e-HIGHWAY 2050

Modular Development Plan of the Pan-European Transmission System 2050

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Annex to D3.1 - Technology Assessment Report

Demand-side Technologies: Heat Pump technologies

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Document information

General purpose

This document is an annex of deliverable D3.1 focusing on the technology assessment (technical and economic performances) of generation, storage, transmission and demand-side technologies. It deals with heat pump technologies which addresses a series of end-uses on the time horizon set by the e-Highway2050 project, i.e. from today until 2050.

The present document is complemented by an attached Excel file providing the data compiled according to the methodology described in the in the next sections.

Change log

Revision	Date	Changes description	Authors
V1.0	05-07-2013	Creation and first review	C. Coujard
V1.1	23-09-2013	Update according to collected comments (Eurelectric, EHPA, KU Leuven)	C. Coujard
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Heat Pump technologies

1 Introduction

1.1 Scope of the report

The scope of the study is the quantification of the main characteristics of the Electric Heat Pump technology: key variables (cost, performance, etc.) are selected to describe the technology, and values are collected to quantify each variable.

Section 2 of this report presents the data collection and validation methodology, as well as the organization of the database gathering the collected values attached to each variable. The database is under Excel format (one file, annexed to this report).

Sections 3 to 9 present individually the seven 'families' (data types) of variables, review the data collected on each of them and analyses the possible discrepancies between different data sources.

Section 10 provides recommendations on how to use the data, i.e. proposals of adjusted value ranges for the key variables.

1.2 Rationale for selection

The heat pump technology has been retained as a key demand technology for WP3 database for the following reasons:

- The high performances of heat pumps make very plausible their wide diffusion across Europe by 2050, with a total installed park that could reach 50 to 100 million units at that time horizon.
- The deployment of heat pumps means a shift in the primary energy vector from gas/fuel to electricity for the end uses of space heating, but also space cooling and water heating. In other words, this means an increased electricity load to be served by the grid, even though large improvements in building insulation should reduce the needs for heating/cooling.
- Under massive deployment of heat pumps, the load profile for the heating/cooling end use would therefore be significantly modified, in particular with increased peaks for the grid related to the cooling demand[1] (though one must note that the future grid extension requirements to integrate RES should largely overpass the ones relative to the increased peaks coming from heat pumps).
- On the other hand, wide possibilities of load flexibility management are at reach ("smart grid ready heat pump"), through energy management systems coupled with thermal storage and hybrid solutions with alternative fuels. In particular in the Nordic countries of Europe, heat pumps could significantly help to the integration and management of increased wind energy.

The expected market growth for heat pumps will rely on the general trend towards the electrification of heating and cooling end uses, identified in all energy roadmaps. The heat pump technologies market will be driven by:

- Policies in support of energy efficiency and renewable energy (regulation, financial incentives), as heat pump technologies present both high efficiency and renewable features;
- The development of the (huge) building renovation market, as heat pumps present the advantage of a size flexibility covering from small residential to large commercial segments.

[1] Potential peak increase due to heat pumps' heating demand should be limited and therefore not significantly impacting the grid: building insulation and inertia limit a peak consumption behavior for heat pumps. With regards to cooling demand, the peak increase should be partially counterbalanced by the development of hybrid systems and coupling of generation and consumption directly onsite.

2 Methodology for data collection and validation

2.1 Data collection process, type of sources and nature of data

The data collection on heat pumps is based on literature review (knowledge formalized and published) and on more informal knowledge gathered through interviews of experts. The full list of published sources is detailed in the bibliography section. The three key references to be mentioned are the IEA Building Roadmap (2011), the Heat Roadmap for Euroheat & Power (2013), and European Heat Pump Association statistics (2012).

The contributing experts come from:

- French Heat Pump Association,
- Swedish Heat Pump Association (SVEP) and Energinet.dk through EURELECTRIC,
- ADEME (French Energy Agency),
- European Heat Pump Association (EHPA).

With regards to the literature review, 13 main sources provided the collected data. They are of different types: facts and figures about the present situation; forecasts on market penetrations; and roadmaps addressing medium or long term. Therefore, the resulting database includes data of different nature:

- 'Real-life' figures about the present (for instance real Seasonal Performance Factor[2] experienced on field tests),
- Modeling assumptions (for instance average size of heat pumps in 2030, 2050) as used to model roadmap scenarios,
- Targets set by roadmaps (for instance +40% cost reduction by 2050).

