A set of guiding principles to develop quality schemes for heat pump systems based upon an SPF

D5.1.

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1. INTRODUCTION

For new homes and offices it is, or it is becoming popular to install a heat pump for heating, cooling and domestic (sanitary) hot water production. A heat pump is a proven and cost-effective technology to achieve further energy reduction in the domestic and commercial building sector. With the combination of heat pumps solar-PV or other renewable energy sources it will possible to build CO₂-neutral buildings (Nearly Zero Energy Buildings), as already proven in several building projects. With a further increase in energy (i.e. gas-) prices the economy of the system will improve over the life time. But that is not the only advantage: with low temperature (floor, fan convector) heating, refreshing or cooling in the summer, heat pump systems also give comfort benefits in the domestic sector, which fits well within the concept of healthy housing.

The SEPEMO-project has shown that that it is possible to get a good performance of heat pump systems, but a heat pump is not a gas or oil boiler and many aspects have to be taken into account to get an optimal working system for which the performance can be guaranteed. A market split can be made in new buildings or new building projects and retrofit, individual or large scale projects. Actually there are many different markets which all need a tailor made approach and for which there are general guidelines but also a lot of details. This report will deal with some general guiding principles in order to develop quality schemes for heat pump systems based upon an SPF.

For new domestic buildings the focus is on larger housing projects which can be collective flat buildings or a larger number of terraced houses which are built within one project. For these types of projects a heat pump system is an integral part of the building design process and is in many ways intertwined with it. By that physical cohesion, it is no longer possible to just add a heat pump to a once-chosen dwelling concept. Moreover, the installation of a heat pump is process oriented interwoven with the construction and development of the building. The quality will have to be assured during: design, procurement, implementation, and upon completion in the user phase. Special aspects to be dealt with are questions on collective or individual system, interference in ground source system and the grid load. Project developers should guarantee the performance of the overall building and specifically of the performance of the heat pump system so that the customer really gets what is promised!

This process is clearly deviating from the traditional building process with a multi layered responsibilities of sub contractors. Optimising this process towards a more industrial process of building construction is needed in order to achieve the ultimate goal of nearly zero energy houses. It is an interesting change over which is already occurring in the market [1]. More than often heat pump manufacturers are directly involved in this process and if installers are involved these are often large installers directly linked to the manufacturer.

For existing domestic buildings the market in the Netherlands is roughly split 60/40 into privately owned houses and houses owned by Housing Corporations.

For privately owned houses the decision to install a new heating system is not often made and mostly only when the old heater is non-operational. The installation of a heat pump system is then dependent on the often local installer and therefore not often undertaken as installation is more complex than traditional heating systems. Manufacturers have taken up this challenge by developing standardized plug and play hybrid systems. Training, master classes by manufacturers, for their specific products is the basis for further market development. The quality of systems is closely monitored by the manufacturers themselves.

For houses, terraced and flat buildings, owned by housing corporations it is often the question of large scale renovation or just replacement of the heating boiler. In large scale renovation the envelope of the building can be replaced, triple glazing installed, etc. Important in this process is to get into standardized concepts for different applications [2].
During the SEPEMO-project under WP5, several reports have been delivered focusing on the quality of systems:

- D5.2. Report on current European quality concepts, giving an overview of certification schemes in Europe and the importance for harmonisation where EU-CERT is having a good basis for further development.

- D5.3. Report on important factors for improvement of heat pump system performance and quality, giving an overview of different experiences in different partner countries, which is leading to the final conclusion that certification of the installer and system is an important part of an overall building process quality.

- D5.5. Position paper on heat pump system quality was written under the title: EU heat pump system quality: well on its way, but roadworks ahead! This manifesto sums up the needs to get toward a uniformly accepted certification for system quality based upon the building codes.

- D5.6. Easy to understand” guidelines for installation of reliable and energy efficient heat pump systems as a basis for courses and certification of installers within the scope of the RES directive, Annex IV. This paper was written by DHPA and commented upon by the partners in SEPEMO.

- D5.7. Easy to understand” guidelines for installation of reliable and energy efficient heat pump systems for architects/planners is written together with NEPROM (Dutch project developers). It has led in Netherlands to a paper published by NEPROM under the title of 'Warmtepompen in de woningbouw, de do's-and-don'ts voor ontwikkelaars' [3] (heat pumps in domestic buildings, do's-and-don'ts for project developers). Parallel to this the same type of paper was published on commercial buildings.

