E-RETROFIT-KIT

Tool-kit for »Passive House Retrofit«

Intelligent Energy Europe

Content

SUMMARY

The E-RETROFIT-KIT tool-kit

Energieinstitut Vorarlberg, Austria, is the host of the E-RETROFIT-KIT tool-kit. The web address of the tool-kit is: **www.energieinstitut.at/retrofit/**

The tool-kit has been developed for Austria, Denmark, Lithuania, Spain and The Netherlands and is translated into totally 10 languages covering 13 countries: Czech language, Danish, Dutch, English (Great Britain-Europe), French (France-Belgium), German (Germany-Austria-Luxembourg), Italian, Portuguese, Slovenian and Spanish.

The tool-kit contains information of Passive House Retrofitting. General information: Principles, economy (sources of information for developing the economy part of the tool-kit), non-energetic aspects, best practice, building types of this country ("the entrance" into the tool-kit concerning more specific information related to specific building categories) and measures (with short description and main data of energy and economy).

For each country there is a number of building types, and for each of these there is information about: Actual state (photo, general information about the building, U-values, building materials etc., heating system and energy need), energy savings, retrofitting measures, energy costs and energy consumption with incomplete Passive House Retrofitting.

Results on Passive House Retrofitting

The results on energy savings on heating and cooling energy cost savings based on the data from building typologies of the E-RETROFIT-KIT tool-kit.

Country	Heating/cooling consumption, kWh/m^2 per year		
	Before PHR	**After PHR**	**Savings**
Austria	193	19	172
Denmark	166	40	126
Lithuania	208	30	178
Spain	49	12	37
The Netherlands	173	14	159
Average	***158***	***23***	***135***
Climate, building traditions and building regulation have influence on the results of energy savings by PHR		PHR-ranking of countries: on energy savings 1) Lithuania 2) Austria 3) The Netherlands 4) Denmark 5) Spain	

Heating/cooling energy savings by Passive House Retrofitting in 5 EU countries

Country	Energy costs per year, EURO (per apartment)		
	Before PHR	**After PHR**	**Savings**

Austria	1,404	155	1,248
Denmark	845	300	545
Lithuania	1,244	280	964
Spain	606	90	516
The Netherlands	1,500	282	1,218
Average	***1,120***	***221***	***899***
Climate, building traditions and building regulation have influence on the results of energy cost savings by PHR		PHR-ranking of countries on energy cost savings: 1) Austria 2) The Netherlands 3) Lithuania 4) Denmark 5) Spain	

Energy costs savings by Passive House Retrofitting in 5 EU countries

The building categories which have the highest energy heating/cooling savings and highest energy cost savings in all 5 EU-countries are the 1-2 storey terrace (single) buildings with a low value of volume/surface ratio. The basic reason for this is the high heating/cooling energy consumption before retrofitting.

The building categories which have the poorest heating/cooling energy savings and poorest energy cost savings in all 5-EU countries are the multi-storey compact buildings. The basic reason for this is the low heating/cooling energy consumption and energy costs before retrofitting.

1. The E-RETROFIT-KIT project

1.1 The partners and the aim

1.1.1 The partners of the project

The partners of the project are:

- FaellesBo, social housing company, Denmark (Coordinator)
- Energie Institut Vorarlberg (EIV), regional energy institute, Austria
- Energy Research Centre of The Netherlands (ECN), national energy research centre, The Netherlands
- Asociacón de Investigación Industrial de Andalucia (AICIA), research institute of the School of Engineering, Technical University of Seville, Spain
- COWI A/S, consulting engineering company, Denmark
- BKA Housing Agency, public housing agency, Lithuania

1.1.2 The aim of the project

The aim of the project is to develop a web-based tool-kit for passive house retrofitting applied to social housing comprising the elements of:

- General guidelines based on best practise
- Examples of passive house retro-fittings applied to social housing
- Catalogue of passive house retrofitting building components
- Methodology for making your own solutions.

The tool-kit has been disseminated to a number of other EU-countries through guidance activities for social housing companies and dissemination activities on a European level.

1.2 The methodology and accomplishment of the project

1.2.1 The overall methodology of the tool-kit

The overall methodology of the tool-kit is to use a typology of buildings (building categories) as the "entrance" into the "operative part" of the tool-kit. Passive House Retrofitting measures, energy and economy calculations and results are related specifically to the building category chosen. This means that for using the E-RETROFIT-KIT tool-kit the user shall identify, what building category of the E-RETROFIT-KIT tool-kit the social housing company's building, which shall be evaluated for Passive House Retrofitting-feasibility, it is most similar to.

When the right building category of the tool-kit has been identified, the tool-kit gives information on:

- Actual state
- Energy savings
- PHR-Measures
- Energy costs and incomplete PHR
- Summary

In general a specific building will not be precisely the same as the model building category of the E-RETROFIT-KIT tool-kit, so it must be evaluated, what the difference means to the results of Passive House Retrofitting.

The tool-kit has not been developed for all EU-countries, meaning for "other countries", the effect of using the results, e.g. for Sweden (not part of the tool-kit), compared to Denmark (being part of the tool-kit) has to be evaluated, not least concerning the energy costs.

So you can say that E-RETROFIT-KIT tool-kit in many cases does not provide a precise result. But the tool-kit can give a relatively good idea about the feasibility of carrying out Passive House Retrofitting of a specific building.

If a precise result of Passive House Retrofitting-feasibility shall be made, it is necessary to carry out PHPP-calculations based on a registration of the building.

Investment costs in Passive House Retrofitting are not included as an element of the tool-kit, although the information would be most useful to give a full picture of the feasibility of Passive House Retrofitting. The reason for including investment costs is a decision only to stick to tool-kit elements related to calculation of energy savings, including costs for heating/cooling, because this type of information is the most reliable. Information on Passive House Retrofitting investments are considered to be too insecure.

1.2.2 Registration of best practice on Passive House Retrofitting (work package 2)

The registration of best practice on Passive House Retrofitting has established the basis for developing the tool-kit with respect of identifying the Passive House Retrofitting experience, which can be the basis for developing the tool-kit, e.g. on identification of the building categories to be used as "entrance" into the tool-kit.

For the tool-kit element of best practice on building retrofitting there has been established a cooperation with the IEE-project, EI-Education, which has developed a format for presenting the best practice examples. The format has been used also for E-RETROFIT-

KIT best practice registrations. The best practice registration of the E-RETROFIT-KIT tool-kit includes also registrations from EI-Education.

1.2.3 Developing the tool-kit

Because Passive House Retrofitting experience mainly has been made in Austria and Germany and with an Austrian partner in the project, the Austrian version of the tool-kit has been applied for the tool-kit with respect of:

- Description of Passive House Retrofitting measures for Central and Northern European countries: Austria, Denmark, Lithuania and The Netherlands
- The tool-kit for Austria has been used for "additional" Northern and Central European countries involved as dissemination countries, meaning that the Austrian version of the tool-kit has been translated and used for: Czech Republic, European Union, France, Germany, Luxembourg, Italy (northern) and Slovenia.

At the time of developing the tool-kit the PHPP calculation tool was not developed for countries with over-heating problems as a main issue. Therefore the description and energy calculations for the Spanish part of the tool-kit was made using the software "LIDER", which is the Spanish official tool to verify the requirement of the limitation of the energy need in the Spanish building code (CTE-HE1, 2006).
The software uses an hourly 3-D multi-zone calculation method, taking into account the solar position, external obstacles (other buildings), shading devices, infiltration etc. etc. For the calculation of the delivered energy, AICIA assumed some usual energy efficiency ratios used in Spain (heating, cooling and domestic hot water).

The Portuguese "dissemination" version of the tool-kit is a translation of the Spanish version of the tool-kit.

The Great Britain "dissemination" version of the tool-kit is a translation of the Dutch version of the tool-kit.

For the 5 involved partner-countries (Austria, Denmark, Lithuania, Spain and The Netherlands) was developed specific versions of the tool-kit with respect of:

- Building categorization
- Energy calculations using the PHPP methodology (except for Spain, using a different calculation method)
- Economy calculations:
    - For Austria, the Netherlands and Lithuania using Austrian cost data
    - For Denmark using German cost data, because calculation was carried out by Energie Institut Darmstadt.
    - For Spain using Spanish cost data.