2.2 Building the database

When considering heat pump performances, efficiency and cost data vary significantly according to the type of end use (heating, cooling), sector (residential, services), and technology. When possible (i.e. when data is available), the database is therefore hierarchically structured to reflect this segmentation. The maximum hierarchical structure for one variable is as follows:

1. ***End use (different variables for heating and cooling performances)***
2. ***Sector (residential, services)***
3. ***Technology (ground, air or water sourced)***

The principle used to fill in the database is to display only 'meaningful' information, i.e. only data directly provided by reliable sources. In consequence, in case no data is available for certain variable or for certain time horizon, the base is left empty. Possibly contradictory figures have been kept for analysis.

The database is organized so that the reader can identify the source and nature of the data displayed. Color codes are used on this purpose:

- The color of cells relate to the data source
- A figure in red color indicates that the data is a modeling assumption.

The database is under Excel format: all collected values are displayed in one single sheet called Database. Complementary sheets provide reading guidelines, assumptions and calculations when required. A specific sheet provides recommendations of value ranges for the key variables.

2.3 Data validation

The discrepancies in numerical values provided for each variable by different sources are analyzed in the sections x.3 of this document (robustness of data) and conclude on the degree of divergence or consensus on a given variable, and the potential need for further data validation.

2 See definition in section 3.1

In addition, the last section of this report provides recommendations on how to use the data, i.e. proposals of adjusted value ranges for the key variables.

2.4 Technology glossary

Only electrical heat pumps are considered in this report. In the database, the following definitions apply:

- Ground Source Heat Pump refers to heat pumps using the ground as heat source/ sink. It includes Ground to Water and Ground to Air technologies (respectively using water and air as distribution medium);
- Water Source Heat Pump refers to heat pumps using ground water as heat source/ sink. It includes Water to Water and Water to Air technologies (respectively using water and air as distribution medium);
- Air to Air heat pumps refers to heat pumps using air as heat source/ sink and as distribution medium;
- Air to Water heat pump refers to heat pumps using air as heat source/ sink and water as distribution medium.

3 Technology performance characteristics

3.1 Variables selected

Quality assurance frameworks for heat pump performance evaluation are not harmonized so far (ISO standards are under writing). For the present database, variables were defined as much as possible according to the technical report "*Definition of Performance Figures for Solar and Heat Pump Systems*" from the Austrian Institute of Technology, SEPEMO project, Intelligent Energy Europe 08/593/SI2.529236. Though, the different data collected does not necessarily comply with the exact definitions (see section: "underlying assumptions").

3.1.1 Typical size

Typical rated thermal power of an installed heat pump in kilo Watts [kW].

3.1.2 Average heat size (modeling) [kW]

Ratio: total installed capacity of heat pumps / total number of heat pump installed, in kilo Watts [kW].

3.1.3 Coefficient Of Performance COP

Heating efficiency of a heat pump measured in laboratory under optimal steady state operating conditions [no unit] based on EN 14511/EN 12309. Computation: heating power delivered by the heat pump in kW/ electricity input (or gas in case of gas heat pump) in kW.

3.1.4 Seasonal Coefficient Of Performance sCOP

Performance of the heat pump unit based on EN 14825, for defined cold, average and warm climates. Calculation: based on EN 14511 data: heating energy provided over a season in kWh /energy (electricity or gas) input in kWh [no unit].

3.1.5 Energy Efficiency Ratio

Cooling efficiency of a heat pump measured in laboratory under optimal steady state operating conditions [no unit]. Computation: cooling power delivered by the heat pump in kW / rated power of the compressor (or burner in case of gas heat pump) in kW.

Note that the EER as defined here is a ratio between kW and kW, and not BTU, i.e. it is the exact equivalent of the COP for heating.

3.1.6 Seasonal Energy Efficiency Ratio

Performance of the heat pump unit with the same system boundary as for the EER, for defined climate conditions and reference cooling demand. Calculation: cooling energy provided over a season in kWh /energy delivered to the compressor over the same period in kWh [no unit].

3.1.7 Heating Seasonal Performance Factor (SPF)

Overall heating efficiency of an overall heat pump system working under real operating conditions [no unit]. Computation: heating energy delivered in kWh/ total energy supplied to the system over a season in kWh [no unit].