An important part of the work in Netherlands has been focusing on what the added value of the SPF-definition could be for existing installation guidelines for heat pumps. These guidelines are used as the basis for training and certification of installers. Together with National Heat Pump Platform (NPW) and its members (installers and manufacturers/suppliers) this was taken up in the discussions on installer certification in line with the RES-directive Annex IV. SPF if monitored in the right way can give valuable information on the performance of systems and give possibilities for performance guarantees and monitoring. Therefore it was decided to update the existing installer guidelines for heat pumps with the SPF-definition from SEPEMO.
2. MARKET SEGMENTATION

2.1 New building projects

A heat pump system is an integral part of the building and is in many ways intertwined with it. By that physical cohesion, it is no longer possible to just add a heat pump to a once-chosen dwelling concept. Moreover, the installation of a heat pump is process oriented interwoven with the construction and development of the building. The quality will have to be assured during: design, procurement, implementation, and upon completion in the user phase.

In development of new building project the pre design phase is important. For a large housing or commercial building projects the phase of urban design is involved. Therein not only the orientation of the building is determined (and thus the final heat demand and solar gain for the renewable electricity) but also the construction of infrastructure. The application of electric heat pumps makes the construction of a gas grid not needed while then in an all-electric design, the grid has to be sized correctly based upon smart grid principle in relation to the electricity demand and local generation. If that is not the case it can lead to malfunctions especially on moments with a peak demand. Already in this stage of development it is important to think together with the operator of the grid and/or the energy company about a vision for the energy structure. When a ground source heat pump is considered, a permit is required and the possible interference with other ground source systems has to be taken into consideration. For larger systems a test drilling or a thermal response test is advised.

The installation of a heat pump system however does not fit in the traditional building process of development and construction with sub-contractors, contracted at their lowest costs. A heat pump is part of a system that consists from a source, the heat pump itself, a delivery system, the dwelling itself. All the parts of the system fit together in a process chain which is as strong as its weakest link. The heat pump system and installation process is in all phases of construction associated with the dwelling, both physically and process.

For a heat pump to be able to work optimally a support before, during and after the technical design is required. This is why in the Netherlands more and more heat pump manufacturers/suppliers are involved in the projects and do not supply without knowing the principles and preconditions of the project. In France the thermal regulation implemented at the end of 2012 and the “Grenelle of Environment Rules” should lead to involve more and more of the different contributors. In contrast to the installation of traditional heating systems, with a heat pump it is essential to take into account the position and size of the installation area, the installation, the heat source, the dimensioning of the heat demand for space heating and cooling and of DHW and quality of the housing envelope.

In the choice of a heat pump system, it is therefore important that the dwelling and the installation can be integrated into one concept!

During the design of the house, important decisions are consciously or unconsciously as in tradition taken, with great impact on the property as climate concept. Even the choice of whether or not to open the window, has an effect on the perception of the climate within the housing.

Together with the client the heat pump suppliers must be involved in the pre design phase and the preliminary thinking about the principles of an optimal operating system. The focus is on the source selection, system selection, and the delivery system and user expectations. The result of all these considerations must fulfil the ambition of the customer and the level of comfort for the user. During the preliminary phase heat pump suppliers can facilitate in finding suitable parties for source construction, installation, management and maintenance as well as getting the needed legal permits.
To be able to guarantee a good performance of the concept the supplier should take the responsibility to set the system into operation and to monitor it.

That has added value to the residents because it qualifies them to determine their combustion behaviour. From preventive maintenance monitoring can also be controlled. For developers deliver the learning gains for subsequent projects. And generally delivers the data to not only the bad projects, but also the successful projects for the limelight.

The use phase of the house actually starts at the beginning of the process. This means that the developer in all phases of the construction and development should define how the decisions will benefit the interests of the end user and therefore how the choices made with the resident to communicate.

2.2 Existing building projects

For an energy neutral built environment in 2050, the biggest challenge lies in the existing building stock. It is expected that by 2050 at least 90% of current housing stock is still in use. Improvements applied in the next couple of years be applied, especially when it comes to structural facilities and energy infrastructure in and outside the buildings, should therefore be geared to that ambition of energy neutral buildings by 2050. Since in the next decades fossil fuels will become expensive and scarce renovation concepts which are free of fossil fuels will have to be considered. Concepts with heat pumps, with or without thermal storage, solar thermal and / or a combination thereof seem obvious solutions.

