Accelerating market uptake of heat pump systems: Challenges, visions and steps for change – results from a stakeholder process in four European countries

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Abstract

Electrification of heating via heat pumps is one important step to improve the building sector and to achieve the European Commission's 2030 target of a 40 % share of renewables in the energy mix. While the use of heat pumps increased steadily in most European countries, the market share of heat pumps still varies strongly between market segments and countries. According to EurObserv'ER 2018, heat pumps are well established in new constructions. In the renovation market with multi-family buildings, the share of heat pumps is much lower, reaching only around 10 % in Germany, Austria and France (EurObserv'ER 2018).

The contribution will present results from a stakeholder process, which was carried out to better understand the conditions of market uptake of innovative heat pump systems in different European countries. The analysis was carried out as part of a Horizon 2020 funded research project on trigeneration systems based on heat pumps (https://www.tri-hp.eu/).

The objective was to investigate key social and contextual factors that influence the social and market acceptance of renewable heating and cooling systems. The analysis included a literature review and in-depth interviews with change actors in the heat pump markets in Germany, Switzerland, Spain and Norway. Among others, the perspective of heat pump manufacturers, HVAC planners, installers and building owners were taken into account.

As a result, we could identify important barriers, drivers and incentives for the adoption of heat pump systems in general and innovative trigeneration heat pumps systems. Besides economic factors, such as high upfront costs, issues of practical implementation and feasibility emerged as important topics. Organisational factors, such as the cooperation between different trades on the construction site, or country specific heating cultures also turned out to be important issues.

In the contribution, we will link these findings to the outcomes of a series of workshops, in which steps to actions were discussed with key stakeholders on a national and European level.

Introduction

EU and national climate targets call for a shift towards a decarbonisation of the building sector in all European countries, entailing a need to replace outdated fossil heating systems by newer and less carbon-intensive ones. Electrification of heating via heat pumps is an important step to achieve the European Commission's 2030 target of a 40% share of renewables in the energy mix. In Germany, rapid market penetration of heat pumps is seen as a priority for national energy policy to reach the German 2030 targets in the buildings sector (BMWK 2022).

In the last years, the use of heat pumps for heating, cooling and hot water generation increased steadily in most European countries. However, the market share of heat pumps still varies strongly between market segments and countries. In new buildings, heat pumps are well established: According to a market analysis in 2017, the market share of heat pumps in newly constructed single-family houses was above 90 % in Norway,

Sweden and Finland and around 35 % in Austria and France. In the renovation market with multi-occupied buildings, the share of heat pumps was much lower, reaching only around 10 % in Austria, France and Germany (EurObserv'ER 2018). In the renovation market and in particular in multi-family buildings heat pumps have a huge, but largely untapped potential for GHG reduction.

In this paper we will explore barriers, hindrances and incentives to market adoption of heat pumps in Europe in multi-family buildings. We present the results of an in-depth empirical investigation of factors affecting the social acceptance of heat pumps in four European countries. The investigation included two steps: In a first step, stakeholder interviews were carried out in Germany, Switzerland, Spain and Norway. In a second step, the findings of the interviews were discussed and validated in national stakeholder workshops. Participants of the workshops were also invited to sketch strategies of action to overcome these barriers and hindrances.

The paper draws on a stakeholder analysis which was carried out as part of a research project on innovative trigeneration heat pump (TRI HP) systems. These systems are based on electrically driven natural refrigerant heat pumps coupled with photovoltaics to provide heating, cooling and electricity to new and refurbished multi-family residential buildings with an on-site renewable share of 80 %. The flexibility will be achieved by allowing the use of three heat sources: solar (with ice/water as storage medium), ground and ambient air. These systems are still under development, and only some of the TRI-HP components, e.g. natural refrigerants, are entering the market. Only few stakeholders were familiar with TRI-HP systems and most of them referred to heat pumps in general. Thus, our paper has a broader scope going beyond the narrow topic of TRI-HP systems, including also the views of stakeholders towards "conventional" heat pumps. If no particular reference is made, findings refer to heat pumps in general. If TRI-HP systems are addressed, this is mentioned explicitly.

