D2.2c. Innovation Readiness Level Report

Energy Efficiency in Buildings

July 2019

About this report

In the framework of the REEEM project, three Innovation Readiness Level (IRL) reports are developed focusing on three groups of energy technologies. This report is the third and final IRL assessment, dedicated the buildings' energy efficiency technologies. The report particularly focuses on solar roof tiles (as advanced roofing material), heat pumps, and wood fibre insulation material. The technologies are from different groups of energy efficiency technologies and with different maturity status in order to provide a wider picture of the energy efficiency market.

This report will be complemented by the REEEM Technology and Innovation roadmap on the energy efficiency of buildings, submitted in July 2019.

Authors

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REEEM partners

About REEEM

REEEM aims to gain a clear and comprehensive understanding of the system-wide implications of energy strategies in support of transitions to a competitive low-carbon EU energy society. This project is developed to address four main objectives: (1) to develop an integrated assessment framework (2) to define pathways towards a low-carbon society and assess their potential implications (3) to bridge the science-policy gap through a clear communication using decision support tools and (4) to ensure transparency in the process.

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Summary

*Buildings are responsible for about one-third of the total European greenhouse gas emissions. This high share has motivated the European Union (EU) to aim for enhancing the **energy efficiency of buildings**. In accordance, the European Commission has introduced long-term European targets to enable effective policy measures to support improving the buildings' energy efficiency. The set EU targets oblige a 20% improvement in energy efficiency by 2020 and 32.5% by 2030 compared to 1990 levels. More specific targets for building efficiency are also set. They oblige improving the energy efficiency of public buildings by 3% yearly and suggest an 80% reduction in buildings' energy consumption by 2050 compared to 2010 data. Although these targets have managed to drive the energy efficiency market, they need to be more ambitious and detailed in order to enable a complete renovation of the European building stock by 2050.*

*So far, different **energy efficiency technologies and solutions** have entered the European market aiming to improve buildings' energy efficiency. These technologies have experienced different levels of success when accessing the market. While researchers and analysts often take technology maturity and development status as the reasons for their varied success levels, this report explores several additional reasons.*

*This report assesses the potentials and risks of a selected number of energy efficiency technologies in accessing the European energy market, by using the **Innovation Readiness Level (IRL)** methodology. This methodology, developed by InnoEnergy, assesses the IRL of technology along 5 dimensions: technology readiness level, Intellectual Property (IP) readiness level, market readiness level, consumer readiness level and society readiness level. The methodology explores factors and processes that are prerequisites for successful technology development and access to market.*

*The IRLs of three energy efficiency technologies are assessed in this report, namely: solar roof tiles, heat pumps and wood fibre insulation material. These three technologies were selected in order to cover both supply (of heat and electricity) and demand (energy efficiency). It has been decided to focus on sun tiles instead of solar thermal energy or solar PV in order to cover electricity while having a more innovative approach. For the assessment of this report a customised version of **the IRL tool**, adapted to the REEEM project, has been used. This customised version has been implemented in earlier REEEM IRL reports on energy storage and renewable energy technologies and has been subsequently revised and improved based on the collected results.*

*The **findings** of this report shed light on points related to technology, IP, market, consumers and society of energy efficiency technologies which could positively influence their development and deployment in the European energy market for buildings. The results provide suggestions for policymakers, investors and industries about the strengths and drawbacks of the innovation processes of the studied technologies.*

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I. Introduction

Europe is pushing for the reduction of Greenhouse Gas (GHG) emissions and carbon footprints. To do so, the European Commission has set key targets for 2030 within the Clean Energy for All package: at least 40% reduction of GHG in comparison with 1990 data; at least 32% increase in the share of renewable energy; and 32.5% improvement in energy efficiency. For the latter, a top priority has been given to technologies and methods that can improve the energy efficiency of European buildings. The reason behind this prioritisation is that buildings contribute to 40% of the overall final energy consumption (see figure 1) and produce 36% of the CO_2 emission in Europe [1]. These numbers highlight the high potential of improving buildings' energy efficiency in reducing the overall GHG emission in Europe.

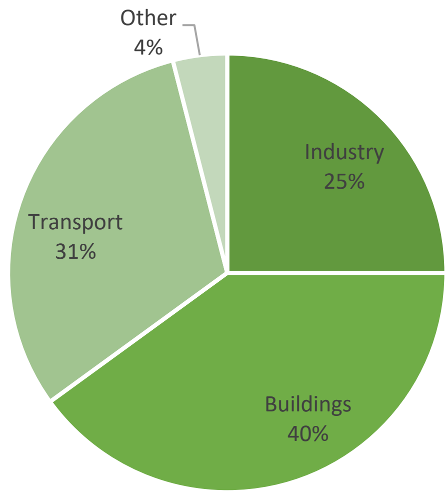

Figure 1 – Share of different sectors in EU energy use [1]

Accordingly, the market for buildings' energy efficiency has been growing over the past years across European countries. Currently, in the market, there is a need for more progress and advances in order to realise the full potential of the energy efficiency market for buildings. As discussed in the REEEM roadmap on the energy efficiency of buildings [2], Europe aims to renovate 100% of the European building stocks and reduce buildings' energy consumption by 80% (compared to 2010 data) by 2050 [2,3]. To contribute to improving the building's energy efficiency, different technologies and solutions are developed and introduced into the market. These technologies can be categorised into three main groups:

1. Energy efficient insulation materials,
2. Energy efficient heating and cooling technologies,
3. Energy efficient electric appliances (including lighting).

Improving each of these groups can contribute effectively to the reduction of the overall energy consumption of buildings. To understand better the importance of these technologies, Figure 2 and 3 depict the breakdown of energy consumption in households and commercial buildings. As shown in Figures 2 and 3 heating and cooling alone cause more than half of the total energy consumption in buildings [4]. This means changing our heating and cooling technologies to more efficient systems and devices can effectively reduce the buildings' energy consumption. However, investing in efficient heating and cooling technologies would be only reasonable when the inside temperature could be kept at the desired level through effective and efficient insulation. Finally, about 10-30% of the energy consumption of a building is dedicated to electric appliances and lightening of buildings. Therefore, utilising efficient electrical appliances could as well improve buildings' energy efficiency.