In the great diversity of existing buildings a focus should be on achieving numbers of application of renewable technologies through large-scale renovation by housing corporations. There are however no standardized solutions available for this in the renovation process which are attractive in the quest for a better energy label. The idea of the European is to develop a series of standard solutions for label jumps for the different housing types, describe them and focus on applying them to build up experience and market.

Concepts such as described in handbooks or the toolkit are developed as desktop studies by consultants / researchers. In a renovation process users of these handbooks find solutions by selecting an installation concept to be worked out by their architect and consultants into and the plan that will be contracted out. Subsequently, the party that won the tender will search for suppliers of components, usually selected on price. Then all assembled on site one is surprised when things do not operate immediately and that performance often lag behind expectations.

Seeing the increasing complexity a development of integral solutions of installation concepts is needed which can be standardized and commercially offered. By seeing solutions for energy and building physics as one system solution the coherence between these is guaranteed, the function between different components is optimized and the responsibility of performance is in one hand, that of the company selling the integral solution. This way forward involves companies of initially different disciplines to work together as co-makers of these solutions. It also means that the solution will not only be a heat pump, or insulation or a solar water heater, but will be a combination of several technologies to build up these solutions.
3. PROJECT DEVELOPERS

Project developers are both for large scale new building projects and renovation projects important key stakeholders in the process. Although seemingly only interested in quick project gains an important segment of these are deeply involved in heat pump projects, especially in large commercial building developments. However the mind-set of quick gains is having effect of the performance of systems and especially in Netherlands is giving heat pumps a bad press. Therefore a special project was done with a group of innovative project developers (DEPW), parallel to the SEPEMO-project, to get insight into the decision mechanisms of such building projects under the title ‘Mete is weten’ (measuring is getting knowledge).

During the discussions of the project an important focal point was the question how to ensure that you deliver what you promise.

The question on delivering what you promise involves more than just energy. It should also apply to the other benefits that are promised in the sales brochures, including: healthy indoor climate, comfort, quality being robustness and reliability, economy on investments and running costs. The property value in all this is at stake. DEPW partners, i.e. building companies, project developers and energy companies, could structurally measure and monitor their projects on these topics. Understanding successes and shortcomings are the basis for improving and scaling up and are the basis not to miss in a market switch towards even more renewable energy in innovating concepts.

Measurements can be complementary to what energy companies are already measuring, based upon a measurement protocol which has already been developed under SEPEMO. Agreements on who is measuring and sharing of knowledge will lead to acceleration in the acquisition of knowledge and innovations. Test results could also be made visible for the residents and housing corporations, so that they get feedback on behavioural aspects. Residents will also get more involved. It was generally agreed that a better insight must still be gained and new projects should be monitored according to the SEPEMO-protocol. Thus the drive of DEPW to get to a level of knowledge to be able to understand successes and shortcomings fits well in the strategy of SEPEMO.
As the future of heating and cooling systems will consist of renewable energy technologies which are relatively new in the market and will change the market structure completely, it is necessary to optimise the systems in order to reach a high level of efficiency, durability and comfort for end-users. Additionally, the systems will have to manage all the particularities of renewable energy sources, like the availability depending on the climate, the stored energy, as well as the input from non-renewable energy sources. An in-depth understanding of the system approach is crucial and specific research in this field is needed. In fact in many cases the systems performances of installed complex systems are behind the expectations derived from the single components, because of not optimal hydraulic solutions, choice of supporting components and control strategy. Specific simulation, demonstration and monitoring research projects are needed in order to overcome this drawback. For small scale systems such activities should enhance the number of integrated turnkey solutions offered on the market. Overall it is expected that in the end consumer satisfaction can be reached by giving performance guarantees and possibly a system or building certificate.

As a result of this work guidelines are written in the report D5.7. Easy to understand” guidelines for installation of reliable and energy efficient heat pump systems for architects/planners. It has led in Netherlands to a paper published by NEPROM under the title of ‘Warmtepompen in de woningbouw, de do's-and-don'ts voor ontwikkelaars’ (heat pumps in domestic buildings, do’s-and-don’ts for project developers). Parallel to this the same type of paper was published on commercial buildings.
4. MANUFACTURERS

4.1 Maintenance and user phase

Proper maintenance of larger heat pump systems and guaranteeing long term problem free operation is not possible without monitoring [3].

In order to ensure that the residents/occupants in the long run are satisfied with the heat pump system, it is thus advisable to offer a maintenance contract and at least come back after half a year and one year to fine tune the operation of the system and to verify whether the inhabitants properly understand the operation of the system. If there are symptoms, these can often simply be remedied.