1.2.4 Testing the tool-kit (work package 4)

The regional testing of the tool-kit was carried out letting regional social housing companies using/looking into the tool-kit and having them filling out evaluation questionnaires on the feasibility of the tool-kit. The main results of the testing were the following:

Testing Questions	Country							Totally	
	AT	DK	LT	ES	GB	NL	BE	No	%
1.Familiar-Yes	3	2	1	1	1	2	1	11	55
1.Familar-No	0	2	4	3	0	1	0	10	45
2.New tool-Yes	- 0)	-	5	-	1	3	1	10	(100)
2.New tool-No	-	-	0	-	0	0	0	0	0
3.Structure clear-yes	3	4	5	4	1	3	1	21	100
3.Structure clear-no	0	0	0	0	0	0	0	0	0
4.Operational-yes	3	4	5	4	1	3	1	21	100
4.Operational-no	0	0	0	0	0	0	0	0	0
5.Interesting-measures	-	2	4	3	1	2	1	18	(100)
5.Interesting-economy	-	2	1				1	4	-
5.Interesting-diff. 1)			3					3	-
6.Bad-cost data	-	3						3	-
6.Bad-energy 2)		3						3	-
6.Bad-diff.		1		2				3	-
7.Cost data correct-yes	2	3	4	-				9	45
7.Cost data correct-?					1	3	1	5	23
8.Missing-explan.		3						3	-
8.Missing-% 3)		3						3	-
8.Missing-diff.	1		3		1		1	6	-
9.Consistent-yes	3	4	5	4	1	3	1	21	100
9.Consistent-no	0	0	0	0	0	0	0	0	0
10.Efficient-yes	3	4	5	4	1	3	1	21	100
10.Efficient-no	0	0	0	0	0	0	0	0	0
Totally	3	4	5	4	1	3	1	21	100

0)-: Meaning data collection has not been made
1) Diff.: different
2) Energy: Difference between delivered energy and energy consumption
3) %: Percentage instead of absolute numbers

Table 1.1, Results from testing activities

21 social housing companies have been involved in testing the E-RETROFIT-KIT tool-kit. The main results are that the social housing companies find that the tool-kit is:

- New (10 out of 10 asked)
- Clear in the sense of structure
- Operational
- Consistent
- Efficient
- Correctness of cost data is hard to evaluate.

In general the evaluation of the tool-kit is positive.

Additionally there have been additional comments on missing data etc.

1.3 Using E-RETROFIT-KIT for guidance activities

1.3.1 3 types of guidance activities

The main dissemination activities of the tool-kit was carried out as guidance activities targeted towards social housing companies. 3 levels of guidance activities were carried out:

- 45 initial guidance cases
- 22 thorough guidance cases
- 17 sketch proposals

1.3.2 Initial guidance activities

Initial guidance - the social housing companies tested the tool-kit by looking into the tool-kit. The result of the initial guidance activity was evaluated by having the social housing companies filling out a questionnaire. Below an example of an "Initial guidance case".

Initial guidance- Braendgaardsparken, DK	
Questions	**Comments from the Social Housing Company**
Name of the Social Housing Company	Boligselskab Fruehøjgaard, 7400 Herning, Denmark
Form filled out by (name, e-mail, phone)	Hans Bjerregaard, hans@bjerregaard.com, +45 2015 0520
1. Is Passive House Retrofitting (PHR) interesting to you?	Yes
2. Are you willing to go on with this tool?	Yes
3. Do you have a building to	Yes

renovate within 0-3 years? - If yes to these questions go to "Thorough guidance", but you shall also answer questions below.	
4. What are the main advantages, you expect from PHR?	• How economical viable is the proposed energy savings measures proposed • Proposed measures can be compared to alternatives.
5. What are the main barriers, you expect from PHR?	• Have all costs related to retrofitting an existing building being included in the PHR or will unexpected costs (insulation, air tightness of joint etc.) be higher than assumed when implementing the measures.
6. Why are you not interested?	We are interested

Table 1.2 Example of Initial guidance-case

1.3.3 Thorough guidance activities

Throughout guidance - the tool-kit was used for carrying out an evaluation of the Passive House Retrofitting-feasibility of a specific building of a social housing company. Below an example of a "Thorough guidance-case".

Thorough guidance - Braendgaardsparken, DK	
Questions	**Answers to the questions**
Name of the Social Housing Company	Boligselskabet Fruehøjgaard, Denmark
Representative of SHC (name, e-mail, phone	Søren Jellesø, sje@fruehojgaard.dk, +45 9626 1494
Form filled out by (name, e-mail, phone)	Hans Bjerregaard, FællesBo, hans@bjerregaard.com, +45 2015 0520
Input data available for thorough guidance: Photo, plan, type of wall/roof/cellar/windows, energy consumption, insulation standard	Yes, drawings of current building mass is available
1. What is the building category - relating to building categories given in the tool?	Block of flats (four floors) erected in the late 1960'ties, which is considered similar to the block of flats in the 1970'ties in the web tool.
2. What measures are relevant for the specific building (go	• The facade is constructed by an inner concrete wall and an exterior wall consisting of wood cover plates.

through the list together)?	• Retrofitting of block of flats are assumed to comprise additional insulation of building facades (for instance pre-fabricated facade elements equipped with windows), roof constructions and basement constructions to fulfil requirements of the Danish legislation in year 2010 named energy class 1 (heat loss from buildings are equal to approx. 29.0 kWh/m2/yr). • Activities to achieve as air tightness construction joints as possible. • New windows with a total (window glass and window frame) U=0.8 W/m2K • Thermal bridges defused as good as possible. • 0.6-1.0 l/hour should be possible • Ventilation system (sensor operated) with heat recovery shall be installed • Space heating maintained • Night ventilation to avoid over-heating
3. Differences in measures compared to reference building category (make a list), explain in short terms the reasons for the differences.	The project of retrofitting Brændgårdsparken comprises most of the measures included the proposal elaborated by Dr. Wolfgang Feist. The difference in measures is related to the heat losses when the success criteria of the Brændgårdspark project is the Danish Energy class no. 1 (29 kWh/m2/yr), but economy can change this assumption.
4. Estimated heating and cooling demand of the specific building after retrofitting - using the building category model of the web-tool for carrying out PHPP/AICIA-calculations only changing for the energy saving measures which are different for the actual building compared to building category model building. The estimation is done by us, not by the SHC (they do not have the PHPP model for the building type)	Tender dossier (Brændgårdsparken) will present requirements equal to heat loss from buildings equal too 29.0 kWh/m2/yr (Danish legislation of year 2010). However, tenders bids submitted can alter this assumption if the price of the bids is too high.
5. Is PHR possible, and is the result of the retrofitting feasible/not feasible? Estimated costs of PHR - using the building category model of the web-tool for carrying out PHPP/AICIA-calculations only changing for the energy saving measures which are different for the actual building compared to building category	Present cash value of investment costs in PHR= 80 €/m2 Present cash value of energy consumption saved=90 €/m2 The investment in PHR is economic feasible

model building. The estimation is done by us, not by the SHC (they do not have the PHPP model for the building type)	
6. Do you have any comments on the tool?	Abbreviations and measures used could be more detailed described in a section of terms, abbreviation etc. See comments of testing of the tool

Table 1.3 Example of Thorough guidance-case

1.3.4 Passive House Retrofitting sketch proposals

17 sketch proposals for Passive House Retrofitting-cases carrying out PHPP calculations in Austria, Denmark, Lithuania and the Netherlands and carrying out LIDER-software calculations in Spain. For each of the sketch proposals are made reports of Passive House Retrofitting-feasibility.

1.3.5 Overview over guidance activities etc.

An overview of the guidance activities carried out, see table below.

Country	Initial guidance	Thorough guidance	Sketch proposal
Austria	6	5	5
Belgium	2	1	0
Denmark	7	6	6
France	2	0	0
Germany	2	0	0
Great Britain	3	1	0
Italy	1	1	0
Lithuania	5	5	1
Luxembourg	1	0	0
Slovenia	1	1	0
Spain	5	4	4
The Netherlands	10	3	1
Totally	***45***	***27***	***17***

Table 1.4 Guidance activities in 12 countries

An article about Passive House Retrofitting and the E-RETROFIT-KIT tool-kit was published in Renewable Energy World in April 2008.

2. The E-RETROFIT-KIT tool-kit

2.1 The structure of the tool-kit (how to use the tool-kit)

Energieinstitut Vorarlberg, Austria, is the host of the E-RETROFIT-KIT tool-kit. The web address of the tool-kit is: **www.energieinstitut.at/retrofit/**

The E-RETROFIT-KIT tool-kit is characterized by:

2.1.1 "Entrance" into the tool-kit through the countries (flags)

The overall "entrance" into the tool-kit is through flags of 13 countries + EU (Europe). This means that for users of the tool-kit not represented with a flag, the users have to find the flag best representing their countries conditions. The Europe-version of the tool-kit is an English version of the Austrian version.

The tool-kit is translated into 11 languages:

- Czech language
- Danish
- Dutch
- English
- French
- German
- Italian
- Lithuanian
- Portuguese
- Slovenian
- Spanish

For Austria=Europe, Lithuania and Spain there is also an English version of the tool-kit. For Denmark and The Netherlands the English version is not complete and should not be used.

