Ref. Ares(2021)1539740 - 28/02/2021

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources |

Social acceptance of innovative RE H/C systems: barriers, hindrances, drivers and incentives

Deliverable number: D2.2

Version 1.0

Funded by the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

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Project acronym:	TRI-HP
Project URL:	http://www.tri-hp.eu
Responsible partner:	ISOE
Deliverable nature:	Report (R)
Dissemination level:	Public (PU)
Contractual delivery date:	28th February 2021
Actual delivery date:	28th February 2021
Number of pages:	45
Keywords:	Stakeholder acceptance, renewable energy, heating and cooling technologies, social barriers, social drivers
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Revision History

Date	Version	Changes
February 28, 2021	v1.0	1st version submitted to EC

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Executive Summary

Deliverable 2.2 presents the results of Task 2.3, “Social acceptance of innovative renewable heating and cooling (RE H/C) systems: barriers, hindrances, drivers and incentives”. This task is part of TRI-HP’s work package 2 (WP 2) which has the overall objective to explore potential social implications of TRI-HP systems and improve the stakeholders’ acceptance towards these systems. Particular emphasis is given to market acceptance in order to understand potential barriers and hindrances for the adoption of TRI-HP by market participants.

In Task 2.3, interviews with experts in Germany, Switzerland, Spain and Norway were carried out to understand and determine barriers and drivers that influence the acceptance of (RE H/C) systems. The focus is on those market participants who are key stakeholders for adopting RE H/C systems, including:

- 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 H/C systems in buildings (architects, HVAC consultants, building engineers, etc.)
- Experts for the successful installation of H/C systems (Installers, tradesmen, plumbers etc.)
- Manufacturers and distributors of HP systems
- Building or facility managers in charge of operating and maintenance of H/C systems

The in-depth investigation of stakeholder views covered a broad range of topics: economic-financial aspects, issues related to the practical implementation and feasibility as well as psychological, socio-cultural and organisational aspects. Risks and safety concerns, standards and regulations and the importance of different stakeholder groups are further topics which were explored in the interviews. In order to understand how these topics and concerns may vary according to differing basic conditions, the empirical investigation took climatic, geographical, regulatory, market and cultural conditions in four European countries into consideration.

Thirty-six expert interviews were conducted in Germany (DE), Switzerland (CH), Spain (ES) and Norway (NO). Due to the COVID-19 pandemic, most of the interviews could not be realised face to face, as initially planned, but were held by telephone. Potential interviewees were identified, using different sources: internet research via search engines, publicly accessible contact portals and personal networks of TRI-HP project partners. Finally, numerous contact recommendations were made by the interviewees themselves. All interviews were conducted between March and November 2020 by ISOE. An overall interview guideline was developed by ISOE which was translated in national languages. Data management and evaluation were carried out exclusively by ISOE. All interviews were fully transcribed and coded with the MaxQDA analysis software.

The analysis yielded rich findings on barriers and drivers which impede or foster a market uptake of RE H/C systems. High investment, upfront costs and additional costs, especially if refurbishment measures are required, were the most frequently mentioned financial hurdle for RE H/C systems such as TRI-HP. High operating costs which are closely due to electricity prices were seen as another barrier, because they reduce the cost effectiveness of RE H/C systems. 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).

Poor energy efficiency standards of existing multi-family buildings (MFB) have often been identified as an important practical barrier that impedes a broader adoption of RE H/C systems in this segment of the building market. Many stakeholder held the view that an efficient operation of HP systems requires expensive and disruptive measures such as insulation of the building façade or the installation of underfloor heating. An accurate

design of RE H/C systems and the need to adapt these systems to user behaviour profiles were seen as another major challenge, especially with regard to configuration of the individual components, and quality control.

Another major barrier is the shortage of qualified installers, who were described as a “bottleneck” in many countries. Qualification and training paths as well as the business model of many heating installers are still strongly rooted in fossil technologies, hampering a swift decarbonisation of the heating sector. The extensive technical and practical knowledge required for planning, implementation, operation and maintenance of RE H/C systems was identified by many stakeholders as a major challenge for broader acceptance,.

In the interviews, many drivers and incentives were mentioned that could enable and support a broader market acceptance of RE H/C systems. The low operating costs of RE H/C systems and their reliance on basically inexhaustible energy sources were emphasised by many interviewees. 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 RE H/C systems and increase social acceptance of this technology. Maximising self-consumption of RE generated on site – as is the case with TRI-HP – is considered a very effective means of keeping operating costs as low as possible and becoming largely independent of the electricity market. Innovative business models such as energy contracting can ease the burden of high upfront costs and reduce financial risks for property owners.

A higher standardisation of HP 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, an HP with PV and electrical storage would be appreciated by investors and installers.

Many stakeholders highlighted the importance of non-technical aspects. Awareness raising and trust building among end users and professional actors are key to increasing social and market acceptance of RE H/C systems. Prevailing prejudices and rumours among end users, heating installers and architects must be countered with transparent information on the benefits of RE H/C systems. 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 energy production.

The expert interviews show that in all countries with the exception of Norway, the heating sector still sticks to fossil business models and path dependencies, and a decarbonisation of the residential building sector is only in its early stages. Nevertheless, the uptake of HPs is gaining momentum in some countries and market segments. In Germany, existing laws, regulations and funding conditions relevant for the market diffusion of RE H/C were assessed as basically favourable. A critical major bottleneck is seen to be the lack of sufficiently qualified installers. Existing offers for vocational training and further qualification are hardly used by tradesmen and installation businesses. High prices for electricity in Germany can lead to high operating costs unless a high share of self-sufficiency with on-site generated electricity is achieved. In Switzerland the HP System Module was highlighted as a successful quality standard which could serve as a best practice example for other countries as well. The HP System Module includes a standard for the planning, construction and commissioning of HPs (until ca 15kW), certification, binding procedures, and performance guarantees, easy-to-understand documentation and regular quality checks. The adoption of the HP System Module is supported by specific funding conditions.

In Spain RE funding policy is still less elaborated compared to Germany or Switzerland. Building and apartment owners have only little economic capacity, and so the upfront costs play a major role for many residents. Direct savings are often preferred over long-term savings. In addition, extensive H/C systems are generally not yet very widespread, partly because there is a very individualistic heating and cooling culture, with a strong desire for individual H/C solutions for each flat.

Norway abounds in electricity from hydropower, and electricity prices are very low. The country has a huge potential for HPs due to cheap electricity. Heating systems are predominantly based on electricity and cooling demand is low due to the climate. Moreover, since operating costs are low, a heating culture prevails in which it is not very common to save energy. For complex RE H/C systems such as TRI-HP this can be a hurdle, as the population's willingness to pay for alternative heating systems is rather low. Advanced sector coupling with a high share of e-mobility offers additional opportunities to integrate smart RE H/C systems in the energy grid.

List of acronyms

ASHP	air source heat pump
COP	coefficient of performance
GSHP	ground source heat pump
H/C	heating and cooling
HP	heat pump
HVAC	heating, ventilation, air conditioning
MFB	multi-family building
NR	natural refrigerant
SHAC	sanitary, heating, air conditioning
PV	photovoltaic
RE	renewable energy
RE H/C	renewable energy powered heating and cooling
SFB	single-family buildings
ST	solar thermal

1 INTRODUCTION

The overall aim of the TRI-HP project is to develop tri-generation systems providing heating and cooling (H/C), as well as electricity for multi-family buildings (MFB). These systems are based on electrically driven heat pumps (HPs) with natural refrigerants (NRs), using multiple renewable heat sources and thermal storages. The proposed systems make use of photovoltaics and electrical batteries to increase self-sufficiency.

The focus of WP 2 is on the social impacts of TRI-HP systems. Its main objective is to analyse and identify the interests and needs of end users and stakeholders in relation to TRI-HP systems in different countries to understand and determine key stakeholders' acceptance of these systems.

Deliverable 2.2 presents the results of Task 2.3, "Social acceptance of innovative RE H/C systems: barriers, hindrances, drivers and incentives". For this task, an in-depth empirical investigation of factors affecting the social acceptance of renewable energy technology was carried out. The investigation took as its starting point the results of a literature review exploring which key social and contextual factors could promote or impede the further development and upscaling of innovative RE H/C systems (see Deliverable 2.1).[1] As a result of this review, it was possible to identify barriers, hindrances, drivers and incentives in connection with such systems as perceived by relevant stakeholder groups.

In Task 2.3, these topics are further explored in more detail. Interviews with different stakeholders in Germany (DE), Switzerland (CH), Spain (ES) and Norway (NO) were carried out to understand and determine barriers and drivers that influence the acceptance of renewable heating and cooling systems in these four countries. The focus is on market participants that can be considered as key stakeholders for the adoption of RE H/C systems. According to Freeman et al., we understand stakeholders as any people or groups of people who can affect or are affected by the achievement of a project and organization objectives (Freeman et al. 2010).[2] In the case of RE H/C cooling systems, the following persons and groups are considered as key stakeholders, having immediate influence on the decision-making process, installation and maintenance of innovative RE H/C systems. These groups include:

- 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 H/C systems in buildings (architects, HVAC consultants, building engineers, etc.).
- Experts for the successful installation of H/C systems (installers, tradesmen, plumbers etc.).
- Manufacturers and distributors of HP systems.
- Building or facility managers in charge of operating and maintenance of H/C systems.

Furthermore, the in-depth investigation is taking into consideration climatic, geographical, regulatory, market and cultural conditions in four European countries (DE, CH, ES, NO). The aim is to understand how topics and concerns may vary according to differing basic conditions. 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, and opening up new opportunities for RE H/C systems. However, the national differences in the political frameworks for a transformation of the building sector is giving

[1] Friedrich and Stieß (2019): Social issues of novel renewable energy heating/cooling systems. http://doi.org/10.5281/zenodo.3763715

[2] Freeman, R.E.; Harrison, J.S.; Wicks, A.C.; Parmar, B.L. and de Colle, S. (2010): Stakeholder Theory – The State of the Art. Cambridge University Press, New York

rise to differing options and possibilities for building owners and other market actors. In order to examine these topics more closely, semi-structured qualitative interviews were conducted with representatives of the three groups of market actors in the four countries studied. Among the experts interviewed were owners of MFBs, architects, heating ventilation and air conditioning (HVAC) consultants, engineers, heating installers, HP manufacturers and distributors.

The report is structured as follows: first, the methodology and the empirical sample are explained, followed by the general findings from the expert interviews which apply for all investigated countries. These include the main economic–financial, practical, psychological, socio-cultural and organisational barriers and drivers that have been identified. Further sections present findings on the role of end users and key stakeholders, risks and safety issues, and the assessment of standards, regulations and laws. Country-specific findings form the content of Section 4. Conclusions are provided in the last section.

2 METHODOLOGY

Thirty-six expert interviews were conducted in four countries: Germany, Switzerland, Spain and Norway. Due to the COVID-19 pandemic, most of the interviews could not be realised face to face, as initially planned, but took place by telephone. With the consent of the interview partners, the interviews were recorded and then transcribed. The average length of an interview was 74 minutes, so that the total length of the audio material of all interviews exceeded 44 hours. The transcriptions and their translations comprise more than 500 pages in total.

Table 1 shows the structure of the sample by country and stakeholder group. Interviewees were selected according to their assignment to the user and stakeholder groups that were identified as relevant to the implementation and market uptake of TRI-HP systems (see Introduction). During the recruitment process, care was taken to ensure that representatives of the groups were distributed as evenly as possible in all countries. Efforts were also made to ensure that the interviewees came from a variety of regions within the countries surveyed, covering different *Bundesländer* (DE), *Kantone* (CH), *Comunidades Autónomas* (ES) and *Landsdeler* (NO) as units of reference. The average age 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.

Stakeholder	***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 1: Primary assignment of stakeholders

Structuring the target sample according to the primary stakeholder group assignment was helpful for recruitment purposes. However, during the process of data collection and evaluation, it became clear that, in practice, the affiliation of the interviewees to a distinct stakeholder group was rarely exclusive and, in many cases, interview partners could be assigned to more than one stakeholder group. For example, one interviewee was a heating installer by training, who had completed a postgraduate degree in mechanical engineering and now manages the family heating business that he took over from his father. Another example is an architect who is also a property owner and landlord. Table 2 shows how these multiple spheres of competence, i.e. the assignment of several areas of expertise to each interviewee, was dealt with.

The 36 experts were recruited using different strategies. First, extensive internet research was carried out via search engines, for example Google. The combination of certain search terms such as technological components and stakeholder groups (e.g. "heat pump" and "architect") led to search results which, upon follow-up, often resulted in publicly accessible contact addresses. Further results were obtained via publicly accessible contact portals such as websites of professional associations or LinkedIn. The personal networks of TRI-HP project partners involved in this work package were also an indispensable starting point for recruitment. In addition to ISOE, numerous valuable contact recommendations from TECNALIA, IREC, SPF-OST, NTNU and REHVA were helpful in finding suitable interview partners. Finally, numerous contact recommendations were made by the interviewees themselves upon completing their own interviews.

Stakeholder	***DE***	***CH***	***ES***	***NO***	***total***
House owner, investor, property manager	4	2	2	3	**11**
Technical consultant, project planner	4	3	3	2	**12**
Manufacturer, distributor	3	1	2	1	**7**
Installer, tradesman	5	1	2	1	**9**
Architect	3	2	1	1	**7**
Engineer	7	6	5	4	**22**
Total	**26**	**15**	**15**	**12**	**68**

Table 2: Stakeholder expertise of all 36 interviewees

The first contact was usually established by email. An attached information sheet informed the recipients about the TRI-HP project, i.e. its objectives, content, the consortium and how it is funded. In addition, it was explained to them why they were being contacted and how their personal data would be secured. In very rare cases, respondents replied quickly to this e-mail, stating their agreement to an interview. More often, a phone call was necessary in a second step if the phone number was known. The success rate of completed interviews based on the number of candidates originally invited to take part was at least 4:1, but this varied significantly between countries and stakeholders. It is important to note that only a minority of respondents had carefully studied the material provided on the TRI-HP project and were therefore able to comment on it specifically. The vast majority referred to aspect(s) of RE H/C systems based on electrical HPs, of which they had professional experience. For example, many stakeholders stated that they had no experience with ice storage or smart control systems.

All interviews were conducted by ISOE in DE and CH between March and November 2020, with support from SPF-OST in CH. In ES and NO, external professional market researchers were entrusted with the interviewing under the guidance of ISOE. A universal interview guideline developed by ISOE was used in all countries. Care was taken to ensure the questions covered all the different topic areas and addressed the different types of knowledge. This means that not only technical knowledge was surveyed but also specific experiences of the experts, for example with certain processes. The final guideline consisted of around 20 questions, depending on the stakeholder type. While most of the questions addressed all stakeholders equally, there were special questions for each stakeholder group. The topics covered included the items listed in Section 3, which were discussed alongside those technologies relevant for TRI-HP systems such as HPs, storages and smart control (see Deliverable 2.1). The guideline was tested twice with project partners and revised before the first interview took place.