A simple monitoring system can explain a lot and many manufacturers are already supplying software to monitor the technical functioning of the heat pump. In the design of the project and the choice of the heat pump these needs in the end user phase should be taken into account.

A lot of misunderstanding with the end user can exist:

- Complaints about the high energy costs can often be explained by the temperature settings in use or the large use of DHW. In the same project these can vary for space heating by a factor 2 and for DHW by a factor of 4 and more. Also the occupancy can be a disorder in the energy use. Especially in Low Energy and Nearly Zero Energy Buildings these differences can be large as monitored in the SEPEMO project.

- There is also sometimes misunderstanding that cooling consumes a lot of energy, while in ground source heat pump systems this technology is often applied to regenerate the ground source system can also be used for free cooling.

- Consumers may be dissatisfied with the capacity and heating up speed of the system.

It is important that in the selling contract to house owners or occupants of commercial buildings a separate section is dedicated to the heat pump system. This can be explicitly explain under which conditions the system works and what the resident can expect. In collective systems, the contract also shows how the contract with the operator is handled at which costs.
A heat pump (with associated source and delivery system) works best when it works smoothly. That cannot be simply checked upon completion of the system and in the transfer to the occupant/owner of the building as the quality of a heat pump installation proves itself only in the course time.

This is of course the case when the building is transferred out of the heating season and is the case in open source aquifer systems. A certification scheme on these systems proposes to have a technical transfer and a functional transfer two years after the technical transfer. This will show whether the source is properly dimensioned and whether the system is properly working up to its specifications in practice.

It is recommended under a maintenance contract for the planner/project developer (or the company selling the project in the market) to monitor the delivered project according to the SPF performance indicators as specified under SEPEMO to guarantee the performance.

4.2 From installer quality towards performance guarantees

The large up-take of renewable energy installations in the building sector signifies a penetration of the technology into the mass market; this will require a significant number of highly qualified installers capable of integrating renewables in both new and existing buildings. The European RES-Directive therefore states that Member States need to establish certification schemes for small-scale RES installers, among them those installing heat pumps, by 31.12.2012. The system needs to comply with a set of criteria laid down in Annex IV of the directive.

Proper training for the installation of Heat pump systems is a complex task that is not handled uniformly across Europe. The same holds true for installer certification (both for the installer company and the installer persons). The European heat pump industry has taken up the challenge in 2003/2004 and has developed the European Certified Heat Pump Installer programme (EUCERT) within the FP6 project EUCERT-HP. Today, EUCERT is coordinated by the EHPA and is one of the most refined schemes (of all RES sources) for installer training and certification. Experience from the EUCERT programme shows that the success of the programme strongly relies on support from the industry and governments. Agreement on one education system supported by relevant industry actors seems to be of particular importance, especially since the RES Directive asks for mutual acceptance of the certificate across Member States. Under EUCERT there is a direct relation with the European Quality Label for Heat Pumps and GEO-TRAINET, the certification for driller quality of ground source systems. A rapid uptake of education and training programmes, as well as of certification options in the workforce seems to be needed in the short term since a lack of sufficiently educated installers can severely limit market development and the goals for renewable for 2020. Such a lack has triggered BUILD UP Skills, an initiative geared at speeding up the process of work force qualification (www.buildup.eu). Consequently, overcoming this limitation is in the interest of Member States that have set ambitious targets as well as of industry that needs to deliver quality systems.

4.3 Towards performance guarantees

The clear objective of certification is to increase the number of highly-qualified market players. The main question to be answered seems to be, if certification of installers and the supporting education of installers will give the needed improvement of heat pump operating performance in practice. Market experience in the Netherlands shows that a significant number of heat pump projects are not running as expected, although these are installed by qualified installers working in line with broadly accepted installation guide lines from ISSO, the Dutch Building Services Knowledge Centre. The result of poor workmanship is consumer complaints that are quickly reaching the media and are giving rise to questions in the Dutch Parliament about the performance of heat pump systems. Currently a project of 160 houses in De Teuge near Zutphen is under heavy scrutiny. While this is an individual case in an overall growing market, it should be taken as a learning example. One goal of the SEPEMO project is the identification of key success criteria that
should be taken into account when designing and maintaining efficient heat pump systems. Agentschap NL as the Dutch partner in the SEPEMO project is following this idea, analysing the performance of heat pump systems in the Netherlands. Special focus is given to larger housing districts with collective or individual heat pump systems. As the installation can be standardized, cost can be reduced and installation quality improved. “Collective” means here either a collective heat pump providing energy to one heat distribution or a collective open aquifer source providing a stable energy source (low temperature loop) to individual heat pumps. The structure of ownership can differ, but in most cases an intermediary like Energy Company, an EsCo or a Housing Corporation taking a managing role.