Figure 2.1

2.1.2 Options within the country specific part

Within the country specific part there are 3 main choices:

- General information about Passive House Retrofitting with the following options:
    - Introduction - short introduction into Passive House Retrofitting, how does the tool work etc.
    - Principles - short introduction into the principles of Passive House Retrofitting
    - Advantages - short description of advantages from Passive House Retrofitting
    - Economy - information about the sources of information for developing the economy part of the tool-kit
    - Non-energetic aspects - information about other aspects than energy in relation to retrofitting of building
    - Best practice - the best practice information is different for each nation, typical dependent on how much best practice information has been translated into the specific language
    - Disclaimer - also including information about who are the partners behind the tool-kit

- Building types of this country - "the entrance" into the tool-kit concerning more specific information related to specific building categories
- Measures - of Passive House Retrofitting with short description and main data of energy and economy.

Figure 2.2

2.1.3 Measures

Within "Measures" there are a number of choices on different Passive House Retrofitting-measures. The following main categories of measures are included in the tool-kit:

building element	measure
1. external wall	1.1 external insulation + plaster
	1.2 external insulation + weather protection
	1.3 external insulation GAP solar
	1.4 external insulation - prefabricated system
	1.5 internal insulation
2. external wall with cavity	2.1 insulation of cavity wall
3. roof	3.1 insulation of tilted roof between and under rafters
	3.2 insulation of tilted roof between and on top of rafters
	3.3 insulation of flat roof - under new sealing
	3.4 insulation of flat roof - on top of new sealing
4. attic floor	4.1 insulation of attic floor
5. floor	5.1 insulation of floor
6. basement ceiling	6.1 insulation of basement ceiling
7. window	7.1 high efficiency double glazing
	7.2 high efficiency triple glazing
8. thermal bridges	8.1 minimisation of thermal bridges
9. air tightness	9.1 improvement of air tightness
10. ventilation	10.1 mechanical ventilation system with heat recovery - central system for whole house
	10.2 mechanical ventilation system with heat recovery - one system for each appartement
	10.3 mechanical ventilation system with heat recovery - decentralized

Figure 2.3

For each of the measures there is a short description with information on:

- General description
- Things to consider/avoid
- Related aspects
- Typical costs
- Economic feasibility

2.2 "Building types of this country"

2.2.1 Introduction

The different building types of the tool-kit are presented with photos. The typologies of the 5 partner-countries (Austria, Denmark, Lithuania, Spain and The Netherlands) are different concerning the number of building types and the way the typology is made:

- Austria - 5 types, from the 1960's and the 1970's, related to building period, type of building materials and surface-volume ratio.
- Denmark - 4 types, from 1900-1980, related to building period, type of building materials and surface-volume ratio.
- Lithuania - 3 types, related to building period and surface-volume ratio.
- Spain - 9 types from 1960-1980, with a matrix of 3 time periods (<1960, 1960-1979, >1979) and 3 surface-volume ratios (>4 storey, <4 storey, terrace).
- The Netherlands - 9 types from <1966-1988, related to building period, type of building materials and surface-volume ratio.

For all building typologies focus has been put on buildings from 1950's to around 1980-90. These buildings have a need for retrofitting, and they are also potentially feasible for Passive House Retrofitting because the are typically established as "building blocks" and their architectural value is often limited, so its possible just to add an outside insulation etc.

For "additional" countries besides the 5 partner countries of the IEE-project, Austria, Denmark, Lithuania, Spain and The Netherlands, has been applied building typologies of these 5 countries in the following way:

- Austrian typology used for:
    - Austria
    - Czech Republic
    - Europe
    - France
    - Germany
    - Great Britain
    - Italy
    - Luxembourg
    - Slovenia
- Danish typology used for:
    - Denmark
- Dutch typology used for:
    - Belgium
    - The Netherlands
- Spanish typology used for:
    - Portugal
    - Spain

To access further information on each building category, the building category shall be "clicked".

Figure 2.4

2.2.2 Information about the building type

For each building type the following information and options are available:

- Actual state:
    - Typical appearance - photo
    - General information - about the building
    - Building elements - U-values, building materials etc. of existing building
    - Heating system
    - Energy need
- Energy savings
- PHR (Passive House Measures)
- Energy costs and incomplete PHR
- Summary

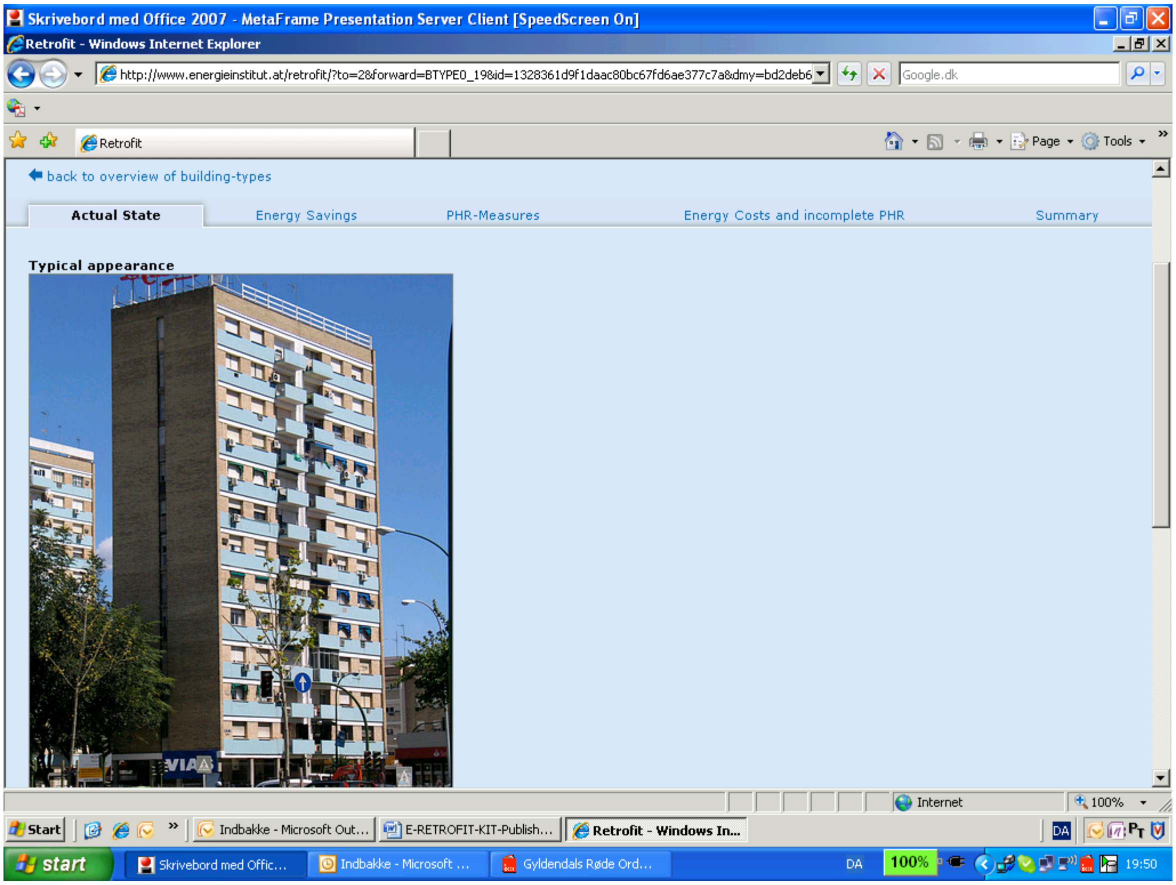

Figure 2.5

2.2.3 Energy savings

"Energy savings" contain information as column diagrams about:

- Energy needed for heating and cooling, kWh/m^2 per year:
    - Actual state
    - According to building code
    - After Passive House Retrofitting
- Delivered energy in kWh/m^2 per year, including auxiliary electricity, cooling, domestic hot water and space heating:
    - Actual state
    - According to building code
    - After Passive House Retrofitting