For the SPF values displayed in this report, the heat pump system boundaries used for measurements include the heat pump unit, the equipment to make the source energy available and the backup heater. The SPF is referred to as 'SPF3' in the SEPEMO report and "SPF2" in Fraunhofer study, but they do refer to the equivalent system boundaries.

As the backup heater is also included in the measurement, the share of heat demand met by the backup heater (bivalent point) as well as its performance do impact the final SPF value of the considered system.

3.2 Underlying assumptions

3.2.1 "Cooling only" end use

- The performances of heat pumps used in a cooling mode only (room air conditioners) are not considered in this study for the residential sector[3], as they are expected to disappear beyond 2020 due to the progressive "integration" of cooling and heating functions into the related appliances, and the progressive merge of the heating and AC equipment industries (see European Heat pump Association Outlook 2012).
- There is a question mark on the need to address in this report the performances of "cooling-only" heat pumps in the service sector by 2050. It is not clear if this market will follow the same 'merging' trend as in the residential one. According the EHPA expert, it is most likely that a dual use of large heat pumps will spread to meet both heating and cooling functions.

3.2.2 COP and EER, SCOP and SEER:

- Most sources examined provide efficiency data in the form of "COP" values both for heating and cooling end uses. In this document, the collected COP values for cooling are renamed EER (Energy Efficiency Ratio) and expressed without unit (i.e. a ratio of kW/kW), as an exact equivalent to the COP calculation.
- The IEA Technology Perspectives 2010 report provides efficiency data for heat pumps per heat source. In the report, the IEA refers to "COP", but we assume that the values actually refer to Seasonal COP (SCOP) for ground to water and air to water technologies, and to Seasonal EER for air to air heat pumps and large chillers, or whenever it refers to cooling end use. Indeed, IEA indicates that values can change from one country to another due to "different climate and operating conditions".
- The values mentioned in the IEA building roadmap for the indicator "efficiency" are clearly in the ranges of COP values, rather than efficiency values (when considering efficiency as a primary energy ratio). Further to the recommendation of EHPA expert, such efficiency values expressed in % have therefore been considered as COP values.
- The same has been applied to the efficiency values expressed in the Heat Roadmap Europe and the data provided by the Swedish heat pump association.

[3] An indicative maximum EER value is provided in the database for Room Air Conditioners, but not included in the present analysis.

- ADEME provides "seasonal yield indexes", which we consider here as equivalent to our SCOP definition.
- In the Eurelectric survey about Denmark, given the values displayed and the context, it is assumed that the "COP" variable means Seasonal COP according to our definition.
- For the COP values, the operating conditions are A/W 2/35 ; B/W 0/35, W/W: 10/35

3.2.3 Seasonal Performance Factor of overall system:

- Note that the SEPEMO European project report measurements of heat pumps in operation (air/air, air/water and ground source heat pumps) during a one-year campaign on 44 sites across Europe. Seasonal Performance Factors are measured on the heat pump system defined as "containing the heat pump unit, the equipment to make the source energy available and the backup heater". Only heating use is considered in the report.
- The same system boundaries are considered for the results presented by the Fraunhofer study on 110 measurements in Germany.

3.3 Conclusions on robustness of the produced data

This section first reviews the sets of data focusing on present values for the variables, and then analyses the trends up to 2030-2050 as forecasted by the different data sources.

3.3.1 Typical size and average size:

For the residential sector, the EHPA data provides ranges of heat pump capacities per European country. The tables below shows that the capacity ranges per technology are broad: this is due both to the diversity in average capacity among European countries (due to climate conditions and building insulation level mainly).

Installed capacity in kW, per technology (EHPA data)	Average capacity	Lowest capacity among EHPA member countries	Highest capacity among EHPA member countries
Air to water	**12,2**	8,0	18,1
Water to water	**16,6**	8,0	48,2
Brine to water	**14,0**	10,0	26,3
Reversible HP (Air to air)	**8,0**	4,0	21,6

The IEA Building Roadmap also provides detailed information about the size of installed heat pump in service and residential sectors, and per type of dwelling. The ranges of capacities estimated are much broader than EHPA data displayed above.