The paper is structured as follows. First, we outline the background and objective of our paper. Methodology of data generation and validation are presented in the third section. In the fourth section, we give a short overview on the results of the stakeholder process. Finally, we will discuss main conclusions that can be derived from these findings.

Background and Objective

SOCIAL ACCEPTANCE OF RENEWABLE ENERGY TECHNOLOGIES

Social acceptance of energy technologies has been a major topic of social energy research in the past decades. The use of the term 'social acceptance' in research literature is manyfold, with various interpretations and approaches associated with it. While the meaning of 'social' can range from a general 'public' to specific groups of stakeholders (Heiskanen et al. 2014; Wolsink 2018), the term 'acceptance' is used for attitudes and behaviour varying between passive consent and more active participation Thus, a distinction can be drawn between 'acceptance in principle', which is more interested in general evaluations and attitudes of people, and 'acceptance in actual adoption and use', which looks more closely into actions, decisions, use, and behaviour of decision makers (Jung et al. 2016: 815).

Furthermore, social acceptance can be broken down to different levels of acceptance. According to the much-cited distinction made by Wüstenhagen et al., three dimensions of social acceptance – socio-political, community and market acceptance – can be distinguished (Wüstenhagen et al. 2007). Whereas social-political acceptance deals with the acceptance of institutional settings, community acceptance refers to local renewable energy (RE) plants, like windmills, and the reactions of the local stakeholders. Finally, market acceptance refers to the diffusion of RE technologies within the market and the extent to which its participants, such as consumers and companies, accept them (Schumacher et al. 2019: 316).

OVERALL OBJECTIVE

In this paper, we focus on market acceptance of heat pumps in multi-occupied buildings in general and specific issues regarding innovative heat pump systems. The overall objective is to explore barriers, hindrances and incentives for actual adoption and use, distinguishing between different groups and stakeholders, each with different and often conflicting interests and motives for action. The focus is on the views and perspectives of actors which are considered as key stakeholders playing a critical role for adopting heat pump systems in buildings:

- decision makers (e.g. investors or building owners who make investment decisions for a building);
- planners and technical consultants for the design and technical functionality of heat pump systems in residential buildings (architects, HVAC consultants, building engineers, etc.);
- experts for the successful installation of heat pump systems (installers, tradesmen, plumbers, etc.);
- manufacturers and distributors of heat pumps;
- building or facility managers in charge of operating and maintenance of heating systems.

As markets and (climatic, geographical, regulatory, political and cultural) context conditions for market adoption of heat pumps vary in Europe, we apply a cross-national perspective, focusing on four European countries (Germany, Switzerland, Spain, Norway). These countries represent different climate zones with differing heating and cooling demand in Europe as well as different context conditions for market adoption of heat pumps.

Methodology

The analysis of barriers, hindrances and incentives for actual heat pump adoption and use included two steps:

- As a first step, expert interviews were carried out in Germany, Norway, Spain and Switzerland in order to explore key stakeholders' expectations, benefits, requirements and risk perception associated with heat pump systems and components as well as geographical, legal and cultural differences.
- As a second step, the interview findings were discussed in a series of national stakeholder workshops in the four countries. During the workshops stakeholders and experts

were invited to assess and validate the interview findings from the point of view of their professional expertise and the specific conditions in their country. Furthermore, the workshops were dedicated to elaborate in greater detail suggestions and conclusions for measures and actions to improve market uptake of heat pump systems in a national context.

The methodology of the expert interviews and the stakeholder workshops is explained in the following sections.

EXPERT INTERVIEWS: SAMPLE AND METHODOLOGY

Semi-structured narrative in-depth-interviews were conducted in Germany, Norway, Spain and Switzerland with end-users (owners of multi-family houses) and key stakeholders for heat pump planning, installation and maintenance. The interviews were carried out along an interview guideline with open questions. The guideline was structured along topics, derived from comprehensive literature analysis (Friedrich, Stieß 2019). Each topic was addressed by a small set of questions. In response to the interviewee's answer, additional questions could be asked in order to explore the view of the interviewee deeper. The order of questions was not fixed (= fully structured), but could be adapted to the course of the conversation (=semi-structured). Interviewees were selected according to a sampling scheme.

