Energy Performance Contracting Plus

Technical Toolbox for Technical Measures for use in SPIN-constellations

Heat pumps

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www.epcplus.org

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Content

1. General description and explanation how-to-use

EPC+ aims at standardizing technical measures in order to make them predictable for other SPIN members (including the SPIN coordinator) and thereby to reduce transaction costs.

The toolbox can serve as a guide for the providers of EPC+-services for the standardization of the measures (design parameters, calculation method, process flow) and defines quality standards for the M&V-method. Text-modules of the descriptions may also be used for the communication with the client in order to create trust into the proposed measures.

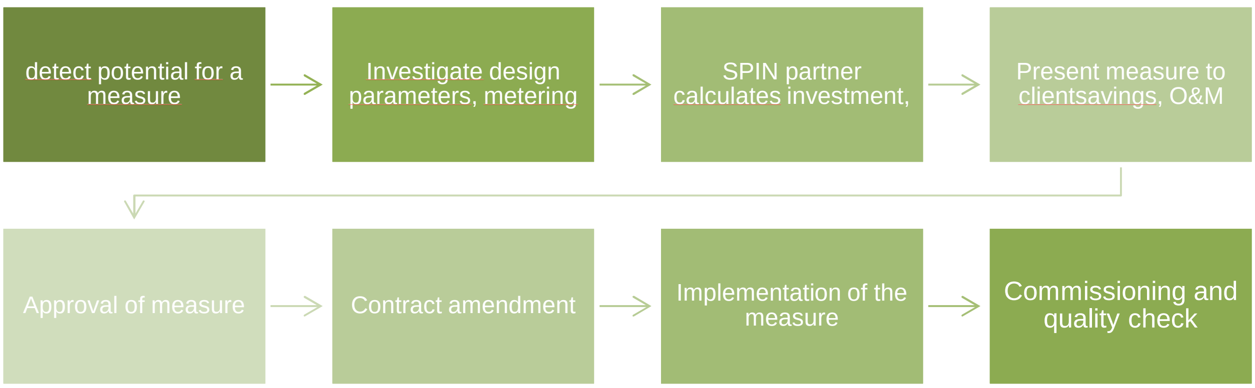
Each measure applicable for EPC+ is described on a general basis. Moreover the design parameters and the possibilities for application are defined, last but not least including a list of situations, where the specific measure is not applicable.

Calculation method

For the facilitation to introduce the measures for a SPIN the generic method of calculating effort for implementation, O&M and savings is described, ideally in form of a product-unspecific, open-source calculation tool.

Process flow

The generic process flow is identical for all measures. Therefore it is also part of the business model of EPC+, variations might be necessary for specific business cases, i.e. if measures interact with each other during their implementation or in their performance phase. See therefore also the interaction matrix of EPC measures, which serves as a quick indicator in which way measures might interact.



1.1. Toolbox

All measures are being described in general and in detail. The measures are categorized in energy-efficiency and renewable energy measures.

Energy-efficiency-measures:

1. indoor lights: LED lights + control system
2. hydraulic adjustment of heating system
3. modernization of pumps
4. modernization of electrical motors
5. energy efficient ventilation and/or cooling
6. HVAC control systems, incl. integration of boilers
7. Programmers of BMS-systems of different suppliers: Siemens, Honeywell,...
8. Renovation/replacement of heating boilers

Renewable energy measures:

1. Solar DHW
2. Biomass heating systems
3. CHP
4. PV-panels
5. Wind-power
6. ***Heat pumps***

2. Heat pumps

2.1.1. Technical description

2.1.1.1. General description (PU)

What is a heat pump ?

Heat pumps take heat from the ground, water or air, and use it for space heating, and/or to heat water. Heat pumps are like a fridge in reverse. The fridge takes heat from the food you put in it, and pumps that into the kitchen, keeping the food cold. The heat pumps take heat from the ground (or air or water) and pumps it into a house, keeping it warm. While air conditioners and freezers are familiar examples of heat pumps, the term "heat pump" is more general and applies to many HVAC (heating, ventilating, and air conditioning) devices used for space heating or space cooling. Most heat pumps are powered by electricity.

How does a heat pump work ?

Heat pumps use a refrigerant as an intermediate fluid to absorb heat where it vaporizes, in the evaporator, and then to release the heat where the refrigerant condenses, in the condenser.[1].

Why is a heat pump attractive as energy conservation measure ?