The specific focus for each interview was selected according to the expertise of the interviewee. Ensuring coverage of a broad range of topics while addressing certain issues in greater depth proved to be challenging but doable. In Spain and Norway, the guideline was translated into the respective national language. For Germany and Switzerland the interviews were held in German.

Each interview was preceded by a briefing, in which the interviewees were guaranteed anonymity and had the opportunity to ask questions. The audio recording was then started and the oral consent form read out. After switching off the audio recorder, there was a short follow-up conversation in which the interviewees were asked about their age and further contact recommendations. In many of the briefings and follow-up talks, which together often lasted up to half an hour, additional interesting aspects were addressed. This information was documented in individual protocols and also considered in the data analysis.

Data management and evaluation were carried out exclusively by ISOE. All interviews were fully transcribed and coded with the MaxQDA analysis software. The thematic clusters or codes used to structure the transcripts included the topics listed in Section 3. Other check codes were used to monitor whether certain content was appropriately covered. Such content included not only the technological components relevant for TRI-HP but also the often-made distinction between new and refurbished MFBs. In summary, the codes were assigned to the respective text sequences in the interviews more than 3000 times. 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. It was then possible to filter the generalised results with regard to their overarching or country-specific significance. For example, the conditions for RE funding were assessed far more unfavourably in Spain than in the other three countries. At the same time, a critical examination of individual statements and evaluations of the stakeholders interviewed was carried out by comparing them with each other. As with the country comparison, this made it possible to identify similar cases and relate them to those with different characteristics. Questionable individual statements by experts that could not stand up to subsequent scrutiny were not included in the evaluation.

3 General Results

3.1 Important Notes on How to Interpret the Results

As described in the methodological approach above, the **results presented here are the product of qualitative data collection and qualitative data analysis**. First of all, this means that the **results are not representative**. The findings represent the variety of typical views and opinions among different stakeholder groups, but do not display a quantitative distribution of these opinions. It should also be noted that the small target sample does not allow for an exhaustive collection of all possible views – neither with regard to the countries studied nor with regard to the stakeholder groups investigated. The main objective – and the particular strength – of the qualitative methodology applied is to gather knowledge based on professional experience, and to elaborate stakeholder-specific perspectives, practices and contexts of reasoning.

Secondly, this also means that the 36 interviews conducted were based on a structuring guideline, not on a standardised questionnaire. The questions were formulated in such a way that the interviewees were able to respond freely and thus help shape the course of the interview. In turn, it was possible for the interviewers to ask more in-depth questions at any time, or even introduce completely new topics, for example if new interesting aspects were raised by the interviewees. As a consequence, **each interview was as unique as the interviewees themselves**, with different expertise, focal topics and opinions. A permanent comparison of the interviews with each other, focusing on the project-relevant topics on the one hand and new topics that emerged from the interviews on the other, eventually allowed **similarities and differences to be carved out**.

While interpretation was quite easy in the case of certain items of content, some statements or evaluations explicitly shared by a number of experts were more challenging to analyse. A characteristic of guideline-based, open interviews is that **many statements or evaluations tend to be implicit**, i.e. based on prior assumptions and background knowledge that are rarely elaborated. For this reason, it was an important analytical step to always interpret the given indications and reference points in comparison to all other interviews in order to obtain a conclusive overall picture. For a qualitative analysis, even **individual statements can therefore be relevant and included in the overall assessment if they prove to be valid and plausible**. They were taken into account in the overall evaluation as long as they did not contradict the content of comparable interviews. This was the case, for example, when a certain aspect was discussed in great depth in one interview but the same intensity was not reached in other interviews. However, the subsequent comparative analysis showed the statements to be coherent with each other. Thus, the findings presented in the following sections do not represent **objective facts but should be understood as shared views or opinions of experienced experts** on certain issues with regard to the social acceptance of RE H/C systems. The findings reflect **valid and reliable evidence to support specific statements, assessments or conclusions**. As such, they form the basis and starting point for further inquiry and deliberation in the stakeholder workshops (Task 2.4), which will draw on the main findings of this empirical investigation.

The following sub-sections of Section 3 represent the **synthesis of all findings** derived from the analytical process described. They focus predominantly on commonalities between countries and stakeholders. Country-specific differences will be presented later in Section 4. Further reading should take this into account.

To better understand these generalised findings, we have selected quotes from specific interviewees which were particularly illustrative of **a typical stance of a stakeholder group**. Each quote is provided with information on country, gender, age and assigned stakeholder group.

> At the end of each sub-section, the results are briefly and concisely compiled in a grey box like this. These summaries are made explicitly with reference to the potential relevance for TRI-HP systems.

3.2 Barriers and Hindrances

The distinction between the different barrier categories already made in D2.1 of the TRI-HP project are taken up again here and developed further. The first category includes economic–financial barriers that can hinder social and market acceptance of RE H/C systems, including TRI-HP systems. In this category, investment, operating and maintenance costs are included, but also economic viability or the distribution of costs and benefit. The second category covers all aspects of the practical implementation and feasibility of innovative RE H/C systems. This involves not only technological components but also other material contextual conditions such as building characteristics. The third category describes non-monetary and non-technical barriers and hindrances. They are related to the "human factor", including, for example, the understanding or handling of complex systems such as TRI-HP, the cooperation between different stakeholders on the construction site, or country-specific heating cultures. It should be noted that the categories are not necessarily mutually exclusive, since barriers in one category may affect other categories. For example, the inadequate planning and installation of a RE H/C system will detract from the technical performance and also curtail the economic efficiency of the system.

3.2.1 Economic–financial barriers and hindrances

In all expert interviews, the **high investment costs of RE H/C systems compared** to fossil heating systems were mentioned as the biggest economic obstacle for wider market penetration and acceptance. Investment costs encompass not only the expenditure for the HP but also **costs for additional installations and components required to make the system work.** In particular, the drilling costs in the case of GSHPs, possible costs of excavation for the ice storage if it cannot be placed in the basement of the MFB, or the elevation of the PV modules were mentioned by different stakeholders across all countries. Especially for densely populated urban areas where space is scarce and difficult to access, interviewees emphasised that **drilling and excavation can be very expensive** under certain (local) conditions.

In **existing buildings**, in particular, **a shift to RE H/C systems** can incur additional costs for **requested expert assessments, permits, levies or taxes**. Moreover, **maintenance and servicing costs** are to be considered, which may differ greatly for the respective technology components. In complex RE H/C systems such as TRI-HP, it is essential to carry out **regular quality control, monitoring and maintenance** (e.g. periodic cleaning of pipes and filters) for proper and efficient operation.

The high expenditures for RE H/C systems **confront investors** with the problem of **high upfront costs**. This hurdle can persist even when funding programmes are available, and it varies widely across countries, according to funding conditions. If funding is only provided once installation is completed, the investor must pay the investment amount upfront. This then becomes problematic if subsidies are only disbursed months or even years later.

The **basic funding and financing conditions** were assessed quite differently in the countries surveyed. For example, funding conditions were assessed less favourably in Spain than in Switzerland in this regard (see Section 4). A heating system distributor from Spain described the application for funding based on his experience as follows: first, the applicant applies to a regional energy institute to get a grant for a project. It can take up to 1.5 years for all documents to be checked, the project approved and the grant awarded. After that, it can take another 1 to 2 years for the grant to be paid out. For this, an invoice must be submitted upon completion of the work. This makes access to funding more difficult, especially for smaller companies and those without sufficient capital.

The problem of high upfront cost was considered even more urgent when RE H/C systems are installed in existing MFBs. As mentioned by many stakeholders, additional costs may arise if measures to **reduce the total energy demand of the building** and to **adapt the heat distribution to a lower flow temperature supply system** have to be carried out first. Investors, architects and planners in Germany and Switzerland, in particular, often emphasised that, depending on the type of building, such measures are in many cases a necessary prerequisite for the technically and thus economically efficient operation of HP systems in MFBs that are in need of renovation. Therefore, these potential **additional costs need to be considered before installing RE H/C systems in existing buildings, as they increase upfront costs.**

The **risk of poor energy efficiency** was highlighted by several stakeholders as another important barrier that can impact economic efficiency of the system. While HPs require higher initial expenditure, they use energy very efficiently once they are installed, and most of the energy for heating and cooling is taken from the environment without having to pay for it. However, it was frequently mentioned that **economic efficiency was dependent on parameters such as appropriate design, careful installation or initial line-up of the system**. In particular, many ASHPs are not installed properly and do not achieve the projected annual coefficient of performance (COP), resulting in an overall distrust in the performance and economic viability of HPs (see also below the sub-section on psychological, socio-cultural and organisational barriers and hindrances).

In some interviews, respondents raised the point that most conventional HPs only achieved a sufficient level of performance if the difference in temperature was on the moderate side. In regions with a cold climate or in buildings with poor insulation, the efficiency of most HPs was considered somewhat low. Advanced HPs, such as those running with NRs like CO_2, were mentioned as an alternative, because they can work at higher temperatures, but they are only provided by small and innovative enterprises and have not yet reached broader market penetration.

Energy costs were mentioned as another hurdle, as they also determine when an H/C system based on electric HPs will achieve a **return on investment**. HPs draw most of their energy for heating and cooling from the environment. But to what extent this leads to **cost savings compared to a conventional heating system** and how quickly the new **system pays off its investment** depends on energy prices, and varies considerably from country to country. For example, in countries, where electricity costs are rather high compared to natural gas, a shift towards a RE H/C system appears less attractive from an investor's point of view because the remaining costs for electricity are relatively high. But **an overly low electricity price can also be an obstacle to investment**, as the example of Norway shows. If heating is already provided by a system that runs on cheap electricity which is mainly generated from renewable sources, the expected operating cost savings do not make much difference from an economic point of view and render an investment in a system with PV, ST, ice storage, etc. less appealing (see Section 4.4).

The **temporal distribution of costs and gains** can pose an additional economic barrier for RE H/C systems, in particular in MFBs. The so-called **tenant–landlord dilemma** describes the lack of incentive for landlords to bear the higher investment costs compared to a fossil system when they are unable to reap a personal benefit from the lower operational costs which are reducing the energy bills of their tenants. The tenant–landlord dilemma refers not only to new buildings but can also emerge when fossil heating systems are replaced by RE H/C systems. A similar problem arises when an investor acts as a developer who sells a new building to a third party. Some of the interviewees pointed out that an investor sees **only little incentive to adopt a lifecycle perspective** and calculate costs and benefits over the whole lifecycle of the heating system, because this might reduce their gains when selling the building.

Experts who are specialised in the planning and implementation of RE H/C systems pointed out that these systems require a **new approach to planning and implementation** compared to conventional fossil heating systems. This also has economic implications. Unlike fossil heating systems, the efficiency of **HPs is more sensitive towards the conditions of the building and the user profile.** Assessing the appropriate design of the system and its installation requires more information and greater planning effort than installing a fossil heating system. It also requires specific skills and training, and entails significantly **greater effort for planning** and – for more complex systems – also **more effort for coordinating the installation work**. All this reduces the installer's profit compared to installation of a fossil heating system. In some countries or regions, subsidies are only granted if the installation is assessed by an energy expert. In some interviews, cases were reported that this can then increase the costs to such an extent that it is no longer worth applying for subsidies. Therefore, for many smaller projects, this additional effort results in homeowners or investors not applying for funding.

High investment, upfront costs and additional costs, especially for refurbishment measures that may be required in existing buildings, were the most frequently mentioned financial hurdle for RE H/C systems such as

TRI-HP. Additional costs for drilling and excavation, such as that required for an ice storage, contribute to the reduced competitiveness of RE H/C systems. High operating costs which are closely linked to electricity prices were seen as another barrier, because they reduce the cost effectiveness of RE H/C systems. This risk increases when HPs 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). Since complex systems such as TRI-HP require more planning and coordination effort, it is necessary to factor in additional costs for energy management, quality control, maintenance, etc.

3.2.2 Barriers and hindrances regarding practical implementation and feasibility

The assessment of this category of barriers and hindrances differs greatly between new and existing buildings. Due to the high energy efficiency of new buildings, the practical feasibility of RE H/C was seen as fairly unproblematic for SFBs and MFBs. To some extent, a challenge in newly constructed buildings was seen in the **need to adapt the RE H/C system to the user profile and projected user behaviour** (see Section 3.4).

The largest and most frequently mentioned barrier, however, was the **poor energy efficiency standards of existing (multifamily) buildings**. Experts from Germany and Switzerland held the view that RE H/C systems could only achieve good efficiency in buildings with a high energy efficiency standard resulting from **good insulation of the façade, roof and windows** (see Sections 4.1 and 4.2). Even though HPs can deliver higher flow temperatures, an improvement of the building's energy efficiency is considered an essential prerequisite for efficient operation, as stated by this project planner and trained heating installer:

> *"There are machines that can also run at 70°C flow temperature, even ASHPs can do that to some extent now. But in my opinion, that is not the solution. The solution would be to start with the house, to optimise it so that the flow temperatures go down, and then to use a well-functioning heat pump again. Just because the heat pump can do it, raise it to 70°C, doesn't mean it's a good solution." (DE, m, 57)*

Improving the energy efficiency of a building before, for example, an old fossil heating system is replaced with a RE H/C system would not only mean more overall costs, but also significantly more planning and implementation effort. It may mean, for example, that **disruptive measures have to be undertaken on the building structure**, such as **replacing old radiators with low-temperature underfloor heating** and laying new pipes. In addition, ventilation may have to be considered, especially if underfloor heating is also used for cooling purposes, as this can lead to the formation of **moisture and mould** in some climates. Additional moisture prevention may thus be required (see Section 4.3). Such measures can be further complicated by the fact that, depending on the age of the building, some of these alterations may not even be possible for reasons of **building preservation orders or other regulations** (see Section 3.8).

A second major hurdle, in particular for MFBs, is **the space required for the installation of all technological components** of a RE H/C system, for example the HP and the heat exchanger. This is especially true in **urban, densely populated settlements with small lots**, or when, as is often the case in Spain, HPs are installed on the roof, where **competition for space** with PV and ST can arise (see Section 4.3). Also, the **ice storage unit requires a lot of space**. A German managing director of a sanitary, heating and air conditioning (SHAC) company commented on the space issue as follows:

"You cannot install a heat pump in every building. I mean, theoretically it is possible, but practically it is not. […] We have also installed HPs in 7-family houses. It's all possible. But at a certain point the building is so large that you don't even know where to put the HP because the property is too small or you don't have sufficient drilling space." (DE, m, 61)

As this interviewee stated, GSHPs can provide a possible solution but they also need **space for the drilling of boreholes**, which is often unfeasible or complicated in an urban context. Further drilling will have to be even deeper and will therefore be more expensive (see above). And, of course, the **use of the ground or groundwater as a heat source or sink usually requires regulatory approval**, which may be an additional barrier to feasibility (see Section 3.8).