4.4 Collective heat pump systems

The SEPEMO project has in the Netherlands focused on analysing the performance of heat pumps and ground source systems in 70 larger residential building projects where both open and closed loop ground sources are used. Open sources are mainly found in larger newly built housing projects, either having a collective heat pump in a collective flat building or individual heat pumps in terraced houses. Although mostly under service with an intermediary these systems are rarely evaluated. Anecdotal evidence suggests that several problems occur in their operation, which is possibly generally applicable to residential buildings: The design of the source is too small, leading to a performance during operation that is below expectations. Sources of this problem are most often a higher than expected heat demand due to low quality insulation of the building, a lower grade of source regeneration and smaller than expected energy output by the source (in the long run, this problem is most likely to get worse).

Insufficient or missing monitoring systems make an early identification of design/user mistakes difficult or even impossible and leading to higher system cost, higher prices per kWh of heat and generally dissatisfied consumers. While it is fairly easy to install a monitoring system in building projects by the owner in order to upgrade them and to run them optimally, the SEPEMO survey for the Netherlands shows that this solution is rarely taken. In the SEPEMO projects of Oosterheem and Houten all identified problems were overcome as a result of a detailed system performance monitoring identifying SPF values for all system boundaries (SPF 1-4) defined by SEPEMO. In Oosterheem the management system Monavisa developed by DWA-consultants is applied and in Houten the WADUS monitoring system, developed by Doorgeest Koeltechniek is used. After interference based on the monitoring results, the optimized systems will be measured for a second year within SEPEMO to evaluate the impact of measures taken. As an interim result, the application this type of monitoring as part of the building management of collective systems leads to increased performance (of heat pumps), lower cost and satisfied occupants. It is thus highly suggested to building companies to follow this approach. Finally, it will enable them to even give a cost/performance guarantee to tenants.

4.5 Individual heat pump systems

A monitoring system able to analyse and upgrade individual heat pump systems is a more difficult exercise and thus it seems to be difficult in such a way to guarantee the performance of the system. The quality of the building envelope has a major impact on heat pump and source performance. The heat pump should be sized to cover the actual energy demand of a building, which implies that the building should have the quality that is expected in the planning. Guaranteeing that all details will be put in place on the building site is difficult to achieve in the building sector. In the Netherlands, a number of major heat pump manufacturers are tackling this problem by influencing the building process. They demand minimum standards for building quality, checked by thermography and blower tests (for air-tightness). These manufacturers have upgraded their heat pumps by an error detection algorithm, capable of determining technical problems in the heat pump system (including source, auxiliary energy and circulation loop). The system is then connected to the company server via data networks enabling the manufacturer and the installer to monitor performance online. The combination of a guaranteed building quality and a monitoring of
the individual system is a precondition for the manufacturers to give performance guarantees on their heat pumps in the field. The guarantee comprises the energy use as well as comfort and fault free running and maintenance. Seasonal efficiency (SPF) is not a major concern: experience has revealed that the total energy demand is more important to the user than the efficiency of the system.

SPF should however not be ignored completely, as the user behaviour has a significant impact on differences in heat demand and performance. This became obvious when analysing another SEPEMO installation monitored by ITHO-Daalderop: A building with 76 apartments showed large variations in space heating demands and demands for domestic hot water, largely due to user behaviour. The problem was not severe, however, as the performance of the heat pumps was according to expectations, mainly due to the fact, that the building envelope delivered the energetic quality as designed. Ways to tackle such challenging realities for heat pump systems are now being examined under the SEPEMO-project. A group of project developers is cooperating with heat pump manufacturers on integral building and system quality. In this approach heat pumps are only applied when the building is built according to certain minimum standards on (quality of) insulation, thermal bridges and air tightness.