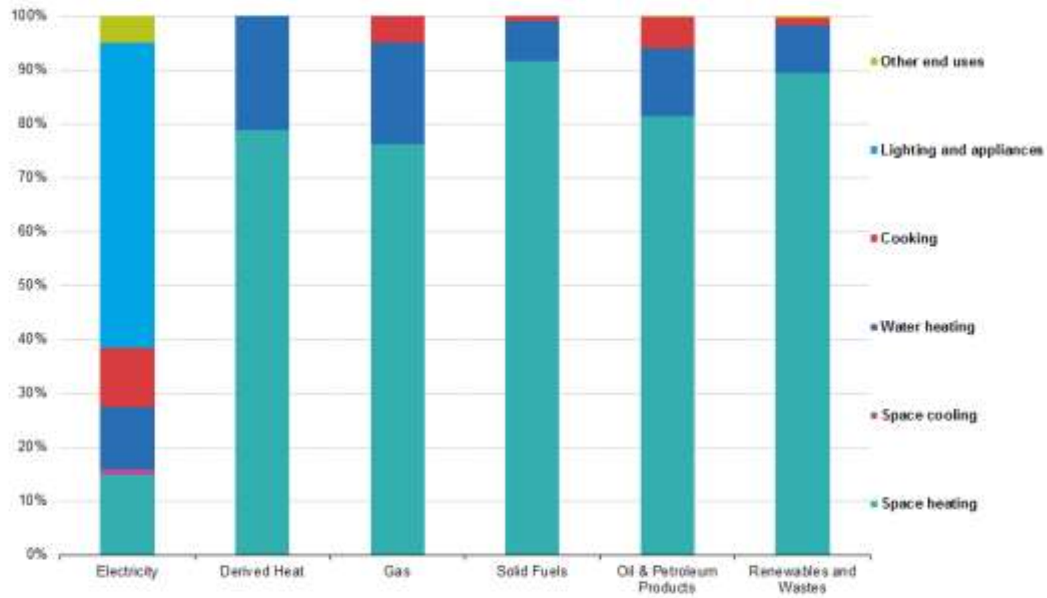

Figure 2 – Final energy consumption in the residential sector by type of end-uses for the main energy products, EU-28 [5]

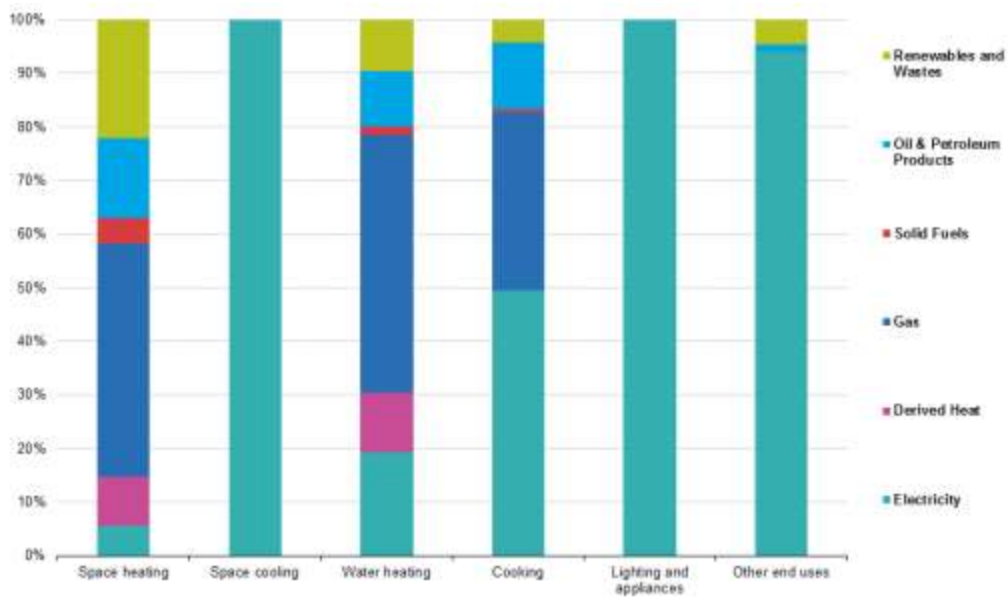

Figure 3 – Part of the main energy products in the final energy consumption in the residential sector for each type of end-use, EU-28 [6]

This report underlines that the understanding of the potentials and risks of technology in accessing the market is important in order to facilitate its development and deployment in the market. To take a step in this direction, this report assesses the Innovation Readiness Level (IRL) of three energy efficiency technologies for buildings. The technologies are selected from different technology categories (as defined above) to provide a more comprehensive overview of the market. To understand the utilised methodology of this report, below an overview of the technology assessment tool is provided. Next, the utilised IRL methodology and the context of this report are explained in details.

I.1. Technology development assessments tools: an overview

I.1.1. Technology Readiness Level (TRL)

In 1989 NASA introduced a systematic approach to study the development of technology, with the creation of the Technology Readiness Level (TRL) tool. The TRL describes the technology maturity level on a 0-9 scale, where 1 is the development of the idea in a laboratory and 9 represents the full technology readiness for deployment in the market. The tool assesses the technology maturity before its integration in the market, and studies asymmetries during the development process. The TRL tool is widely used in economic practice.

I.1.2. Demand Readiness Level (DRL)

For a technology to be successful in a market, the demand and innovation needs of different actors should be considered in the process of technology development and deployment. This, however, has been ignored in the assessment of the TRL. Hence, in 2011 the concept of Demand Readiness Level (DRL) was developed in order to better understand and manage the process of technology deployment by combining market pull and technology push approaches [7]. DRL has 9 levels and studies the maturity of market demands identified by innovation actors. The levels range from 1, identification of a need in a market, to 9, building an adapted answer to the market needs.

I.1.3. Innovation Readiness Level (IRL)

The Innovation Readiness Level (IRL) tool has been developed by InnoEnergy with the purpose of assessing the level of maturity of innovative technology, product, service or emerging business (i.e. Start-up and venture). The tool empowers the assessment of innovation potential of a technology, product or service by analysing all the dimensions that can influence its innovation process. The IRL extends earlier efforts that were focused on TRL and DRL and assesses a technology's development along five different dimensions (Figure 4): Technology Readiness Level (TRL), Intellectual Property Readiness Level (IPRL), Market Readiness Level (MRL), Consumer Readiness Level (CRL) and Society Readiness Level (SRL). Note that in the IRL assessments, TRL and its levels are taken exactly from the original TRL definition by NASA, but analys of DRL is undertaken through the other four developed dimensions. In the IRL assessments, each of the 5 dimensions consists of several levels representing the technology readiness in that dimension. Successively, the IRL of technology is assessed by considering the technology's levels in all five dimensions. The five dimensions and their levels are explained below.