The interview partners were recruited using different strategies. First, extensive internet research was carried out via search engines. Further results were obtained via publicly accessible contact portals such as websites of professional associations or LinkedIn. In addition, the project partners TECNALIA, IREC (Spain), SPF-OST (Switzerland), NTNU (Norway) and REHVA (Belgium) provided valuable contact recommendations from their professional networks. Finally, numerous contact recommendations were made by the interviewees themselves.

Interviews were conducted between March and November 2020. In Spain and Norway, the guideline was translated into the respective national language. Due to the Covid-19 pandemic, all interviews were conducted by phone or video call. The response of the interviewees was rather positive and the quality of the in-depth interviews was very good.

Interviews in Germany and Switzerland were carried out by ISOE, with support from SPF-OST in Switzerland. In Spain and Norway, external professional market researchers were entrusted with the interviewing under the guidance of ISOE. Fieldwork in Norway was done by Opinion AS (Oslo). Interviews in Spain were carried out by Astrid Zarcos Lamolda (Càlig, Castellón). A universal interview guideline developed by ISOE was used in all countries.

The final sample included thirty-six expert interviews. Table 1 shows the structure of the final sample by country and stakeholder group. Interviewees were selected according to their assignment to the stakeholder groups that were identified as relevant to the implementation and market uptake of heat pumps. Efforts were made to ensure that the interviewees came from a variety of regions within the countries surveyed.

The average age of the interviewees was 50 years, with the youngest interviewee being 28 and the oldest 72 years old. Only four of the 36 people were women, which reflects the well above-average proportion of men in this area.

Data management and evaluation were carried out exclusively by ISOE. All interviews were fully transcribed and coded with the MaxQDA analysis software. The codes were structured according to thematic clusters. For each topic code, a condensed summary was then produced for each of the four countries studied. The respective content was categorised according to dominant topics, which in turn were compared with each other in order to interpret the results. Generalised results were evaluated with regard to their overarching or country-specific significance.

STAKEHOLDER WORKSHOPS

The findings from the interviews were discussed in national stakeholder workshops in Germany, Norway, Spain and Switzerland. The concept and the evaluation of the stakeholder workshops was provided by ISOE. Each stakeholder workshop (SWS) was organised by a national partner of the TRI-HP project consortium and supported by project partners in terms of moderation and documentation. Table 2 provides an overview on the four national SWS and the number of attendees.

All stakeholder workshop had the same structure, however the number and composition of attendees, the thematic focus and the schedule were adapted to national contexts. Carefully selected representatives of the key stakeholder groups identified in the interviews were invited to the SWS in order to represent a broad spectrum of different perspectives and interests and to be able to capture and discuss barriers and drivers in a most inclusive way. Between seven and 26 stakeholders from different sectors participated in the national SWS, including representatives from relevant associations, organisations, companies or practitioners (see Table 3).

All stakeholder workshops were divided into two parts: In the first part, members from the TRI-HP project consortium

Table 1. Sampling structure of expert interviews.

STAKEHOLDER GROUP	DE	CH	ES	NO	TOTAL
House owner, investor, property manager	1	2	2	2	*7*
Technical consultant, project planner	3	2	1	2	*8*
Manufacturer, distributor	2	1	1	1	*5*
Installer, tradesman	2	1	2	1	*6*
Architect	3	1	1	1	*6*
Engineer	1	1	1	1	*4*
Total	**12**	**8**	**8**	**8**	***36***

Table 2. Overview of the four SWS and number of attendees.

	Germany	Switzerland	Spain	Norway
Date and time	09.06.2021 09:30-12:30	24.06.2021 09:30-12:30	23.06.2021 09:00-11:00	16.06.2021 09:30-12:30
SWS organiser	ISOE	SPF	Tecnalia	NTNU
Moderation and support	ISOE, SPF	ISOE, SPF	SPF, Tecnalia, NTNU, IREC	ISOE, SPF
Participants total	20	19	37	23
Stakeholders	7	9	26	7

Table 3. Representatives of stakeholder categories that participated in the four SWS.

