]	Total annual savings on energy costs (fuel costs) for space heating per m^2 of energy reference area for different heating systems

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NPV_env_HS	[EUR/m²EBF/year]	Net present value for envelope refurbishment methods including changes regarding heating systems per m² of energy reference area

2.3 Analysis by country

The dataset includes two tabs with pivoting tables and different figures, which intend to help the visualization of the data (tabs *"Analysis_Env"* and *"Analysis_HS"*). The values shown in both tabs are on the single building level referring to measures on the building envelope only (archetypes) and not aggregated values. Moreover, they are given per m² of energy reference area (EBF). The EBF for each of the archetypes covered (building typologies) is given in the dataset, therefore it can be used to obtain total values at the building level. The tab *"Analysis_Env"* includes values which consider changes regarding the reduced energy demand due to a more efficient building envelope. The table in the tab *"Analysis_HS"* provides additional information which also includes changes in the installed power of the heating system and its related cost savings.

The figure in the *"Analysis_Env"* tab as well as the third figure in the *"Analysis_HS"* tab show the net present value (NPV) for each of the refurbishment packages (investments and benefits combined) applied to the building typologies covered (Figure 1). The two additional figures in the "Analysis_HS" tab (one for SFH and one for MFH) provide the total investment in building envelope components and the savings on the installed power of heating systems for each measure (Figure 2).

Below, example figures for SFH and MFH from Austria, built before 1961, supposing a heating system fuelled by natural gas, are shown.
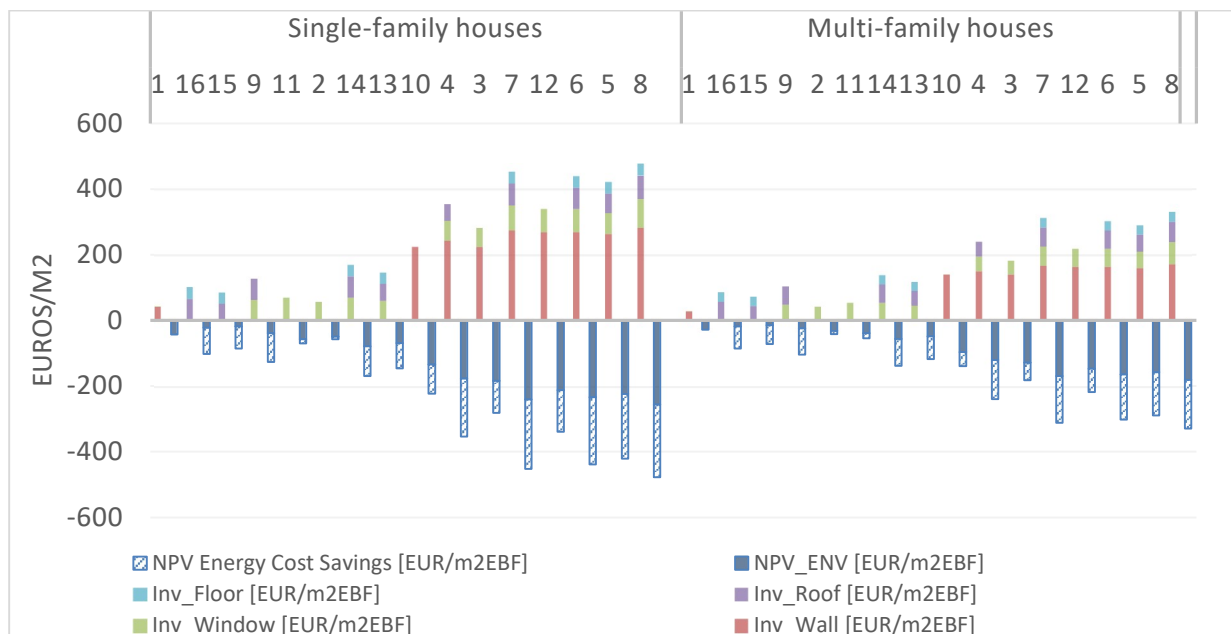
Figure 1. Investment and NPV for different energy-efficiency measures in the envelope
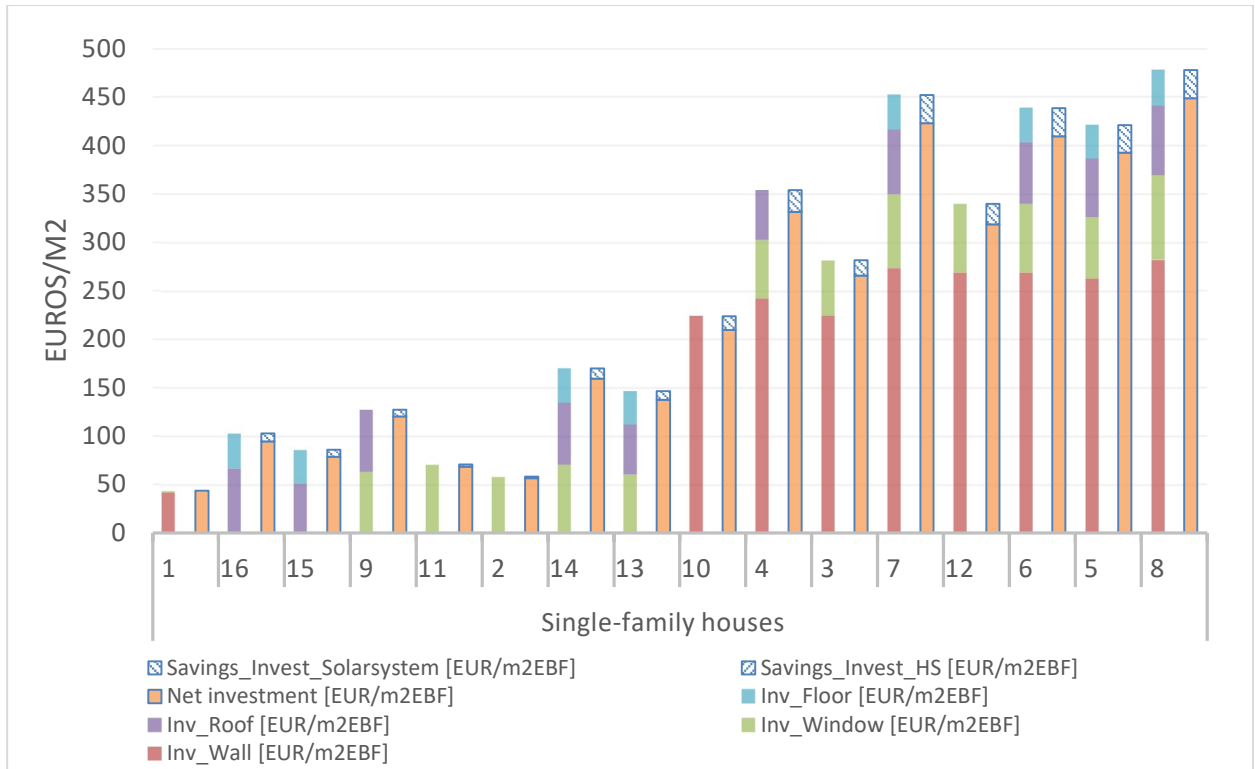
Figure 2. Investments and savings for different energy efficiency measures in the envelope and the heating systems in single-family houses