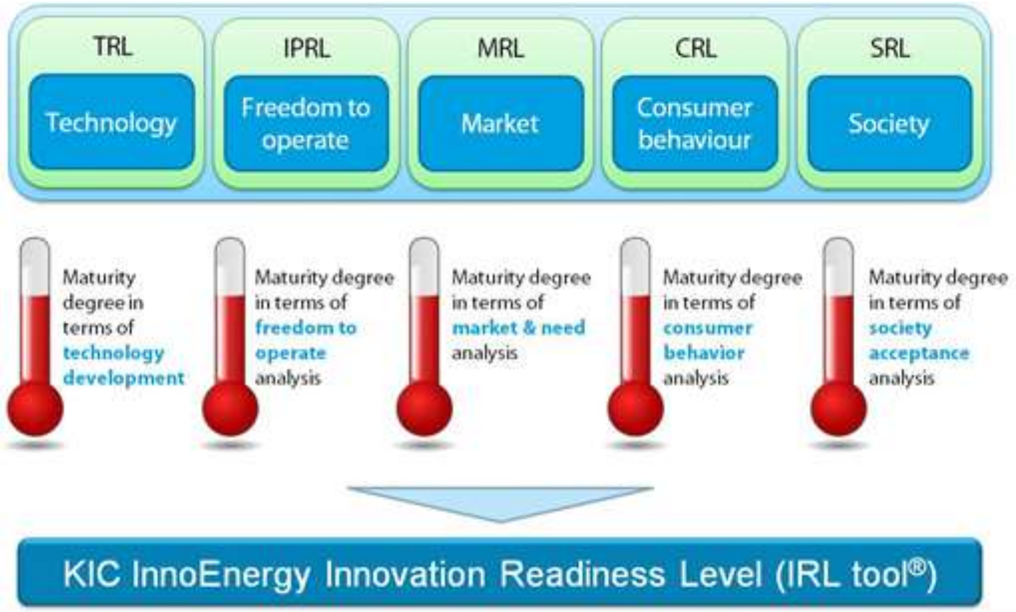

Figure 4 – InnoEnergy IRL tool

TRL: this dimension includes 9 levels and assesses the maturity of technology by exploring its development process from research to sales and certifications. In this assessment, TRL investigates the technology's objectives and studies its production and demonstration processes.

IPRL: this dimension includes 3 levels and assesses whether a technology could freely access and operate in a market, or its deployment is blocked due to already-established IPs and patents. Companies' knowledge about the existing patents in the market is evaluated and it is investigated how and if the companies cooperate together with respect to their IP rights.

MRL: this dimension includes 12 levels and investigates market parameters that affect the need for a given technology in the market. The analyses explore, among other things, existing competition in the market, alternative technology solutions, or cooperation among the technology's value chain. When available, the future market trend of technology is studied and the potential market size is explored in order to envision the technology deployment potential. The overall objective is to explore the market need for the technology and investigate the road toward full commercialisation and successful deployment of the technology.

CRL: when consumers of energy are different from customers, CRL assess consumers' readiness level as well as their need for the new technology through the 6 levels. For example, in some European countries, electricity is purchased by retailers from electricity generators, which makes the retailers the electricity customers. Next, the retailers transmit the electricity to households to be used by residents. In this case then, the building residents are the consumers. The CRL estimates the consumers' willingness to engage in the technology development and analyses their needs, routines, resources and abilities. In addition, the Consumer Readiness Level explores consumers' contributions to technology deployment. Figure 5 provides an overview of existing building stocks and their consumers.

SRL: this dimension includes 5 levels and investigates the technology's actors. Stakeholders do not only include consumers and customers, but also governments, NGOs, supply chains and any other authority involved in the process of technology development and deployment in the market. The assessment aims to identify if for a given technology the stakeholders are identified, informed and involved in the process of technology deployment. It also explores the concerns of the stakeholders and investigates if these concerns are tackled.

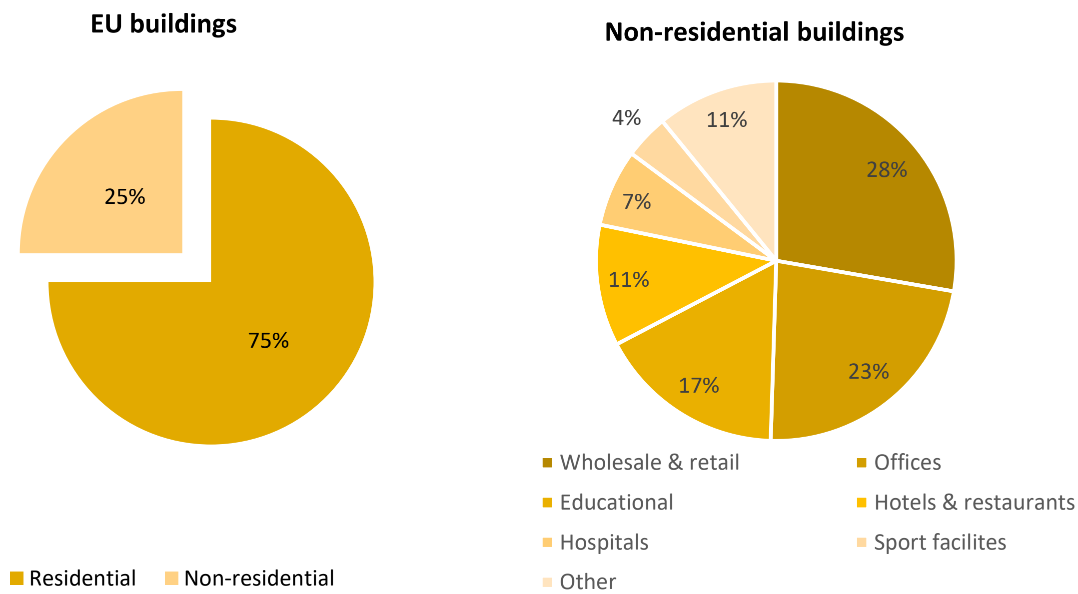

Figure 5 -Share of different types of buildings in Europe [3]

I.2. REEEM Innovation Readiness Level Methodology

For the purpose of the REEEM project, a customised version of the IRL tool has been developed. The first version of this customised tool was used to assess the IRL of energy storage technologies in 2017. The customised IRL tool has been revised afterwards based on the gained experience during the implementation process. The aim of this revision was to enhance the tool to collect more elaborate and representative data. One year after, in 2018, the second updated version of the customised IRL tool was used to evaluate the IRL of renewable energy technologies. This report uses the third version of the customised IRL tool for assessing the IRL of energy efficiency technologies for buildings.

For the IRL assessment, data are gathered by means of an extensive questionnaire. Each of the questions addresses a specific parameter or condition of the IRL assessment (e.g. questioning the availability of alternative technology in the market). The questionnaire includes binary or predefined answers to minimise the influence of biases and external opinions on the results. The answers are coded in order to report the results quantitatively (e.g., Yes=1, No=0, Partly=0.5). Next, the quantitative answers are summed and scaled in order to calculate the technology's level in each of the studied IRL dimensions. There is no weighting of the questions, meaning that all the questions within the questionnaire are treated equally. Note that there is only one IRL questionnaire and it is used for evaluating all technologies studied in this report. The obtained results from the IRL questionnaire are validated through literature studies and several interviews with InnoEnergy experts as well as the experts who were involved in filling out the questionnaire. Note that due to the confidentiality of the IRL tool and its questionnaire, it was not possible to send the questionnaire to a large number of experts. Instead, InnoEnergy has used its trusted network of experts to conduct detailed interviews and analyses with firms and players involved in the development of each of the studied technologies. The number of interviews ranged between 1 and 3 for each technology. This is considered as a limitation of this study and shall be addressed in the future analyses after resolving issues related to IRL confidentiality.