Stakeholder	Germany	Switzerland	Spain	Norway
Heat pump associations	X		X	X
Heat pump (component) manufacturer	X	x	X	X
HVAC planners / energy counselling	X	x	X	X
Installing / tradesmen associations	X			X
Investors / housing company	X	X		X
Facility management / energy contracting	X	X	X	X
Architects / building engineers	X	X	X	
Other		X	X	X

presented key technical achievements of the project (e.g. heat pumps with CO_2 or propane as natural refrigerants or coupling of solar thermal and ice storage systems). In the second part, key challenges regarding a better uptake of heat pump systems in general and specific issues regarding innovative heat pumps were presented and discussed in an interactive session with the SWS attendees. The challenges were derived from the findings from the expert interviews and were assessed by the stakeholders. After presenting some of the most important issues that were frequently mentioned in all interviews, stakeholders were given the opportunity to add challenges if they missed any, or they could change or even delete existing ones. In this way, they were able to contribute and include in the discussion certain aspects specific to certain stakeholder groups or countries. After the list of key challenges was deemed complete, a voting process followed. Each stakeholder could cast a vote on which challenges he or she thought were most important. Depending on the voting results, the participants of the SWS4 divided into moderated small groups in which different challenges were discussed and action steps were developed.

All SWS were held as virtual events due to the COVID-19 pandemic. In addition to the conference software, virtual whiteboards and an online voting tool were used.

The main results and conclusions of each SWS summarised in condensed documentations, which were then subjected to a comparative analysis. For this purpose, ISOE provided a documentation template to the national partners. In addition, the information from the whiteboards and the votes were evaluated. The findings of the SWS process are documented in Friedrich, Stieß (2021).

Results from the expert interviews

In the following, main findings from the stakeholder interviews on barriers and drivers towards the adoption of renewable heating and cooling technologies are presented. While barriers and hindrances refer to the adoption of heat pumps more generally, drivers and incentives point to aspects that might help overcome these challenges. These aspects include specific advantages of tri-generation technology as well as external factors, such as political framework conditions, funding schemes or new business models that support the market introduction of tri-generation systems. They also include suggestions from stakeholders for further action that could improve social and market acceptance of these systems.

The numerous barriers and drivers that have been identified in the interviews can be grouped into three categories: economic-financial, practical implementation and feasibility, and psychological, socio-cultural and organisational aspects.

ECONOMIC-FINANCIAL BARRIERS, DRIVERS AND INCENTIVES

Economic-financial barriers and hindrances

High investment, upfront costs and additional costs, especially for refurbishment measures that may be required if heat pumps are to be installed in existing buildings, were the most

frequently mentioned financial hurdle for heat pump systems. Additional efforts for drilling in the case of ground source heat pumps, result in further increase of installation costs.

High electricity prices compared to gas were seen as another barrier for conventional heat pumps, because they increase operating costs and reduce the system's cost effectiveness. This risk increases when heat pumps are not properly installed and configured.

The uneven distribution of costs and gains can pose another barrier when an investor is unable to reap personal benefit from low operating costs (landlord–tenant dilemma).

Economic-financial drivers and incentives

The low operating costs of renewable heating and cooling systems and their reliance on basically inexhaustible energy sources were emphasised by many interviewees. Maximising self-consumption of electricity generated on site by photovoltaic panels is considered a very effective means of keeping operating costs low and becoming largely independent of the electricity market. Operating costs can be reduced further through intelligent system control that can make use of flexible electricity tariffs.

Carbon taxation and ongoing changes in the regulatory framework of energy markets are expected to further increase the competitiveness of renewables. Public subsidies were highlighted as a main lever with which to ease the burden of the high upfront cost of renewable heating and cooling systems and increase social acceptance of this technology.

Innovative business models, like energy contracting, based on the investment of a third party who is paid for the heat or cooling production can overcome the hurdle of high upfront costs and reduce financial risks for property owners.

Novel forms of cooperation, for example housing cooperatives or energy networks, can also help renewable heating and cooling systems achieve wider market acceptance, as they support a long-term perspective, rather than seeking a rapid return of investment.

