TESSe2b
the smart energy storage

Thermal Energy Storage Systems

for energy efficient building an integrated solution for residential building energy storage by solar and geothermal resources

Exploitation of research results and transfer to market

1st TESSe2b Workshop

Dr. Olympia Polyzou, Dr. Spyridon Karytsas, Dr. Constantine Karytsas – CRES

European market study

The market study identified the need for TESSe2b solution, it included a list of possible stakeholders and target application, related costs of the project have been identified, sensitivity analyses have been performed and an assessment of the market penetration of the TESSe2b technologies have been carried out.

Market Analysis

The market analysis includes a list of the possible stakeholders and target application fields, description of the heating and cooling markets, description of the GSHP, solar and PCM markets, as well as a depiction of the European residential sector.

List of possible stakeholders and target application fields

Possible stakeholders: **Installers, manufacturers, end users, energy agencies and consultants**.
Target application fields: Focus on **single-dwelling houses**.

- **Heating and cooling is the biggest energy sector in Europe**, a trend that is projected to remain at least until 2050.
- **The residential sector is the largest consumer** of energy for heating and cooling in the EU, with **2/3 being consumed for space heating, 13% for water heating and 0.7% for cooling.**
- The percentage of cooling is low, however it is necessary in warm climates; in addition, **the need for cooling is projected to increase**.
- **The needs for space heating, space cooling and DHW are over 80%** of a household's energy needs; these needs can be covered by TESSe2b solution.
- Concerning the characteristics of the European dwellings it could be mentioned that **more than 50% are detached and semi-detached houses, 45% are constructed between 1946 and 1980 - while only 10% after 2001, their average size is 96m^2 and almost 70% are owner occupied.**

The conducted market analysis concluded that **the heating and cooling markets are of high potential**. Additionally, concerning the technologies used in TESSe2b system, it should be noted that both **GSHP and solar thermal markets are in decline in Europe** during the last years; **the diffusion of TESSe2b solution can give a push to these markets.**

Social Survey in 5 EU countries

The survey intends to analyse and understand in what extent the TESSe2b solution could be adopted in different European Union countries. The online questionnaire survey was conducted between June 2016 and February 2017.

- Austria
- Spain
- Portugal
- Greece
- Germany

Sample: about 600 questionnaires in total

Questionnaires

Four sections of questions: a) personal interests about environmental and energy issues, b) TESSe2b solution: intention to use, c) housing/ household characteristics and d) sociodemographic information.

583 questionnaires in total have been collected.

Austria ⟹ 17 Spain ⟹ 132 Germany ⟹ 166 (mainly students)

Portugal ⟹ 109 Greece ⟹ 159

Descriptive statistics

a) Housing/ household characteristics

	Austria	Greece	Portugal	Spain	Germany
Residential area	40% Town or small city	> 40% big city			
Household members	Around 35% 4 members				2 members
House ownership	> 70% house of their own				rented
Housing type	41% detached single-unit house	>44% in flat			
House size	> 150m^2	100-150m^2	50-100m^2		50-100m^2 > 150 m^2
Number of bedrooms	> 30% have 3			40% 4	30% 3
Year of construction (or large renovation)	35% 1990-1999	Around 25% 1970-1989			20% Don't know
Energy sources for space heating	> 40% Natural gas	49% Heating oil	50% Electrical	> 40% Natural gas	
Energy sources for space cooling	88% No	72% Electrical	> 50% No		
Energy sources for domestic hot water	41% Electrical	50% Solar panel	28% other	> 50% same as heating	
Feel about household's income nowadays?	Around 50% coping on present income				
Total monthly income	47% 2000-2500€	26% 1000-1500€	22%500-1500€	29% 1000-1500€	38% < 500€
Total household income percentage used for energy costs	> 33% between 5 and 10%				Don't know

d) Sociodemographic information

	Austria	Greece	Portugal	Spain	Germany
Gender	> 63% males				
Age (median)	48	42		43	24
Civil status	> 62% Married / civil union				80% Single
Children (median)	2	1			0
Education level	> 42% Second stage of tertiary				
Professional / Employment status	70% Private sector	30% Self-employed	40% Public sector	36% Private sector	90% Students

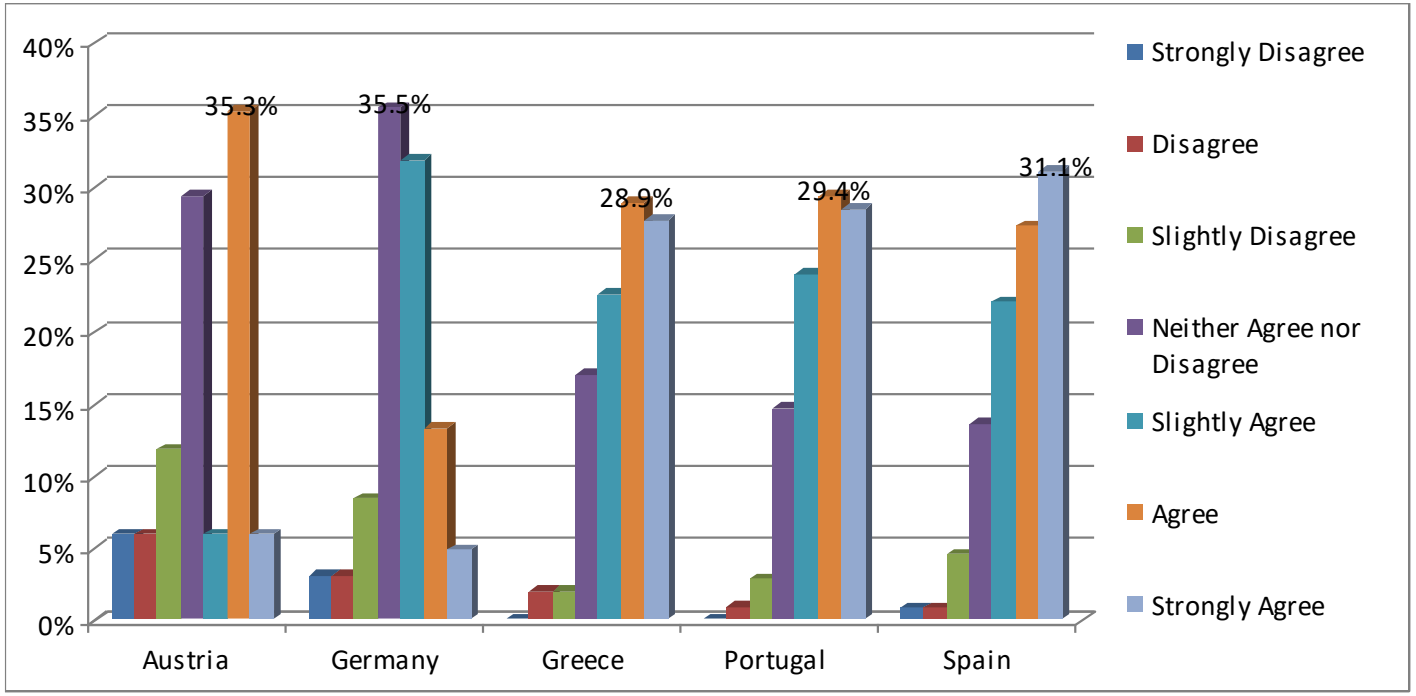
c) Personal interests about environmental and energy issues