The overall IRL score of technology is assessed and calculated by considering the readiness level of that technology in all the five dimensions, namely TRL, IPRL, MRL, CRL, and SRL. This means that the IRL as a whole is reported as the sum of the readiness levels of technology in all the five dimensions (0-35) and it is called the IRL score. In order to understand and interpret the IRL score of technology, it is important to evaluate innovation readiness of technology along the five dimensions. In other words, the IRL score cannot be understood as a standalone number, but rather as a description of a technology's readiness levels in all the five dimensions. This is because, for some technologies, a specific dimension could play a more significant role than others. Note that, the IRL score provides only an overview of the current status of technology without making any projections about its future development or deployment.

The results of the IRL assessment of technology are illustrated in a radar graph similar to Figure 6. In this figure, the recorded level of each dimension is scaled to 0-1 in order to make a comparison between the dimensions clearer. The noted numbers in the parentheses illustrate the minimum and maximum levels of each IRL dimension. The blue line shows the status of the studied technology in each dimension of IRL.

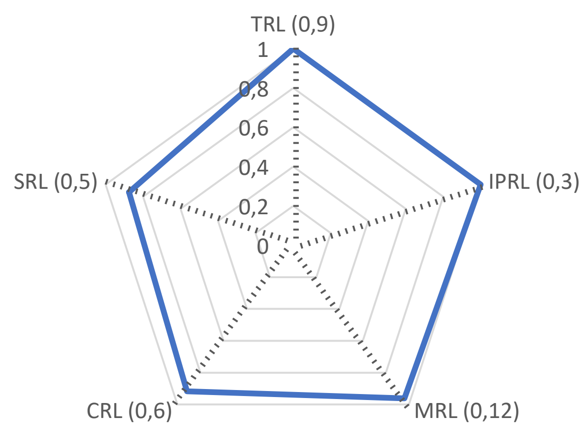

Figure 6- Illustration of the results of the IRL assessment

Figure 7 summarises the methodological steps of this report.

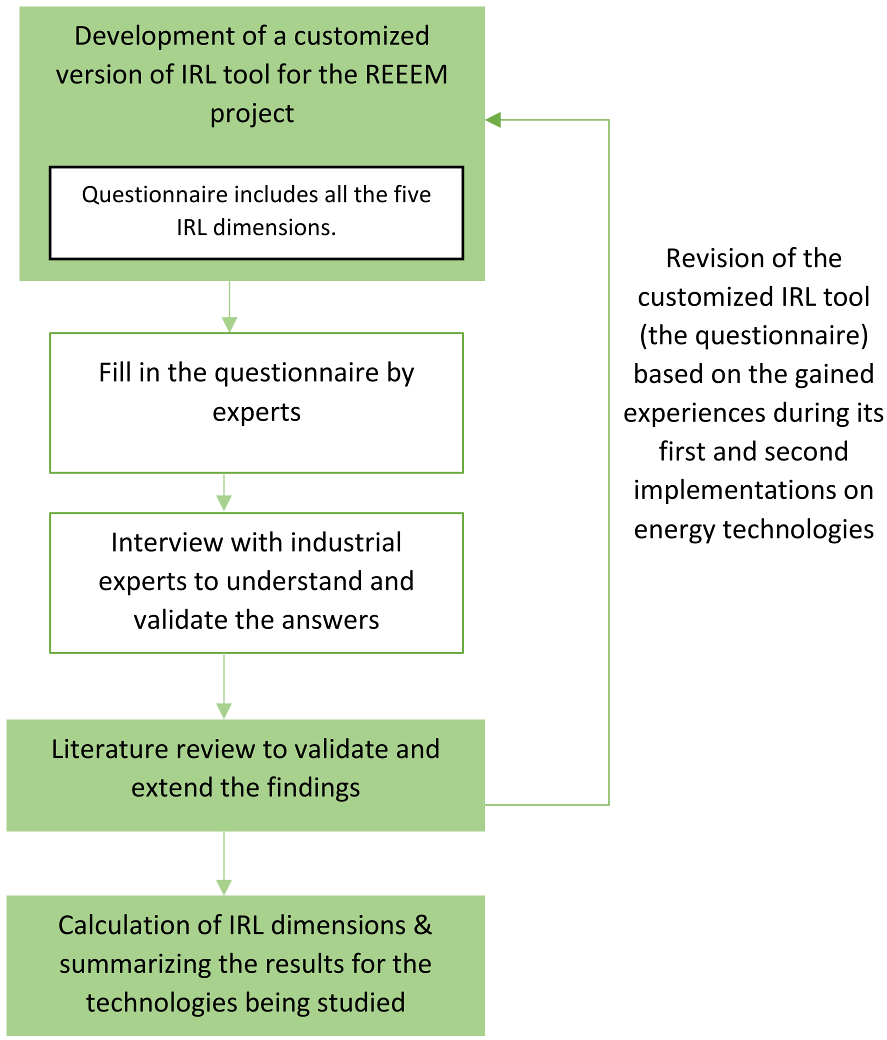

Figure 7 – Overview of the methodology used for the development of the customised IRL tool for the REEEM project

I.3. Context: Energy Efficiency Technologies

This report is the last implementation of the IRL tool for the purpose of the REEEM project. The IRL reports aim to extent the findings of the REEEM roadmap by providing a more extensive overview on the innovation processes of selected energy technologies.

This report focuses on technologies utilised for improving the energy efficiency of buildings. Three technologies are selected for the IRL assessment of this report. These technologies are selected from different groups of technologies which can contribute to improving the buildings' energy efficiency. As mentioned earlier in this reports, these technologies could be categorised to three groups of heating and cooling, insulation materials and electric appliances. By selecting a technology from each of these groups, this reports aims to provide a more comprehensive overview of the market.

The selected technologies are solar roof tiles, heat pumps and wood fibre insulation.

II. Innovation Readiness Level Assessment

II.1. Solar tiles - Advanced roofing system

Solar roof tiles are a special type of solar panels designed to look and perform like roofing materials. The tiles are a form of Building-Integrated Solar PV (BIPV) and considered as a type of advanced roofing materials. In the market, solar tiles have gained good reputation, especially after the announcement of Tesla about the plan to develop solar tiles with competitive price and desirable performance and similar visual features to traditional roof tiles. Tesla is probably the most known company when it comes to solar roof tiles, but it is neither the only nor the most successful one [8]. So far, different companies have entered this market and different solar PV technologies have been developed. To illustrate, CertainCreed, a subsidiary of Saint-Gobain, has been producing solar roof tiles over 6 years now [8]. Another example, SmartRoof[1], a European start-up supported by InnoEnergy, is producing solar roof tiles with attractive characteristics ready for sales. SmartRoof has labelled itself as one-stop-shop for solar energy in Europe.