PRACTICAL IMPLEMENTATION AND FEASIBILITY

Barriers and hindrances towards practical implementation and feasibility

Poor energy efficiency standards of existing multi-family buildings have often been mentioned as a practical barrier that impedes a broader adoption of renewable heating and cooling systems in this segment of the building market. In many cases, the efficient operation of heat pump systems requires expensive and disruptive measures such as insulation of the building façade or the installation of underfloor heating.

The technological complexity of advanced renewable heating and cooling systems and the need to adapt these systems to different energy consumption profiles were seen as another challenge, especially with regard to configuration, coordinated interplay between the individual components, and quality control.

Other barriers to feasibility relate to a lack of space required for the technological components and boreholes, plus the noise emissions of air source heat pumps, which amplify, when the installation is not done properly.

Drivers and incentives to practical feasibility

A higher standardisation of heat pump manufacturing could take the pressure off installers, who would no longer have to grapple with a variety of barely compatible systems from different suppliers. Compact, space-saving systems or modules that come off the shelf and can be installed and replaced via plug-and-play increase feasibility for both new and existing buildings. Ready-made and simple solutions such as combined packages of, for example, a heat pump with photovoltaic and electrical storage would be appreciated by investors and installers.

Refurbishment measures are considered important to achieve a high performance from a heat pump in existing buildings. A new generation of high temperature heat pumps can meet the needs of older buildings, having a modest insulation standard and undersized emitters. Disruptive changes to the heat distribution system can be avoided, if technological components such as low-temperature radiators are used as an alternative to underfloor heating.

The individual thermal needs and the social structure of residents lead to a variety of heat consumption profiles of individual residential buildings. These profiles should be assessed accurately in order to determine the ideal sizes of heat pumps, photovoltaic panels, heat storages and other technological components. In multi-family buildings, intelligent control systems that automatically adapt to individual user behaviour can help boost the efficiency of the system.

The use of natural refrigerants such as propane or CO_2 instead of fluorinated gases further reduces environmental risks. Technical risks and safety concerns linked to the use of natural refrigerants in tri-generation systems were considered to be very low as installation and maintenance rules were observed. Existing regulations, for example regarding safety measures in the maintenance of heat pumps so that no leakage or contamination can occur, were evaluated positively. There were a few suggestions, however, that called for permissible maximum levels when filling a device with natural refrigerants to be increased for larger heat pumps installed in multi-family buildings.

Due to technical development and regulations, air source heat pumps have become significantly quieter in the last years. Nevertheless, they should be set and programmed in such a way that noise levels remain constant. Noise protection equipment should be considered and night and quiet times respected. Complaints from neighbours can thus be minimised.

PSYCHOLOGICAL, SOCIO-CULTURAL AND ORGANISATIONAL ASPECTS

Psychological, socio-cultural and organisational barriers and hindrances

Lack of awareness of the ecological impacts of fossil heating and cooling systems and knowledge deficits were seen as important obstacles to social acceptance of heat pump systems. Preconceptions about renewable energy technologies and ignorance about available funding opportunities by many professionals and stakeholders in the heating and cooling sector are further barriers.

A shortage of qualified installers for renewable heating and cooling systems was described as a "bottleneck" in many countries. Qualification and training paths as well as the business model of many heating installers are still rooted in fossil technologies, hampering a swift decarbonisation of the heating sec-

tor. The extensive technical and practical knowledge required for planning, implementation, operation and maintenance of renewable heating and cooling systems was identified as a major challenge.

The increasing demand for information on a multitude of funding opportunities, regulations, and other framework conditions was seen as another factor that limits broader acceptance of renewable heating and cooling systems among heating installers. Fragmented responsibility and difficulties in coordination between planners and craftsmen on the construction site can make quality assurance more difficult which in turn means a higher risk for investors.

Existing country-specific heating and cooling habits of end users may clash with the specific requirements of low-temperature systems, thus affecting their efficient operation.

Psychological, social-cultural and organisational drivers and incentives

Awareness raising and trust building among end users and professional actors are key to increasing social and market acceptance of renewable heating and cooling systems. Prevailing prejudices and rumours among end users, heating installers and architects must be countered with transparent information on the advantages and benefits of renewable heating and cooling systems.