Heat pumps are a good replacement for fossil fuel based heating devices, especially in those contexts where electricity is available at an attractive cost level. The latter may be the case if the electricity is generated through photovoltaic panels. If heat pumps are powered by renewable electricity, they are expected to contribute in a major way to decarbonizing the built environment's heating demand[2].

Various types of heat pumps[3]

Various heat pump technologies exist, based on the choice of the medium where the heat is extracted from (ground, water, ambient air) and on the choice of the medium that distributes the heat within a building (water, air).

A wide variety of these heat pump technologies is being commercially promoted, but only a limited choice of pump types are truly justified from energy efficiency perspective. This choice will to a large extent depend on the climatological setting in which heat pumps are being considered. This is further explained in paragraphs 2.1.1.3 and 2.1.1.4.

Ground source heat pump

[1] Source : Wikipedia

[2] Source : Wikipedia

[3] Source : http://www.yougen.co.uk/renewable-energy/Heat+Pumps/

- A long loop of pipe, filled with water and anti-freeze, is buried in the earth. Depending on the available space, it can be horizontally spread in a trench of at least 1.5m deep, or vertically inserted into a borehole
- The liquid in the pipe (or ground loop) absorbs heat from the ground which is a fairly stable 8 - 12 degrees Celsius all year round
- As it passes through an electrically powered heat pump, the absorbed heat is extracted, and the liquid goes back into the underground loop
- Using electricity, the heat pump boosts the heat from the ground to the level needed by the heating system, heating water in a buffer tank
- The heating system is fed from the buffer tank.

Water source heat pumps take their heat from a lake, river or stream

Air to water heat pumps

- Air to water heat pumps extract heat from the ambient air using an evaporator coil.
- Using electricity, the heat pump boosts the heat from the air to the level needed by the heating system, heating water in a buffer tank.
- The heating system is fed from the buffer tank.

A typical air to water heat pump is a split system that consist in 2 parts :

- An indoor unit that contains the buffer tank and the steering system,
- An outdoor unit where the excess cold is released by means of a fan. The look of such a device is similar to air conditioner units that are often fixed to an outside wall of a building.

Air to air heat pumps extract the heat from the ambient air, boost it to the required temperature level, and blow out hot air into a room, or through vents around the building. They can also be used for cooling (air conditioning).

Within the context of EPC+ services, all above mentioned technological options may in principle be considered. However, the (hydro) geological context of the site will provide certain constraints, e.g. the proximity of surface water, the presence of groundwater, etc. These considerations are elaborated in paragraphs 2.1.1.3 and 2.1.1.4.

2.1.1.2. Design parameters

- Which parameters are necessary to survey for the design of the measure?
    - Technical parameters:
        - Heat pump's efficiency (preferably expressed as Seasonal Performance Factor (SPF))
        - Heat pump´s lifetime
        - Heat pump's power consumption

- Choices of technology: ground/water, water/water, air/air, air/water.
- Sub-choices within each technological system: e.g. water from horizontal or vertical wells, …
- Electrical connection to the grid (voltage; 1 or 3 phase connection, frequency,)

o Operational parameters:
- Operating hours
- Maintenance cost

o Economic parameters
- Initial cost
- Present energy cost
- Inflation rate on energy costs
- Interest rate on money

2.1.1.3. Measure suitable for[4]

- Heat pumps aren't suitable for every building. They work best in **well insulated buildings**.
- Heat pumps require an **appropriate heat emitting device** as they heat water to a lower temperature than traditional boilers. As a result the ideal place for them is an extremely well insulated building with **underfloor heating**. Heat pump can be used with radiators, but to get the same level of heat **larger radiators** are needed. Many older buildings are not energy efficient enough to use underfloor heating or low temperature radiators.
- To install a **ground source** heat pump, **plenty of outside space** is needed for the pipework which is generally buried in trenches. It can also be inserted in a borehole, which costs a bit more. In this case, suitable access for the drilling machinery is needed. The **geology of the ground** around the property is important as well in determining whether a ground source heat pump is suitable. For example, sandy soil drains fast and does not hold heat well; heat pumps will not perform well in an area with this soil.
- **Air source** heat pumps take up much less space, but a bit of **distance is needed between it and the neighbours**. Because they do not take up much space, air source heat pumps are more likely to be used in flats and in urban areas, particularly in places where there is no mains gas supply, or to replace electric heating.