	Austria	Greece	Portugal	Spain	Germany
The efficiency in thermal energy systems is very important to me	>53% Strongly agree				Agree
The Green House Gases reduction is very significant to me	Strongly agree around 58%				Agree
I measure and record my thermal energy usage	41.2%	35.8%	18.3%	37.9%	17.5%
I have invested in thermal energy systems in the past 5 years	17.6%	> 38%			14.5%
I have invested in thermal energy systems using renewable energy in the past 5 years	5.9%	> 22%			6%
I have invested in thermal energy storage in the past year	-	Around 12%			7.2%
I am involved in social media	42.2%	54.7%	36.7%	75%	44.6%
I am involved in energy and/or environmental fields	Around 62%				31.3%

d) TESSe2b solution: intention to use

	Austria	Greece	Portugal	Spain	Germany
The adoption of TESSe2b solution will improve my quality of life	29% neither agree nor disagree - slightly agree	Strongly agree around 30%			38% neither agree nor disagree
The adoption of TESSe2b solution will reduce my energy expenditure	35% agree	>30% strongly agree			30% neither agree nor disagree
The use of TESSe2b solution will increase my disposable income	neither agree nor disagree		slightly agree	strongly agree	neither agree nor disagree
The energy security that is expected to be provided by TESSe2b solution will contribute to my empowerment	30% agree	28.9% slightly agree	27% agree - strongly agree	30% agree	39.2% neither agree nor disagree
TESSe2b solution adoption will contribute to a change of mentality in the direction of the self-sustainability of the building (s)	~ 30% neither agree nor disagree	>30% strongly agree			~ 30% neither agree nor disagree
I feel confident with the idea of adopting TESSe2b solution (in the future)	29.4% strongly agree	Around 25% slightly agree			
I feel comfortable with the idea of adopting TESSe2b solution (in the future)	Agree	slightly agree	Agree	strongly agree	neither agree nor disagree -slightly agree
I think it will be easy for me to adopt TESSe2b solution (in the future)	Around 25% slightly agree				neither agree nor disagree
I intend to use the TESSe2b solution (in the future)	30% agree	>22% neither agree nor disagree		25% strongly agree	>22% neither agree nor disagree
I predict that I will use the TESSe2b solution (in the future)	35.3% disagree	25% neither agrees nor disagrees	22% agree	25% neither agree nor disagree	
Depending on the price, I am willing to pay for TESSe2b solution (in the future)	29.4% 3,000 -6,000€	> 50% 0-3,000€		41% 3,000-6,000€	27% 3,000-6,000€
I am willing to pay for TESSe2b solution (in the future) if the payback period	35.3% 8-10 years	around 38% 3-5 years			24.7% 5-8 years

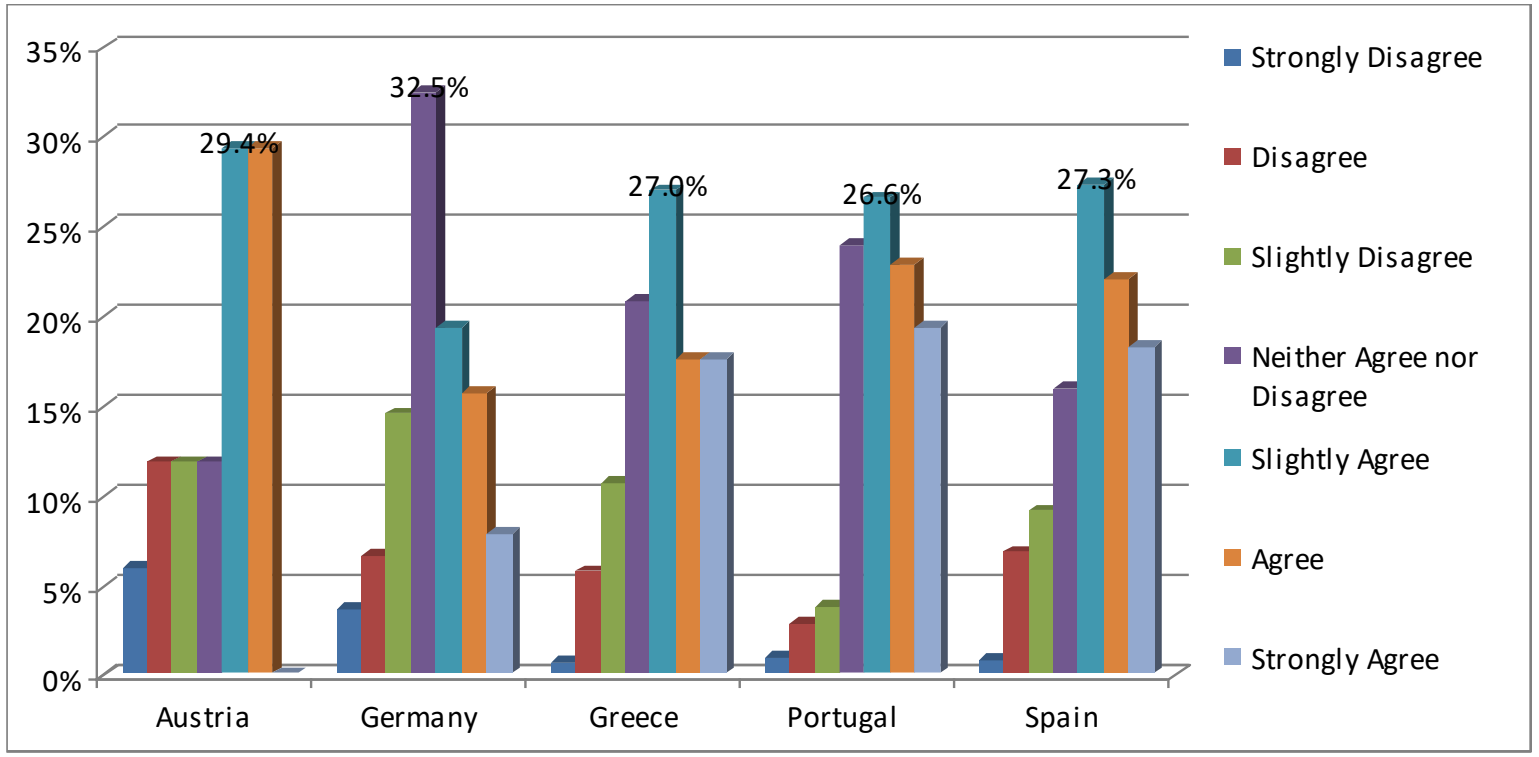
Perceived benefits of TESSe2b solution (improvement of quality of life, reduce of energy expedinture, increase of disposable income, empowerment (in terms of their autonomy and freedom of choice) in the energy security and contribution to a change of mentality in the direction of the self-sustainability of the building(s).