While solar PV is already a mature technology, the development of solar tiles is challenging for several reasons. First of all, the tiles should satisfy the customer's visual standards and expectations. This is particularly the case in Europe because some houses and buildings are located in regions with a strong historical and architectural background. Second, the tiles should have a similar performance level as traditional roofs, in term of resistance to water and wind. Third, solar tiles must provide high insulation capacity and thermal heat efficiency for buildings. Currently, in the market, solar roof tiles include an air duct or tube to keep the temperature of the tiles to the minimum. In this process, solar tiles produce heat which flows underneath the tiles. In some models of solar tiles, the generated heat can be stored and used later on for different purposes such as in heat pump boilers. This means that there will be more energy saving options as the stored heat could be used later on for saving the cost of producing hot water.

The analysis of this technology indicated the overall IRL score of 29.1 out of 35 for solar roof tiles (Figure 8).

The findings show that what lowers the IRL of solar tile technologies is particularly related to their MRL and CRL. Below the details of solar tiles' innovation readiness levels along the five dimensions of IRL are discussed.

[1] *http://www.smartroof.be/*

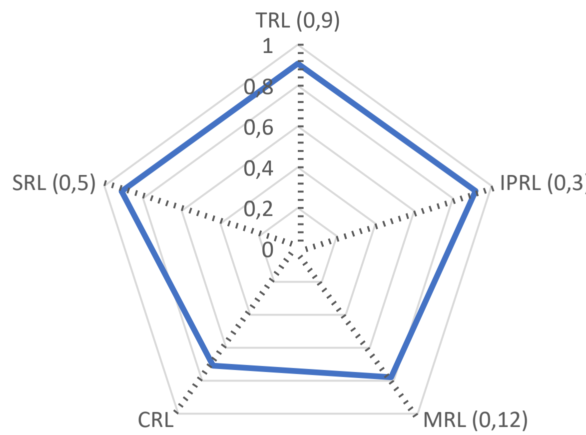

Figure 8 –The IRL assessment of solar roof tiles

Technology Readiness Level

The assessment of this report indicated the TRL level of 8.2 out of 9 for solar roof tiles. Solar tiles are commercially available in the market since 2005 [9]. So far, different types of solar tiles have been deployed in the market. Note that the characteristics of solar tiles developed by different companies active in this market are different from one another. The analyses of this report shed light on the general status and potential of these tiles.

The TRL assessment showed that for the solar tiles, the basic principles are identified and understood and potential applications are foreseen. The TRL assessment also shows that different elements of the technology are designed and integrated together. All the certifications for the technology have been completed. The technology has been tested and has demonstrated an acceptable level of performance in targeted site conditions.

The assessments show that the operating conditions of the technology are identified and investigated. The most important operation condition is "weather" as it can influence the performance and efficiency of tiles. The weather conditions vary according to the different European regions and this creates varied efficiency, thereby a challenge for solar tiles. Although this challenge is an overall concern related to solar PV and not specific to solar roof tiles. Overall, the solar roof tiles are commercially available and satisfy their application objective meaning producing efficiently energy while keeping some aesthetic.

What lowers the TRL of solar tiles is that the current cost of these technologies (around $21.85 per square foot) needs to become more competitive to justify their applications and encourage investments. Besides, there is room for improving their efficiency and ease the installation of these technologies in different locations and sites. Currently, developing solar tiles which are resistant to any types of weather and are suitable for different site conditions is a challenge in the market. Finally, although certification processes have been done for solar tiles, in some regions with a lack of local suppliers, receiving certificates for this technology (e.g. certify their fireproofing) is a challenge due to the lack of customised products.

IP Readiness Level

The IP readiness level assessment recorded a level of 2.8 out of 3 for this technology. The analysis showed that there are established patents and IPs in the market, evidencing on the established knowledge in the market for this technology. The number of active companies in this market is limited, yet there are collaborations among the companies to further facilitate the development of solar tiles. The collaborations enable the companies to benefit from each other's' knowledge base. Generally, there is no particular patent blocking the progress and development of solar tiles. However, there are patents on the innovative and particular features of solar tiles which make the product of one company different from another. An example of such patents is "Uniformly and Directionally Coloured Photovoltaic Modules" which is published by Tesla in 2018, enabling the company to produce solar tiles with colour variant [10]. The analyses show that there is a need for better marketing of different types of solar tiles to clarify the technologies' potentials and differences from one another.

Market Readiness Level:

MRL recorded the number of 9.4 out of 12. While it has been more than a decade that the tiles are commercially available in the market, the market share of solar tiles is still low. The MRL assessment showed that solar tiles address an unsatisfied need in the market, which is to provide efficient insulation material for buildings and simultaneously produce sustainable and cheap electricity. The solar tiles can satisfy this need by providing households with sustainable energy at a low price, provided that the price of this technology decreases in future market. The value of solar tiles in a house or building becomes more significant if these technologies also harness the heat which follows underneath the tiles (for example for a heat pump boiler). This innovative type of solar tiles has been already deployed and operationalised in the European market, for example by a Dutch company called ZEP[2]. The analysis did not record any risk of lack of supplier.

The assessment also showed that customers of the technology are identified. Generally speaking, customers with the highest potential are new buildings or households who need to change and/or renovate their roofs. Households with functioning roofs (meaning roofs which are not yet at the end of their lifetime) are less likely to invest in solar tiles, due to the associated financial burden.

The MRL analyses identified policies as parameters to enhance or hinder the development of solar tiles. On one hand, they can support the development of solar tiles via subsidies provided for renewable energy production. Policies also support solar tiles through tax incentives or financial support for households when they manage to reduce their energy or heat demand. On the other hand, policies block the deployment of solar tiles through tough standards and certifications of safety performance (e.g. fireproofing). What makes these standards and certifications particularly challenging are their differences across EU countries and regions. This hampers large scale production of solar tiles with similar features. Overall, in Europe, policies influencing solar tiles are different across European countries.