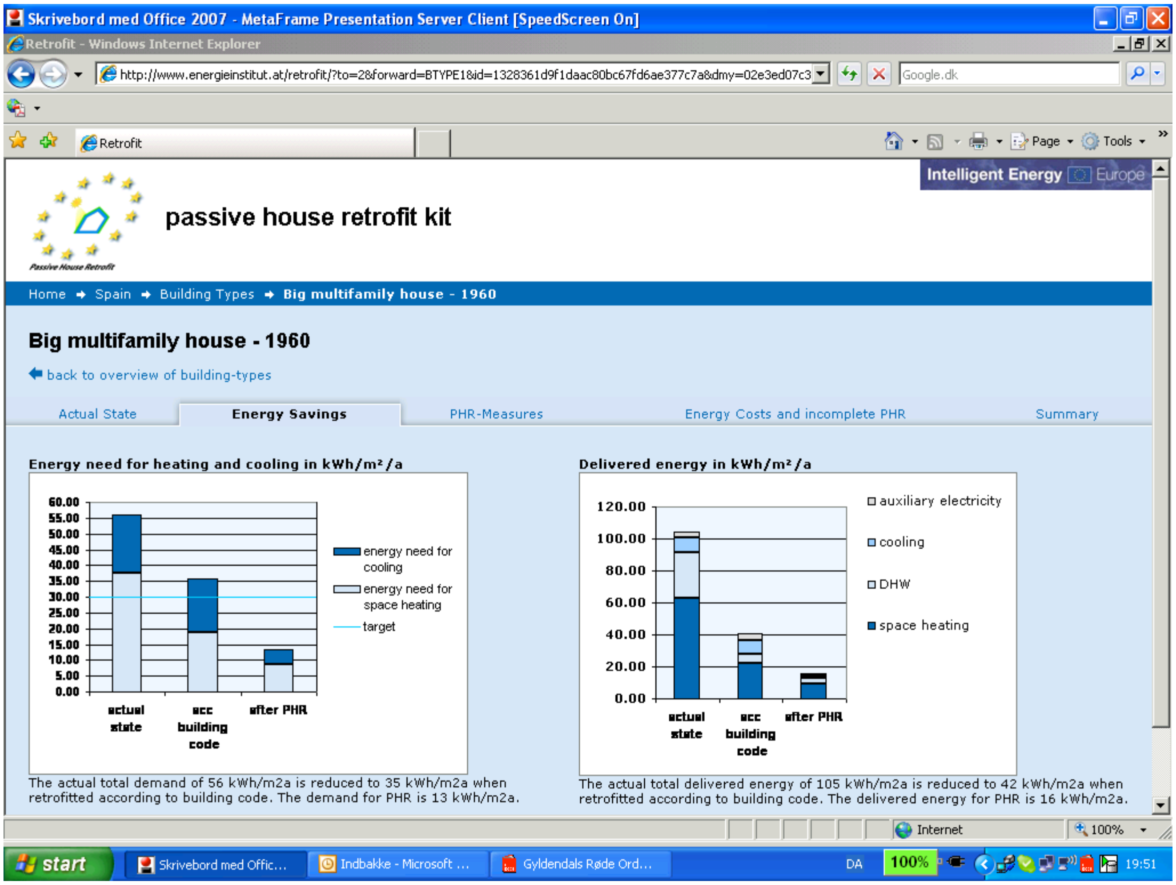

Figure 2.6

2.2.4 Passive House Retrofitting (PHR) measures

The PHR-Measures contains a list of Passive House Retrofitting measures to be applied for the specific building type. There is short information about each measures:

- Building element
- Value (U-value)
- Sketch
- Description - very short description, for further information shall be "clicked" for more information

Figure 2.7

2.2.5 Energy costs and incomplete PHR

The energy costs (EURO per year), including auxiliary electricity, cooling, domestic hot water and space heating, is presented for:

- Actual state
- According to the building code
- After Passive House Retrofitting

The delivered energy in kWh/m^2 per year for "incomplete PHR" is presented for:

- Complete PHR
- Insulation of wall according to the building code
- Insulation of the roof according to the building code
- Insulation of the floor according to the building code
- Insulation of the windows according to the building code
- Air tightness 2 ACH (2 times the room volume per hour)
- No heat recovery
- Heating system not modified
- No passive cooling

These concepts are chosen because they can be typical for "incomplete PHR".

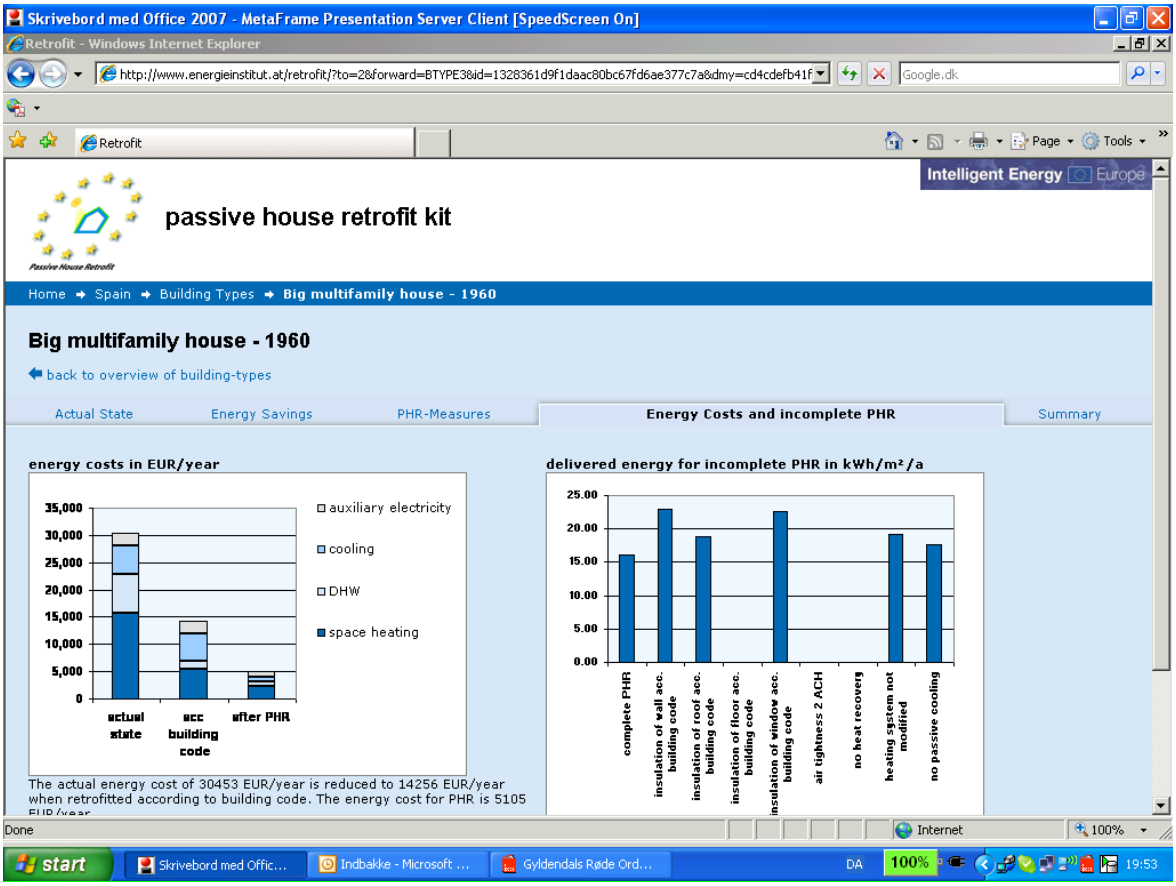

Figure 2.8

2.2.6 Summary

In "Summary" is presented the energy costs (EURO per year), including auxiliary electricity, cooling, domestic hot water and space heating, for:

- Actual state
- According to the building code
- After Passive House Retrofitting

The results are summarized in a short text with proposal to "Next step".