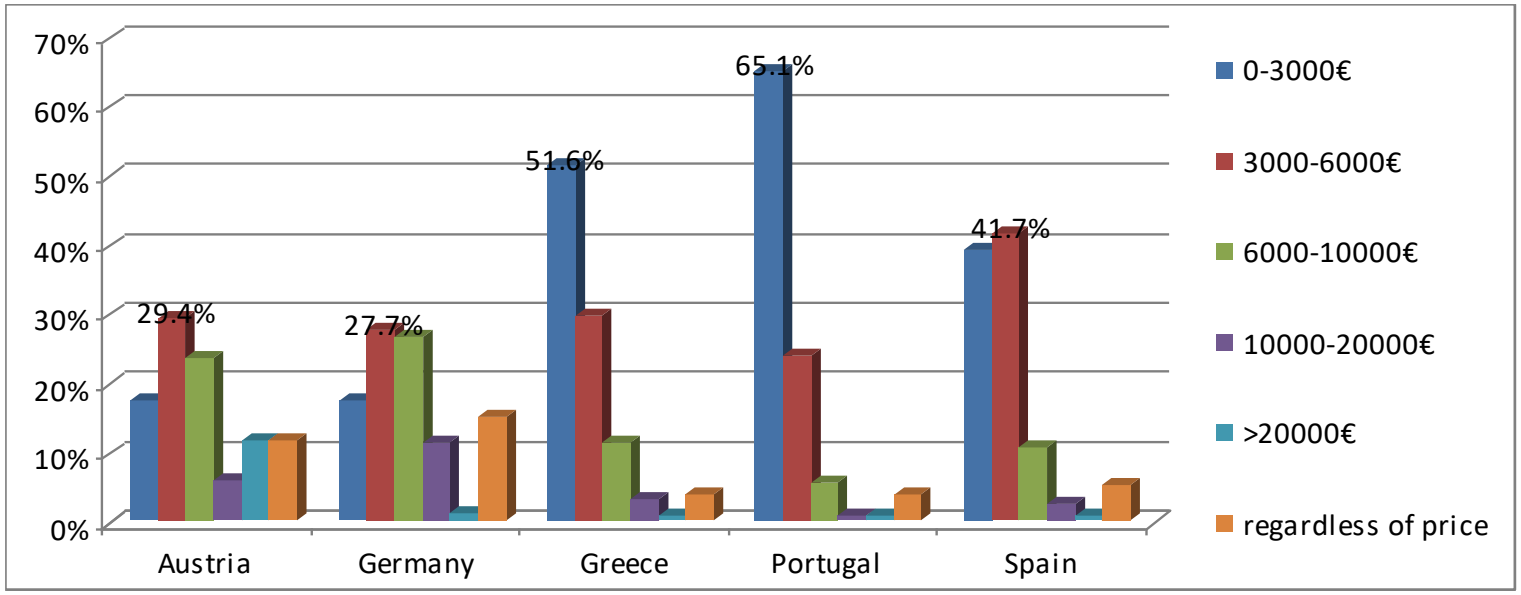
- > 29% agree in Austria, Greece and Portugal
- 31% strongly agree in Spain
- 35% neither agree nor disagree in Germany

Intention of adopting the TESSe2b solution (confidence with the idea of adopting TESSe2b solution in the future, comfortable with the idea of adopting TESSe2b solution in the future, easy to adopt TESSe2b solution in the future, intense to use the TESSe2b solution in the future and prediction that they will use the TESSe2b solution in the future)

- 27% agree in Greece, Portugal and Spain
- 30% slightly agree and agree in Austria
- 32% neither agree nor disagree in Germany

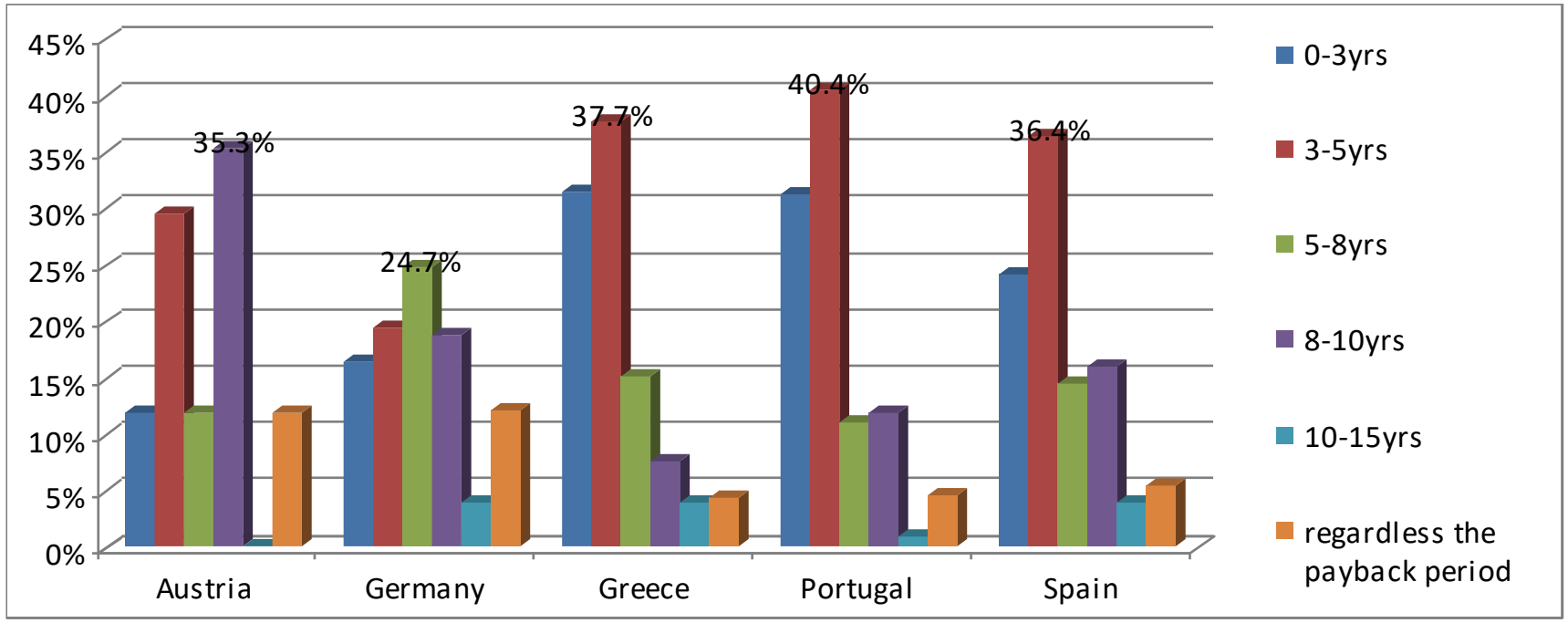


Amount I am willing to pay for TESSe2b solution in the future



- > 50% 0-3,000Euros in Greece and Portugal
- 3,000 – 6,000Euros in Spain, Austria and Germany