As declared by our interviewees, a number of parameters help reducing the MRL of solar tiles. Firstly, in the market, there has been no specific R&D budget dedicated to solar tiles by governments. Most of the dedicated R&D budget is so far provided by industry. Secondly, due to the uncertainty associated with the existing policies or customers responses, there are no concrete market projections for the future market trend of solar tiles. Thirdly, in spite of the competitive advantages of solar tiles, their position could be threatened by traditional

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[2] *https://www.zep.solar/*

roofs, which are cheaper, or by new types of roofs with more desirable characteristics. The price, services and accessibility of this technology are just only partly justifiable. This influences the MRL of this technology. In some countries, the price of this technology is less competitive due to the high cost paid by companies to obtain complete certifications before the installation. Finally, the IRL assessments showed that although the value chain of this technology is established and identified, it faces a number of challenges to develop a product which can meet the standards and requirements of different buildings or houses across Europe. This is not possible without raising the cost of this technology from its current level, due to reducing the potential of economy of scale.

Consumer Readiness Level

This dimension recorded a level of 4.3 out of 6. The technology fits the consumers' needs when their awareness about sustainability issues is a decisive factor. The technology does not affect the consumers' energy consumption routine, which further facilitates the deployment of solar tiles in the market. The CRL assessment explained that consumers' acceptance varies according to the ownership status of buildings. In most cases, consumers are more prone to accept (or even invest in) solar tiles if they live in a house/apartment which they own rather than if they rent it.

What lowers the consumer's readiness about this technology is primarily the fact that solar roof tiles are, to some extent, visually different from old and traditional roof tiles. Besides, the cost of solar tiles ($3.63 to $3.75 per watt) in comparison with other alternative options ($3.18 per watt for solar panels) lowers the interests of consumers in these technologies. In addition, consumers are not currently engaged in the process of technology development, which slows down the progress which could be made, based on their feedback. Although if consumers are not further engaged, this is partly due to the limited deployment of these technologies.

Society Readiness Level

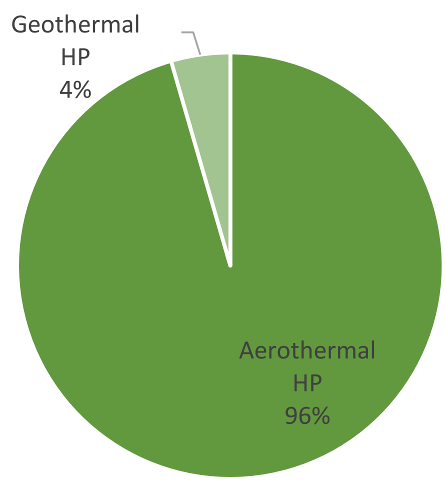
The SRL recorded a level of 4.5 out of 5. The stakeholders around this technology are identified and can influence the development and deployment of solar tiles. Among different stakeholders, the role of governments is identified to be important. By setting standards and safety requirements, the governments could directly influence the deployment rate of the tiles.

The assessment explored the concerns and expectations of stakeholders. Varied rules on safety, standards and installation of solar tiles in different European countries underline the concerns and issues deemed important by the stakeholders. The analyses also identified that the uncertainty about the time it takes to benefit from financial investments in solar tiles can be a concern among stakeholders. Payback period is indeed not so clear when it comes to solar tiles (between 5 and 15 years according to the regions). This is in spite of the fact that most of the stakeholders are aware of the financial benefits of investments in solar tiles such as financial national incentives (i.e. tax credits). These concerns will be resolved if the cost of the solar tiles decreases in the coming years. Overall, the assessments did not find any unresolved concerns about the influence of solar roof tiles, in particular on the environment, health or safety.

What lowers the SRL of this technology and its potential for large scale application is the ambiguity of European policies. Besides, there are differences among concerns and priorities of national and European stakeholders. To resolve this issue and improve the SRL of solar tiles, on the European level, the European Commission could promote the establishment of harmonised standards and policies across Europe. On the national level, governments and authorities can influence the technology deployment by facilitating the process of getting permission for the installation of the technology using simplified process and harmonised laws. Besides, the limited engagement of stakeholders in the development process of solar tiles is another factor influencing negatively the SRL of solar tiles.

II.2. Heat pump

Heat pumps are fairly developed and have been deployed in Europe since the 19th century. In 2017, the number of heat pumps in Europe exceeded 33 million units (see Figure 9) [11]. Heat pumps transform renewable energy from the surrounding (air, water, ground, waste heat) into useful heat through a refrigerant cycle. A fluid is used to transfer this heat from a low-energy source to a higher energy sink. This is done through a process run by the compressor and pumps, for which a form of high-grade energy such as electricity is used. The captured and transferred heat is then used for raising or lowering the temperature of a building as well as water [12].



** Geothermal Heat pumps = 1544560 units; Aerothermal heat pumps = 32880160 units (Aerothermal includes are-air HP, air-water HP and exhaust air HP)*

Figure 9 – Total number of heat pumps in operation in Europe till 2017 [13]

Heat pumps can be categorised into different groups based on the energy sources from which they extract the energy. Heat pumps have the potential to be used for space heating and cooling or hot water depending on the need. The common energy sources of heat pumps are in the form of ground, water or air. This creates three main categories for heat pumps:

- **Ground-source heat pumps (GSHPs)**: this heat pump uses the heat stored in the ground. The energy efficiency of this type of heat pump is generally high because the temperature of the ground normally stays stable throughout the year (between 0 and 20°C at ground level from winter to summer while 10°C stable all year long under 7 meters). This type of heat pump is useful for space cooling in summer and heating during the winter.
- **Air-source heat pumps (ASHPs)**: this type of heat pump uses outside air temperature and transfers it by means of a compressor and two coils made of conductive copper tubing. When heat is needed, a

refrigerant extracts the heat from the air outside of the coil to evaporate. The gas then is turned into a liquid and provides warmth into a household heating system [14]

- **Water-source heat pump (WSHPs)**: this technology works similar to the GSHPs with only a difference that it uses from localised water sources to draw heat.

Among these types of heat pump, the air heat pump remains the most common energy source used in the European heat pump market. ASHPs constitute about 85% of the total market share. Figure 10 illustrates the sale development of the three types of heat pumps between 2005 and 2013 in Europe [15].