Close and trusted cooperation between manufacturers and installation companies were seen as particular important. Heat pump manufacturers should insist on quality control to guarantee proper installation, offer savings guarantees and maintenance contracts. The appointment of a single responsible overall coordinator for complex projects would improve stakeholder cooperation and enhance customer satisfaction.

Further training for heating installers should be targeted to technological issues as well as to communication and skills that are helpful for advising clients or marketing heat pumps more effectively. Monetary incentives for vocational training and further qualification could help address the quantitative and qualitative shortage of skilled workers in the field of heating installation, especially if such incentives are linked to certification.

Public communication should not only focus on technical aspects and financial benefits, but also address environmental values that intrinsically motivate stakeholders and end users to invest in renewable technologies and systems. These include, for example, the desire to lead a more environmentally friendly life, to practice energy self-sufficiency, or to participate in the decarbonisation of the energy system.

COUNTRY-SPECIFIC FINDINGS

In *Germany*, existing laws, regulations and funding conditions relevant for the market diffusion of renewable heating and cooling systems were assessed as basically favourable. A critical bottleneck is seen in the lack of sufficiently qualified installers. Low energy efficiency of the building stock is considered a major challenge for broader diffusion of heat pumps in the building stock. A much discussed topic concerns the renovation of existing buildings and when it is reasonable (and under which circumstances) to replace an old (fossil) heating system with a heat pump. The high level of electricity prices in Germany was considered by most experts to have a detrimental effect on acceptance of renewable heating and cooling systems. Systems, like trigeneration heat pumps, with a high share of on-site generated electricity might prove to be beneficial, because they can ease the burden of high operating costs

In *Switzerland*, the Heat Pump System Module was highlighted as a successful quality standard and certification system which could serve as a best practice example for other countries as well. The module includes a standard for the planning, construction and commissioning of heat pumps (<15 kW), certification, binding procedures, and performance guarantees, easy-to-understand documentation and regular quality checks. Also in Switzerland, shortage of qualified heating installers was raised as an important issue. Tradesmen in Switzerland have a very influential position, also in multi-family buildings. Advice of heating installers is often biased towards fossil heating systems. Alternatives such as heat pumps are rarely discussed.

In *Spain*, in the building sector there is a strong dependence on fossil paths, and it is only recently that political frameworks have changed in favour of promoting renewable energy technologies. But still, renewable energy funding policy is less elaborated compared to Germany or Switzerland. Compared to other EU countries, building and apartment owners have only little economic capacity, and so the upfront costs play a major role for many residents. Direct savings on investments are seen as more important than long-term savings through lower operating costs. Central heating and cooling systems are generally not yet very widespread. A reason for this is a strong desire for individual heating and cooling solutions for each flat. Being able to consume as much heat or cold as personally desired without thinking about the immediate costs is seen as an expression of "quality of life". Hampering the change to larger centralized heating and cooling systems in multi-family buildings.

Norway abounds in electricity from hydropower, and electricity prices are very low. Low cost of electricity offers a great advantage and a huge potential for heat pump deployment in Norway. But residents are accustomed to cheap electricity and the willingness to pay for alternative heating systems is rather low. Water-based heating systems, as used in Germany and Switzerland, are the exception. This hampers the introduction of (water based) tri-generation systems, because they require a shift in heating distribution systems.

Outcomes from the Stakeholder Workshops

RESULTS

Germany

In Germany, the following main challenges regarding a higher market penetration of heat pumps in multi-family buildings were identified

- High planning and coordination effort
- High investment and upfront costs
- Shortage of skilled workers, training and deployment
- Electricity price and electricity market
- Complexity of the planning and implementation process for investors and developers

With regard to the *high planning and coordination effort*, participants emphasised that for proper planning, an understand-

ing of the overall system is required. Especially when installing heat pumps in existing buildings, proper dimensioning is important. This requires an exact and elaborate calculation of the heat demand of the building.

The following action steps were identified to best tackle the challenge of high planning effort:

- A training offensive should be launched to enable professional associations and manufacturers to better understand heat pumps and acquire the knowledge they need to install heat pumps.
- Manufacturers should align heat pumps more with the needs of installers and design them to be more standardized and easy to install.
- Installers should be provided with a planning manual with detailed operating steps, including a catalogue of building types and suitable heat pumps systems.