Acceptable payback period in order to be willing to pay for TESSe2b solution



- 38% 3-5 years in Greece, Portugal and Spain
- 25% 5-8 years in Germany
- 35% 8-10 years in Austria

Conclusions

• The majority of the respondents in five EU Member States have a **positive view of the outcome expectations** of the TESSe2b solution, as well as of the possibility to adopt the innovative system.
• Concerning the **amount that they are willing to pay for TESSe2b solution** in the future, most respondents chose **0-3,000€ in Greece and Portugal**, while in **Austria, Germany and Spain**, the most common amount is between **3,000 and 6,000€**.
• Regarding the **acceptable payback period** that would lead respondents to be willing to pay for TESSe2b solution in the future, the most acceptable period was **3-5 years in Greece, Portugal and Spain**. In **Germany the payback period was 5-8 years, while in Austria 8-10 years**.

The main sociodemographic and residence characteristics that were found to **positively affect** the perceptions and the willingness to pay issues regarding the TESSe2b solution were:

- **income,**
- **percentage of income spent for energy,**
- **educational level,**
- **previous investments in related technologies,**
- **profession or interests related to energy or environment and household size,**
- **year of construction,**
- **energy source for space heating and area of residence.**

Financial and environmental comparison

- Comparison between current fuels and TESSe2b solution
- Comparison in the participating countries
- Including heating mode and domestic hot water
- Including cooling mode where necessary
- Financial indicators calculated (NPV, IRR, SPBP, DPBP, etc.)
- CO_2 saving
- Sensitivity analysis

Austria

1st case: TESSe2b (cooling) vs. HEAT OIL (no cooling)
Total annual operation cost savings: 83.44%
CO_2 savings: 90%
SPBP: 7.5 years
DPBP: 8.5 years

2nd case: TESSe2b vs. ASHP
Total annual operation cost savings: 68%
CO_2 savings: 66%
SPBP: 15 years
DPBP: 19 years

Cyprus

1st case: TESSe2b vs. HEAT OIL+ASHP
Total annual operation cost savings: 66.7%
CO_2 savings: 53%
SPBP: 5.8 years
DPBP: 6 years

2nd case: TESSe2b vs. ASHP
Total annual operation cost savings: 56%
CO_2 savings: 55.5%
SPBP: 10.5 years
DPBP: 12 years

Germany

1st case (no cooling): TESSe2b vs. HEAT OIL
Total annual operation cost savings: 60.6%
CO_2 savings: 74%
SPBP: 18 years
DPBP: 23.5 years

2nd case (no cooling): TESSe2b vs. NAT GAS
Total annual operation cost savings: 62.6%
CO_2 savings: 63.6%
SPBP: 17 years
DPBP: 22 years

Greece

1st case: TESSe2b vs. HEAT OIL+ASHP

Total annual operation cost savings: 69%
CO_2 savings: 49%
SPBP: 5.6 years
DPBP: 6 years

2nd case: TESSe2b vs. NAT GAS+ASHP

Total annual operation cost savings: 58.7%
CO_2 savings: 43%
SPBP: 8.5 years
DPBP: 10 years

Poland

1st case: TESSe2b vs. HEAT OIL+ASHP

Total annual operation cost savings: 83%
CO_2 savings: 51%
SPBP: 9.26 years
DPBP: 10.5 years

2nd case: TESSe2b vs. NAT GAS+ASHP

Total annual operation cost savings: 54.7%
CO_2 savings: 34.8%
SPBP: >25 years
DPBP: >25 years

Portugal

1st case: TESSe2b vs. HEAT OIL+ASHP

Total annual operation cost savings: 79%
CO_2 savings: 79%
SPBP: 4.5 years
DPBP: 5 years

2nd case: TESSe2b vs. NAT GAS+ASHP

Total annual operation cost savings: 78%
CO_2 savings: 72%
SPBP: 5 years
DPBP: 5.38 years

Spain

1st case: TESSe2b vs. HEAT OIL+ASHP

Total annual operation cost savings: 79%
CO_2 savings: 75%
SPBP: 5.8 years
DPBP: 6.34 years

2nd case: TESSe2b vs. NAT GAS+ASHP

Total annual operation cost savings: 70%
CO_2 savings: 68%
SPBP: 9 years
DPBP: 10.5 years

UK

1st case (no cooling): TESSe2b vs. HEAT OIL

Total annual operation cost savings: 71%
CO_2 savings: 76%
SPBP: 19 years
DPBP: >25 years

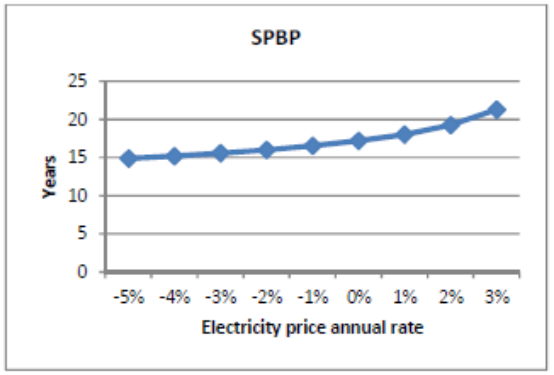
2nd case (no cooling): TESSe2b vs. NAT GAS

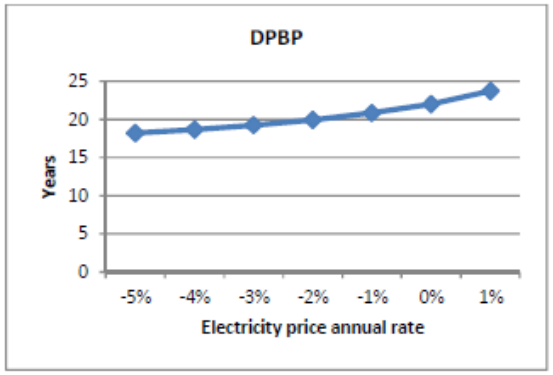
Total annual operation cost savings: 71%
CO_2 savings: 67%
SPBP: 18.5 years
DPBP: 25 years