From an architectural point of view, the **construction and statics of a building might pose a barrier** that impedes a shift to larger RE H/C systems, in particular when the building was not equipped with a central heating system, before as emphasised by this architect and building engineer:

"[When planning an RE H/C system], don't think about the technological system alone, think about how you're going to integrate it into the architecture. It is important to think about its mass, where to place its technological components, whether the building structure will withstand its weight, where the pipes will go, etc. Everything has a great impact on the architecture." (ES, m, 34)

Another obstacle to practical implementation is the **noise emission from ASHPs**. While the social and psychological implications such as neighbour complaints will be addressed in more detail below, the noise factor also has a spatial dimension, as it plays a role in the choice of location for the outdoor units of ASHPs. If installed improperly, for example on walls or in building corners, the noise volume may increase (see also Section 3.8). Especially, but not exclusively, in densely populated areas, this must also be taken into account from the perspective of **competition for space** – for example if an ASHP has to be installed on the roof of an MFB to avoid possible noise complaints, which is quite common in Spain. This may also limit the **accessibility of the unit for maintenance purposes**.

Further practical challenges, especially for the installation trades, concern **accurate assembly of the various technological components, quality control** of the installation, and the **correct adjustment of the interplay between the system's components**. Interviewees in all countries repeatedly pointed out that proper installation of RE H/C systems is a crucial point, with a **high degree of technological complexity**. The on-site configuration of the individual components was classed as challenging, because **components from different manufacturers are often not truly compatible**. This makes the installation and subsequent readjustment and maintenance enormously challenging, as an architect with an engineering background explains:

"If I look 30 years into the future, I believe that we should actually have PV and ST combined. Then we can get the maximum heat from the roof, produce electricity at the same time and store the whole thing in an optimised way. And integrating an ice storage into the system makes perfect sense to me. On the other hand, it also has to be technically manageable. If I need three specialist engineers to look after my system so I don't get into critical situations, then nothing is gained." (DE, m, 45)

Poor energy efficiency standards of existing MFBs have often been identified as a practical barrier that impedes a broader adoption of RE H/C systems in this segment of the building market. The efficient operation of HP systems requires expensive and disruptive measures such as insulation of the building façade or the installation of underfloor heating. The technological complexity of RE H/C systems and the need to adapt these systems to user profiles were seen as another major challenge, especially with regard to configuration, coordinated interplay between the individual components, and quality control. Other barriers to feasibility relate to the space required for the technological components and boreholes, plus the noise emissions of ASHPs, which amplify, when the installation is not done properly.

3.2.3 Psychological, socio-cultural and organisational barriers and hindrances

This final group of barriers and hindrances to RE H/C systems includes a variety of non-technical and non-material aspects such as a **general lack of awareness of the ecological impacts of non-RE H/C systems**, **knowledge deficits** about the relevant technologies or **ignorance about corresponding funding opportunities**. However, the most frequent mention in all interviews concerns issues arising from the **complexity of these systems,** such as the **extensive technical and practical knowledge** needed for planning, implementation, management, and maintenance of these systems.

The way that users and stakeholders perceive the complexity of an innovative H/C system can lead to a serious barrier: if the understanding, implementation and management of the system is considered too difficult, people may be reluctant to choose this option, despite potential economic benefits. Further non-technical complexity arises from the knowledge and correct handling of the **multitude of funding opportunities, regulations and other basic conditions**.

The implementation of complex RE systems requires specialised expertise and know-how. Many interviewees pointed to a **lack of appropriate expertise and skills among fitters and tradesmen.** In most of the interviews, the heating installer was mentioned as a key actor, since they are often the first contact and the person responsible for putting in the HP (see Section 3.6). In Germany and Switzerland, where water-based heating systems are more common than in the other two countries, the **heating installation trade was even described as the "bottleneck"**, lacking both quantity and quality of skilled workers to install HPs properly (see also Sections 4.1 and 4.2).

Lack of expertise was identified especially in connection with the proper adaptation of the HP to the building, the accurate determination of the demand for heating and cooling, and the correct dimensioning of the heat distribution system (see next section). In Germany and Switzerland, hydraulic balancing was pinpointed as a task often carried out incorrectly by heating installers. The reasons put forward for this were manifold. One dominant line of argument concerned the **path dependencies associated with the professional training and practice** of the heating installers**. Education and training are still focussing on fossil heating systems** and do not impart the knowledge and skills needed for the planning and installation of HP technology such as electrical and plumbing installations, calculation of heat demand, an understanding of the technical specifications provided by HP manufacturers, or the handling of refrigerants, including corresponding standards and safety regulations. When the competence of the heating installers was discussed in the interviews and whether they meet the challenges of HPs, the overall assessment was rather negative. In Germany and Switzerland, especially, many experts stated that the **training has reached an overwhelming level of complexity in terms of theoretical and technical knowledge** (see Sections 4.1 and 4.2). Furthermore, installers need to know about funding opportunities and how to make use of them – for their own advantage but also because many end users expect them to provide information and comprehensive customer advice. However, virtually none of this is taught to them in their professional training. In response to a "feeling of being overwhelmed" that this creates, **most installers stick to what they are familiar with: the fossil heating systems**.

Another expression of this path dependency in the installation industry which can likewise be seen as a major obstacle to change is the **optimised and successful business model** that the trade has established in recent decades, a model that relies strongly on fossil energies. For heating installers, a switch to HPs is not very attractive as it is associated with **new problems, breaks in routine, uncertainties and an increase in unpaid work**. As this business model has been – and still is – very profitable, the need and motivation for further training is deemed to remain low, despite numerous existing offers. Moreover, further training would also entail **additional costs and sales losses due to loss of working hours**, as illustrated in this quote from an interviewee, who himself runs a German SHAC family business:

> *"I think that one of the key factors is the people who bring heat pumps to market. By that, I don't mean the manufacturers who produce them, but us, the installers or tradesmen. I think we are the biggest brakes. That's what I call it. And it's because there are simply many older tradesmen and SHAC business owners [...], who have not received the appropriate further training over the past decades." (DE, m, 30)*

The lack of knowledge about the functioning and requirements of an HP was also noted for other stakeholders such as architects, end users or planners, albeit to a much lesser extent. The common denominator, however, was that **if things get too complicated in one way or another, it can make acceptance very difficult or even prevent it**. For planners and construction companies, this can mean they fear **liability problems if too many companies and subcontractors are involved**, with too many **issues stemming from coordination between the installing trades.** Stakeholders in all countries with experience in the practical implementation of different RE H/C systems have pointed out that **the more fragmented the responsibility, the more difficult the task of quality control** – during construction, operation and subsequent maintenance. Since ensuring quality is of vital importance for the efficiency of these systems, unclear responsibility poses a major hurdle.

For end users such as homeowners and residents, non-technical complexity is also of great importance. For example, the **control of the system interface** should ultimately not be too complicated. As noted by some interviewees who also have experience as landlords, some tenants quickly become overwhelmed if a control unit has too many functions. In the event of a (self-inflicted) malfunction, this then often results in complaints and a technician has to be called. For MFBs, this raises the question of **who sets, manages and regulates system control**. If this is done by an unskilled person, it can have serious effects on the efficiency of the system. In the Swiss and Norwegian interviews, for example, it was mentioned that heating systems in MFBs are usually operated by janitors:

> *"In housing cooperatives, they have a janitor. Janitors are not experts in energy systems, [...] which means that years can go by with poorly functioning heat pumps and energy systems before someone discovers that something should be done. To solve this, you need a regulation that says, for example, that a heat pump connected to a certain type of housing unit must be maintained and that an annual report must be made on its efficiency." (NO, m, 33)*

This **dependence on different user needs and behaviour**, along with the aforementioned coordination difficulties on the construction site, is in turn something that can **deter investors, who see high risks** here. In this regard, interviewees occasionally expressed reservations about complex RE H/C systems such as TRI-HP, since they appear to be very sophisticated and associated with **too many uncertainties**. The effort, costs and risks involved in implementing such systems, including possible building refurbishment for existing buildings, were said to be quite high and something of a deterrent.

Another non-technical barrier is the **issue of noise**, which can lead to social acceptance difficulties, especially in urban, densely populated environments. The problem is aggravated by something known as **"visual noise (pollution)"**, which was mentioned predominantly by German and Swiss experts. It refers to the psychosocial phenomenon of neighbours feeling disturbed by the noise from an ASHP merely on seeing it (when it is not even switched on). However, visibility and audibility can also be barriers to acceptance within buildings.

Finally, this group of barriers and obstacles also touches on the **issue of heating cultures or heating routines**. This aspect was addressed especially in Spain and Norway, stating that residents in both countries have **specific cultural heating routines that may in one way or the other contradict the efficient use of HP systems** (see Sections 4.3 and 4.4).

> Non-technical and non-material barriers and obstacles include among other things the general lack of awareness of the ecological impacts of fossil H/C systems, knowledge deficits and preconceptions about RE technologies, and ignorance about corresponding funding opportunities. Another major barrier is the shortage of qualified installers, who were described as a "bottleneck" in many countries. Qualification and training paths as well as the business model of many heating installers are still strongly rooted in fossil technologies, hampering a swift decarbonisation of the heating sector. The extensive technical and practical knowledge required for planning, implementation, operation and maintenance of RE H/C systems was identified by many stakeholders as a major challenge for broader acceptance. 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 RE H/C systems among heating installers. Fragmented responsibility and difficulties in coordination between planners and craftsmen on the construction site can make quality assurance more difficult and lead to uncertainties, which in turn means a higher risk for investors. When residents and adjacent owners perceive ASHPs as "visual or noise pollution", it can lead to neighbour complaints, in particular on small lots in urban settlements. The prevailing heating cultures of end users can clash with the need to adapt heating routines to low temperature heating systems, thus impairing the operation of RE HP systems.

3.3 Drivers and Incentives

In the stakeholder interviews, a broad range of topics were raised which can help enhance market acceptance of RE H/C systems. The drivers and incentives fall into two categories: those that highlight advantages of heat pumps, for example being able to run without fossil energy and related greenhouse gas emissions, and those that refer to measures and interventions such as special subsidy programmes or a change of regulatory framework conditions with which to further strengthen acceptance. The drivers and incentives mentioned are manifold, but it is important to note that **a suitable driver or incentive was not proposed for every barrier or hindrance** mentioned above. An important insight underlying this research report should also be kept in mind: while **barriers to and drivers for the acceptance of RE H/C systems** can be described separately for analytical purposes, they are in fact closely linked. In the following section, care has been taken to avoid repetition, for example by making cross- and back-references to other sections, but it was nevertheless occasionally necessary to include contextual information for reasons of comprehensibility and readability.

3.3.1 Economic-financial drivers and incentives

The economic benefits of **low operating costs** for RE H/C systems and the fact that they rely on basically inexhaustible energy sources were emphasised by many interviewees. A change in the regulatory frameworks of the energy market and the **introduction or increase of a carbon tax** were mentioned as another major lever that will **improve the competitiveness** of renewables compared to fossil systems.

Operating costs are an important factor in how fast a return on investment is achieved, and few investors are willing to wait much longer than 10 years to see a return. An HP with a high annual COP can help reduce the payback period of a RE H/C system, as it keeps operating costs low. In addition, **maximising self-consumption of the RE generated on-site** is considered a very effective way of further reducing operating costs and **becoming less dependent on electricity prices**. For the remaining share of electricity demand that has to be drawn from the grid, **cheaper tariffs for HPs could provide an additional advantage.** Operating costs could be further reduced if **flexible time-variable tariffs could be used by smart control systems**. Both a high rate of self-consumption and intelligent use of the electricity tariffs available are targeted by TRI-HP systems.

To counteract the higher investment costs compared to non-RE technologies, **public funding, subsidies and financial incentives** were mentioned in all countries as the most effective economic–financial drivers. Funding conditions and measures vary considerably from country to country, as does the assessment of these conditions by the interviewees. In general, subsidies should **increase the economic viability of RE technologies compared to fossil alternatives.** It was often argued that **subsidies for energy-efficient refurbishment measures** could also be beneficial because they **increase the efficiency of RE H/C systems.** This could include, for example, the **funding of low-temperature radiators** that are compatible with HP systems and can be installed in existing buildings with less disruption, making the installation of underfloor heating unnecessary.

Particularly in Spain, it was suggested that **subsidies should be granted directly**, for example as an immediate discount. In this context, interviewees pointed out the key importance of processing applications quickly so that reimbursement does not take up to several months or even years. This issue was also addressed in Germany, with reference to the special difficulties it poses to many small businesses with weaker solvency. Financing schemes such as **low-interest loans** for RE technologies are not available to the same extent in all of the countries studied and for all market participants. For the same reason, some of the investors and homeowners interviewed expressed a desire for much **more straightforward RE financing**, with better marketing of **easy-to-understand information on available funding opportunities and simplified approval procedures**.

The obstacle of high upfront costs can be addressed using **innovative business models such as energy contracting**, which has many advantages for building owners. Firstly, they do not have to **pay the full investment amount in advance**. And secondly, they do not have to **bear the financial risk**, as this is assumed entirely by the contractor, for example if the agreed energy savings have not been achieved at the end of the contract term. Energy contracting involves a **comprehensive assessment of the total costs and revenues over the entire lifetime of the H/C system**. On this basis, according to one energy contractor, and with the appropriate subsidies, **RE H/C systems can be operated economically thanks to low operating and maintenance costs**. It can be profitable in the long run for both contractor and owner (DE, m, 45). Specifically for HPs, this means they are the **lower cost alternative when total costs are considered**. However, not all investors take a long-term perspective of many decades. This is especially true for investors who sell the building after completion, as this project planner explains:

"The big difference is whether the property developer sells or manages the building after its completion. If he sells it, he will only include REs if they increase the market value of the building. Thus, public perception of an efficient building with REs is crucial for how it is valued in the market." (ES, m, 55)

Since the property developer's investment and purchase decision depends on how the market rates energy-efficient buildings, it would be beneficial for the market acceptance of RE H/C systems if energy efficiency and REs were evaluated similarly to, for example, the location of a building. This would increase the value of the property and allow higher mortgages. In some countries such as Switzerland, banks have already developed rating schemes allowing for **higher private mortgages when buildings are equipped with RE technologies.**

Another option that can accelerate return of investment is **profitable feed-in tariffs for self-produced electricity**. Surplus electricity could also be sold at low cost to surrounding buildings to form energy communities. An **exemption from taxes and fees on electricity**, especially for systems with a high share of on-site self-consumption of RE generation, could also be expedient.