In order to overcome the barrier of *high investment and upfront costs*, it was raised that installation costs must be considered holistically by taking into account the entire life cycle of heating and cooling systems. In the case of refurbishment, not only additional radiators or adding an underfloor heating are a significant cost factor from an investor's point of view, but also the insulation of the building envelope. However, on the other hand, this can decrease costs of heat pump itself: better insulation will reduce the energy demand, thus a smaller, less expensive heat pump will be required. The following steps were suggested to tackle with

- Adequate planning for the entire building must be carried out, whereby the heat demand of the building must be determined individually in order to be able to calculate the appropriate dimensioning of the heat pump and potential additional costs.
- Planning should be carried out by an independent energy consultant, who furnishes a manufacturer-independent expert opinion and calculates the life-cycle costs for different scenarios, including future price increases for fossil fuels.
- Awareness should be raised among building owners' that good planning saves money rather than being a cost factor.

Switzerland

In Switzerland, the deployment of heat pumps is more advanced compared to many other countries, which is why the discussion of the challenges focused more on the specific case of solar-ice systems. The following issues were seen as the most urgent challenges concerning renewable heating and cooling systems:

- high planning and coordination effort
- investment and upfront costs
- and shortage of skilled workers

With regard to the *high planning and coordination effort*, it was emphasised by participants that building owners and architects need practical examples of solar-ice systems so that they can build confidence in the technology. Further, they need comparative offers from which they can choose. As another problem it was discussed that architects are not remunerated for the extra work and prior research they have to do on such innovative systems. In particular, the following actions were suggested:

- More demonstration sites need to be built to enhance confidence in the technology.
- Where such demonstration sites already exist, they need to be better promoted in order to significantly increase the awareness of such systems across relevant stakeholder groups.
- Extra work done by the construction management, architects or planners must be remunerated.

With regard to the *investment and upfront costs*, it was pointed out that the installation costs must be considered holistically by taking into account the entire lifecycle of heating and cooling systems but also buildings. Opinions differed on the time horizons for which lifecycle costs should be calculated. Periods of more than 20 years appear not very attractive for investors. Another challenge is the tenant-landlord dilemma, which will not be resolved by a lifecycle assessment alone. In order to tackle with this challenge the following suggestions were made:

- Change in tenancy law is needed to adequately take into account investment costs for heat pump systems and clear regulation under which conditions landlords can pass on costs of investments to tenants.
- Depreciation and tax breaks for large investments in energy efficiency and heat supply should be extended, e.g. by staggering tax deductions over several years.
- Funding for innovative heating and cooling systems that combine several technologies (e.g. heat pumps, solar thermal and PV), should be increased, as well as support for business models such as energy contracting.

Spain

The Spanish stakeholders rated the following topics as main challenges:

- Investment and upfront costs
- Regulatory and administrative barriers
- Shortage of skilled workers
- Lack of available space for heat pumps in densely settled urban areas

According to the views of the stakeholders, the following steps could help tackle the barrier of high upfront costs:

- Proposals for heating and cooling systems based on heat pumps should include detailed life cycle assessment, including operating costs, to allow a fairer comparison of systems and avoid an un-due focus on investment costs.
- Life cycle assessments should also include refrigerants, e.g. their global warming potential.
- Awareness raising of all relevant stakeholders should be done as well as improved dissemination of knowledge about the benefits and opportunities of heat pumps to enable better decision making.

Norway

The participants of the stakeholder workshops in Norway ranked the following topics as key challenges that hamper a better adoption of heat pumps:

- Lack of ecological awareness
- Investment and upfront costs
- High planning and coordination effort
- Missing water-borne heating
- New building code

The lack of ecological awareness was highlighted as a major challenge, as many homeowners do not care what heating technology they use or which refrigerant it contains as long as it is legal and cost-effective. In Norway, heating is predominantly powered by electricity, which is commonly understood as "green". Therefore, for the Norwegian population heating is not seen as an urgent environmental issue, which means that there is no incentive to switch to renewable and more environmentally friendly heating systems.