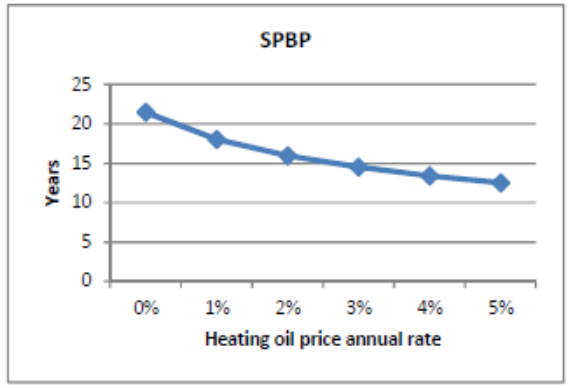
Sensitivity analysis

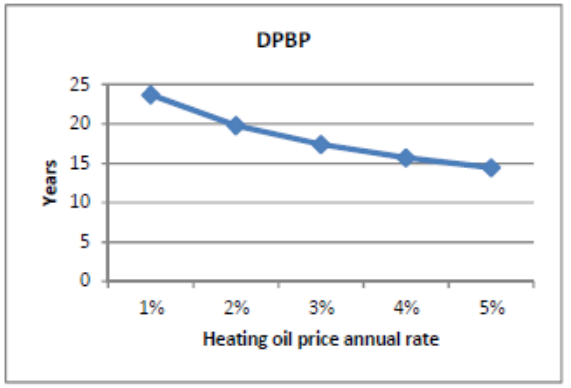
Germany

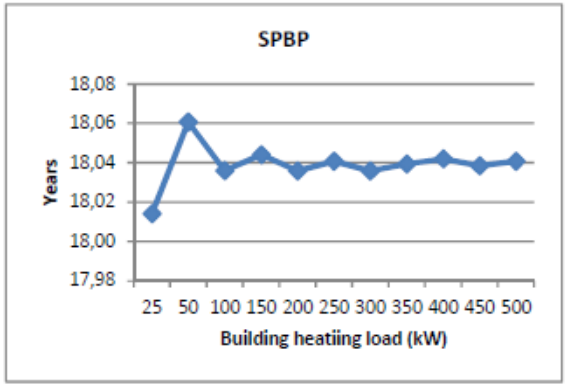
1st case (no cooling): TESSe2b vs. HEAT OIL