[4] http://www.yougen.co.uk/renewable-energy/Heat+Pumps/

2.1.1.4. *Measure not suitable for*

Heat pumps are actively promoted by the heat pump installation sector, but it remains important to realize that heat pumps suit only certain applications. These units can have large capital costs and can cost more to run than the system being replaced if installed in the wrong place.

Referring to paragraph 2.1.1.3 above, heat pumps are not suitable

- *Air* based heat pumps are not justified being installed in climatological settings, where the delta between outside and inside temperature is not sufficiently large to run a heat pump efficiently.
- In buildings that are not sufficiently insulated
- In buildings not having an appropriate heat emitting system (e.g. underfloor heating, large radiators)
- In buildings that are not surrounded by sufficient and accessible space to install a heat collection pipe system (this criterion is only relevant when *ground* based heat pump technology is chosen)
- In buildings that are located in inappropriate geological settings (this criterion is only relevant when ground based heat pump technology is chosen)

2.1.2. Calculation method

From a methodological perspective, installing a heat pump is not merely replacing an old, non-efficient device with a new, better performing one. As a heat pump has limited modulation possibilities, it is likely that it will only foresee in the basic heating need of a building, and will be topped up (or backed up) by a 'classic' heating system (e.g. condensing boiler) at times when additional heating capacity is required. In other words, two reference scenarios are likely to be encountered:

1. An existing heating system is already in place, and is deemed sufficiently up to date, to be maintained in combination with the new heat pump to be installed.
2. The existing heat production system is outdated, and has to be replaced anyway.

So, before stipulating the input data of the business case, the boundary conditions of the calculation method should be clear, both with respect to the reference scenario and with the target situation. We have assumed the following scenarios:

- **Reference scenario ($S_{reference}$) :**
  The existing heat production system is outdated, and has to be **entirely replaced**.
- **Target scenario (S_{target}):**
  The existing heat production system will be replaced by **a heat pump, backed up by a new – modulating – heat production device** (e.g. condensing boiler), simultaneously with the installation of the heat pump. This implies that the cost for the installation of the backup heating system has to

be included in the business case analysis. These days, combined ('hybrid') systems are available on the market.

A selection of existing tools and calculation methods are listed below. It is noted that they were developed for specific geographic areas[5], and may not immediately be applicable within the Member States where the EPC+ project is being implemented. Anyhow, the tools are definitely recommended for consultation purposes when considering to develop a dedicated tool.

- US Gov / Dpt. Energy
  Energy and cost savings calculators for energy-efficient products
  http://energy.gov/eere/femp/energy-and-cost-savings-calculators-energy-efficient-products
- Canada Gov / Natural Resources
  Heat pump pre-screening tool
  http://www.nrcan.gc.ca/energy/software-tools/17889

2.1.2.1. Expected savings

The relative cost savings that can be expected from installing and running a heat pump depend on a number of factors, including:

- The cost of electricity versus the cost of fossil fuels (e.g. gas).
- The type and the efficiency of the heat pump.
- The reference scenario.
- For air based heat pumps: The climatological setting of the building.

Taking into account the boundary conditions that are explained above, the expected energy savings are defined as:

Expected energy savings = energy use for heating a building in the target scenario, minus the energy use for heating a building in the reference scenario.

As the reference situation is not known, and as the target situation should be engineered on a case by case basis, it does not make sense to provide a standard calculation method.

[5] The US tools are very well developed, but compute in non-SI units, which makes use in Europe cumbersome.

2.1.2.2. *Investment costs*

Several heat pump technologies exist, in various power ranges. So, no typical material cost can be put forward in this toolbox. The most realistic option is to contact a specialized contractor – or specialized SPIN-partner - to provide a quote for the installation of a suitable system.

On top of this comes the cost for installing a back-up heat production system, e.g. a classic condensing boiler.

2.1.2.3. *Running costs*

The running cost consists in the Operating and the Maintenance cost.
The **Operating cost** to generate heat by means of a heat pump is explained in the formula underneath:

Operating cost =
(Heat pump’s electrical capacity / efficiency of the heat pump) * operating hours * electricity cost

The electricity cost is the major part of the running cost. The amount of electricity required to power the heat pump, depends on the efficiency of the heat pump. The efficiency of heat pumps is measured by their **co-efficient of performance (COP)**; the ratio of heat produced per unit of electricity consumed in pumping that heat. The higher the ratio, the more efficient the unit. A COP value of 3 means that you get 3kWh of heat output for every 1kWh or electricity used to run the pump. Higher COP values represent relatively more efficient heat delivery.
Heat pump manufacturers’ estimates of their COPs should be treated with caution, because real operating conditions will not reflect the test conditions. The **seasonal performance factor (SPF)** addresses this issue, as it also takes into account the outside temperature as well as the fluctuating demand for heat. Put simply, the colder it is, the less efficient heat pumps become and the more warmth is needed. In mild weather, the COP may be around 4, but at temperatures below around 8°C an air-source heat pump can achieve a COP of 2.5.
The most correct way of assessing a heat pump’s efficiency *in respect to fossil fuel based heating* systems, is by calculating the **primary energy ratio** (PER), which takes into account the efficiency of a power plant.