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3 Input data sources

Basis for the calculations are the building stock calculations described in the HRE4 project report (Fleiter et al., 2017) which were extended to additional 14 EU countries within this work package. Additional literature research was conducted to adjust for cost estimates on the applied refurbishment measures. Different sources were gathered and analysed to be included in the overall calculations. An overview on the considered sources is given in Table 7. Where no updated data sources are available, we reference to the HRE4 approach applying labour and material cost indices on selected countries.

Table 7. Country-specific list of references considered for refurbishment costs

ID_Country	Country	References
1	Austria	(Thomsen et al., 2013), (Stocker & Koch, 2017)
2	Belgium	
3	Cyprus	
4	Czech Republic	(Karásek et al., 2018), (Sojkova et al., 2019)
5	Denmark	
6	Estonia (Baltics)	(E. Pikas et al., 2014), (Kuusk & Kalamees,
7	Finland	(Niemelä et al., 2017), (Mohamed et al., 2015)
8	France	
9	Germany	(Hinz, 2015),
10	Greece	(Magyar et al., 2015)
11	Hungary	(Magyar et al., 2015)
12	Ireland	
13	Italy	(Corrado et al., 2017), (Penna et al., 2015)
14	Latvia (see Estonia)	
15	Lithuania (see Estonia)	
18	Netherlands	
19	Poland	(Ferdyn-Grygierek & Grygierek, 2017)
20	Portugal	(Asadi et al., 2012)
21	Slovakia	
22	Slovenia	(Harmathy et al., 2019)
23	Spain	(Evola & Margani, 2016)
24	Sweden	(Bonakdar et al., 2014), (Liu et al., 2016),
25	United Kingdom	(Magyar et al., 2015)
26	Romania	(Magyar et al., 2015)
27	Bulgaria	(Magyar et al., 2015)
32	Croatia (see Slovenia)	

4 Conclusions

We refer to the following deliverable D1.2 in respect of the conclusions on efficiency potentials and related costs curves.