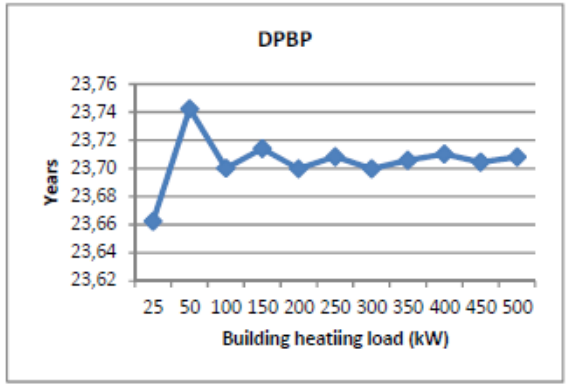


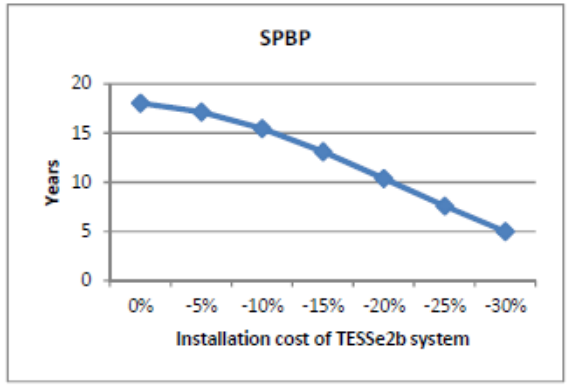


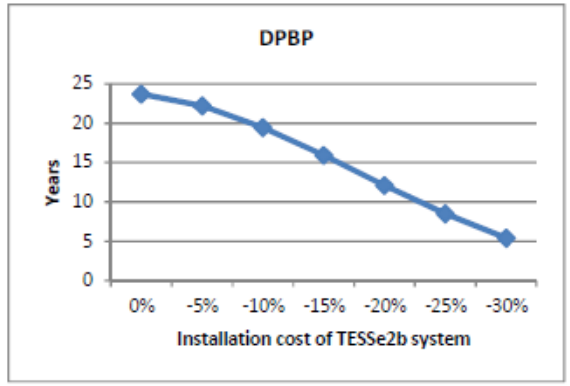






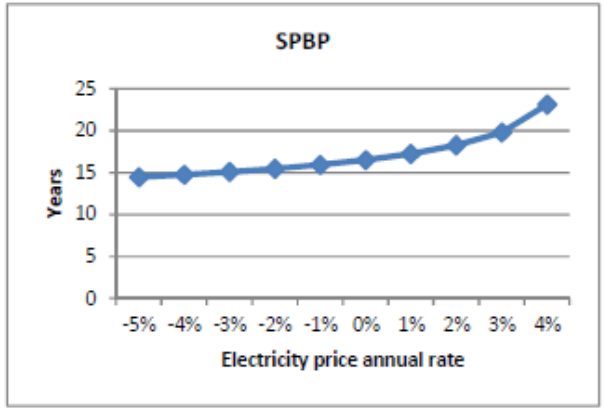


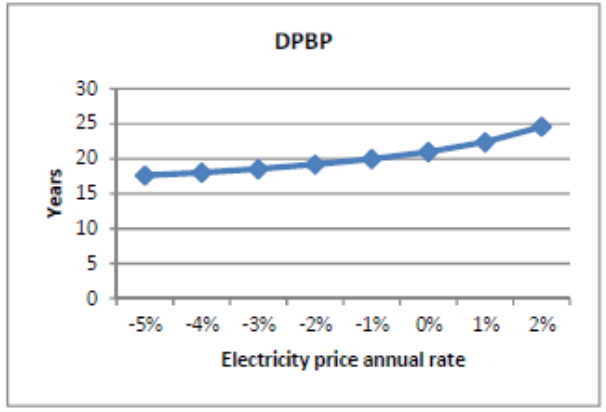


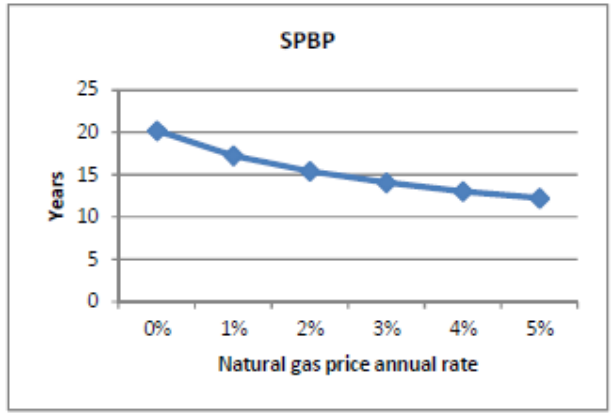


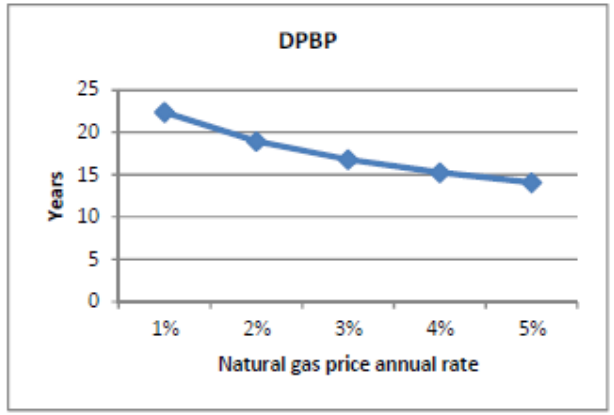
Germany

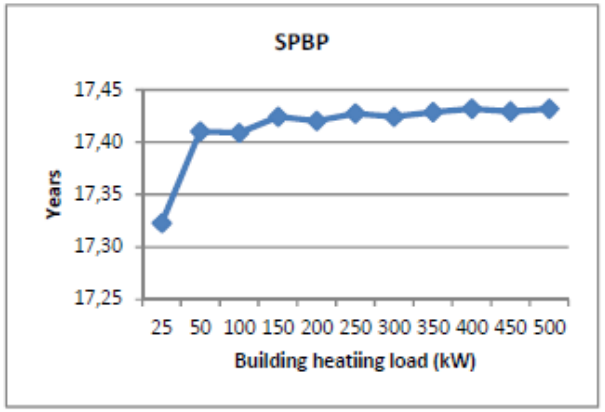
2nd case (no cooling): TESSe2b vs. NAT GAS