The following action steps on how to best tackle the challenge were worked out by the group:

- A labelling system should be introduced that transparently maps the environmental impact of heating systems and thus that of houses, so that heat pumps systems with natural refrigerants receive a better rating.
- Before building a house, owners should declare which heating system they choose and why not a more environmentally friendly one.
- For better awareness raising and to demonstrate that it works, public actors such as schools should step forward.
- Not only positive incentives should be set but also penalties introduced.

Overall findings

In terms of the overall objectives, the drivers and barriers identified in the stakeholder interviews were validated and affirmed during the four country-specific SWS. This applies both to the ten preselected challenges, none of which was considered irrelevant by the stakeholders or even suggested for removal, and to the modified or added answer options. Aspects from all three categories of barriers and drivers were vividly discussed in all SWS.

For example, "investment and upfront costs" were found among the key challenges in three out of the four country workshops as well as "shortage of skilled workers" and "high planning and coordination effort". As already shown in the interviews, very similar challenges were discussed in Germany and Switzerland, although the proposed solutions varied due to different market situations and stakeholder constellations. The important role of upfront costs, already evident for Spain in the interviews, was likewise confirmed in the stakeholder workshops. And the Norwegian stakeholder workshops could also reaffirm a lack of environmental awareness as a major challenge in their country.

Another validation of the interview results are the changes and additions to the answer options, as they are a clear indication of country specificity. This applies in particular to the issues of "shortage of skilled workers, training and deployment of skilled workers", and "electricity prices and electricity market" in Germany, "regulatory and administrative barriers" in Spain, and "lack of water-borne systems" in Norway.

With the joint elaboration of the action steps and the stakeholders to be activated for this purpose, numerous ideas and practical suggestions for improvement were developed in all stakeholder workshops. In many cases, these corroborate the incentives elaborated from the interviews. This includes, for example, the frequently made argument that the economic efficiency of heat pump systems should be considered over the entire life cycle, or the proposal to support new business models such as energy contracting. It was also suggested that the complexity of such systems and their components should be reduced and that they should be easier to install. Especially in Germany and Switzerland, the significance of heating installers became evident once again. Further qualification for the installation of heat pumps but also awareness raising across all stakeholder groups were frequently mentioned aspects in the stakeholder workshop.

With regard to the third objective of the workshops, it became clear that the country-specific framework conditions are very different. This concerns various (future) market developments, political legislations, funding availability, geographical and weather conditions as well as cultural contexts. For TRI-HP systems, it is therefore recommended to consider these non-technical aspects at an early stage of development.

Conclusions and recommendations

Even though the number of participants in the stakeholder workshops does not allow for representative conclusions, each of the suggestions for improvement and recommendations for action from the national workshops can be checked for plausibility and transferability. As this shows, none of the action steps seem to be categorically valid only for the country in which they were developed. For example, the idea that the time and effort required to adequately plan an energy-efficient and cost-efficient heat pumps system should be remunerated was mentioned in one way or another in several interviews and workshops. Addressing this apparent need, e.g. by simplifying the systems and providing easy-to-use planning tools that significantly reduce planning effort and thus planning costs, should be considered in the development of trigeneration systems. Moreover, topics and challenges such as raising awareness or better qualification of installers were recurrently discussed in stakeholder workshops even if they were not selected as major challenges in the voting before. This reflects the complex interdependencies that exist between the challenges and why it is problematic to look at them in isolation from each other.

Approaching the challenges "holistically" was a view that was put forward repeatedly by many stakeholders in both interviews and workshops. Ultimately, this could explain why the action steps, which were all discussed and evaluated against the background of different challenges regarding the common vision, seem to be largely compatible with each other.

All results developed in the stakeholder workshops can be understood as stimulating contributions for enhancing stakeholder' acceptance of heat pump systems. Any measures and

actions to improve the framework conditions for market acceptance of advanced heat pump systems – such as new funding instruments, qualification offers or communication activities – should therefore take this holistic perspective into account. To enhance the acceptance of heat pump systems among key stakeholders, their different needs and expectations as well as key national challenges should be included in communication and dissemination approaches.

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