For the service sector, very little statistics are available. It is therefore interesting to look at the estimated "average size" of heat pumps used as assumptions in the Heat Roadmap Europe[4], and at the one national figure available in the EHPA outlook 2012:

SERVICE SECTOR	Today	2030	2050
Average size in service sector (Heat Roadmap Europe) in KW	240	240-264	240-264

[4] Heat pump size assumptions are defined for today, 2030 and 2050. They are calculated based on an estimation of the number of boilers in Europe (among which heat pumps are differentiated) divided by the heat demand. Two scenarios are considered for the heat demand: 1) the Energy Efficiency scenario of the EU Energy Roadmap; and 2) own scenario called HRE-EE with slightly larger primary energy supply. For detail on HRE-EE scenario and heat demand assumptions, see pages 11 and 83 of Heat Roadmap Europe. As in both scenarios heat demand is reducing over time, the average individual heat pump capacities are reduced between 2010 and 2050.

Average heat pumps size in service sector in Ireland	39.4	-	-

Conclusion:

- ***There is quite a wide spread of heat pump sizes in the residential sector, depending on the climatic conditions and the thermal performances of buildings in the different European zones.***
- ***Few data are available for the service sector, and the one source providing assumptions for modeling does present the arguments supporting the assumption.***
- ***For the residential sector, there is clear consensus on the long term trend, with a reduction by 20 to 25% by 2050.***

3.3.2 Present values on heating performances (SCOP, HSPF):

Heating performances for the overall building sector

Two reports from IEA provide ranges of SCOP values per heat pump technology. The IEA Technology Perspectives 2010 provides ranges for "typical" SCOP, while the IEA Building Roadmap provides broader ranges of SCOP, taking into account the diversity of technologies.

In addition, the Heat Roadmap Europe sets average COP assumptions for its scenario modeling exercise (for air to air and ground source heat pumps). The proposed values are in line though a bit pessimistic compared to IEA figures (they fall close to the minimum values of IEA ranges).

	Air to air Heat pump		Air to water Heat pump		Ground source Heat pump	
	min	max	min	max	min	max
"Typical" SCOP – IEA Technology Perspectives 2010 data (2010)	2.5	3.5	2.5	3.5	3.5	5
SCOP – IEA Building Roadmap data (2011)	-	-	2.2	5	2.5	6
COP (Heat Roadmap Europe 2013) (assumption for simulation)			2.5		3	

One must note that in the next years, the implementation of the new EC regulation on eco design of heat pumps (Ecodesign Directive 2009/125/EC) will impose the following minimum SCOP

	Air to air Heat pump	Air to water Heat pump		Ground source Heat pump	
Eco design Directive: minimum standards for SCOP	3.80[5]	2.5 (55°)	3.13 (35°)	2.5 (55°)	3.13 (35°)

Heating performances for the residential sector

When considering only the COP of heat pumps, an interviewed expert from the French Heat Pump Association indicates that the latest heat pumps technologies have reached a COP of 4 over the last years and that the new machines reach a COP of 5 this year.

The French Energy Agency (ADEME) provides average sCOP values for air to water and ground sourced heat pumps. The IEA building roadmap also displays value ranges for the different technologies. The draft SRA of

[5] For Global Warming Potential > 150

Renewable Heat & Cooling ETP 2013 provides a sCOP value for small residential air/air heat pumps. The Swedish Heat Pump Association (SVEP) provides a COP value of Ground source heat pumps for retrofit installations in Sweden.

In the SEPEMO European project , Seasonal performance factors based on 44 European site measurements have been estimated. On a wide national scale, Fraunhofer led a measurement campaign on 100 heat pumps in Germany installed in new energy efficient residential buildings.

Overall, the values from the different sources mentioned above are very coherent.

	Air to air Heat pump		Air to water Heat pump		Ground source Heat pump	
	min	max	min	max	min	max
SCOP in residential sector – ADEME data	-		3		3.5	
HSPF on 44 field tests across EU- SEPEMO data (20% extreme values excluded)	3,3	3,8	2,3	4	2	5,2
HSPF on 110 field tests across Germany- Fraunhofer data			2.88	3.4	3	5
COP in single family dwellings (IEA data)	2.5	3.5	2.5	4.4	2.8	5.0
Ground source heat pumps for retrofit installations in Sweden (SVEP data)					3.4	
sCOP (draft SRA of Renewable Heat & Cooling ETP 2013)	3.5[6]					

Heating performances for the service sector

When considering only the COP of heat pumps, an interviewed expert from the French Heat Pump Association indicates that compared to small sized heat pumps from the residential sector, larger machines of 20 -30 KW and beyond would always perform about ½ to 1 COP point lower (i.e. a COP 3.5 to 4.5 for best technologies).