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5 Annexes

5.1 Screen capture dataset file

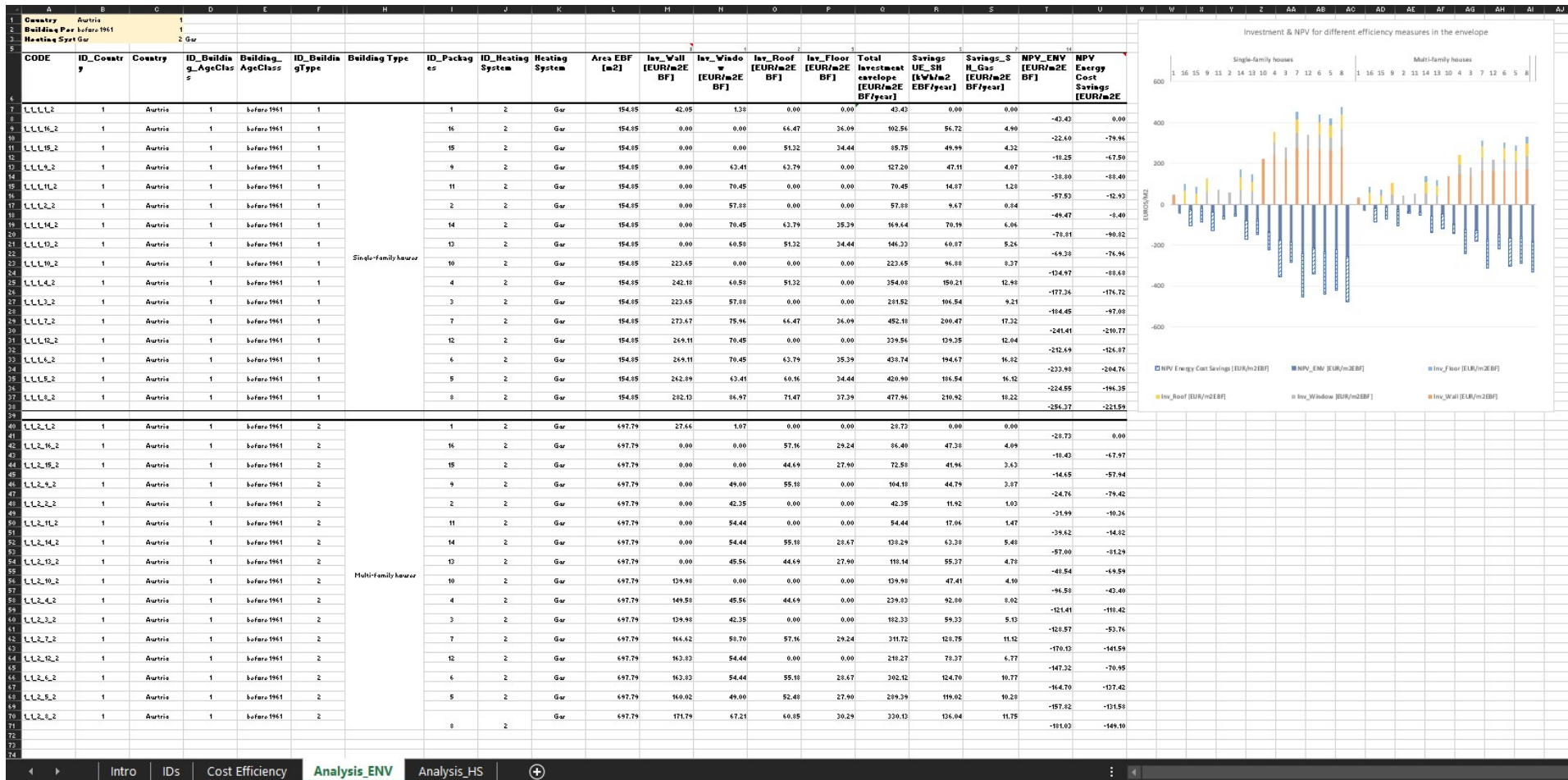Figure 3. Screen capture dataset: tab *"Cost Efficiency"*

Figure 4. Screen capture dataset: tab "Analysis_ENV"

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