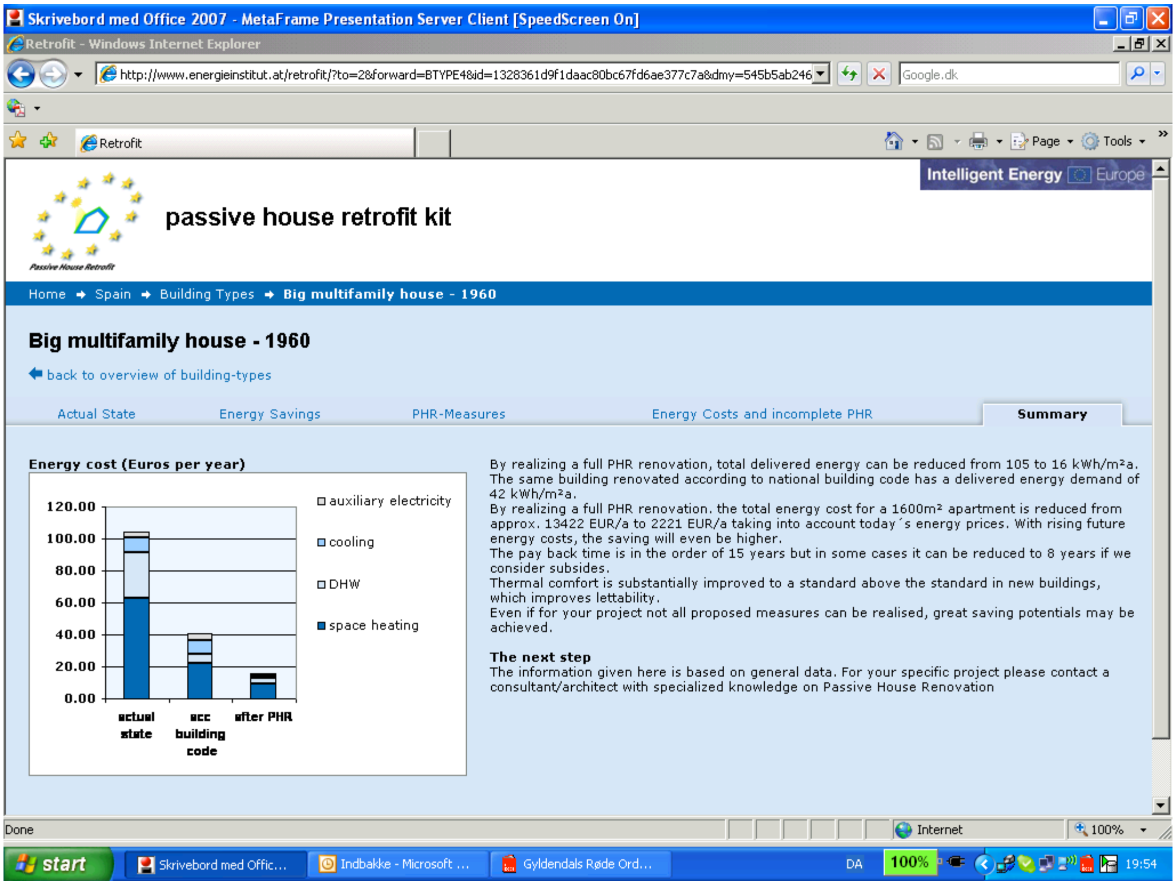

Figure 2.9

3. Data and results on Passive House Retrofitting in 5 EU-countries

3.1 General

In connection to developing the tool-kit has been described different building categories with information on of Passive House Retrofitting measures, energy savings, energy costs and energy consumption for incomplete Passive House Retrofitting - for each building category.

The main results will be presented for each of the 5 "partner countries" of the project, Austria, Denmark, Lithuania, Spain and The Netherlands, by presenting "the best" in terms of highest energy savings, "the poorest" in terms of smallest energy savings for heating/cooling and "the average" with the average energy savings for that country. As information source is used the data from the building type categories and thereby representing "typical data". This information source is used as the basis for evaluation the possibilities for Passive House Retrofitting (of social housing company buildings), because these buildings categories) are the most representative of the typical building mass, exactly because they have been chosen as "the building categories".

The amount of data for making overall evaluation of results and conclusions on Passive House Retrofitting is from only 5 countries and the data is limited. Selections have been made for the building categories, which are data basis for this report. Only for Denmark and Spain have been selected building categories, which seem to be older than around 1950-60. This influences the results, in the sense that older buildings can on one hand be difficult to make efficient energy efficiency retrofitting, e.g. due to architectural reasons. On the other hand such buildings can have a very high energy consumption giving a potential for big energy savings.

But the selected building categories can be seen as typical for social housing company buildings with a potential for Passive House Retrofitting, so in this sense the selected material can be seen as feasible for making some overall resume of results and conclusions.

3.2 Austria

3.2.1 Building categories

Austria has the following building categories:

1) Big apartment house from 1960-1969
2) Big apartment house from 1970-1979
3) Row house from 1970-1979
4) Small apartment house from 1960-1969
5) Small apartment house from 1970-1979

3.2.2 Energy measures

The energy measures proposed for the different building categories are the typical Passive House Retrofitting-measures (see table below).

Austria					
Passive House Retrofitting Measures	**Building category**				
	1	**2**	**3**	**4**	**5**
1.1 External insulation+ plaster		x		x	x
1.2 External insulation+ weather protection			x		
1.3 External insulation+ GAP solar					
1.4 External insulation - prefabricated system	x				
1.5 Internal insulation					
2.1 Insulation of cavity wall					
3.1 Insulation of tilted roof betw/under rafters					
3.2 Insulation of tilted roof betw/top of rafters					
3.3 Insulation of flat roof under new sealing					

3.4 Insulation of flat roof on top of new sealing	x	x			
4.1 Insulation of attic floor			x	x	x
5.1 Insulation of floor					
6.1 Insulation of basement ceiling		x	x		x
7.1 High efficiency double glazing					
7.2 High efficiency triple glazing	x	x	x		x
8.1 Minimization of thermal bridges	x	x	x		x
9.1 Improvement of air tightness	x	x	x		x
10.1 Mechanical ventilation central system		x			x
10.2 Mechanical ventilation each flat	x		x		
10.3 Mechanical ventilation decentralized/room				x	
11.1 Glazed balconies					x
12.1 Solar collectors for hot domestic water	x	x		x	x
12.2 Thermal collectors for HDW and heating					
12.3 Photovoltaic systems			x		
13.1 High efficiency gas fired boilers	x				x
13.2 Heat pumps					
13.3 Compact units			x		
13.4 Biomass fired heating systems		x		x	
13.5 Biomass fired combined heat and power					
14.1 Energy efficient household appliances					
15.1 Reducing solar radiation by design					
16.1 Shading devices, interior/exterior					
17.1 Thermal mass					
18.1 Night ventilation					
19.1 Efficient active cooling systems					

Table 3.1 Energy measures in Passive House Retrofitting in Austria

3.2.3 Energy savings - energy consumption

The results in terms of heating/cooling energy savings and energy consumption for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	Building type	Heating/cooling consumption, kWh/m^2 per year		
		Before PHR	After PHR	Savings
Best	Small apartment house,1960-1969	255	23	222
Poorest	Big apartment house, 1970-1979	136	16	120
Average of the 5 building categories	-	193	19	172

Table 3.2 Heating/cooling energy savings in Passive House Retrofitting in Austria

3.2.4 Energy costs

The results in terms of energy costs for heating/cooling for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	Building type	Energy costs per year, EURO (per apartment)		
		Before PHR	After PHR	Savings
Best	Row house, 1970-1979	1,835	110	1,725
Poorest	Big apartment house, 1970-1979	1,037	167	860
Average of the 5 building categories	-	1,404	155	1,248

Table 3.3 Energy costs for heating/cooling after Passive House Retrofitting in Austria

3.2.5 Austria - conclusions

For both energy savings for heating and cooling and for energy costs the apartment/terrace buildings included have the highest potential for savings due to relatively bad energy standard before retrofitting, again due to low volume-surface ratio.

The poorest result on both energy savings for heating and cooling and for energy costs reductions is for more compact buildings.

3.3 Denmark

3.2.1 Building categories

Denmark has the following building categories:

1) Apartment block, brick facade from 1900-1940
2) Terrace houses, wood (normally it typical is bricks), 1960's
3) Concrete building blocks with cold bridges from balconies into the facade, 1965-1980
4) Apartment block, lightweight/massive facades, 1970's

3.2.2 Energy measures

The energy measures proposed for the different building categories are the typical Passive House Retrofitting-measures (see table below).

Denmark				
Passive House Retrofitting Measures	Building category			
	1	2	3	4
1.1 External insulation+ plaster				
1.2 External insulation+ weather protection		x	x	x
1.3 External insulation+ GAP solar				
1.4 External insulation - prefabricated system				
1.5 Internal insulation	x			
2.1 Insulation of cavity wall				
3.1 Insulation of tilted roof betw/under rafters				
3.2 Insulation of tilted roof betw/top of rafters	x	x		x
3.3 Insulation of flat roof under new sealing			x	
3.4 Insulation of flat roof on top of new sealing				
4.1 Insulation of attic floor	x	x		x
5.1 Insulation of floor	x		x	x
6.1 Insulation of basement ceiling	x	x	x	x
7.1 High efficiency double glazing				
7.2 High efficiency triple glazing	x	x	x	x
8.1 Minimization of thermal bridges	x	x	x	x
9.1 Improvement of air tightness	x	x	x	x
10.1 Mechanical ventilation central system	x	x	x	x
10.2 Mechanical ventilation each flat				
10.3 Mechanical ventilation decentralized/room				
11.1 Glazed balconies				
12.1 Solar collectors for hot domestic water				
12.2 Thermal collectors for HDW and heating				
12.3 Photovoltaic systems				
13.1 High efficiency gas fired boilers				
13.2 Heat pumps				
13.3 Compact units				
13.4 Biomass fired heating systems				
13.5 Biomass fired combined heat and power				
14.1 Energy efficient household appliances				
15.1 Reducing solar radiation by design				
16.1 Shading devices, interior/exterior			x	x
17.1 Thermal mass				
18.1 Night ventilation			x	x
19.1 Efficient active cooling systems				

Table 3.4 Energy measures in Passive House Retrofitting in Denmark

3.3.3 Energy savings - energy consumption

The results in terms of heating/cooling energy savings and energy consumption for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	Building type	Heating/cooling consumption, kWh/m^2 per year		
		Before PHR	After PHR	Savings

Best	Terrace houses, wood (typical bricks), 1960's	210	45	165
Poorest	Concrete building blocks with cold bridges from balconies into the facade, 1965-1980	130	24	106
Average of the 4 building categories		166	40	126

Table 3.5 Heating/cooling energy savings in Passive House Retrofitting in Denmark

3.3.4 Energy costs

The results in terms of energy costs for heating/cooling for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	Building type	Energy costs per year, EURO (per apartment)		
		Before PHR	**After PHR**	**Savings**
Best	Terrace houses, wood (typical bricks), 1960's	1,360	400	960
Poorest	Apartment block, brick facade,1900-1940	710	400	310
Average of the 4 building categories	-	845	300	545

Table 3.6 Energy costs for heating/cooling after Passive House Retrofitting in Denmark

3.3.5 Denmark - conclusions

For both energy savings for heating and cooling and for energy costs the smaller terrace buildings included have the highest potential for savings due to relatively bad energy standard before retrofitting, again due to low volume-surface ratio.