4.6 Conclusion

As heat pumps are the most simple and effective solution towards reaching the RES targets for several types of buildings the market will develop into a mass market. A successful development in this direction requires continuous efforts to maintain (and sometimes regain) consumer confidence in the technology. If installations fail, this will nearly always find its way into social networks and/or traditional media, a risk that manufacturers can no longer afford. While in the past, consumer misbehaviour and installer mistakes where often cited as cause for error, in addition the quality of the building envelope needs to be looked at more closely. Manufacturers could be in the lead to ensure systems quality in order to avoid simple, but not always helpful policy action asking for product labels and installer certificates. With regard to collective systems and individual installations, evidence shows clearly, that the installation of monitoring systems is essential to determine proper system operation – even from remote. This development is made easier by an increasing market penetration of high speed data net access in conjunction with the use of smart phones and tablet devices. Smart heat pumps in smart grids may sound like the future – but it is only a step away from becoming reality.
5. STATISTICS

How to determine the Seasonal Performance Factor (SPF) for the calculation of Renewable Energy Sources? – A SEPEMO project perspective

5.1 Introduction

The RES Directive (2009/28/EU) sets out the measures and regulations concerning the use of renewable energy sources, including those used by heat pumps. Article 2 of this Directive defines what ‘renewable energy sources’ (RES) comprise, while article 5, in combination with Annex VII, describes how to calculate the share of energy from renewable sources, delivered by heat pumps. According to the Directive, the Commission is obliged to define a calculation method on how to estimate the renewable energy provided by heat pumps as well as guidelines on how the Member States are to perform data collection on renewable energy. In order to monitor renewable energy targets at EU and Member State level, statistics on the contribution of renewable energy from heat pumps must be made available. DG TREN requested EUROSTAT to develop the statistical system that will allow the identification of the contribution of heat pumps to the RE targets. This includes the preparation of guidelines on how MS will estimate the $Q_{usable}$ and the SPF. EUROSTAT requested input from the involved industry associations - including the EHPA - on the calculation procedure to properly record the renewables share of heat pumps in energy statistics.

5.2 Problem definition

In order to calculate the share of renewable energy sources used by heat pumps ($E_{RES}$), one has to have knowledge about both the estimated total usable heat delivered by heat pumps ($Q_{usable}$) and the annual efficiency of the heat pump expressed as Seasonal Performance Factor (SPF).

In most simple terms, the performance can be determined by

\[ SPF = \frac{\text{useful energy}}{\text{energy input}} \]

putting the total energy production (heating and cooling) in relation to the total energy input. As heat pumps always produce heating and cooling at the same time, their efficiency is particularly high, when both services are needed at the same time.

The RES Directive covers the use of renewable energy for heating and cooling (Article 5 §1b). With regards to heat pumps, Article 5(4) states “aerothermal, geothermal and hydrothermal heat energy [...] shall be taken into account” and thus only presents a calculation method for the determination of their RES share in heating mode (Annex VII):

\[ E_{RES} = Q_{usable} \times \left(\frac{1}{1 - SPF}\right) \]

\[ Q_{usable} = E_{RES} \times (1/SPF) \]

\[ Q_{usable} = E_{RES} / SPF \]

where only heat pumps with SPF > 1,15 * 1/η shall be taken into account.

The IEE SEPEMO project provides an important holistic approach by determining the boundary conditions for the RES calculation in heating and cooling mode (see deliverables D2.4 and D3.4 on www.sepemo.eu/deliverables). This article addresses the issues that arise from the use of the rather undefined variables in the RES directive's calculation formula and it presents one possible approach to determining the RES contribution from heat pumps on the EU-27 level.

5.3 How to determine the «missing» variables $Q_{usable}$ and SPF?

The RES Directive did define neither the SPF nor the $Q_{usable}$ which lead some Member States to the conclusion that the share of RES cannot be calculated until the European Commission and/or EUROSTAT come up with suggestions on which values to use.
While it is rather simple to determine the energy demand of an individual building as well as the efficiency of a heat pump installed (see paragraph 2), resulting data cannot simply be applied to the installed heat pump stock on MS or EU level. Unfortunately no quick and easy solution exists to overcome this issue, as data on the energy demand in the building stock as well as on the performance of heat generators used - including heat pumps - is poor. Most Member States' statistics on the building stock are not detailed enough for this purpose and if energy statistics include heat pumps, efficiency is usually not documented.

In order to present a useful yet simple method on how to proceed, industry has proposed a first solution based on available data.

The useful thermal energy (Q_{usable} \leftarrow \text{heat}) provided to buildings is determined by using

- the number of installed HP units per energy source (as documented in the EHPA heat pump statistics),
- an estimated average installed capacity per energy source (agreed upon by industry experts from the three climate zones), and
- the average operating hours (Q_{usablefactor}), again agreed upon by industry experts).

With regard to the seasonal efficiency, the situation is more complex, as available approaches have different targets and choose different system boundaries. In general, seasonal efficiency can be measured in the real installation, or it can be calculated based on a variety of data, including lab tested performance for the individual unit/type.