No other data is available for the service sector. With regards to district heating, value ranges are provided by the related BAT report.

Conclusion:

- ***The different sets of data provide converging values for the current heating performances.***
- ***There is limited data available for the current performances specific to the service sector.***

3.3.3 Present values on cooling performances (EER, SEER):

Cooling performances for the residential sector

We remind that the heat pumps considered here are only the ones performing BOTH cooling and heating functions. Room air conditioners are not considered.

An expert interviewed from the French Heat Pump Association indicates that compared to the heating COP, the cooling performances of a heat pump would be about 1 COP point lower due to the fact that heat pumps are usually optimized for the heating mode. That would mean that the best technologies can reach an EER of 3 to 4 today in the residential sector.

With regards to Seasonal Energy Efficiency Ratio, ADEME estimates an average of 2.5 for reversible heat pumps. No other comparable data is available.

One must note that in the next years, the implementation of the new EC regulation on eco design (Ecodesign Directive 2009/125/EC) of air to air heat pumps will impose the following minimum SEER:

[6] for small reversible HP for near-zero energy houses

	Air to air Heat pump	
Eco design Directive: minimum standards for SEER[7]	4.6 (< 6kw)	4.3 (>6kW)

Cooling performances for the service sector – Air conditioning

Following the logic proposed by the AFPAC expert, the maximum cooling performance of heat pumps (that perform both heating and cooling functions) would reach 2.5 to 3.5 EER today, considering that systems are optimized for the heating function. However, the draft R&D agenda from the Renewable Heat & Cooling ETP mentions that some manufacturers announce SEER of 7 today for 100kW air/air systems ensuring both heating & cooling functions in non-residential buildings.

The IEA provides data on the cooling performances of Air Conditioning devices, i.e. heat pumps that do not provide heat, or at least not as primary function. The IEA/IRENA Technology Brief provides EER values for the service sectors, and the IEA Building Roadmap provides ranges of SEER values per type of compressor, as shown in the table below.

	Large ASHP		centrifugal chiller		reciprocating compressor		screw compressor	
	min	max	min	max	min	max	min	max
EER - IEA/IRENA Technology Brief data 2013	3	> 6		> 7				
SEER - IEA Building Roadmap data, 2011			4.5	7.2	2.5	3.5	2.5	3
SEER draft SRA of Renewable Heat & Cooling ETP 2013	7[8]							

Conclusion:

- ***For the residential sector, the two sets of data provide converging values for the current cooling performances.***
- ***The data sets available for the current performances specific to the service sector are difficult to compare, as some sources consider systems with cooling as primary function and others consider systems optimized for both heating and cooling functions.***

3.3.4 Trends: expected evolution of heating performances (COP, sCOP, SPF) by 2030 and 2050:

With regards to COP values, an expert interviewed from the French Heat Pump Association indicates that in the best scenario (large technology deployment), the COP will reach a maximum value of 5.5 to 6 in 2050 for the residential sector: if additional R&D efforts would allow further marginal performance improvements, it would not be worth the huge R&D investment required. For the service sector, the performance of larger machines would always stand at least about ½ COP point below the residential COP on the long term.
The main technical improvements driving the expected performance increase are listed in section 8.

The draft R&D agenda of the Renewable Heat & Cooling ETP provides some targets by 2020 (+57% for very small reversible HP (2kW) and +43% for larger ones (100 kW)), which are not included in the table below, the focus being kept on long term targets (in addition, those values are specific to "extreme" size heat pumps and therefore not very representative). But the trend is quite in line with the 2030 figures presented below.

[7] For Global Warming Potential > 150

[8] For 100 kW capacity heat pumps providing hot water at 40°C and chilled water at 10°C.

The IEA building roadmap foresees improvements of the COP by +40 to 60% by 2050. This trend can be compared with the SCOP and COP values provided by ADEME and SVEP, as detailed in the table hereafter.