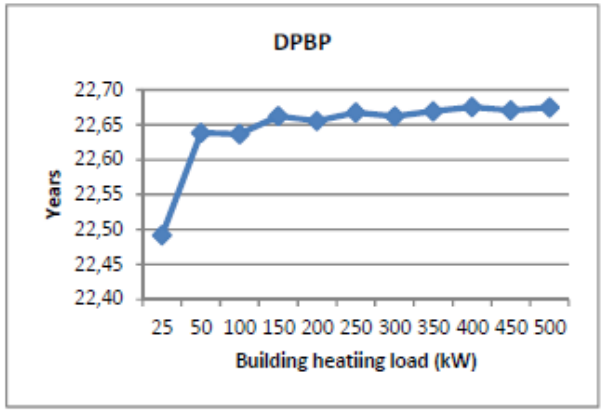


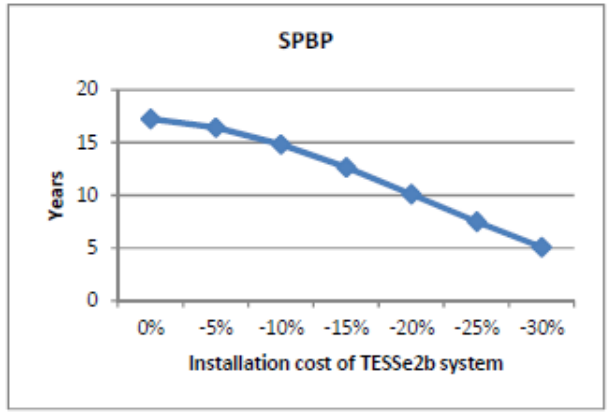


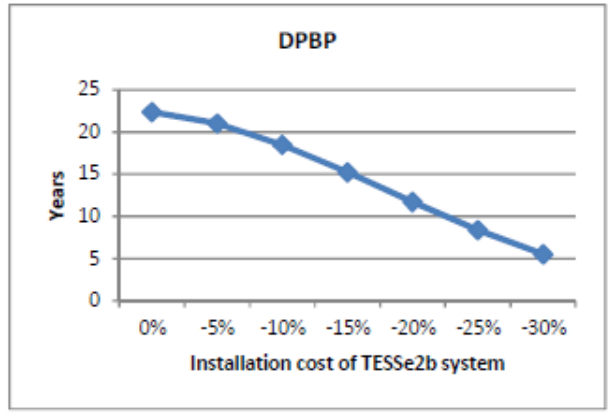






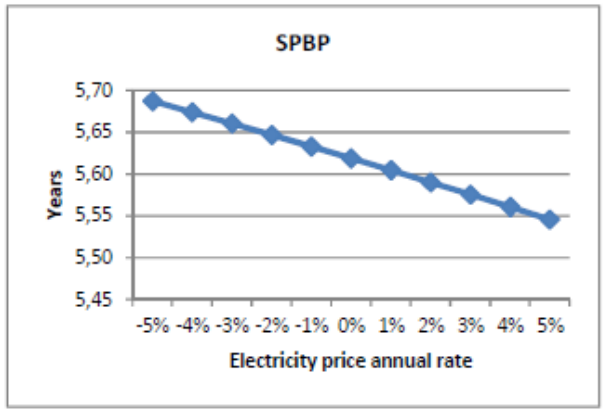


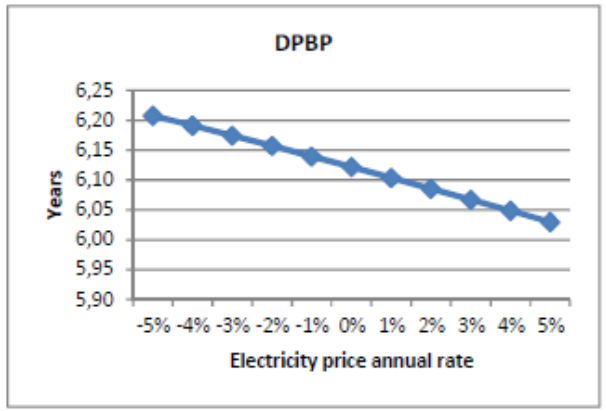


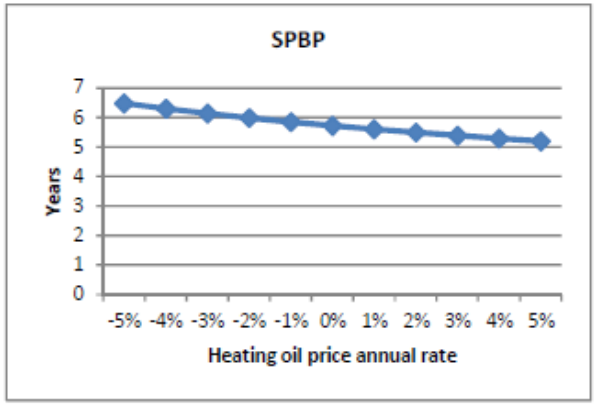


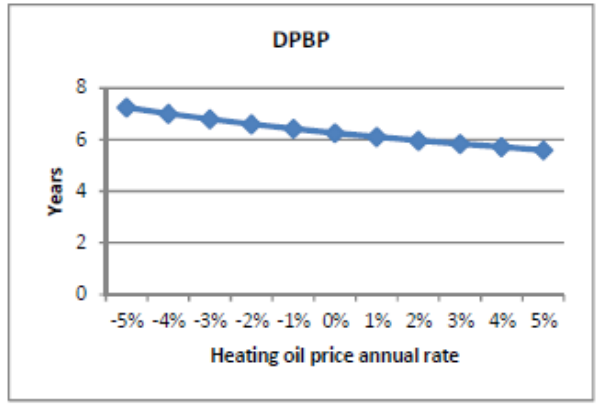
GREECE

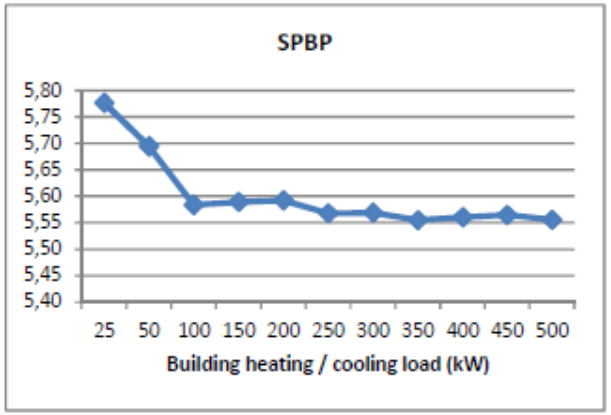
1st case: TESSe2b vs. HEAT OIL+ASHP

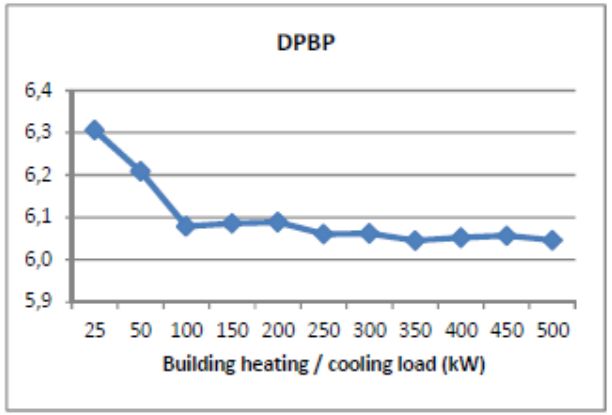


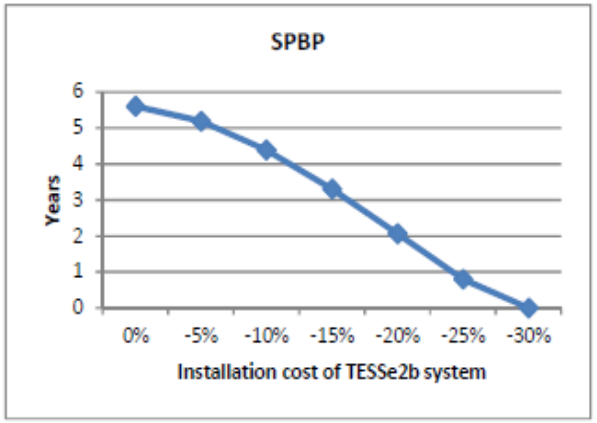


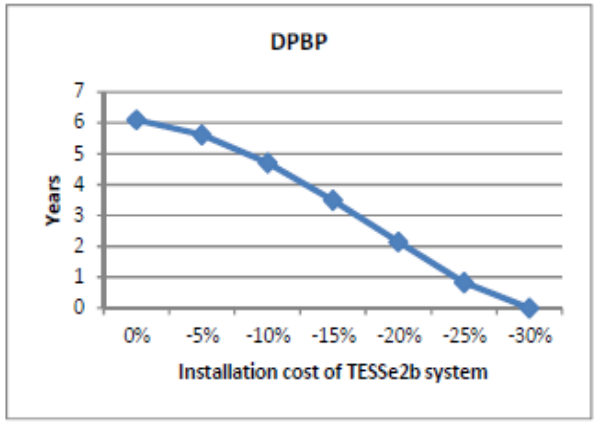






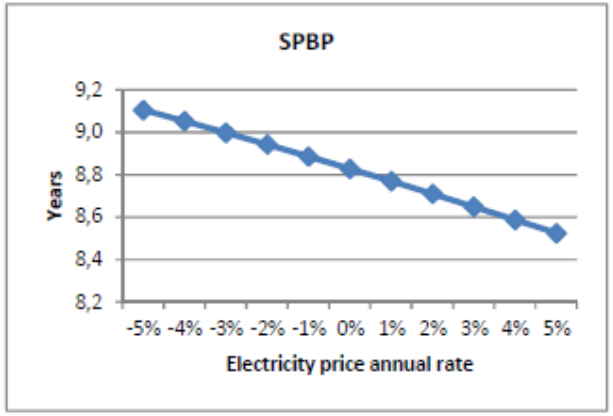


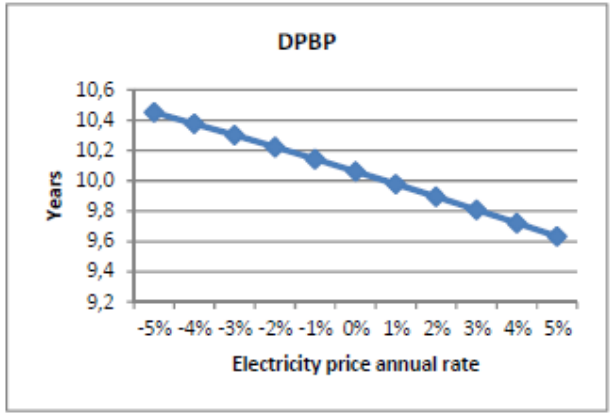


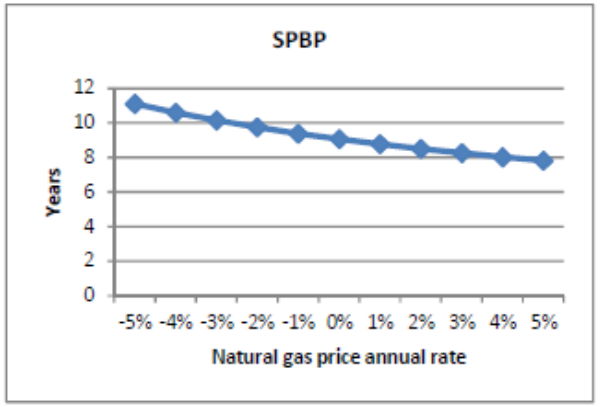


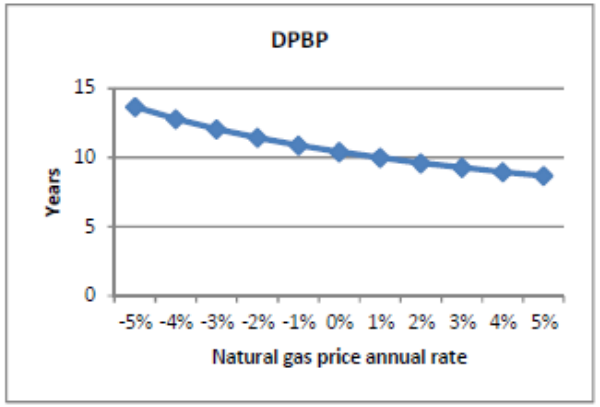
GREECE

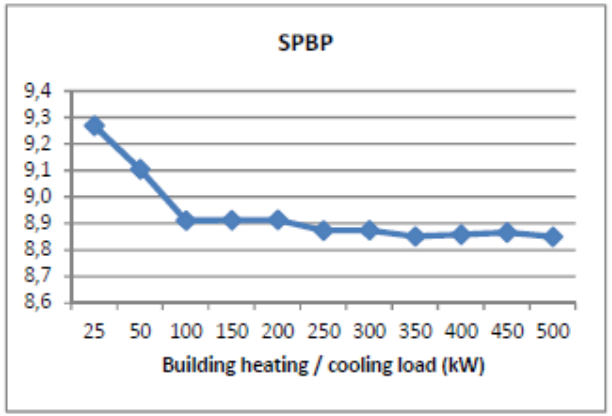
2nd case: TESSe2b vs. NAT GAS+ASHP

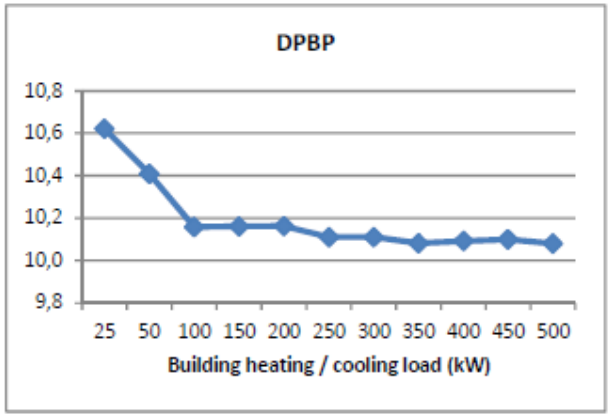


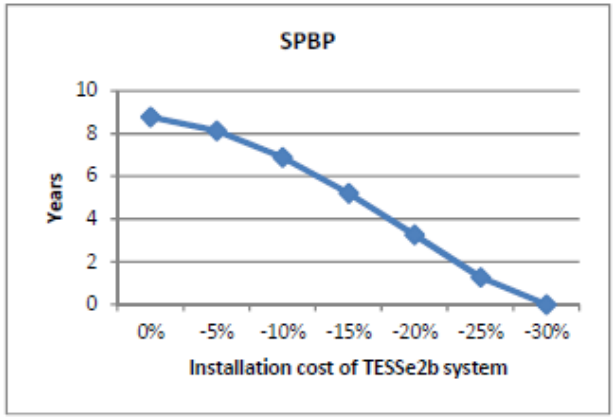


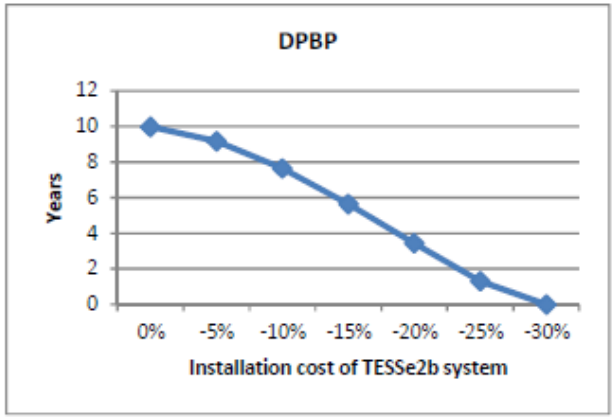












Conclusions

• **Operation cost savings range from 55%** (Poland: NAT GAS+ASHP) **to 83%** (Austria: HEAT OIL+NO COOLING and Poland: HEAT OIL+ASHP). **CO_2 savings range from 35%** (Poland: NAT GAS+ASHP) **to 91%** (Austria: HEAT OIL+NO COOLING); CO_2 savings depend on CO_2 conversion factors for electricity, natural gas and heating oil in each country. Both operation cost and CO_2 savings are on average 70% in all participating countries' case studies.

• **The payback period of TESSe2b system compared to heating oil and ASHP for cooling** is on average **between 5 and 10 years;** however the payback period can be rather high in cases where the price of the conventional energy is very low, when the system is not used for cooling or when the installation cost of TESSe2b is high for a specific reason (e.g. relatively low useful energy that solar thermal collectors can deliver for heating needs and DHW in the case of the UK).