For property owners of MFBs, **improved regulations and ordinances on the handling of ancillary costs** can create an incentive to better allocate investments to tenants and so stimulate refurbishments and modernisations. The tenant–landlord could thus be addressed. Another possible solution that can favour the successful implementation of RE H/C systems in MFBs is **cooperative housing projects**, where members share the investment costs and risks, and reinvest capital gains in the project. Here, too, there is more of a **long-term perspective**, in which **not only the return on investment is decisive but also comfort and quality of life**. As pointed out by one expert from Spain, who has managed a large and innovative cooperative project with a RE H/C system from design to construction to management, the joint discussion of all issues and decisions within such a long-term project leads to broader cooperation, which in turn leads to fewer cutbacks in design and quality control. Housing cooperatives, he stressed, encourage **investment in the quality of materials or services**, such as effective building insulation, proper operation by a good technician, and comprehensive quality control measures, which ultimately has a **significant overall impact on the efficiency of the system**. Another expert from Norway confirmed that as follows:

"Housing cooperatives have everything. They are more willing to invest in a better system. And many housing cooperatives upgrade their buildings with a higher standard of insulation: better windows etc., and retrofit heat pump systems, among other things. We have a number of examples for this." (NO, m, 58)

On a neighbourhood level, forms of cooperation such as **energy networks can also lead to cost savings**, for example when several residential buildings share a common ice storage unit. For this, however, RE H/C **systems must be designed more openly** and beyond the system boundary of a SFB or MFB.

And finally, another very important incentive has to do with the **training and qualification schemes available to heating installers** working with HP technology. Many of the heating installers interviewed and experts that work closely with them disagreed that these offerings needed to be expanded. Instead, the problem was seen to lie more on the demand side. A commonly heard explanation was the **lack of effective incentives for heating installers to take up these offers**, as described by this HP installer from Norway:

"People like me often get to a point where the barrier is usually that, if you don't get paid for what you do, it largely comes down to your own interests and use of spare time. Obviously, you can't spend your whole working day trying to increase the market share of heat pumps, when no one will pay you

to do it. And of course, if you can't sell something and make money on it, it's limited how much time you can spend on it. That goes back to the suppliers and the equipment, and the industry. You need to make an effort to promote it and acquire the equipment." (NO, m, 33)

In order to tackle the qualitative deficits of skilled labour, **financial incentives can help entrepreneurs train their employees**. In addition to the cost of the training itself, the cost of lost earnings that arise from the time spent in further training must also be taken into account. The aforementioned **carbon tax** was also listed as an incentive that could lead to increased demand for RE H/C systems from relevant stakeholders and end users, which in turn would more strongly motivate installers to upskill.

In addition to direct or indirect financial incentives for training and qualification for heating installers, **certification in conjunction with the application of existing subsidies** was discussed as another incentive.

The low operating costs of RE H/C systems and their reliance on basically inexhaustible energy sources were emphasised by many interviewees. 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 RE H/C systems and increase social acceptance of this technology.
Maximising self-consumption of RE generated on site – as is the case with TRI-HP – is considered a very effective means of keeping operating costs as low as possible and becoming largely independent of the electricity market. Operating costs can be reduced further through flexible electricity tariffs and intelligent system control.
Innovative business models such as energy contracting can ease the burden 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 RE H/C systems achieve wider market acceptance, as they support a long-term perspective, taking into account the entire lifecycle of an investment rather than primarily seeking a rapid return of investment. Financial 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 were linked to certification.

3.3.2 Drivers and incentives regarding practical implementation and feasibility

In this section, drivers and incentives have been identified that can facilitate the practical implementation of RE H/C systems based on HPs. In this regard, **most stakeholders made** a **clear distinction between new and existing building stock.** A building's **high energy efficiency standard** was considered an important **precondition for the successful implementation and efficient operation** of RE H/C systems. This view was held not only by architects and investors, who have a long-term interest in the building and the H/C system, but also by heating installers and planners. While high standards apply to new buildings where **HPs are already the first choice for heat generation** in countries such as Germany and Switzerland, lower standards apply to most existing buildings. Many interviewees agreed that in most existing buildings **renovation measures** would be needed in order to achieve a satisfactory HP performance. These measures cover everything that **reduces the heat demand of the building**, including the façade and roof insulation, modern windows, ventilation systems with heat recovery, and shading solutions as a precondition for passive cooling. Respondents emphasised that it was the **combination of these measures that was effective, not so much each individual measure** on its own.

The question of how much insulation a building should have was assessed quite differently within the stakeholder groups. In addition to the building's efficiency, the electricity source for the HP was also raised as a crucial issue. The suggestion was that in cases where electricity is generated from renewable sources on-site, it may be sufficient to **make only minor improvements of the building's envelope and invest in an HP with a higher capacity** instead, even if an optimal annual COP is not achieved in this way.

Planners in particular, but also heating installers, repeatedly emphasised that the installation of a RE H/C system in an existing building often requires changes to the heat distribution system. These changes involve a high degree of effort and substantial costs (see Section 3.2). A less disruptive alternative would be the installation of **low-temperature radiators, which can be used in existing buildings**.

Another expedient factor would be to make **the installation of RE H/C systems as straightforward and standardised as possible**. For example, the installation of an HP should not be much more complicated than that of a gas boiler. **Compact off-the-shelf systems or modules** that can be **installed and replaced via plug-and-play** were recommended by various stakeholders in the expert interviews. **Ready-made, simple solutions are less likely to deter investors**, as confirmed by this investor in one of the interviews:

> *"If you have a multi-family building and want to install a gas boiler in the basement, everyone knows that it costs €10,000 or €20,000, including installation and so on. It's not a question of whether it works. It's quite simple. Just call the installer, he will do the work and your worries are over. With a heat pump, you'd have to be able to say that there's a box that works just as well. And that it's right there with a maintenance contract. So it's basically a 'fire & forget' solution. That would be a dream from my point of view." (DE, m, 44)*

Yet it should be noted that this view was not supported by all stakeholders unanimously. Those who highlighted the greater planning effort required to adjust an HP to the specific building conditions stressed the **need for innovative forms of cooperation between manufacturers, planners and installers** (see below).

A higher standardisation of HP manufacturing would also take the pressure off installers, who would no longer have to grapple with a broad variety of barely compatible systems from different suppliers. This would be ideal when **combining** components **of HP, PV and electrical storage**. Being able to **offer customers off-the-shelf packages for the specific conditions in different countries** instead of always having to assemble individual components from different manufacturers on site is a suggestion that lends itself well to TRI-HP. **Compact and simplified systems for HPs** are also appreciated by heating installers, as these would **simplify installation and dispense with work on the refrigerant circuit**. More **compact HPs would also reduce space requirements** (see Section 3.2). However, as two HP installers from Germany and Norway noted, this can also prove to be a disadvantage in terms of service and maintenance, for example when valves and connecting tubes are more difficult to reach or new tools are needed. Nevertheless, **more compact and integrated systems could** significantly **reduce the effort required for planning and installation**, while specific additional qualifications for installers, for example in how to handle refrigerants, would no longer be needed. **Certification and classification** were other keywords that were frequently mentioned, along with references to the automotive industry and how it can serve as a role model for manufacturers and associations in the RE sector.

Intelligent control was explicitly and repeatedly mentioned as an important prerequisite for efficient management of complex RE H/C systems. As an investor and building owner put it during one of the interviews, "***energy management is key***" (ES, m, 59). It should include, for example, internet-enabled remote control and remote maintenance but also take into account weather forecasts and electricity tariffs. Some stakeholders, who also have experience as landlords, further argued that intelligent control interfaces should be programmed in a way that makes them understandable and easy to use for end users, with a **manageable level of individual influence and control**. **Automatic error detection and self-learning adaptation to user behaviour** were emphasised as important features of smart control in order to establish social acceptance and consequently **increase willingness to invest** in such devices (see Section 3.4). Moreover, it should be possible to **combine smart control interfaces with technological components from different suppliers**, for example via standardised connections.

With regard to noise emission from ASHPs in particular, it was noted that technological development has made great progress in recent years and **units have become significantly quieter**. Nevertheless, ASHPs 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 (see below). GSHPs installed in the basement of the building were cited as the ideal solution for MFBs in terms of sound emissions. This presupposes the **availability of a suitable room of sufficient size for technological component**, such as a GSHP but also energy storage devices etc. However, the installation of GSHPs can be very challenging, especially in an urban context and in existing buildings (see Section 3.2).

Concerning the lack of space, especially in densely populated areas, it was predominantly the Swiss experts who thought it reasonable to consider RE H/C for MFBs as **open systems** and to perceive them as **part of local energy networks**. This makes particular sense in an urban context, where the energy density is higher and there is high potential in terms of heat sources, consumers and storage units that can be used for synergies. As well as reducing space requirements, this can also save investment costs (see above), for example if the ice storage is built on communal land and can then be used by several buildings in a neighbourhood. Among the advantages of an ice storage system mentioned was that they **allow RE H/C systems even on properties where, for example, the drilling of boreholes is not allowed** due to geological conditions or political regulations.

Some of the experts interviewed also touched on the appearance and aesthetics of ASHPs and energy storage devices. There was general agreement that manufacturers could make these components more attractive and "sexier". Particularly with visible in- and outdoor installations, **appearance also plays a role in the purchasing decision**. A Norwegian engineer elaborated on this a bit further, adding a cultural perspective:

> *"Aesthetics is pretty important. It's like, how attractive can a manufacturer make a box like that? You can try to make it attractive, but I think Norwegian homes are so pretty, with wall panels and wooden floors, that it's really obvious if there's something not so attractive. […] I would say that in Germany, the style is more random and not as nice, which means that a heat pump is not the first thing you see when you enter a room. Whilst here you do, I'd say." (NO, m, 31)*

Again, it was stated that lessons could be learned from the automotive industry, such as how to **create an emotional connection to technological products through design and marketing**. Otherwise it remains true that "heating has no emotions", as another expert put it (CH, m, 53).

A higher standardisation of HP 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, an HP with PV and electrical storage would be appreciated by investors and installers.

Refurbishment measures are considered important to achieve a high performance from an HP in existing buildings. To avoid disruptive changes to the heat distribution system, technological components such as low-temperature radiators can be used as an alternative to underfloor heating. For effective energy management, an intelligent and easy-to-use control system that can also adapt to different user behaviour patterns is recommended. Ice storages offer the practical advantage of allowing RE H/C systems to be installed even on properties where the drilling of boreholes is not feasible due to geological conditions or political regulations. Soundproofing devices can be effective against noise emissions from ASHPs.

3.3.3 Psychological, social-cultural and organisational drivers and incentives

The high importance of non-technical and non-economic factors for the market acceptance of RE H/C systems was emphasised by many stakeholders. First and foremost, the **need for more public relations work and better marketing for RE** in general was mentioned many times in the interviews. The possibilities for RE H/C were described as still too little known, and the demand for them as very small. **Awareness of and confidence in the technology should therefore be significantly increased**, for example via associations, scientific institutions, energy agencies, trade fairs, etc. It was repeatedly suggested that **media such as television or YouTube should be used more intensively** to disseminate reports of real-life experiences from people who have installed RE technologies. An HP manufacturer, who also manages a SHAC company that promotes its products on YouTube, expressed his own amazement at the success:

"The older ones, when they watch our YouTube videos, they learn them by heart. Sometimes I go to clients and they quote whole sentences from my lectures and from my videos. Just like in the theatre. They have seen the video so often that they have simply internalised it." (DE, m, 61) He and others stated that energy managers, technicians and heating installers are still too focused on the technology and do not address non-material values and benefits such as **fostering a more ecological lifestyle or increased thermal comfort** (see Section 3.4). These non-material and non-monetary values and benefits should not be underestimated, because they **intrinsically motivate individuals to invest in RE H/C systems** and can help promote their market diffusion. In addition, awareness-raising measures can **stimulate behavioural changes** that can lead to **more efficient heating and cooling**. This also touches on the issue of culture. In Spain and Norway, for example, a greater need was expressed for changes in traditional heating routines (see Section 4.3 and 4.4).

The importance of environmental values was expressed in one way or another in virtually all interviews. Above all, the **orientation towards sustainable development** and the **desire to actively tackle climate change** were mentioned. The **decarbonisation of energy production (fossil phase-out)** can also provide a motivation to act, offering the opportunity to contribute to a future-oriented, resource-efficient path towards a more liveable environment. Associated with this, feelings such as **pride of ownership** and the wish to be **energy self-sufficient** were also mentioned as motivations. An **increase in living comfort via HP systems** in combination with underfloor or panel heating systems was emphasised in all countries, both in terms of heating and cooling, the latter less so in Norway (see Section 4.4). Better indoor air quality was also mentioned, for example in Spain in winter, when an old chimney is replaced by an HP and smoke is no longer produced in the house.

Another decisive factor is the **willingness to pay for RE technologies**. The experts in all stakeholder groups assessed this very differently in their respective countries. Despite different views and suggestions, what many of the stakeholders agreed about was the need for what they called a "new way of thinking". On the one hand, this referred to **new business models such as energy contracting** (see above), and on the other hand to the fact that end users, stakeholders and political decision-makers are still not paying sufficient attention to the life-cycle costs of a technology. In several interviews, reference was made to the **need for a more "holistic" approach to profitability considerations and construction permits for REs**. For example, one proposal from a Swiss expert was that the cantons should only approve installation of fossil technology on a property if RE technology were to be significantly more expensive in terms of life-cycle costs. The idea of regulatory measures such as bans on fossil systems was also raised occasionally. An expert from Spain further suggested **changes in tendering practices**. Public tenders should be issued separately for buildings and heating installations so that savings are no longer made at the expense of heating installations, as is usually the case. And finally, a shift in mind-set should be encouraged among end users and building owners which rewards the long-term benefits of investing in aspects such as smart control or regular maintenance and other forms of quality control.

Some interviewees recommended that specific stakeholder groups should be encouraged to change their routines and practices in order to more strongly promote the dissemination of RE technologies (see Section 3.6). Many experts **deemed more awareness-raising and educational work necessary**, especially among heating installers, but also among homeowners, planners and architects. More efforts should also be made to disseminate up-to-date information on the advantages of RE H/C systems among end users. Here, the primary objective was seen to **reduce reservations, ignorance and persistent rumours** about HPs, for example regarding their efficiency in existing buildings or noise emissions. A **need for further training for heating installers** was repeatedly described as very high, not only in terms of technological issues but also **communication and skills** that are helpful for advising clients or marketing HPs more effectively.