	Performance evolution	
	2030	2050
COP - IEA data	+30 to 50%	+40 to 60%
SCOP - ADEME data	+33%	+66%
COP for ground sourced HP - SVEP	+23%	+47%

All three sources mentioned above agree on a significant progression by 2050, the ADEME forecast being the most optimistic one on the long term (+66%).

ADEME provides a maximum SCOP value of 5.85 for ground source heat pumps by 2050, which is very close to the "COP 6" limit mentioned by the FHPA expert, though the expert was referring to COP and not Seasonal COP: that might suggest that the maximum value proposed by ADEME for 2050 is very optimistic.

With regards to district heating, the SCOP values provided by the technological report on district heating for Denmark are forecasted to evolve by 6% to maximum 14% by 2050 (depending on the heat source).

Note that, if technical performances are expected to increase due to technological improvements (see technology readiness and maturity section), improvements related to installation and in labour skills also represent a significant source of gain in costs.

Conclusion: there is consensus on a significant improvement in heating performances by 2050, despite differences in appraising the extent of the performance gains.

3.3.5 Trends: expected evolution of cooling performances (EER, SEER) by 2030 and 2050:

The available data from ADEME provides SEER values up to 2030, all technologies considered. The SEER is expected to increase by 20% by 2030. This can be compared to the IEA Building Roadmap data:

	Performance evolution	
	2030	2050
EER **(IEA data)**	+20 to 40%	+30 to 50%
SEER **(ADEME)**	+20%	N/A

The ADEME figure for 2030 is in line with the minimum value estimated by IEA.

Conclusion: There is consensus on the cooling performance trend by 2030 among the two sources, with a progression of performances by at least 20% in 2030.

4 Technology readiness and maturity

4.1 Variables selected

This section lists the technology groups selected as presenting a high potential for either performance or cost improvement.

The evaluation of the Technologies' Readiness Levels (TRL) for each of those variable remains to be performed by experts. It is therefore not included in the Excel database.

4.1.1 Compressors

It is considered that the inverter technology for variable speed compressor is already mature.

Improvement can be achieved in terms of better compressor designs for heating, small systems and new refrigerants. The components should evolve from “on the shelf” compressors used in heat pump systems today, towards dedicated compressors designed and adjusted for the specific heat pump usage, allowing better integration into the system.

4.1.2 Smart systems

- Optimization of the overall cooling/heating system: for instance integration of prediction scenarios, intelligent control strategies to adapt operation to variable loads and optimize annual performance, automatic fault detection and diagnostic tools. Interaction with building Energy Management System.

- Communication and control system for interaction with the grid in view of peak shaving and load shifting (switch to hybrid or back up source).

4.1.3 Integrated and hybrid systems with PV and storage, or solar collectors

- Significant gains of performance through integration (TRL9 in 2020 according to IEA building roadmap), smart grid ready label of the German HP association.

- Significant gains of performance when combining technologies (TRL9 in 2020-25 according to IEA building roadmap).

4.1.4 Fluids

A real breakthrough in fluid solutions is possible beyond 2020, but totally unknown today.

- Next generation low - GWP and low life cycle climate performance (LCCP) refrigerants.
- Nanolubricants to improve chiller performance.
- Replicating the efficiency of water across a much wider temperature range.

4.1.5 Heat exchanger

More compact heat exchangers to reduce heat pump size.

5 Possible implementation constraints

5.1 Variables selected

5.1.1 Skilled workforce

This variable has an impact on the reliability of installed heat pumps and on their maintenance costs (better installation should imply fewer failures and therefore less repair and maintenance operations, and consequently little need for spare parts).

5.1.2 Number of installers and drillers

This variable has a direct impact on the costs of installed heat pumps: with the current provision, nearly no competition exists and prices remain high.

5.1.3 Installation time, measured in man-hour [mh]

This variable is influenced by the development and deployment of more compact/standardized systems.

5.2 Conclusions on robustness of the produced data

Across Europe, the degree of **skills and experience** of the workforce involved in heat pump distribution, installation and maintenance is not spread evenly. Even in developed heat pump markets, a more standardized training approach and early integration of heat pump technology into vocational training as well as university level education for civil engineers and architects is deemed necessary.

The key limiting factor is the complexity of designing a heating system that fits the energy demand of the building, both new and renovated.