• Compared to **natural gas and ASHP for cooling, the payback period of TESSe2b system is on average between 5-10 years**. Again, the payback period can be rather high in cases where the price of the conventional energy is very low, when the system is not used for cooling or when the installation cost of TESSe2b is high due to a specific factor.

• Compared to **ASHPs (used for heating and cooling) the payback period of TESSe2b solution is higher compared to heating oil or natural gas**, due to the common pricing of the energy used by the two systems and the higher efficiency of ASHPs compared to systems using fossil fuels.

• **The increase of the annual rate of electricity price will decrease the payback period** of TESSe2b system when there are high cooling needs.
• **The increase of the annual rate of heating oil/natural gas price will generally decrease the payback period** of TESSe2b system.
• **The increase of the building heating/cooling load will lead to economies of scale** (lower installation cost per kW), thus **reducing the payback period** of larger installations. This means that **largest installations** (office buildings, hotels, etc.) are of **higher interest**.
• **The decrease of the installation cost of TESSe2b will decrease the payback period of TESSe2b system**. The installation cost can be reduced through the larger penetration of TESSe2b system. The GSHP and solar thermal markets are already established, so the factor that can really reduce the installation cost of TESS2b is the further development of PCM market, leading to the decrease of its price.

TESSe2b
the smart energy storage

Thank for your attention

Thermal Energy Storage Systems

for energy efficient building an integrated solution for residential building energy storage by solar and geothermal resources

European Commission