The poorest result on both energy savings for heating and cooling and for energy costs reductions is for more compact buildings.

3.4 Lithuania

3.4.1 Building categories

Lithuania has the following building categories:

1) Up till 5 storey, panel-concrete walls, flat roof, 1977
2) >9 storey, panel-concrete walls, flat roof, 1984
3) 1-2 storey, stone-brick walls, tilted roof, 1989

3.4.2 Energy measures

The energy measures proposed for the different building categories are the typical Passive House Retrofitting-measures (see table below).

Lithuania			
Passive House Retrofitting Measures	**Building category**		
	1	**2**	**3**
1.1 External insulation+ plaster			x
1.2 External insulation+ weather protection			
1.3 External insulation+ GAP solar			
1.4 External insulation - prefabricated system	x	x	
1.5 Internal insulation			
2.1 Insulation of cavity wall			
3.1 Insulation of tilted roof betw/under rafters			
3.2 Insulation of tilted roof betw/top of rafters			x
3.3 Insulation of flat roof under new sealing	x	x	
3.4 Insulation of flat roof on top of new sealing			
4.1 Insulation of attic floor			
5.1 Insulation of floor			
6.1 Insulation of basement ceiling	x	x	x
7.1 High efficiency double glazing			
7.2 High efficiency triple glazing	x	x	x
8.1 Minimization of thermal bridges	x	x	x
9.1 Improvement of air tightness	x	x	x
10.1 Mechanical ventilation central system			x
10.2 Mechanical ventilation each flat	x	x	
10.3 Mechanical ventilation decentralized/room			
11.1 Glazed balconies			
12.1 Solar collectors for hot domestic water		x	x
12.2 Thermal collectors for HDW and heating			
12.3 Photovoltaic systems			
13.1 High efficiency gas fired boilers			
13.2 Heat pumps			
13.3 Compact units			
13.4 Biomass fired heating systems			x
13.5 Biomass fired combined heat and power			
14.1 Energy efficient household appliances			x
15.1 Reducing solar radiation by design			
16.1 Shading devices, interior/exterior	x	x	x
17.1 Thermal mass			
18.1 Night ventilation	x	x	
19.1 Efficient active cooling systems			

Table 3.7 Energy measures in Passive House Retrofitting in Lithuania

3.4.3 Energy savings - energy consumption

The results in terms of heating/cooling energy savings and energy consumption for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	**Building type**	**Heating/cooling consumption, kWh/m^2 per year**		
		Before PHR	**After PHR**	**Savings**
Best	1-2 storey, stone-brick walls, tilted rood, 1989	235	35	200
Poorest	Up till 5 storey, panel-concrete walls, flat roof, 1977	190	25	165
Average of the 3 building categories	-	208	30	178

Table 3.8 Heating/cooling energy savings in Passive House Retrofitting in Lithuania

3.4.4 Energy costs

The results in terms of energy costs for heating/cooling for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	**Building type**	**Energy costs per year, EURO (per apartment)**		
		Before PHR	**After PHR**	**Savings**
Best	1-2 storey, stone-brick walls, tilted rood, 1989	1,566	353	1,213
Poorest	Up till 5 storey, panel-concrete walls, flat roof, 1977	833	183	650
Average of the 3 building categories	-	1,244	280	964

Table 3.9 Energy costs for heating/cooling after Passive House Retrofitting in Lithuania

3.4.5 Lithuania - conclusions

For both energy savings for heating and cooling and for energy costs the smaller building included has the highest potential for savings due to relatively high energy consumption before retrofitting, which gain is due to low volume-surface ratio compared to the more compact buildings.

The poorest result on both energy savings for heating and cooling and for energy costs reductions is for more compact buildings.

3.5 Spain

3.5.1 Building categories

Austria has the following building categories:

1) 1960 typical Multifamily house >4 storey, compact
2) 1960-1979 typical Multifamily house >4 storey, compact
3) 1979 typical Multifamily house >4 storey, compact
4) 1960 typical Multifamily house <=4 storey, compact
5) 1960-1979 typical Multifamily house <=4 storey, compact
6) 1979 typical Multifamily house <=4 storey, compact
7) 1960 typical terrace house, compact
8) 1960-1979 typical terrace house, compact
9) 1979 typical terrace house, compact

3.5.2 Energy measures

The energy measures proposed for the different building categories are the typical Passive House Retrofitting-measures (see table below).

Spain									
Passive House Retrofitting Measures	**Building category**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1.1 External insulation+ plaster	x	x	x	x	x	x	x	x	x
1.2 External insulation+ weather protection									
1.3 External insulation+ GAP solar									
1.4 External insulation - prefabricated system									
1.5 Internal insulation									

2.1 Insulation of cavity wall									
3.1 Insulation of tilted roof betw/under rafters									
3.2 Insulation of tilted roof betw/top of rafters									
3.3 Insulation of flat roof under new sealing									
3.4 Insulation of flat roof on top of new sealing	x	x	x	x	x	x	x	x	x
4.1 Insulation of attic floor									
5.1 Insulation of floor									
6.1 Insulation of basement ceiling									
7.1 High efficiency double glazing	x	x	x	x	x	x	x	x	x
7.2 High efficiency triple glazing									
8.1 Minimization of thermal bridges									
9.1 Improvement of air tightness									
10.1 Mechanical ventilation central system									
10.2 Mechanical ventilation each flat									
10.3 Mechanical ventilation decentralized/room									
11.1 Glazed balconies									
12.1 Solar collectors for hot domestic water	x	x	x	x	x	x	x	x	x
12.2 Thermal collectors for HDW and heating									
12.3 Photovoltaic systems									
13.1 High efficiency gas fired boilers	x	x	x	x	x	x	x	x	x
13.2 Heat pumps									
13.3 Compact units									
13.4 Biomass fired heating systems									
13.5 Biomass fired combined heat and power									
14.1 Energy efficient household appliances									
15.1 Reducing solar radiation by design	x	x	x	x	x	x	x	x	x
16.1 Shading devices, interior/exterior									
17.1 Thermal mass									
18.1 Night ventilation	x	x	x	x	x	x	x	x	x
19.1 Efficient active cooling systems	x	x	x	x	x	x	x	x	x

Table 3.10 Energy measures in Passive House Retrofitting in Spain

3.5.3 Energy savings - energy consumption

The results in terms of heating/cooling energy savings and energy consumption for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	**Building type**	**Heating/cooling consumption, kWh/m^2 per year**		
		Before PHR	**After PHR**	**Savings**
Best, un-typical due to very high savings	1960 typical terrace house, compact	87	15	72
2nd best - included because "Best" is unusual	1960 typical Multifamily house <=4 storey, compact	60	14	46
Poorest	1979 typical terrace house, compact	27	5	22
Average of the 9 building categories	-	49	12	37

Table 3.11 Heating/cooling energy savings in Passive House Retrofitting in Spain

3.5.4 Energy costs

The results in terms of energy costs for heating/cooling for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	Building type	Energy costs per year, EURO (per apartment)		
		Before PHR	After PHR	Savings
Best un-typical due to very high savings	1960 typical terrace house, compact	1,052	140	912
2nd best - included because "Best" is unusual	1960 typical Multifamily house <=4 storey, compact	670	111	559
Poorest	1979 typical Multifamily house <=4 storey, compact	470	104	366
Average of the 9 building categories	-	606	90	516

Table 3.12 Energy costs for heating/cooling after Passive House Retrofitting in Spain

3.5.5 Spain - conclusions

For both energy savings for heating and cooling and for energy costs the oldest buildings included have the highest potential for savings due to bad energy standard before retrofitting.

The poorest result on both energy savings for heating and cooling and for energy costs reductions is for more new compact buildings.