To enable foreseen growth, nearly all installers need to be trained in the necessary skills and should be able to design and install a heat pump system.

Installation time is still not comparable to a standard heating system (in particular in the case of ground sourced heat pumps when drilling is required). Installation time would benefit from even more integrated units (integrating pumps, three way valves, controls, web interfaces) With regards to installation time, two sources provide data at different levels, that cannot be directly compared: specific data for ground source heat pump including drilling work on the one hand (for residential segment in Sweden), and more general data on the other hand (average for all heat pump technologies - drilling work excluded-).

Conclusion: there is consensus on the current situation related to the skilled workforce. For the other variable, not enough information is available to draw conclusions.

6 Costs

6.1 Variables selected

6.1.1 Capital cost in Euros per kW installed [€ /kW]

The values provided exclude the costs of heat distribution. The variable is provided per technology type (ground source; air sourced heat pump) and per end use (space & water heating, cooling) and per sector (residential, services).

6.1.2 Operation and maintenance cost in Euros per kW installed per year [€ /kW/year], in Euros per kWh [€/kWh] and in Euros per unit installed per year [€ /unit/year]

This variable is provided per sector (residential, services), for heating use only.

6.1.3 Lifetime – [years]

Economic useful lifetime of typical heat pump expressed in years.

6.2 Underlying assumptions

- A UK report presents some assumptions for the average capital cost of heat pumps (Technology Innovation Needs Assessment 2012), but does not indicate if the values address both residential and tertiary sector, or only residential. This data is presented as such in the database.
- The same source provides capital cost for “air-sourced heat pumps” but does not indicate if referring to air to air and/or air to water heat pumps. We assume it refers to air to water systems.
- Values provided by the above mentioned UK report have been converted from Pound to Euro with an exchange rate at 1£/1.18€. This rate can be modified in the database, with automatic re-estimate of the resulting values.
- Values provided by the IRENA technology report 2013 have be converted from US Dollar to Euro with an exchange rate at 1$/0.75€. This rate can be modified in the database, with automatic re-estimate of the resulting values.

- The average cost data per installation provided by the General Secretary of EHPA are assumed to be installed cost, in line with the values displayed in the EHPA outlook 2012.
- The IRENA report displays as well heat pumps market price for the commercial sector. This price table comes from a Japaneese source (the Heat Pump Technology Center of Japan) that performed a “Survey based on price statistics, manufacturers’ catalogues and information from manufacturers” edited in 2012. The technology segmentation in the table is not fully explicit. As the Japanese survey is not available, we make the following assumptions:

Technology segmentation in IRENA report (Japan survey summary)	« ASHP air-cooled »	« ASHP reversible »	« ASHP water cooled »	« Centrifugal chiller »
Correspondance with our glossary	Air to air heat pump for cooling use only	Air to air heat pump for both heating and cooling uses	Air to water heat pump for cooling use only	Centrifugal-compressor heat pump for cooling use only

6.3 Conclusions on robustness of the produced data

6.3.1 Present values on capital cost

Current capital costs for the residential sector

EHPA provides detailed statistics on installed costs per technology in the residential sector for 21 European countries. They can be compared with the average values provided by IEA Building Roadmap, and some statistics issued from a UK national programme (Energy Efficiency Best Practice in Housing programme).

Installed cost in €/kW(drilling excluded)	Air to air	Air to water	Ground source
EHPA data on installed cost (min/max among national average values from 21 EU countries)	*89 - 1250*	266 - 1667	*311 - 2400*
IEA Building Roadmap	*419-1073*	455-2390	*878 - 1700*
UK EEBPH			*708 - 1475*

The different data sets mainly overlap but “extreme” values are not fully coherent between data sets.

Beyond the data displayed above, the value provided by the Swedish Heat Pump Association survey includes the cost of drilling under difficult conditions (drilling a lot of holes) and retrofit installation. The costs depends thus on the drilling and the type of system (whether the water system is installed or not). In Sweden, the cost for a typical house is about 15,000 EUR, that is around 2,000 EUR/kW for a 8 kW average size.

Conclusion: there is consensus between the different sources of data.

Current capital costs for the service sector

Two sets of data are available for the service sector, but not comparable to each other: Japan sources provide market prices per heat source technology; while Denmark reports installed costs for district heating technologies.

Conclusion: the limited data available in this field requires further validation.