Independent of the approach, the basic procedure always remains the same as outlined in the formula mentioned above (1). However, depending on the system boundaries, more or less components are included in the calculation/measurement. Even though the difference in results will most likely be marginal, it is important to keep in mind when applied to the existing and future stock of heat pumps.

Figure 2: Example scheme for the system boundaries of a heating system (source: SEPEMO)

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**Table 1** shows a comparison of approaches to determine the seasonal performance of heat pump units. SPF_{H₁-H₄} applies to field measurements of system performance in real installations and the system boundaries chosen to determine the impact of system components on efficiency. EN 14511:2011, EN 16147:2012 and EN 14825:2012 apply to lab measurements of the heat pump unit performance under fixed conditions. EN 14511 is used for fixed speed, electric compression
heat pumps. It is enhanced by part load conditions and climate data through EN 14825. EN 15316 does likewise, but much more complex, also integrating the building envelope. While these approaches are calculating the efficiency based on final energy, using primary energy as a basis is introduced by the implementing measures to EuP. This approach is as such not appropriate for the RES Directive, which is based on final energy performance.

5.4 Solution & conclusion

For the purpose of this Directive a compromise is necessary between applicability and accuracy. There are several options available:

1) **Field surveys:** Measuring a (large) number of installations could be done based on the SEPEMO methodology. They are however time-consuming and costly.

2) A combination of **measurements and calculation:** This approach is used in the EuP methodology for boilers, hot water production units and air conditioning units. It allows for comparison, yet it is based on primary energy and as such not usable for estimating the RES contribution.

3) **Unit performance** measured according to standards: For heat pumps, basic standards EN 14511 and EN 15879 (heating mode), EN 16147 (domestic hot water production: efficiency is determined in the lab based on a defined tapping cycle), EN 12309 (gas absorption units) are available to measure unit performance under lab conditions.

4) **Calculated seasonal efficiency based on test data: EN14825:** provides an Annex for the calculation of the Seasonal Coefficient of Performance (SCOP), based final energy and different climates, also integrating part load operation. It can be applied on existing measurement data.

In conclusion, the SPF in the context of the RES Directive should be understood as the SCOP according to EN14825 for the provision of heating and the unit COP according to EN 16147 for the provision of domestic hot water. They can be applied to calculated the renewables share based on the measured unit performance and climate data input/tapping cycle, thereby ignoring the multitude of other influencing factors from user behavior to the building envelope. Data is available immediately and its precision is deemed sufficiently close to real life data to justify its use.

Using this approach is still only an approximation and by no means complete: There are heat pump types not covered by these standards, namely hybrids and large units. More work is necessary to fine-tune and extend the coverage of existing standards towards a more complete approach. Field surveys - **based on a standard measurement approach and agreed upon system boundaries** - will be necessary to support this work.
6. SMART GRIDS

6.1 Heat pumps are “smart grid ready”!

The key idea of the Smart grid concept is to balance supply and demand patterns and to optimize the electric grid for the accommodation of different (renewable) energy sources. The safe supply of quality electricity is based on a dynamic management of a network’s balance between production and consumption (peak shaving and load levelling) locally, regionally or at a national level.

The search for energy saving and cost effectiveness control led to maximize the use of all available renewable energy sources. In the construction sector, the heat generators for space heating, domestic hot water and cooling will have to meet the challenges of smart grids. Their ability to interconnect, be remotely controlled (decrease heat production or shutoff period), and store energy are the major advantages that these systems will develop to play a decisive role in this search of the optimal use of renewable energies. In Europe, heat pumps are quite often connected to water loop heating systems, which have their own inertia (or through additional water tanks). These systems are perfectly suited to the network connected with renewable energy sources; and doing so, they will maximise grid and heat pump performances.

Heat pumps provide many opportunities for increasing global building and electric grid efficiency by matching heat production with photovoltaic, wind turbine production, solar thermal, or with the highest outside temperature hours (why not with the help of meteorological forecast data...).

This also includes the opportunity of using air-to-air heat pumps, which will probably be associated with efficient thermal storage materials in the future. And when no heat storage solution is available, heat pumps are very easily connectable to other generators (with any other fuels), and those hybrid solution are also well adapted to remote control requirements.