3.6 The Netherlands

3.6.1 Building categories

The Netherlands has the following building categories:

1) <1966 concrete 7 storey building block with cellar and open balconies
2) 1966-1976 concrete 7 storey building block with cellar and open balconies
3) 1976-1988 concrete 7 storey building block with cellar and open balconies

4) <1966 3 storey brick buildings with cellar
5) 1966-976 3 storey brick buildings with cellar
6) 1977-1988 3 storey brick buildings with cellar
7) <1966 2 storey terrace building
8) 1966-1976 2 storey terrace building
9) 1976-1988 2 storey terrace building

3.6.2 Energy measures

The energy measures proposed for the different building categories are the typical Passive House Retrofitting-measures (see table below).

Spain									
Passive House Retrofitting Measures	**Building category**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1.1 External insulation+ plaster				x	x	x	x		
1.2 External insulation+ weather protection									
1.3 External insulation+ GAP solar									
1.4 External insulation - prefabricated system									
1.5 Internal insulation									
2.1 Insulation of cavity wall								x	x
3.1 Insulation of tilted roof betw/under rafters									
3.2 Insulation of tilted roof betw/top of rafters							x	x	x
3.3 Insulation of flat roof under new sealing				x	x	x			
3.4 Insulation of flat roof on top of new sealing									
4.1 Insulation of attic floor							x	x	x
5.1 Insulation of floor	x	x	x	x	x	x			
6.1 Insulation of basement ceiling	x	x	x	x	x	x	x	x	x
7.1 High efficiency double glazing									
7.2 High efficiency triple glazing									
8.1 Minimization of thermal bridges	x	x	x	x	x	x	x	x	x
9.1 Improvement of air tightness	x	x	x	x	x	x	x	x	x
10.1 Mechanical ventilation central system									
10.2 Mechanical ventilation each flat									
10.3 Mechanical ventilation decentralized/room					x	x			
11.1 Glazed balconies									
12.1 Solar collectors for hot domestic water	x	x	x	x	x	x	x	x	X
12.2 Thermal collectors for HDW and heating									
12.3 Photovoltaic systems									
13.1 High efficiency gas fired boilers	x	x	x	x	x	x	x	x	x
13.2 Heat pumps									
13.3 Compact units									
13.4 Biomass fired heating systems									
13.5 Biomass fired combined heat and power									
14.1 Energy efficient household appliances									
15.1 Reducing solar radiation by design									
16.1 Shading devices, interior/exterior									
17.1 Thermal mass									

18.1 Night ventilation									
19.1 Efficient active cooling systems									

Table 3.13 Energy measures in Passive House Retrofitting in The Netherlands

3.6.3 Energy savings - energy consumption

The results in terms of heating/cooling energy savings and energy consumption for heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	Building type	Heating/cooling consumption, kWh/m^2 per year		
		Before PHR	**After PHR**	**Savings**
Best	1966-1976 2 storey terrace building	198	14	184
Poorest	1976-1988 concrete 7 storey building block with cellar and open balconies	135	14	121
Average of the 9 building categories	-	173	14	159

Table 3.14 Heating/cooling energy savings in Passive House Retrofitting in The Netherlands

3.6.4 Energy costs

The results in terms of energy costs for heating/coolingfor heating after Passive House Retrofitting for best (biggest energy savings), poorest (smallest energy savings) and average (of building categories) are the following.

Rating	Building type	Energy costs per year, EURO (per apartment)		
		Before PHR	**After PHR**	**Savings**
Best	1966-1976 2 storey terrace building	2,450	500	1,950
Poorest	1976-1988 concrete 7 storey building block with cellar and open balconies	1,050	220	830
Average of the 9 building categories	-	1,500	282	1,218

Table 3.15 Energy costs for heating/cooling after Passive House Retrofitting in The Netherlands

3.6.5 The Netherlands - conclusions

For both energy savings for heating and cooling and for energy costs the apartment/terrace buildings included have the highest potential for savings due to relatively bad energy standard before retrofitting, again due to low volume-surface ratio.

The poorest result on both energy savings for heating and cooling and for energy costs reductions is for new more compact buildings.

3.7 Results and conclusions from 5 EU-countries

The results in the 5 partner countries, Austria, Denmark, Lithuania, Spain and The Netherlands, on energy savings for heating and cooling and on energy costs by carrying out Passive house Retrofitting is evaluated by taking the average values of each country and comparing the results.

These 5 EU-countries can be considered being quite typical by Austria representing Central Europe , Denmark representing Northern Europe, Lithuania representing Eastern Europe, Spain (Seville) representing Southern Europe and The Netherlands representing Western (Atlantic climate) Europe.

Statistically the number of cases are limited, but the results can be seen as being typical results, also because the results are from chosen typical building types.

3.7.1 Results on energy savings

Country	**Heating/cooling consumption, kWh/m^2 per year**		
	Before PHR	**After PHR**	**Savings**
Austria	193	19	172
Denmark	166	40	126
Lithuania	208	30	178
Spain	49	12	37
The Netherlands	173	14	159
Average	***158***	***23***	***135***

Table 3.16 Heating/cooling energy savings in Passive House Retrofitting in 5 EU countries

Comments to the results from each country:

Country	Comments	Conclusions
Austria	• Relatively high heating consumption before and low after PHR	• Big energy savings for heating through PHR
Denmark	• Relatively low energy consumption before PHR due to long tradition for energy regulation • Relatively high energy consumption after PHR due to building technical barriers for efficient insulation etc. This again can be a result of including old buildings as one out of 4 building categories	• Relatively small energy savings through PHR because of existing relatively high energy standard of buildings
Lithuania	• Relatively high energy consumption before PHR	• High energy savings through PHR because of high energy consumption before PHR
Spain	• Energy consumption for heating and cooling low before PHR and very low after PHR (Seville) •	• The energy savings obtained through PHR are relatively small
Netherlands	• Relatively low energy consumption before PHR and very low after PHR	• The relatively low energy consumption before PHR means that energy savings are not very high
Average	• Climate, building traditions and building regulation have influence on the results of energy savings by PHR	PHR-ranking of countries: on energy savings 6) Lithuania 7) Austria 8) The Netherlands 9) Denmark 10) Spain

PHR: Passive House Retrofitting

Table 3.17 Comments and conclusions on energy consumption for heating/cooling

Eventual differences in sizes of typical apartments between the countries is not analyzed and taken into consideration.

3.7.2 Results on energy costs

Country	Energy costs per year, EURO (per apartment)		
	Before PHR	After PHR	Savings
Austria	1,404	155	1,248
Denmark	845	300	545
Lithuania	1,244	280	964
Spain	606	90	516
The Netherlands	1,500	282	1,218
Average	***1,120***	***221***	***899***

Table 3.18 Energy cost savings per apartment per year for heating/cooling by Passive House Retrofitting in 5 EU countries

Eventual differences in sizes of typical apartments between the countries is not analyzed and taken into consideration. Comments to the results from each country:

Country	Comments	Conclusions
Austria	• Relatively high energy costs before PHR and low after PHR	• Big energy cost savings for heating through PHR
Denmark	• Relatively low energy costs before PHR due to relatively low energy consumption and low prices on energy (district heating) • Relatively high energy costs after PHR, which can be a result of including old buildings as one out of 4 building categories	• Small energy cost savings through PHR
Lithuania	• Relatively high energy costs before PHR and relatively low after PHR	• High energy cost savings through PHR • Private ownership to individual flats can make PHR difficult to implement
Spain	• Energy costs for heating and cooling low before PHR and very low after PHR (Seville)	• The energy cost savings obtained through PHR are relatively small • Comfort improvements through PHR can motivate PHR
Netherlands	• High energy costs before PHR	• Big energy cost savings for heating through PHR
Average	• Climate, building traditions and building regulation have influence on the results of energy cost savings by PHR	PHR-ranking of countries on energy cost savings: 1) Austria 2) The Netherlands 3) Lithuania 4) Denmark 5) Spain

PHR: Passive House Retrofitting

Table 3.19 Comments and conclusions on energy cost savings per apartment per year through Passive House Retrofitting

3.7.3 Overall conclusions on applying Passive House Retrofitting

The results on energy consumption for heating and cooling and total energy costs per apartment per year can be taken as indications of some major tendencies - and not taken as "the final truth" about the results of Passive House Retrofitting-implementation.

There can be several reasons for only seeing the results as indicators:

- The amount of data is limited
- Different criteria has been applied for the selection of building categories in the different countries, e.g. meaning that some countries include more old buildings than others
- There can be differences in calculations although PHPP has been applied for 4 countries
- The energy prices presented maybe not be representing the statistical average.

The following tendencies can be observed from the results on energy savings for heating and cooling and for total energy costs through applying Passive House Retrofitting.