The **heating installation trade itself was seen by some experts as being in** fundamental **need of reform**, especially in Germany and Switzerland, where it is very closely connected to the plumbing trade (see Sections 4.1 and 4.2). HP topics feature very weakly in its traditional training path, if at all. This gave rise to a demand for the **profession of a heating installer not only to be made more attractive** in order to prevent the shortage of skilled workers but to offer **new career paths**, which would, for example, allow specialisation in HP technology (see Section 3.6). Similar demands were voiced for the study of architecture and engineering.

Installing a complex RE H/C system is not only a technological and planning challenge but a "people business", as one of the experts stated in an interview. Since many different stakeholders are involved not only in the market diffusion of such systems but also in the construction site, **trust-building was emphasised as another important driver for social and market acceptance**. Some of the measures mentioned as a means to this end were **closer contact and exchange** between, say, manufacturers and heating installers or heating installer and property owner. A Spanish expert who works as a professional reseller for HPs stressed that his **role as an independent intermediary**, who often comes to the construction site in an advisory capacity, fills a big demand gap and is therefore highly appreciated. Intermediaries like him know the problems on the construction site, and this enables them to build trust with the installers and other customers. The manufacturers themselves can build trust by giving **guarantees on their products**. Close and **trusted cooperation** between manufacturers and installation companies with regard to maintenance was repeatedly highlighted as positive in the interviews. A Spanish project planner and installer described the problem as follows:

> *"You have to give a guarantee for your product, otherwise it won't work. This is one of the problems that arise: You do an installation and whoever comes afterwards, they should fix it, as we say in Spain." (ES, m, 58)*

An ideal solution was deemed to be when **the person or company who installs a system also commissions, optimises and maintains it**. This should be done in such a way that the system runs efficiently according to the manufacturer's specifications. In other words, HP manufacturers should **insist on the proper and professional installation** of their units and systems. **Energy savings guarantees and maintenance contracts** can support this, avoiding the so-called "blame game" that often arises when a component does not work as expected but neither the installer nor the manufacturer takes responsibility for it. However, there is a third culprit, which will be discussed in the following section.

Trust-building between heating installers and property owners is also of high importance. Installers can contribute to this through **reliability, honesty, advisory competence, good communication skills** and the ability to respond flexibly to individual requests by customers. Further training not only in technical matters but also in this respect was therefore highlighted as very worthwhile. **With better customer satisfaction come more word-of-mouth recommendations**, which eventually benefits many stakeholder groups across the board. Establishing such low-conflict cooperation solutions also helps investors and developers to opt for the technology in the first place. The same applies to the **availability of a single responsible contact person to coordinate a complex project** such as TRI-HP, for example an experienced and knowledgeable planner.

The final group of drivers and incentives that can increase acceptance of RE H/C systems includes everything to do with **reducing non-technological complexity**. This means, for example, that RE technologies and RE H/C systems must become simpler to grasp, for example through **easy-to-understand user instructions and straightforward operation**. In addition, it should be easy for an interested party to obtain information about suitable experts and funding programmes and to obtain a quotation that also shows when and under what circumstances the product will have paid for itself. **The profitability analysis should also be comprehensible to a layperson**. Further, the **application process for funding programmes and possible approval procedures should also be simple** and in no way more complicated than for fossil technologies. Digital platforms can help, but it has also been pointed out that there are some disadvantages when applications can only be submitted online. On the one hand, this makes individual agreements more difficult, and on the other hand, it often excludes older people, who still prefer to use paper-based applications.

Awareness raising and trust building among end users and professional actors are key to increasing social and market acceptance of RE H/C systems. Prevailing prejudices and rumours among end users, heating installers and architects must be countered with transparent information on the benefits of RE H/C systems. In order to better inform society as a whole, more use could be made of new media. 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 energy production.

Trust-building measures between the various stakeholders are also important drivers. Depending on the stakeholder group, these measures can be, for example, quality control of HP manufacturers to guarantee proper installation, savings guarantees and maintenance contracts, or the appointment of a single responsible overall coordinator for complex projects. Providing comprehensible operating instructions and simplifying funding applications or permit procedures can further reduce complexity.

3.4 Risks and Safety

In all interviews, questions were asked about risk and safety concerns in relation to the expertise of the respective experts. The responses covered technical and non-technical aspects. This section only summarises technical risks and safety concerns. Non-technical risks such as risks of complaints by neighbours due to noise emissions or investment risks because of too many uncertainties are dealt with in more detail in Sections 3.2 and 3.3.

All respondents agreed that **technical risks and safety concerns of RE H/C hardly pose any problem**. The safety precautions for the **installation of HPs and their operational safety are considered sufficient and manageable** thanks to existing standards and regulations (see next section). With regard to HPs with NRs, this question was discussed in more depth in many interviews. It was mentioned that NRs can be either toxic (ammonia, not used in TRI-HP systems) or explosive (propane), and that carbon dioxide is a NR that is assigned to the lowest risk class A1. However, it is used under high pressure. The **risks associated with the use of NRs in HPs were also** unanimously **considered to be very low** as long as installation and maintenance rules were observed, such as where and how to install an HP, minimum space requirements for operation rooms, etc. It was highlighted that in the H/C business, there is a long tradition of using NRs such as ammonia. That the installation should be carried out by someone with expertise was declared an important requirement to **minimise residual risks such as leakages of NRs**. Technical solutions such as leakage detectors can be helpful, and **regular professional maintenance with leakage checks** was also considered useful. Such leakage checks can be carried out by qualified heating installers or manufacturers, and perhaps also by chimney sweeps with appropriate training and know-how, providing a promising new field of business activity for them. Especially with CO_2 HPs that operate at higher pressures, the weld seams and seals should be particularly robust.

The use of **compact systems with built-in refrigeration circuit**, **was suggested as a practical solution to minimise the risk of leakages**. This would also simplify installation and maintenance, because installers would then no longer need a specific permit for working with NRs.

In addition to the leakage of refrigerants, the **emergence of legionella was mentioned as a further health risk**. However, the problem could be eliminated by ensuring a drinking water temperature high enough to kill those dangerous bacteria or in conjunction with the use of ultrafiltration systems. A third health risk concerns **mould growth**, which can occur especially in regions with high humidity if underfloor cooling is in place that is not sufficiently ventilated (see also Section 4.3).

Many of the risks and safety concerns discussed in relation to HPs were related to **environmental risks**. First and foremost, this involved the **drilling work necessary for GSHPs**. Some experts reported cases where houses had cracked or sagged after drilling, as an investor and project planner describes:

> *"I'm always a bit cautious about very deep geothermal energy use, because you have to imagine that at depth the changes in the ground naturally have an effect upwards. It's like a crane or a skyscraper – the bigger it is, the bigger the fluctuations. At the bottom, 1cm is significantly more than at the top. You have to imagine the same thing in reverse. If I change the structure at the bottom by heat input or heat extraction, then of course that can have an effect over 100m upwards, depending on how deep the boreholes are. And I've seen a couple of examples where there's been massive damage to the buildings at the top, and not just to your own, but to the neighbouring buildings." (DE, m, 45)*

Thanks to additional safety precautions and improved planning, however, the **risk of severe damage was estimated to be much lower today than 10 years ago**. In some countries, at least, the drilling sector has allegedly learned from past mistakes. It was also stated that **today's geo-information systems are significantly improved**, one benefit of which is that they can help identify **water-bearing layers that should not be destroyed**. Nevertheless, **residual risks must be taken into account**. With water-to-water HPs there is also the **risk of clogging, silting and calcification**. In the case of permitted **interventions in groundwater**, the existing guidelines must be followed so as not to reduce its quality. These guidelines vary from country to country and may even differ between administrative units within a country (see Section 4.3 for an example).

For densely populated areas, experts said it was important to bear in mind that the **capacity of heat extraction decreases as more geothermal energy is used**. This can make it necessary to drill deeper and deeper for further boreholes, which will increase the risks already mentioned but also the costs (see Section 3.2).

Some experts further pointed out that NRs are less harmful to the environment due to their **lower global warming potential (GWP) and ozone depletion potential (ODP)** compared to synthetic refrigerants.

A final safety concern mentioned was **data security** for the end users of smart RE H/C systems. In this context, it should be clarified **who owns the data**, for example on user behaviour, and **how it can be protected**.

In general, the technical risks and safety concerns linked to RE technologies were considered to be very low when installing, operating or maintaining HPs. When handling NR, there are a few things to consider for which there are corresponding regulations. Residual risks, such as the occurrence of leakages, can be minimised, for example through regular leak checks. The emergence of legionella must also be kept in mind as a health risk. A third aspect concerns the environmental risks that can arise, especially from the drilling of geothermal probes, for example when they interfere with groundwater. And finally, the data security of the intelligent control system, i.e. the user data of the residents of the house, should also be guaranteed.

3.5 Standards, Regulations and Laws

Standards, regulations and legislation can influence market acceptance of RE H/C systems in many regards. Given the numerous stakeholders and their areas of expertise, the various technological components of those systems, and the different countries in which the interviews were conducted, it is not possible to provide a comprehensive picture here. Instead, this section will present a generalised summary and an impression of which assessments the experts interviewed largely shared on this topic and where discussions were somewhat controversial.

Political frameworks, laws and government subsidies were unanimously described as very important and necessary prerequisites for the social and market acceptance of RE H/C systems. This includes the EU, national and state levels. Many experts agreed that these parameters contributed to a significant increase in REs and that many conditions have improved. For example, it was reported that the increasingly clear legal regulations and technical codes for new buildings have made cooperation and collaboration much easier today. Nevertheless, many also deemed **legal conditions still to be in need of improvement**. Examples of this were clear regulations on who is allowed to install HPs and regular checking of the systems for efficiency, or mandatory renovation of buildings in cities.

3.5.1 Building codes

Efficiency standards as specified in building codes were a matter of debate. While high insulation standards were predominantly seen as reasonable, some interviewees occasionally described them as too strict. A Swiss architect, for example, expresses his opinion that the **focus should not be so much on** always **simply reducing heating demand but also on maximising the share of REs**:

> *"I always say that we should not insulate much more, but first and foremost ensure that sustainable heating systems are installed. Whether the building then needs a little more or a little less is not so relevant. [...] If I insulate the house super well, I still have significantly more CO_2 with a small oil boiler than with a heat pump, depending on the electricity mix. In this respect, I would like to see people not sticking to this insulation rule but looking instead at the overall system, for example the kg of CO_2 per square meter of floor space. In this respect, however, people are still very much focused on the insulation side, on minimising the demand. I say, if you are 100% renewable, you can use as much energy as you want for all I care. Just like in Iceland. In Reykjavik, the main streets are heated with underfloor heating, but geothermal, so 100% renewable." (CH, m, 56)*

In the context of political frameworks, interviewees discussed not only financial incentives but strikingly often also **penalties and bans**. Some experts took a clear position that fast market penetration of RE H/C systems and associated technologies would not happen without restrictive measures, especially with regard to diminishing the use of non-RE technologies. At the same time, even **regulations with the best intentions to boost the expansion of RE can ultimately prove to be an obstacle to complex systems**. In this context, a Spanish engineer and project planner mentioned a regulation according to which ST must be installed on a roof, even if it is predominantly in the shade. As an expert, he would like to have more freedom to make decisions:

> *"We had designed a hotel in the middle of the city where the building next to it gave us shade. We wanted to use a heat pump with heat regulation when it was cold and heat recovery instead of using solar thermal. They said no. The legislation said we had to use solar panels. We told them we were only getting a small ray of sunlight. Nevertheless, we had to put them up. That is a very clear case, it still exists today. The technical code forces you to do a few things in the end. As an engineer, I would like them to leave that to me." (ES, m, 55)*

3.5.2 Safety standards related to natural refrigerants

The assessment of standards was predominantly positive in all countries, with only a few exceptions. The experts repeatedly asserted that, based on their working routines and experiences, most fields **were sufficiently standardised**, i.e. neither over-regulated nor under-regulated. The same is true for the **safety standards with regard to NRs, which were predominantly assessed as sufficiently strict**. Existing regulations, for example regarding safety measures in the maintenance of HPs so that no leakage or contamination can occur (see also Section 3.7), were evaluated positively in the interviews. The EU regulation of fluorinated gases – the F-Gas Regulation – was consistently viewed positively by those experts with whom it was discussed. The path taken towards more NRs was strongly welcomed. There were a few suggestions, however, that called for **permissible maximum levels when filling a device with NRs to be increased for larger HPs** installed in MFBs.

3.5.3 Technical standards

More **standardisation and thus comparability was also desired with regard to technical data**. The comparison between, for example, two HPs from different manufacturers should become **more transparent** to make it easier to decide which the most efficient or quietest product is. The more standardised the specifications and the more standardised the processes then become, the better it is for market diffusion according to the experts.

Soundproofing is an example of an issue that generated differing opinions. While the majority saw no need for stricter regulations – residual **problems with constant noise should be solved technically** – others desired improved benchmarks for **noise emissions** of ASHPs under real-life conditions, as this would often not be possible due to different manufacturer specifications, and also because the reference figures are produced under laboratory conditions. This manufacturer exemplifies this as follows:

> *"Noise is a very sensitive issue. Manufacturers have dedicated test rooms in the laboratory, where they eliminate all other environmental influences as far as possible and where they optimise compressors and fans etc. to the best of their knowledge and belief in terms of efficiency and noise. Then they put the unit in the field, they then have the situation, for example, that the installer places it on a garage roof and the garage serves as a 'resonating body'. Or they put it in a u-shaped building angle from where it emits noise into the environment. Or they place it in direct view of the neighbours and the noise reaches their terraces and bedroom windows straight away. There are many factors. They just can't measure it outdoors the way they can measure it in a lab." (DE, f, 56)*

3.5.4 Listed buildings

Very **old and listed buildings may also be subject to restrictions** such not attaching anything to the façade, as reported by one interviewee from Norway who works for a housing cooperative. This type of problem also applies to the installation of solar technology on the roof. On the other hand, it was reported in Spain that **this can also be the case for unlisted buildings** in certain regions, where outdoor units of HPs must be placed on the roof of a building and not on the façade. This can then lead to conflicts of use and competition for space with PV and ST.

3.5.5 Cross-cutting issues

Another recurring theme in the interviews concerned the **standardisation of processes when applying for funding or approval**. A desire for **simplification, reduction of hurdles and unification** was expressed in many cases. Very often this referred to regional regulations within a country, such as those of the cantons in Switzerland or the autonomous regions in Spain (see Sections 4.2 and 4.3).

The desire for **more harmonisation of laws, funding programmes, and procedures between domestic political administrative units** was expressed not only in Switzerland but also with regard to the autonomous regions in Spain. In the other countries, too, the **combining of legal requirements, standards and subsidies** was mentioned as the preferred means of speeding up processes.