Table 1 : Overview of heat pump efficiencies

	Air-water HP	Ground-water HP (horizontal)	Ground-water HP (vertical)	Water-water HP	Gas boiler (high efficiency)	Gasoil boiler
COP (*)	3.2	4.9	4.9	5.7	X	x
SPF	2.7	3.7	4.2	3.0-4.0	X	x
PER	1.1	1.4	1.5	1.2-1.4	0.9	0.8

(*) The COP is calculated according to EN14511:
Ground-water system : ground 0°C – water 35°C
Water-water system : water 10°C – water 35°C
Air-water system : air 2°C – water 35°C

Maintenance cost of a heat pump is related to its operating time. Additionally, several member states have imposed audit requirements to check the correct functioning of the heat pumps, as well as to checki the leak tightness of the refrigerants' circuit. This makes that Maintenance costs of heat pumps may vary. Again, a pragmatic solution to deal with this issue, is to contact a specialized contractor to provide a quote.

On top of this comes the cost for running and maintaining a backup heat production system, e.g. a classic condensing boiler.

2.1.2.4. Expected life-span of the measure and resulting replacement-costs (if any)

The expected life-span of the heat pump system depends on the technology:

- Water-water heat pumps as well as ground-water heat pumps have an expected life span of 25-30 years. The ground heat exchangers are made of HDPE conducts, and have an estimated life-time of 50-100 years. The conducts may require intermediate cleaning.
- Air-water pump systems are more exposed to the elements, hence have a shorter life span estimated at 15-20 years;

The expected life-span of the backup heat production system is 15-20 years.

2.1.2.5. Discounted cash flow analysis and Net present value

In order to elaborate a discounted cash flow analysis, amortization rate and net present value of the investment, tools elaborated within the context of the project can be used, please check the European toolbox package at www.epcplus.org/energy-service-packages/.

Mandatory output parameters:

1. Loan Amortization (€/year)

2. *Debt repayment (€/year)*
3. *Interest paid (€/year)*
4. *Remaining amount (€/year)*
5. *Cash flow (€/year)*
6. *Cumulative present value (€/year)*
7. *Internal Rate of Return*

2.1.3. Options on measurement & verification in order to evaluate the performance in relation to the given performance guarantee[6]

The EPC+ project focuses on energy efficiency measures for SMEs. This setting does not allow for extensive M&V procedures. So, a balance has to be struck between gathering sufficient data to avoid disputes, and safeguarding the cost-effectiveness of the data gathering process.

IPMVP Option B is recommended : Retrofit isolation method, whereby both 'performance' and 'operating time' are taken into account when calculating the improved energy performance.

2.1.3.1. Data to be measured in the ***reference scenario****:*

The following data should be available for one, entire and representative heating season (calendar year)

- Fuel consumption of the existing heat production system (e.g. gas consumption), and cost of fuel.
- Heating Degree Days during the reference period.
- Set points of the heating system (i.e. the indoor comfort parameters)

In case functional changes in the occupation of the building have taken place, or are being considered, these should be documented.

Ideally, information about the indoor comfort level in a building should be available as well: e.g. are there any complaints about the indoor comfort level ?

In case the fuel consumption profile is not available, estimates will have to be made based on assumptions and invoices.

2.1.3.2. Data to be measured in the ***target scenario****: heat pump + backup system*

In the target scenario, the following data set should be measured for one, entire and representative heating season (calendar year):

[6] Criteria: minimum effort, but still a proper qualitative proof for solid implementation and a considering performance, not installation only

- Electricity consumption of the heat pump, and cost of electricity.
- Fuel consumption of the backup system (e.g. gas consumption of a condensing boiler), and cost of fuel.
- Set points of the heating system
- Heating Degree days

Functional changes in the occupation of the building have to be recorded, as well as any feedback with respect to the indoor comfort level in the building (if any).