1	Highest energy savings in: • Lithuania/Eastern Europe - high energy consumption before PHR • Austria/Central Europe - high energy consumption before PHR • The Netherlands/Atlantic climate - relatively high energy consumption before PHR and very low after PHR
2	Medium energy savings in: • Denmark/Northern Europe - although cold climate, there is an old tradition for energy regulation
3	Low energy savings: • Spain/Southern Europe - warm climate giving low energy consumption before PHR
4	Highest energy cost savings: • Austria/Central Europe - high energy savings • The Netherlands/Atlantic climate - high energy savings
5	Medium energy cost savings: • Lithuania/Eastern Europe - although high energy savings low energy prices results in medium energy cost savings, this will change when energy prices reach average European level
6	Low energy cost savings: • Spain/Southern Europe - low energy costs before PHR, but improved comfort can play an important role for motivating PHR application
7	Overall PHR-ranking on energy/energy cost savings: 1) Austria 2) The Netherlands 3) Lithuania (can be expected to have higher ranking in years to come) 4) Denmark 5) Spain

Table 3.20 Overall conclusion on applying Passive House Retrofitting

4. Data and results on Passive House Retrofitting of different building categories

4.1 Introduction

In this part of the report is looked into the results on energy savings in heating and cooling and on energy costs savings related to main categories of buildings across the 5 partner countries of Austria, Denmark, Lithuania, Spain and The Netherlands.

The following main categories of building types are included:

- The buildings with the best results in terms of energy savings for heating and cooling and energy cost savings.
- The buildings with the poorest results in terms of energy savings for heating and cooling and energy cost savings

4.2 Energy consumption for heating and cooling

4.2.1 Building types with highest energy savings

The results on building types with the highest energy savings for heating and cooling.

Country	Building type	Heating/cooling consumption, kWh/m^2 per year		
		Before PHR	After PHR	Savings
Austria	Small apartment house,1960-1969	255	23	232
Denmark	Terrace houses, wood (typical bricks), 1960's	210	45	165
Lithuania	1-2 storey, stone-brick walls, tilted rood, 1989	235	35	200
Spain	1960 typical terrace house, compact	87	15	72
The Netherlands	1966-1976 2 storey terrace building	198	14	184
Average	Average	197	27	170
Average of all building categories in all countries	All buildings	158	23	135

Table 4.1 The best results in terms of heating/cooling energy savings through Passive House Retrofitting

Result and conclusions concerning energy savings for heating and cooling through Passive House Retrofitting:

- All the buildings are 1-2 storey terrace/single buildings
- The difference in energy savings between the "best" and the "average" buildings is mainly the difference in heating consumption before Passive House Retrofitting.

4.2.2 Building types with poorest energy savings

The results on building types with the poorest energy savings for heating and cooling.

Country	Building type	Heating/cooling consumption, kWh/m^2 per year		
		Before PHR	After PHR	Savings
Austria	Big apartment house, 1970-1979	136	16	120
Denmark	Concrete building blocks with cold	130	24	106

	bridges from balconies into the facade, 1965-1980			
Lithuania	Up till 5 storey, panel-concrete walls, flat roof, 1977	190	25	165
Spain	1979 typical terrace house, compact	27	5	22
The Netherlands	1976-1988 concrete 7 storey building block with cellar and open balconies	135	14	121
Average	Average of poorest buildings	118	17	107
Average of all building categories in all countries	All buildings	158	23	135

Table 4.2 The poorest results in terms of heating/cooling energy savings through Passive House Retrofitting

Result and conclusions concerning energy savings for heating and cooling through Passive House Retrofitting:

- The main reasons of "poorest" being poor compared to "average" on energy savings are:
    - Low energy consumption before Passive House Retrofitting
    - Lower energy savings obtained
- The tendency is that the "poorest" buildings are compact newer buildings with relatively low energy consumption before Passive House Retrofitting, except for Spain.
- For Spain it is an advantage of not being exposed to the sun with a bigger need for cooling, explaining why the terrace building has a low need for energy.

4.3 Energy costs

In general differences between energy cost reductions can be due to different energy prices, but this can also be relevant in the sense that such differences can be typical. As an example most building blocks are heated from district heating, which normally is relatively low cost, while single/terrace buildings often are heated with expensive natural gas. This difference is relevant, when evaluating the effects of Passive House Retrofitting.

4.3.1 Buildings with highest energy cost savings

The results on building types with the highest energy cost reduction through Passive House Retrofitting.

Country	Building type	Heating/cooling consumption, kWh/m^2 per year		
		Before PHR	After PHR	Savings
Austria	Row house, 1970-1979	1,835	110	1,725
Denmark	Terrace houses, wood (typical bricks), 1960's	1,360	400	960
Lithuania	1-2 storey, stone-brick walls, tilted rood, 1989	1,566	353	1,213
Spain	1960 typical terrace house, compact	1,052	140	912
The Netherlands	1966-1976 2 storey terrace building	2,450	500	1,950
Average	Average the best buildings in each country	1,653	301	1,352
Average of all building categories in all countries	Average all buildings	***1,120***	***221***	***899***

Table 4.3 The best results in terms of energy cost savings through Passive House Retrofitting

Result and conclusions concerning energy cost savings through Passive House Retrofitting:

- All the buildings are 1-2 storey terrace/single buildings
- The difference in energy savings between the "best" and the "average" buildings is due to the difference in heating consumption before Passive House Retrofitting and due to bigger energy cost savings.

4.3.2 Buildings with smallest energy cost savings

The results on building types with the smallest energy cost reduction through Passive House Retrofitting.

Country	Building type	Heating/cooling consumption, kWh/m^2 per year		
		Before PHR	After PHR	Savings
Austria	Big apartment house, 1970-1979	1,037	167	860
Denmark	Apartment block, brick facade,1900-1940	710	400	310

Lithuania	Up till 5 storey, panel-concrete walls, flat roof, 1977	833	183	650
Spain	1979 typical Multifamily house <=4 storey, compact	470	104	366
The Netherlands	1976-1988 concrete 7 storey building block with cellar and open balconies	1,050	220	830
Average	Average the poorest buildings in each country	820	216	604
Average of all building categories in all countries	Average all buildings	***1,120***	***221***	***899***

Table 4.4 The poorest results in terms of energy cost savings through Passive House Retrofitting

Result and conclusions concerning energy cost savings through Passive House Retrofitting:

- Energy cost savings are nearly the same for "average" and poorest"
- Low energy cost before Passive House Retrofitting s the main reason for the difference between "average" and "poorest"
- The tendency is that the "poorest" buildings are compact newer buildings with relatively low energy consumption before Passive House Retrofitting, except for Denmark, where the "poorest" is an older building with low energy cost savings (due to low energy savings)
- For Spain it is an advantage of not being exposed to the sun with a bigger need for cooling, explaining why the terrace building has a low need for energy.

4.4 Overall conclusions on building categories related to savings of energy and energy costs

4.4.1 Introduction

In this context is looked into types of building categories in the different countries in relation to best and poorest savings of energy and energy costs.

Feature	**Building categories**				
	Austria	**Denmark**	**Lithuania**	**Spain**	**Netherlands**
Energy					

savings					
Highest	Small apartment house,1960-1969	Terrace houses, wood (typical bricks), 1960's	1-2 storey, stone-brick walls, tilted rood, 1989	1960 typical terrace house, compact	1966-1976 2 storey terrace building
Poorest	Big apartment house, 1970-1979	Concrete building blocks with cold bridges from balconies into the facade, 1965-1980	Up till 5 storey, panel-concrete walls, flat roof, 1977	1979 typical terrace house, compact	1976-1988 concrete 7 storey building block with cellar and open balconies
Energy cost savings					
Highest	Row house, 1970-1979	Terrace houses, wood (typical bricks), 1960's	1-2 storey, stone-brick walls, tilted rood, 1989	1960 typical terrace house, compact	1966-1976 2 storey terrace building
Poorest	Big apartment house, 1970-1979	Apartment block, brick facade,1900-1940	Up till 5 storey, panel-concrete walls, flat roof, 1977	1979 typical Multifamily house <=4 storey, compact	1976-1988 concrete 7 storey building block with cellar and open balconies

Table 4.5 Building categories related energy/energy cost savings

4.4.2 Best energy savings and energy cost savings

Although not exactly the same the tendency is quite clear, the overall type of building categories for the highest energy heating/cooling savings and highest energy cost savings is the same, so they 2 things can be seen under one.

The tendency is also quite clear on which building categories have the highest energy heating/cooling savings and highest energy cost savings. This is 1-2 storey terrace (single) buildings with a low value of volume/surface ratio. The basic reason for this is the high heating/cooling energy consumption before retrofitting.

4.4.3 Poorest energy savings and energy cost savings

Although not exactly the same the tendency is quite clear, the overall type of building categories for the poorest heating/cooling energy savings and poorest energy cost savings is the same, so they 2 things can be seen under one.

The tendency is also quite clear on which building categories have the poorest heating/cooling energy savings and poorest energy cost savings. This is multi-storey compact buildings. The basic reason for this is the low heating/cooling energy consumption and energy costs before retrofitting.