A final set of issues concerned what is often perceived as the complicated and obstructive bureaucracy involved in areas such as approval procedures or applications for funding. A **reduction of bureaucratic hurdles was considered necessary** in many respects. Especially with regard to approval procedures, the installation of RE technologies should at least not be disadvantaged compared to combustion technologies. There were calls for the

bureaucratic burden surrounding REs to be significantly reduced, thus making it easier not to opt for a fossil system. Currently, however, REs are still burdened with increased requirements such as difficult access to the use of certain heat sources or sinks. Furthermore, owners of PV systems are treated like electricity suppliers when they feed self-produced RE into the grid. This often entails dealing with various authorities such as the regional water authority in the case of geothermal drilling. A German architect who had a GSHP installed in his private house describes this unequal treatment of RE and fossil technologies as follows:

> *"When I think back to when I had my own geothermal probe drilled, I received a letter from the city that was several dozen pages long, telling me everything I had to pay attention to and where problems could arise. And in the last paragraph of these tens of pages it said somewhere: 'Thank you very much, by the way, for choosing a geothermal heat pump. It's also environmentally friendly.' Something like that. But first, dozens of pages of concerns. That's what you'd have to hand over to someone who installs an oil-fired heating system today. But then you wouldn't get such documents." (DE, m, 45)*

Another Spanish expert for geothermal energy also complained that GSHPs are not specifically accounted for in existing laws and regulations, some of which are older than the technology itself. This led to tedious and arbitrary authorisation procedures at the communal level, depending on who was in charge. A **much clearer legal framework regarding the drilling of boreholes would be beneficial** here.

> Standards, regulations and legislation of RE H/C systems have an important influence on social and market acceptance of RE H/C systems. In general, political framework conditions were considered fairly beneficial for RE H/C systems. Building codes should not only enforce restrictive efficiency standards but also allow for greater flexibility in reducing a building's THG emissions. Financial instruments such as carbon tax schemes were approved but should be complemented by bans on fossil H/C technologies.
> NR safety standards were seen to be sufficient. The permissible maximum filling quantity could be increased for larger HPs.
> Technical specifications should be more standardised and transparent for better comparability, for example with regard to noise emissions. Noise problems of ASHPs should be solved by technical means rather than by tightening existing regulations.
> Greater harmonisation of regional regulations, funding programmes and approval procedures would be highly welcomed. Funding applications and approval procedures should also be simplified and standardised within a country.

3.6 Key Stakeholders

As already mentioned in the previous sections, a large number of stakeholders are involved in the implementation of RE H/C systems. This heterogeneity was suitably reflected in the construction of the research sample (see Section 2). In the course of the expert interviews, additional stakeholders were mentioned who are also relevant for market acceptance of RE H/C systems. The importance and role of those stakeholder groups was assessed very differently by the interviewees and also within the countries (see Section 4). Nevertheless, some of them were addressed more frequently than others overall. This section summarises the most common responses to the question as to which actors drive or hinder the market diffusion of HP-led systems to the greatest extent.

3.6.1 Heating installers

A consistently very significant role was attributed to heating installers, as they are usually the ones who install the central technological component of these systems, the HP. For SFBs, especially, but also for MFBs, they were described as common first contacts for building owners, with great decision-making power over whether an HP is selected. A specialist planner and CEO of a company that installs HPs put it as follows:

> *"Due to the position of trust that the [heating] installer has with the end user, he is naturally one of the decision-makers as to which systems are used or not. If he doesn't mention a certain system at all during the consultation, then the decision-maker naturally doesn't think about whether he should consider this system at all or not. [...] If I don't mention a system at all in the consultation, then logically it cannot play a role in the decision-making process." (DE, m, 52)*

This gives heating installers an important advisory function which, according to many opinions in the interviews, they are rarely able to fulfil comprehensively. It was mentioned in all countries that this kind of soft skill is not part of their traditional training path so that large knowledge deficits exist with regard to HP technology or RE in general. Furthermore, their business model is predominantly based on fossil technologies, which means that their knowledge and experience with these is very sound and the effort required for professional installation of, say, gas boilers is comparatively low. It remains a profitable business and, due to the general shortage of skilled labour, the heating sector is working at full capacity anyway. Therefore, the willingness of many heating installers to acquire additional knowledge through further qualification, e.g. how to determine the heating load of an MFB via hydraulic balancing, how to correctly size and adjust an HP, or how to handle various refrigerants, was reported as rather low. Concerns about liability issues that arise when an HP system is not properly adjusted and ends up running inefficiently contribute to further non-acceptance of HPs among heating installers. For this reason, installers were described as "the biggest brakes" and the "bottleneck", although they could in fact be a key driver due to their potentially strong relationship of trust with the end customer. The solutions proposed for this situation ranged from monetary incentives to participate in further training measures to bans on the installation of fossil heating systems down to comprehensive reforms of the traditional training path for heating installers. Since there are also very different regulations between countries as to who is allowed to install, commission and maintain an HP, and under what conditions, other types of installer should also be considered here. In Spain, for example, an electrician with a licence for heating installations, the so-called RITE licence, can install an HP, as can a heating installer in Germany with a so-called refrigeration licence.

3.6.2 Architects

Architects are a second key stakeholder group. The larger the project, especially with new buildings, the more important their role, as they then often act as overall coordinator of all the trades involved. In analogy to heating installers, a large knowledge deficit about alternative heating systems was described here as well, with similar reasons given. Compared to fossil solutions, complex RE H/C systems mean far more work for architects for only a marginally higher fee, and they also bear a higher risk in terms of anything that goes wrong. Furthermore, the advantages and disadvantages of different energy systems and their challenges are not usually covered in the study of architecture. One Norwegian architect, who graduated from university not too long ago, described the situation as follows:

"I'm not that familiar with the technical details of these energy systems because we only touched on them superficially in our Master's programme, but never went into detail. [...] And this Master's programme was all about sustainable building, which doesn't interest every architect. So it might make sense to offer more lectures on different heating systems or energy supply and things like that in architectural studies. [...] For architects in general, further education on how energy systems affect the building and how its carbon footprint is calculated would be appropriate. They should have a general idea of what a life cycle assessment is. Because most architects have no idea what that means, you know." (NO, f, 28)

Other interviewees also made clear how important it is to plan the proper integration of RE H/C systems into the overall building design from the very beginning. If the architects themselves do not possess this knowledge, they should consult an appropriate expert at an early stage. In some interviews, it was concluded that architects who lacked knowledge about renewable alternatives to conventional heating systems would not actively promote them and would more likely hinder than drive their market diffusion. The relevance of architects in this respect can vary depending on the country and its ownership structure for residential buildings (see Section 4.2).

The importance of guilds or corresponding professional associations (e.g. the Chamber of Architects) is also increasing in tandem with the importance of the two professions just mentioned. They can help develop, offer and implement training and further education concepts. In two expert interviews, it was even suggested that further training should be compulsory rather than voluntary. Professional associations can furthermore propagate the use of RE more strongly through tailor-made and needs-based information material.

3.6.3 Project planners

An explicitly positive role was attributed to specialised project planners for large projects. In the interviews, it was repeatedly emphasised how important it is to have a person in charge who (a) has comprehensive knowledge (e.g. with regard to energy management in residential buildings), (b) is responsible for the overall coordination on the construction site, and (c) ensures quality. Although architects can and often do take on this role, it has been described as more beneficial for the efficiency of the overall process and the efficiency of the resulting system if it is carried out by an energy specialist. This obviously requires additional budgeting, but the more complex a project, the more advisable it becomes to involve an experienced project planner to avoid unexpected additional costs. The significance of this was highlighted especially for the early phase of new construction but also refurbishment projects, where it is vital to guide and coordinate all actors involved. For example, project planners can tell the GSHP driller exactly how deep to drill once the building's heating load has been correctly determined. Since not all project planners are experts in RE H/C systems, there is a need for further training here as well.

3.6.4 Energy contractors

One stakeholder group that has been assigned precisely this function of a qualified project planner and can thus be described as the driver of such systems is energy contractors. As they remain responsible in the long term, they have a strong interest in planning, installing, operating and maintaining the system in such a way that it runs highly efficiently and thus economically.

3.6.5 Manufacturers

Manufacturers of RE technologies, in particular HP manufacturers, are another stakeholder group deemed to have a high level of influence. This is not only because they develop the technologies, bring them to the market and make them known, but also because they are seen to have further opportunities for action at their disposal. For example, energy savings guarantees, maintenance contracts, advisory services and qualified installation by their own personnel were named as effective measures to establish trust with end users such as building owners. Ensuring that equipment is regularly maintained enables efficient operation. This eliminates uncertainty on the part of investors and funding bodies and strengthens customer satisfaction. A stronger focus on direct trust-building by manufacturers would also take the pressure off heating installers, who could then refer customers to manufacturers for technical questions, for example. Closer cooperation with qualified or, even better, certified installers was also mentioned as an essential contribution to quality assurance. Furthermore, the manufacturers' portfolio should also include combined systems such as an HP combined with PV. There was a considerable desire expressed in the interviews by investors and building owners for simple and prefabricated overall solutions and (sub-)systems. The better the individual technologies fit together, it was found, the fewer the difficulties in working together on the construction site. For the same reason, the control units of the respective components should be compatible with those of other manufacturers and system providers. With regard to the technical descriptions of their products, there was a request for more transparency and simplification of the values and parameters provided, in order to make the figures more comparable with each other. This would allow even non-experts to understand what performance they may expect under what circumstances. The annual COP or the noise emission figures were mentioned as examples.

As for the use of NRs, not only HP manufacturers have a special role to play but also component manufacturers for compressors, evaporators, condensers, expansion valves, etc. Since only a few companies share the world market here, it depends heavily on them which components are available for small HP manufacturers.

3.6.6 Additional stakeholders

Distributors or suppliers can play an important role at the intersection between manufacturers and installers, for example by providing technical advice and on-site support. As stakeholders with a more independent status, they can take a more critical stance and recommend different systems, which is positive for building trust with the customer. The same can be said of other independent players such as energy agencies, consumer centres, energy consultants or research institutions.

And finally, those stakeholder groups that set important parameters for market acceptance can also be described as particularly influential. On the one hand, this includes political decision-makers both at the national level and at the level of regional administrative units such as provinces or municipalities. They can pass laws, raise or lower taxes, and issue bans. Barriers such as the tenant–landlord dilemma mentioned above can only be solved effectively at policy level. Political decision-makers are thus largely responsible for creating financial and non-financial incentives and establishing investment security (see also Section 3.8). And on the other hand, there are the energy providers, who influence the basic conditions for the market acceptance of RE H/C systems, for example with their investment decisions and pricing policy (e.g. tariff offers).

The following stakeholders and stakeholder groups can be considered particularly important for the market penetration of RE H/C systems: heating installers, architects, professional associations, project planners, energy contractors, manufacturers and suppliers of RE technologies. Further, the expert interviews showed that political decision-makers, energy providers and independent energy advisory services can be very influential for social and market acceptance of these systems.

3.7 User Behaviour

The **importance of the "human factor"** was repeatedly emphasised, especially in interviews with planners and building owners. They indicated that **the efficiency of RE-HC systems in MFBs is not simply determined by technical issues** but also **depends on the residents and their use of energy**. **Individual perceptions of thermal comfort can vary widely**, as do practices around the use of heat and hot water. For MFBs, this creates individual **heat consumption profiles that may vary significantly between buildings** (not to mention that system parameters can change significantly when the tenant structure changes). To design an RE H/C system efficiently, it is important for planners to create accurate heat consumption profiles in order to predict when demand peaks are to be expected or when which flow temperatures are required. This ultimately allows **determination of the ideal sizes of HPs, PV panels, heat storages and other technology components**. And that in turn makes it highly relevant for investors, especially if they own the buildings and operate as landlords.

Since default parameters of HP which are set up by manufacturers do not take account of individual user behaviour, this repeatedly leads to improper design and inefficient operation of HPs in refurbished MFBs and thus to frequent complaints by residents. According to some experts, however, it is **not desirable to give tenants too many options for regulating the smart control system**. They often operate heating or ventilation systems incorrectly and so it is advisable to minimise their control options. Instead, an **intelligent control system that automatically adapts to individual user behaviour,** monitors the system and regulates it to a certain extent can provide a remedy. However, it cannot completely replace the professional readjustment and optimisation of the system, which should take place after about one year and then be repeated from time to time.

User behaviour is therefore one of the reasons why it is **difficult for HP manufacturers to give guarantees for energy consumption**. In addition to good planning and professional installation of H/C systems that include HPs, the way in which residents use their heating, cooling and hot water is very important for the overall energy efficiency ratio.

On a much larger scale, the **differences in user behaviour are also reflected in various country-specific heating cultures**, as exemplified in Section 4 for Spain and Norway.

The efficiency of RE-HC systems in MFBs strongly depends on the social structure of residents and the residential energy use. What is perceived as thermally comfortable can differ considerably between individuals, leading 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 HPs, PV panels, heat storages and other technological components. In MFBs, intelligent control systems that automatically adapt to individual user behaviour can help boost the efficiency of the system.

3.8 Gender

One question in the interviews was about gender differences and the experiences of the experts in their daily work. While the majority saw no differences, the most frequent mention referred to the varying perceptions of what is considered thermal comfort. This may have an impact on whether or not a technology is preferred and how it is used. According to some expert experiences, women seem to be more cautious and critical when it comes to HPs and are more often concerned whether it will actually be comfortably warm for them, while men tend to be more technically inclined. On the other hand, women tend to be more environmentally motivated to opt for RE while men are more economically oriented. In addition to the comparatively higher comfort temperature of women, a higher sensitivity to noise, for example with ASHPs, was mentioned occasionally.

4 Country Specific Findings

While Section 3 presented results that were – to a greater or lesser extent – found in all the countries studied, **this section highlights the differences and particularities** that emerged in the comparison between the countries. Therefore, this section should be read in **addition to the general results**. Besides different climatic and political conditions, differences also include socio-cultural factors, insofar as they have shown themselves to be potentially relevant for the acceptance of RE H/C systems. It again goes without saying that this is not a conclusive analysis of what influences social and market acceptance. However, this section provides some valuable insights into why **different national, regional and local contexts need to be taken into account** and what calls for particular attention in which country.