Finally, even if some improvements have to be done to market products with integrated and reliable control systems able to share information and command with any electricity supplier, we can say that heat pump systems are today already “smart grid friendly” – and more and more inverter machines mean more and more ease to control heat pumps accurately. EHPA is convinced that heat pumps are “smart technology” for future smart grids! State of the art heat pumps are in
most cases "Smart Grid Ready" even today and provide the necessary technology for our future sustainable buildings and cities.

6.2 SEPEMO: smart grids for online efficiency measurements

Smart grids – what is it and why should we bother?

Smart grids are the latest buzz word in the energy sector in Europe. Everyone wants to take part in the smart grid, but not all have more than a holistic idea about what smart grids are all about. Can heat pumps play a role in smart grids? In this article we will take a look at the possibilities smart grids and smart meters could provide.

The definition of smart grids on Wikipedia is: A smart meter is usually an electrical meter that records consumption in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Smart meters enable two-way communication between the meter and the central system. Unlike home energy monitors, smart meters can gather data for remote reporting.

If this is regarded as smart... we have a problem.

Another definition by The Electric Power Research Institute (EPRI) is: "(An) Integrated array of technologies, devices and systems that provide and utilize digital information, communication and controls to optimize the efficient, reliable, safe and secure delivery of electricity". Smart Metering systems feature a number of innovations: digital technology, communications, control and better operation of networks. Smart Metering technologies will change the way that metering works completely. They provide customers with much more information on how they use energy and enable those customers to reduce their usage.

Since heat pumps are quite advanced technologies, better understanding of the operating performance is an important aspect for both manufacturers and end users.

What do smart meters enable?

Smart meters are in itself not so smart, but combined with smart communication protocols and an optimization agent, smart systems could be established, Figure 1.

The main advantages with smart grids are that the consumer’s awareness is raised and empowered through delivery of actual consumption data. For EsCo’s, smart grids also serve to improve production planning, Customer Relationship Management CRM) and services, including automated billing/invoicing based on detailed metering data. They also enable new energy services for improving energy efficiency.
Today, electricity is produced exactly when the customer demands it. A smart grid makes it possible to balance production and demand.

**Better chances to automate service, performance checks and alarms**

The information on efficiency would be useful for both the homeowner as a status check that the heat pump unit is working properly, and with smart grids, a wide statistical material could be made available for EU statistics, giving better basis for the RES contribution from heat pumps. Integrity issues of course must be resolved for this to happen, but the possibility is there.

Access to "live" efficiency data will be key to future services, much like in the PV field, where SMA is selling access to its data to the producers of design software. Technology evolution can thereby speed up, and even better products can come faster to the market.

For HP manufacturers, performance guarantees based on the average performance of a HP in a "standard" application could be offered. A manufacturer would know, how a HP in an average four-person household in Sweden performs, they would know the standard deviation of performance in all four person homes and could thereby guarantee performance at i.e. 90% of the average. If you collect the data of all machines on your server this is so simple.

**Requires measurements of parameters**

"A Smart Grid is never smarter than the quality of its measurements". The meter (sensor) is not intelligent, but what you do with the sensor information is the important aspect. Opening the sensor for third party applications will open up for creativity, and since smart functions has a much shorter life span than the stupid sensor, updating functions could be as normal as updating apps on the smart phones. For this to happen on a wider scale, standard interface for third party application is required.

**Future demands**

The European Commission's Directorate General (DG) has given a mandate (Mandate M/441) to CEN, CENELEC and ETSI for development of an open architecture for utility meters involving communication protocols and functionalities enabling interoperability. The objective of this mandate is to harmonise European standards that will enable interoperability of utility meters (water, gas, electricity and heat), which can improve the means by which the customers' awareness of actual consumption can be raised in order to allow timely adaptation to their demands.

**Smart grids and Load management**

Saving energy is worth 5 – 10 times as much compared to shifting energy consumption to periods with low cost. Therefore, the main objective of smart grids is not to shift loads for cheaper hourly rates. Storing energy is always done at some cost in efficiency. Thus the dynamics in prices has to be high for an overall cost saving. In the Nordic market, the dynamics are just not high enough yet,
but with increasing installations of renewable energy production with intermittent operation (wind, wave, PV), expectations is that this dynamic behavior will change in the future.

SEPEMO-Build and smart grids

In the SEPEMO project, numerous measurements on heat pumps of various heat sources (Aerothermal, Hydrothermal and Geothermal) are monitored in different climates in Europe. The results from these measurements not only give valuable information about the seasonal performance, they also give valuable information about how the heat load patterns look like in different buildings. This information will be very valuable for the ESCO's that can benefit from this information when designing Smart grids.
Literature

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