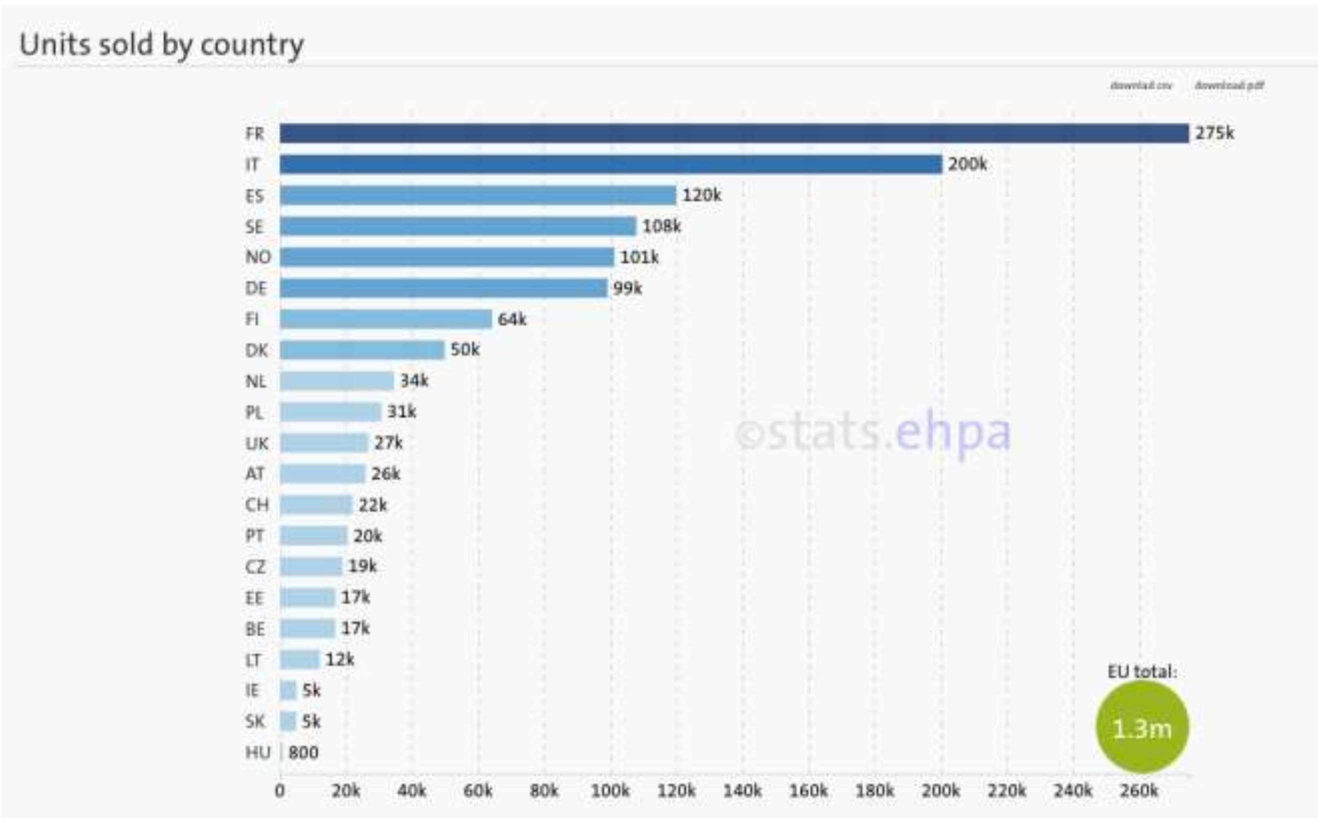


Figure 10 – 2018 Heat Pumps units sold by country [15]

The IRL assessment of this report was conducted on GSHPs in the context of the European market. Still, some of the analyses and discussed points for GSHPs are also applicable to other groups of heat pumps. The analysis of this report recorded the total IRL score of 32.4 out of 35 for GSHP. Figure 11 illustrates the recorded level for each of the IRL dimension for heat pumps. As shown in Figure 11, all the IRL dimensions have recorded fairly high levels, showing the high innovation readiness of heat pumps for application in the European market.

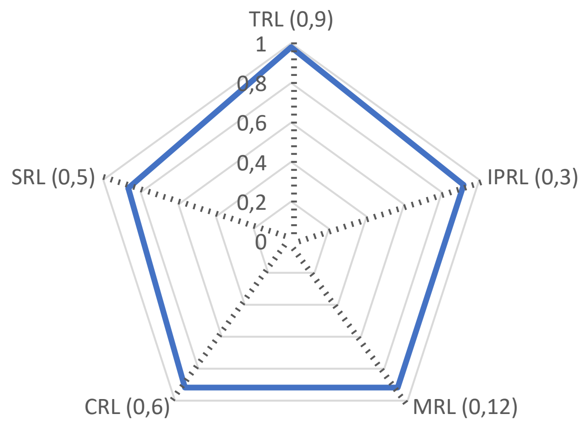


Figure 11- The IRL assessment of heat pumps

Technology Readiness Level

The TRL assessment of GSHP recorded the level of 8.8 out of 9, illustrating the maturity of this heat pump technology. The development of GSHP was first recorded in 1912 in a Swiss patent by H. Zoelly and its first application dates back to 1945 in the USA [16]. When it comes to Europe, the first application of GSHP was recorded in the 1960s [16]. GSHPs has gained a market share in regions with cold climates (such as north of Sweden) when other types of heat pump technologies such as ASHPs are more common in moderate climates.

Heat pumps are a developed and fully commercialised technology and their functionality is proven in relevant working environments. Heat pumps have shown the potential to reach the point of use efficiency of nearly 300% [17]. Interestingly, the efficiency of GSHP could be further improved through different innovative approaches. For example, it is possible to collect solar energy and use that energy for warming the pipes under the ground. This will result in improving the overall efficiency of ground heat pumps. Samster[3], a Swedish start-up, supported by EIT InnoEnergy, has taken innovative approaches in this regard by providing hybrid non-isolated solar panel with a thermal backside.

Another parameter influencing positively the TRL of heat pumps is the completion of the certification processes for this technology. Receiving permission for installation of GSHPs could only be an issue when there are available water resources near their installation site. In such cases, municipalities might oppose the installation of heat pumps, due to the concerns about the influence of GSHP on nearby water resources. Finally, the TRL assessment showed that this technology has a sustainable and established supply chain. In Europe, the vast majority of heat pumps are manufactured in Europe, and European heat pump companies have leading roles worldwide[17].

The assessment showed that the cost can still improve the TRL level of heat pumps. Lowering the cost of heat pumps would encourage larger investments in the heat pump market. This has been also encouraged in the European Strategic Energy Technology (SET) Plan in 2018 requesting (at least) 50% cost reduction of heat pumps

[3] *http://www.samster.se/*

by 2025 compared with 2015 data [18]. The overall cost of a heat pump depends on its energy efficiency and the cost of a (high-grade) energy source used to transfer the heat from a low-energy source to a higher energy sink. Currently, the pay-off time for GSHPs is about 5-10 years.

IP readiness level

This dimension recorded a level of 2.8 out of 3. The first patent for GSHP was recorded in 1912 [19] indicating the long development history of IP for this heat pump. In more recent years, IP has been introduced into the market to protect new and innovative approaches for heat pumps. The IPRL analyses indicated that currently in the market there are enough knowledge and awareness available on the existing IP. There is also a competition in the heat pump market especially for IP on new types of heat pumps such as hybrid systems. Although the existing competition does not hinder the development of heat pumps, it makes it more difficult for companies to get access to the latest innovative approaches and components. All these points have been reflected in the slightly lower IP Readiness Level of GSHPs.