4.1 Germany

One aspect that emerged in the German interviews, in particular, was the predominantly **positive assessment of existing laws and regulations along with the current funding relevant for market dissemination of RE H/C**. The political efforts to drive the decarbonisation of the residential heating sector were recognised, even if they did not yet go far enough for some stakeholders. There are **numerous opportunities to receive financial subsidies** for new construction projects and for renovations. The most recent example is a programme that provides homeowners with a subsidy of up to 45% if they replace an old oil heating system with an HP, for example. German interviewees unanimously report a sharp increase in the demand for HP systems since the launch of the programme. A CEO of a SHAC company and provider of ASAPs explains how this has fundamentally changed his business:

> *"The BAFA [Federal Office of Economic Affairs and Export Control] now offers subsidies for heat pumps. And at the moment they are 35% for gas. So if you switch from gas to heat pumps, it's 35%. If you switch from oil to a heat pump, it's a 45% subsidy. And that's why we only do old buildings at the moment, of course. I' m currently rejecting new buildings altogether. [...] It's incredibly lucrative. Business has never been so good." (DE, m, 61)*

It has occasionally been argued that **high subsidies may have unexpected negative effects**. It does help the market spread of HPs in the short and medium term, but many of them now seem to have been installed improperly by poorly qualified installers, so they end up running inefficiently. This may damage the reputation of the technology in the long run. In addition to financial incentives, it is therefore advisable to implement **accompanying quality assurance measures**. Moreover, programmes like this probably favour ASHPs, being better suited to quickly replace old, fossil systems, even if sometimes GSHPs would be the better choice. For this reason, it was suggested in some interviews that there should also be **more focused funding measures for GSHPs and combined systems** such as HPs with PV.

Since November 2020, laws, and regulations for energy efficiency and REs were integrated into a **new "Law on Energy Saving and the Use of Renewable Energies for Heating and Cooling in Buildings"**. This law was strongly welcomed by many stakeholders, as they hope it will remove some of the bureaucratic hurdles that had existed until then. It will probably make it even easier to apply for funding, get it approved and implement projects more quickly.

Another important issue that was particularly noticeable in the German interviews concerns the **quantitative and qualitative lack of appropriate competence to install HP**. The SHAC trade was described as a "bottleneck" here, even by heating installers themselves. Unlike in Norway, for example (see Section 4.4), most **heating systems in Germany are based on a hot-water circuit**, which means that the work of a heating installer also includes plumbing work. Apparently, the **SHAC trade is already working at capacity**, even without the increased demand for HPs, which is why existing **offers for further training are hardly accepted**. It was stated by some experts that the **SHAC training already includes a vast amount of theoretical and technical knowledge** about sanitation, heating and air conditioning. Additional content such as information on electrical installations or the handling of refrigerants, including associated standards and safety regulations, "simply overwhelms" many installers. As a consequence, they instead stick to the supposedly simpler solution of non-RE technologies, as this expert explains:

> *"Now the situation in Germany is that we have about 50,000 heating installers and just under a quarter of them have installed a heat pump so far. All the others still predominantly advocate predominantly gas and oil, because they can explain that to people easily. And it's quickly installed, plugged in, costs less. So many installers – and it's sometimes simply a question of time – still advise their customers in the direction of gas. [...] And these are a few aspects that come together and lead to the fact that the heat pump already accounts for over 50% in new buildings, but not yet 80-90%." (DE, m, 55)*

A **reform of the traditional SHAC training path** was therefore suggested in some interviews as one way of differentiating more strongly between the fossil and RE shares of H/C and **training more specialists for RE H/C systems**. They should then be able to professionally plan HP systems for new and existing buildings (hydraulic balancing, etc.), install them, put them into operation, and maintain them. This and other approaches were also elaborated in Sections 3.2, 3.3 and 3.6.

One topic that was also voiced more strongly in Germany than elsewhere is **building insulation**. This probably also has to do with the different seasons in the country and the associated differences in temperature. The positions here were quite diverse, which indicates the controversial nature of the topic. On the one hand, the experts largely agreed that it was **necessary to minimise H/C demand** in both new and existing buildings so that HP systems can work as efficiently as possible. On the other hand, this does not automatically mean such systems can only be installed in optimally insulated houses. It was argued that **technical and economic considerations must be carefully weighed** against each other while keeping an eye on existing climate protection targets. This means that a crucial role is also played by how H/C is powered, i.e. by REs or fossil fuels, so the **highest possible energy efficiency should not be the sole requirement**. In this sense, an HP with a low annual COP that runs entirely on renewable energy would be better than no HP. This HP manufacturer explains why there is a **strong need for action, especially in existing buildings**:

"We now have, I think, 21 million heated buildings in Germany. We now have just over one million heat pumps installed, mostly in new buildings. The renovation rate is well below 1%. Unless something is done, we will continue to discuss the issue of CO_2 for years and decades to come, because every gas-fired boiler installed today will run for another 20 years." (DE, m, 55)

A final aspect concerns the **price of electricity** – another recurring theme in the German interviews. **Germany is one of the countries with the highest electricity prices in Europe**, the reasons for which are complex and cannot be elaborated here. This factor was considered by most of the experts interviewed to have a detrimental effect on acceptance of RE H/C systems. They called for **electricity to become cheaper in order to reduce operating costs and thus shorten the payback period** of such systems. In addition to the **elimination of certain levies**, it was suggested that energy suppliers offer **more flexible and intelligent electricity tariffs for HPs**. However, these also would need to become significantly cheaper than they are at the moment.

In Germany, existing laws, regulations and funding conditions relevant for the market diffusion of RE H/C were assessed as basically favourable. The possibilities to receive financial subsidies are numerous. Funding should be more focused on GSHPs and combined systems, and should include quality checks.
A critical major bottleneck is seen to be the lack of sufficiently qualified installers. Existing offers for vocational training and further qualification are hardly used by tradesmen and installation businesses.
Low energy efficiency of the building stock is considered a major challenge for HP installation. A much discussed topic concerns the insulation of existing buildings and when it is reasonable (and under which circumstances) to replace an old heating system with an HP. High prices for electricity in Germany can lead to high operating costs unless a high share of self-sufficiency with on-site generated electricity is achieved.

4.2 SWITZERLAND

Any special features of Switzerland mentioned in the interviews had mainly to do with the political organisation of the country. Here, perhaps more than in other countries, social acceptance is strongly linked with market acceptance through the **principle of direct democracy**. This can be seen, for example, in the fact that **large credit volumes are decided by popular vote**, i.e. major investments have to be voted on. RE projects that have a high level of acceptance in Switzerland are usually approved, meaning that they already receive broad support not only from politics and administration but also from local citizens.

A second relevant point concerns the legal **right of objection**, which is particularly important with regard to noise pollution from ASHPs. An architect describes what that means and why it may be a barrier:

"In Switzerland, if you want to build, you have to submit a building application in the municipality where the building is located. And the neighbours have the right to object. And often objections are made as a preventative measure, without any detailed figures being available. And then some owners are afraid to really go down this path and say, well, then I'll just do without it and install a heating system that doesn't cause me any problems." (CH, m, 56)

Switzerland's **federal structure** was also considered an issue but not nearly as strongly as in Spain (see next section). There are **many differences between the cantons**, but there are also **efforts to harmonise** these differences where considered reasonable. In the following quote, the expert illustrated this using the example of energy legislation:

"In Switzerland, energy laws in the building sector are regulated on a cantonal basis. So each canton has its own laws. However, these are coordinated in so-called model ordinances, because it's a bit tedious for planners to have to take 26 different energy laws into account when working in more than one canton. So in this respect, it is currently being harmonised." (CH, m, 56)

The model ordinances must then still be ratified in the cantons via their regional parliaments or plebiscites, which can be a lengthy process. From an economic point of view, however, this was considered worthwhile for all involved.

A unique Swiss feature, for which nothing comparable was found during interviews in the other countries, is the so-called **HP System Module** ("Wärmepumpen-System-Modul"). It is a standard for the planning, construction and commissioning of HP systems up to about 15kW heating capacity, for new buildings and for refurbishment of existing buildings alike. Through **certification, straightforward defined and binding procedures, and performance guarantees**, it aims to ensure the quality and increase the efficiency of the entire heating system. The majority reported that this was **very well received by homeowners, planners, installers, manufacturers and suppliers**. Only a few objections were raised because it meant more work for installers, as they have to deal with many new devices. In addition, one expert noted that some installers consider the financial gain too low, while the additional costs for the customer are perceived as too high. As a result, he said, they sometimes advised against it. However, since **subsidies are linked to the HP System Module** in almost all cantons, demand from building owners has risen sharply, which in turn has increased the pressure on heating installers. By offering them **simplified and easy-to-understand documentation**, for example on hydraulic and electrical schemes, the Module saves them a lot of time. Other additional measures such as **regular random checks ensure quality** in the long run and **strengthen the trust between manufacturers, installers and customers**. The following two quotes, the first from an entrepreneur and expert consultant for HPs and the second from an HP manufacturer, highlight many of the advantages mentioned. It is also expressed that although the module has so far only been used for SFBs, it is currently also being discussed to apply it to MFBs:

"Basically, it's a certificate for the building owner for assured quality in the implementation of a heat pump system. And it's very successful at the moment, because I think 24 cantons have now linked their subsidies to it. So, if the building owner wants a subsidy, they are forced to build according to the heat pump system module. And in the heat pump system module, the procedure for planning and installation is clearly defined. And at the end there are also documents and a clean commissioning with a commissioning protocol. Maintenance is regulated and so on. And a key driver of that is random inspections. So basically, I think 10-20% of the installations are checked. If the installers know their work can be checked with the heat pump system module, then experience shows that better quality is delivered from the start. And what we are discussing now is to extend this successful model [...] to multi-family houses and also add a solar installation component. That is now under discussion. And of course that would also be a discussion to make it possible not only for borehole heat exchangers but also for other sources like ice storage." (CH, m, 37)

"It works very well with this system module. The major well-known companies immediately developed such system modules and also tested and approved them. The big advantage [for the installer] is that they then have the hydraulic scheme, they have the electrical scheme. And if they install it that way, the manufacturer or the supplier guarantees the function. And that is always an advantage. Of course, [the fact] that [there is a need for this] comes from the past, when the plumber was also the heating installer and didn't take into account all the refinements that you need with a heat pump." (CH, m, 72)

In summary, the HP system module covers much of what was mentioned as a driver in Section 3 and what was often missed in the other countries. With this system, the end user does not run the risk of malfunction due to an installer not realising the peculiarities of HPs. It may therefore be a **suitable best practice example** that could be further developed for more complex RE H/C systems such as TRI-HP.

The last sentence of the second quote above refers to the **shortage of qualified installers**, an issue described in Swiss interviews in a similar way to the interviews in Germany. Here, too, **the heating installer was described as a "bottleneck"**. The separation of the sanitary and heating trades, which is apparently already taking place, was also addressed by Swiss experts. Water-based heating systems and electronics both play an important role for HPs, which is why heating installers need to have sufficient knowledge of both. Particularly in the case of renovation, it is often necessary to replace old radiators that are too large for use with HPs (see Section 3.2). In new buildings, however, HP is already the first choice.

One expert explained how **the heating installer is** therefore **traditionally still very influential in Switzerland and is usually consulted first by homeowners**, especially for refurbishments. Architects or planners are almost never consulted, although the likelihood increases the larger the projects become. This also has to do with the **ownership structure of residential buildings** in Switzerland. According to experts, more than half the MFBs are privately owned and the owners often live in the house themselves. When it comes to the renovation of old heating systems, MFBs often follow the same route as SFBs: in most cases, the exclusively consulted heating installers recommend what they always do and what they have had positive experience with, namely oil or gas. Alternatives such as **HPs are rarely discussed**. According to the interviews, the advice of installers to their customers is usually to "stick with fossil as long as it's still allowed." Consequently, the **pressure for further training for this stakeholder group was estimated to be very low**. But even if all available installers were to undergo further training, the shortage of skilled workers would not be eliminated. **Significantly more skilled workers would have to be trained**, as one expert estimates in this excerpt from an interview:

> *"We have about 900,000 buildings in Switzerland where the heating is older than 15-20 years. Let's say about one million. [...] Now you can say, with a little improvement, given the current level of installers, the available capacity, we could build and renovate 60,000 new heating systems. If we say 20,000 of the 60,000 are new, then we can perhaps refurbish 40,000 heating systems a year. And we have a demand of one million. How can that be done? We don't have the capacity. […] Everyone just wants to be an engineer or go into the office. There are fewer and fewer plumbers." (CH, m, 72)*

Due to the principle of direct democracy in Switzerland, the approval of major projects is often accompanied by the acceptance of the local population. Conversely, the right of objection by neighbours can be a hurdle. Efforts to harmonise the different legislations in the cantons, for example with regard to energy laws and the so-called HP system module, are considered to impact positively on the social and market acceptance of RE H/C systems.

The HP System Module was highlighted as a successful quality standard which could serve as a best practice example for other countries as well. The HP System Module includes a standard for the planning, construction and commissioning of HPs (<15kW), certification, binding procedures, and performance guarantees, easy-to-understand documentation and regular quality checks. The adoption of the HP System Module is supported by specific funding conditions.

As in Germany, the shortage of qualified heating installers was also raised as an issue in Switzerland. These tradesmen were described as very influential, also in MFBs, which is partly due to the typical ownership structure of residential buildings.

4.3 Spain

One obvious specificity of Spain is its **climate**, which is very different from that of the other three countries. In addition to the hotter summers and milder winters on average, the **climatic differences within the country** are also of great importance for the use of RE H/C systems. In the north, winters are harsher and wetter, and summers are mild. On the Mediterranean coast, the climate tends to be much warmer and drier. And in the continental climate of central Spain, the differences between seasons but also between day and night can be large. The development, dissemination and deployment of RE H/C systems in Spain should take account of these differences, as they are also associated with **different user needs and thus user behaviour** (see Section 3.4). Especially in regions with extreme heat in summer, it is very important to bear in mind that there is a **high demand for cooling**, as this project planner points out:

> *"Cooling depends on your climate, the same as with heating. In Spain, in some places we have 40 degrees at 11pm in summer, and the next day too. And at noon you have 45 degrees. If you don't have cooling then, you die. You die. It's no longer a question of ecology, it's a question of survival."(ES, m, 58)*

The **prevailing weather conditions can also have an impact on the technical outdoor components** of the systems, for example when it comes to how well the outdoor unit of an ASHP on the roof of a building can tolerate the solar radiation or the salty sea air to which it may be exposed. Another example mentioned in the interviews concerned the **high humidity in some regions, which requires the installation of additional ventilation** in the case of underfloor cooling in order to avoid mould. Technical solutions such as fan coils are common in some regions and should therefore be considered in the planning process.

The vital importance of **political frameworks** for or against a market expansion of RE was outlined in some Spanish interviews, with reference to the recent history of the country. The older respondents in particular remembered that "back in the days" there had been a lot of subsidies in Spain with high, sometimes exaggerated rewards, which eventually "got out of hand", especially in the case of PV. With a moratorium in 2012, the government stopped virtually all feed-in tariffs from RE, which severely slowed the development of the market for the years to come. Recently, however, these restrictions have been reversed and the **generation, feed-in and self-consumption of renewable electricity is being promoted** once more. According to the experts interviewed, a lot of things are now made easier again for the RE sector. **The market now seems likely to grow under the new conditions**. Of course, this does not yet take into account the possible consequences of the COVID19-pandemic.

Apart from the national regulations, the **administrative structure of the country** also represents a significant factor for the social and market acceptance of RE H/C systems. The **Spanish autonomous regions**, as the name suggests, have a **high degree of autonomy in the implementation of national rules and regulations**, such as the handling of subsidies. The budget made available for this is allocated to them proportionally by the national government. How and at what speed it is then handled varies greatly from region to region. This results in **very different regulations**, which is especially complicated for companies operating supra-regionally and can block the implementation of projects. In addition, **the share of RE and energy efficiency of residential buildings varies**

greatly from region to region. Furthermore, some regions interpret certain requirements in a way that is not favourable to the use of renewable heat sources and sinks. A GSHP installer working in different regions reported that in Valencia, for example, a "waste water tax" is charged for water-to-water HPs, although only the energy from the water is used and the water is not consumed. The return of the extracted water into the source costs almost €70 per cubic metre, he said. Several interviewees have therefore expressed the wish for **more harmonisation of ordinances and regulations** with regard to RE H/C systems.

A very striking aspect in the Spanish interviews was the emphasis on the **economic capacity of the country and its citizens**, which was assessed as comparatively lower than in the other countries. This was seen, on the one hand, in the **less elaborate funding programmes** and, on the other, in the fact that **upfront costs appear to play a greater role** in Spain compared to Germany, Switzerland or Norway. One expert who sells heating equipment, including HPs, tried to illustrate the situation with an example to show that for many people in the country **direct savings on investments are more important than long-term savings** through lower operating costs:

> *"An electric boiler is a misdirection from a technological point of view nowadays. You take the appliance, plug it into the socket – 2000W of direct electricity consumption! If you knew how many electric boilers we sell! A worker buys an electric boiler for €150, has hot water and pays the electricity bill every month. Damn! €70 of electricity! What nonsense! But they can pay that amount month after month, even if it is nonsense in the long run. In fact, people say that electric boilers should be banned. [...] But of course, if you suddenly remove electric boilers, you deny many people access to hot water. I mean, it's not feasible." (ES, m, 59)*

A similar behaviour to save one-off costs was attested with regard to maintenance. It was emphasised in several interviews that **willingness to pay for regular maintenance was very low**. One architect stated: *"We always lower the price. Nobody includes maintenance as part of their budget"* (ES, m, 34). As explained above in Section 3.2 and elsewhere, qualified maintenance is very beneficial for the efficiency of complex RE H/C systems, and the need for **more awareness-raising to ensure the efficient operation of RE H/C systems** was indeed occasionally identified in Spain.

Related to this, there was frequent mention in the Spanish interviews of something described as a **heating culture**. As already indicated above, one aspect of this is that H/C needs differ greatly due to the different climatic conditions, both in comparison to other countries and within the country. In some regions, there may even be no heating system at all because the "heating season" is very short and people simply put on more clothes or use electric space heaters during the cold weeks. According to one manufacturer and distributor of HPs, the focus on current savings prevails over a long-term view among the Spanish population, although the latter would be necessary for the continuous and thus efficient operation of HP systems:

> *"A heat pump should not be switched off. But this is what is done all the time. Many users do that. You have to programme the system and let it work. To maximise the performance of the unit and minimise the use of the unit. And that is difficult here in Spain. I think there is more of a heating culture in other European countries. Here, many people turn off the heating system during the day to save money and prefer to turn on the electric blanket in bed in the evening. That is not efficient, especially in terms of running a heat pump." (ES, m, 46)*

Another aspect of the Spanish heating culture(s) is that H/C seems to have evolved in such a way that it is now **distinctly individualistic** in some regions. An architect from the Basque region reported that in many MFBs there is now a boiler for each flat, partly because past experience has shown that central heating systems were poorly managed and **there exists a strong preference to regulate H/C demand individually**. Being able to consume as much heat or cold as personally desired without thinking about the immediate costs was described as an expression of **"quality of life"**. However, it is not only individual preferences that have shaped this, but also the **fossil structures and path dependencies that have developed over time**. A project planner from Catalonia reported how the gas industry dominated the region in the last century. Together with large banks, he explained, they jointly contributed to this structure of individual H/C systems, as it was much more lucrative for these players to install one boiler in each housing unit with its own contract than to install one large boiler for several housing units. **Heating cultures therefore also have a historically evolved structural background**. These obstructive structures for RE H/C systems were described by some stakeholders as difficult to change. A few also expressed **scepticism that large-scale H/C systems would become widespread** in Spanish society, even though more and more projects are being realised. The following quote from a project planner gets to the heart of this as it also summarises many of the issues raised:

> *"This is the big hot potato, as we say in Spain. We know what to do about this problem, but no one is touching it. No one really sets out to implement large-scale projects and projects that favour changes to this structure we have. It is also true that competition is very tough. Natural gas is very cheap and the grid reaches the last corner of our country and it is a very convenient form of energy. Sure, because when you turn on the shower tap your heating boiler comes on. If you turn on the tap 100 times you get hot water 100 times. And there are a whole lot of maintenance services, a whole lot of installers, there are dozens of manufacturers with low competitive prices. And it's not easy to change that with just market elements. You have to do it a little bit cheaper with a system that is much better and also with a customer service that is worth it." (ES, m, 58)*

In Spain, the climatic conditions are very different within the country, creating very different heating and cooling needs from region to region. The cooling demand in Spain is high, which raises the issue of ventilation in some regions where humidity is high. Prevailing weather conditions can also have an impact on the technical outdoor components of H/C systems and thus where to place them.

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 RE technologies. RE funding policy is still less elaborated compared to Germany or Switzerland. Due to the high level of independence in Spanish autonomous regions, the regional implementation of national building regulations and funding policies lacks coherence. Inhibitive regulations for RE H/C aggravate the installation of HPs in some regions (e.g. "waste water tax" for GSHPs).

Building and apartment owners have only little economic capacity, and so the upfront costs play a major role for many residents. Direct savings are often preferred over long-term savings. In addition, extensive H/C systems are generally not yet very widespread, partly because there is a very individualistic heating and cooling culture, with a strong desire for individual H/C solutions for each flat.

4.4 Norway

As in Spain, there is an obvious country characteristic in Norway that has to do with climate. In the interviews, not surprisingly, **the need for renewable cooling was estimated to be relatively low**. Some regions in Norway, however, see summer temperatures of over 30°, and it was reported in a few interviews that **the need for cooling is increasing**.

In virtually all interviews, two interrelated aspects were mentioned that are very typical for the country and may be highly relevant for the acceptance of RE H/C systems such as TRI-HP. One is the country's electricity supply and the other is the price of electricity. Interviewees repeatedly emphasised how **cheap electricity** is in Norway and that it is **largely generated from hydropower**. The dominant perception of the population was said to be that they already consume renewable electricity, even though the country also purchases non-renewable electricity from neighbouring countries. Together with the resulting **low electricity prices**, this has developed a **heating culture that is strongly based on electricity**, for example via radiant heaters on the walls or electric underfloor heating. The **social practice of saving energy is not widespread** in Norway, so a **high potential for raising awareness of electricity consumption** was seen here. One of the interviewees tried to illustrate the point using a comparison with friends of his from other European countries:

> *"They turn off the light every time they leave a room, consciously, because they know that electricity costs money. For us, this has never been natural because electricity has always been cheap. [...] As long as energy is cheap here, we have to find other ways to make people aware of why to save it." (NO, m, 39)*

While the low cost of electricity appears to be a **great advantage and a huge potential for HP deployment** in Norway, the fact that it is already considered renewable can also be a **hurdle for more complex RE H/C systems such as TRI-HP,** i.e. those that are designed to be predominantly self-sufficient in terms of electricity via PV, for example. As elaborated earlier, the high investment costs of RE H/C systems compared to fossil systems can be amortised by reduced operating costs. However, if the **operating costs are already very low**, this argument does not apply, nor does the reference to life-cycle costs if **heating is already provided with electricity**. Another expert who has spent two decades doing research on HPs boiled it down to: *"The energy savings have to be high enough to cover the extra investment"* (NO, m, 58). Due to the low electricity prices, the **assessment of such systems in terms of profitability is thus fundamentally different** in Norway compared to the countries mentioned before. An independent consultant for HPs and refrigerants explains to what extent this also depends on the political frameworks and why the **heating culture in the country is difficult to change**:

> *"I think it's a core problem that Norway has such a huge surplus of electricity. The Norwegian government actually makes it difficult to use anything other than electricity. When it comes to the energy rating of buildings, it's not really enforced in Norway, unlike in any other country in Europe. […] The Norwegian government doesn't want us to use any less electricity. […] They hide this pretty well, but in practice I think it's very obvious that they don't want us to reduce our energy consumption level." (NO, m, 58)*

He went on to say that the fact that **Norwegians had become accustomed to cheap electricity** also has an impact on their **unwillingness to invest in alternative systems**. As he had also worked in many other European countries, he further reported on his experiences, stating that Norwegians "*never really had a culture of spending a lot of money on a heating systems*". Another aspect that becomes obvious in the country comparison between Norway and other European countries is that **water-based heating systems, as used in Germany and Switzerland, are the exception rather than the rule in Norway**. This may not only be an obstacle for existing buildings in terms of retrofitting (see Section 3.2), but also for new buildings due to a **shortage of well-qualified plumbers**:

> *"We definitely need something like a water-based heating system to be able to utilise other sources. Using panel heaters is like death. I think what's important in this kind of interview, is to say that we need to encourage more water-based systems." (NO, m, 58)*

A final interesting aspect raised only but frequently in Norway is the combination of RE H/C systems in residential buildings with **electric vehicles that can serve as batteries**, for example. This points to the **idea of system openness**. Since e-mobility is comparatively advanced in Norway and this is also expected in the other countries in future, it could be worthwhile for TRI-HP to address the question of whether and how this can be integrated.

Norway abounds in electricity from hydropower, and electricity prices are very low. The country has a huge potential for HPs due to inexpensive electricity. Heating systems are predominantly based on electricity and cooling demand is low due to the climate. Moreover, since operating costs are low, a heating culture prevails in which it is not very common to save energy. For complex RE H/C systems such as TRI-HP this can be a hurdle, as the population's willingness to pay for alternative heating systems is rather low.
As water-based heating systems are the exception, there is a shortage of qualified and well-trained professionals who can install HP systems in residential buildings. Advanced sector coupling with a high share of e-mobility offers additional opportunities to integrate smart RE H/C systems in the energy grid.

5 Conclusions

The expert interviews showed a broad range of natural, legal, economic and cultural parameters for the implementation of RE H/C in Europe. In all countries, the heating sector still sticks to fossil business models and path dependencies, and a decarbonisation of the residential building sector is only in its early stages. Nevertheless, the uptake of HPs is gaining momentum in some countries and market segments. Experts and stakeholders expect changing regulatory frameworks such as building codes and regulations and carbon taxation schemes to further promote market adoption of RE H/C systems.

It is possible to generalise some findings that have been drawn from the interviews: one important insight is that HPs call for higher skills on the part of planners and installers, and challenge existing business models in the heating sector. A lack of trained installers and plumbers was reported in all countries. A broader market acceptance of HPs necessitates the creation of incentives for vocational training and further qualification in the installation business. Many stakeholders particularly emphasised a need for improved quality control in the fields of installation and maintenance. The establishment of holistic schemes for quality standards such as the Swiss HP System Module can serve as a model for other countries. This scheme includes specified and documented procedures for installation, commissioning with an individual set-up of HP parameters, and regular maintenance.

A better standardisation of HPs and components would also help simplify HP installation. New business models and new forms of cooperation have to be established between manufacturers, installers and planning experts. Energy contracting can offer new business opportunities for energy service companies that help overcome barriers due to high upfront cost.

And finally, attention should not be limited to the investment costs for RE H/C systems but should adopt a lifecycle perspective. HP operating costs result not only from a good annual COP but also depend on electricity costs. One must therefore conclude that the electricity market provides an important framework for the acceptance of RE H/C systems.

The main barriers, hindrances, drivers and incentives outlined in this report are summarised in the following table. The table presents the three categories of barriers or hindrances that have been identified. To each category barriers and hindrances are listed in the left column of the table. Drivers and incentives that might help overcome these barriers are presented in the right column. It should be noted that the table provides only a selection of topcis and **does not represent an exhaustive summary of the findings of this report**. For more examples and more detailed information, it is recommended to read Sections 3.2 and 3.3.

Economic-financial barriers and hindrances	
Barriers and hindrances	**Drivers and incentives**
• high investment and upfront costs • additional costs, e.g for drilling or refurbishment measures • uneven distribution of costs and gains between investor and buyers/tenants (landlord–tenant dilemma). • high operating costs due to high electricity prices	• higher taxation of carbon fuels • public funding and subsidies • low operating costs due to high self-consumption of electricity generated on-site • new business models, such as energy contracting or housing cooperatives • special electricity tariffs for HPs • rewarding self-consumption of RE • awareness raising for non-monetary benefits (thermal comfort, energy self-sufficiency etc.) • promoting an assessment of total costs and revenues over the entire lifetime of a system

Barriers and hindrances regarding practical implementation and feasibility	
Barriers and hindrances	**Drivers and incentives**
• high heating demand in some existing buildings • additional effort for refurbishment measures in existing buildings • challenging on-site composition of various technological components • high space requirements inside and outside the building (especially in densely populated areas) • high degree of complexity that hampers stakeholder's understanding and acceptance of RE H/C systems and the coordinated interplay of stakeholders • complicated approval procedures and funding applications	• standardised, simple solutions (off-the-shelf modules, plug'n'play sub-systems) • low temperature radiators instead of underfloor heating in refurbished buildings • ensuring compatibility of components from different manufacturers by standardisation • offer compact HP systems to avoid work on the refrigeration circuit for installers • certification schemes for installers/ tradesmen • closer and trusted cooperation between planeners, craftsmen and manufacturers • easy-to-use manuals for installation and operation • cooperation with local planning authorities • making funding applications simple, low-threshold (digital) but also accessible for all ages
Psychological, socio-cultural, and organisational barriers and hindrances	
Barriers and hindrances	**Drivers and incentives**
• lack of expertise and skilled workers • prevailing fossil fuels business model for heating installers • existing heating routines and heating cultures • noise emissions from ASHPs • high level of planning outlay (and investors deterred by complexity and associated uncertainties) • complex energy management • lack of awareness of ecological impacts of fossil heating systems	• further qualification training offers for HP installation • financial incentives for heating installers to take up further training • easy to use smart control that also adapts to user behaviour • develop quieter ASHP equipment and noise control reduction measures • create more awarness, more public relation and better marketing for RE systems, for example via social media

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.