Market Readiness Level

MRL recorded the number of 11.0 out of 12. The need for technology in the market is identified. The technology can provide buildings with renewable and efficient heating and cooling. The need for heat pumps in the European market could be noticed in the total number of units which is more than 33 million until 2017. The data for 2018 are also promising and show that the heat pump market is growing for the 5th year in a row. Only in 2018, more than 12 million units of heat pumps were sold in the global market [20].

In Europe, there are a number of policy frameworks that support the development of heat pumps. The EU Directive (2009/28/EC) credits heat pumps as a renewable energy technology [12], which has been noted as a great political initiative to support the further deployment of heat pumps. Another policy measure that positively influences the development of heat pump market is the Energy Performance of Building Directive (EPBD) [21]. This directive sets strict requirements on the maximum allowed energy demand per metre-squared for buildings. To comply with these requirements there is a need to use technologies that are energy efficient and use renewable sources. Heat pumps comply with both [22].

Moreover, the market acceptance for this technology is high, especially in countries where heat pumps are already implemented and well-known. Our analysis recorded no risk of negative customer behaviour or risk of supply. The services and accessibility of the heat pump are justifiable in the current market. End-users of heat pumps are identified and include, among others, residential buildings or real states companies. GSHP are often more cost-effective when applied on a large scale, which lowers the potential for private customers to engage in this market. End-users could be engaged in the process of technology development, for example by allowing heat pump companies to follow up the energy cost or by sharing data on how efficiently heat pumps function in buildings.

What lowers the MRL of this technology is the high competition that exists between GSHPs and other alternative options. An example is the district heating system which is the preferred option in some regions and is supported by different policy frameworks. Decreasing the price of heat pumps would enhance the position of this technology in the market as well as in competition with alternative options. Note that, electricity prices can influence the profitability of heat pumps and the associated payback time. The higher the price of electricity the more affordable heat pumps will be [15]. Besides, although the value chain for heat pump technologies is developed, it is sometimes challenging to access skilled human resources for the correct installation and development of this technology in the market. Lack of knowledge about heat pumps is one of the main identified reasons that lowers the MRL of heat pumps.

Consumer Readiness Level

The CRL of the GSHP recorded the level of 5.5 out of 6. The characteristics of consumers are identified. It is assured that the consumers have essential resources such as money or service providers to benefit from the technology. The technology fits the cultural background of consumers, especially in Europe as citizens are more concerned about climate change and environmental issues than in other part of the world. Some consumers are engaged in the process of technology development by sharing data on their heat, electricity consumption and savings.

What lowers the CRL of this technology is the fact that consumers currently have other alternative technologies to meet their needs. High competition between heat pumps and other heating and cooling technologies negatively influences the CRL of this technology. This is especially the case since some of the heat pump competitors have a low price and/or high sustainability (e.g. boilers or district heating system). Figure 12 illustrates the share of heat pumps in comparison with other alternative heat carriers for new homes in Germany. As could be seen, a heat pump is only one option among several others for heating the buildings. This figure also shows that the shares of district heating and heat pumps are increasing in Germany over the years.

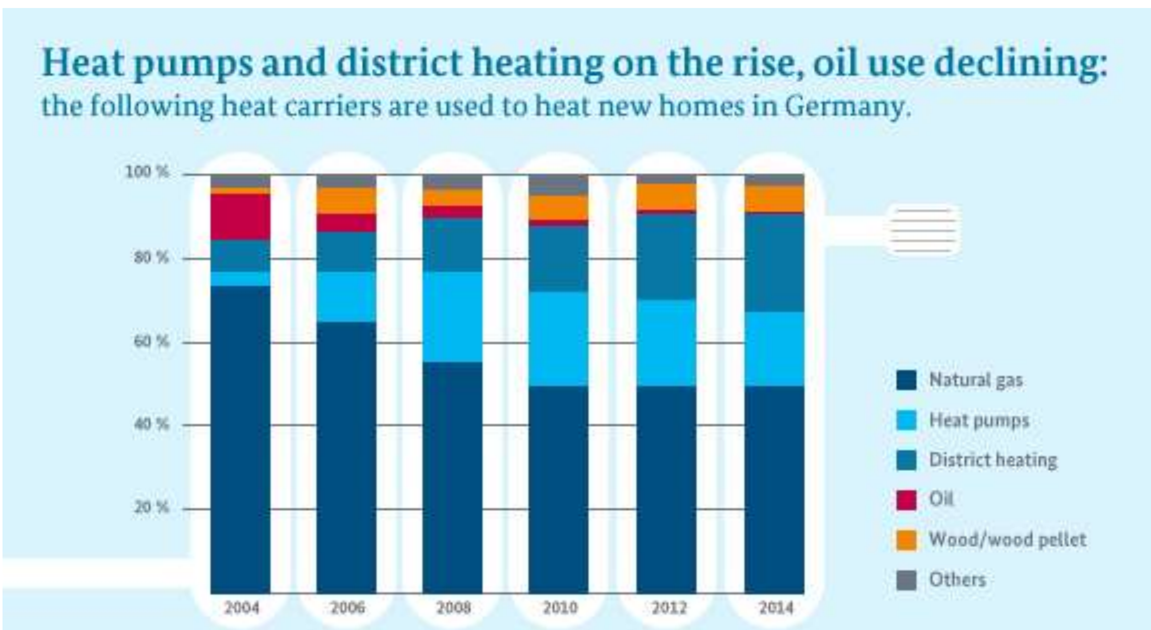


Figure 12 – Share of the heat pump and district heating in new homes in Germany [23]

Society Readiness Level

The SRL of technology recorded the number of 4.3 out of 5 indicating a high readiness level of society for heat pumps. The stakeholders of the technology are identified and their views and concerns on heat pumps are recognised. European and national policies support the development of buildings' energy efficiency and the reduction of heating and cooling demand. This indirectly supports the development and deployment of heat pumps (among the other possible options). The analyses showed that it takes about 5-10 years for the stakeholders to benefit from their investment in heat pumps. Remarkably, with higher energy prices, heat pumps will have a better position in the market which could increase the interest of society in this technology.

The assessment did not identify any issue associated with rare materials used in a GSHP. Heat pumps have limited influence on the surrounding environment. The only raised issue is the refrigerant fluid of GSHP which could potentially have a harmful effect on the environment when it leaks or is not disposed or recycled correctly. This concern has been answered by researchers and relevant R&D efforts aiming to find new types of heat pumps' fluids. As the results of the conducted R&D, the mediums which were used a decade ago (e.g., Chlorofluorocarbon) are forbidden in today's pumps and are substituted by more environmentally friendly materials [24]. When it comes to heat pumps other than GSHP, the analyses recorded other types of concerns. For example, there are concerns about the noises that are associated with ASHPs. Such concerns cause complications for receiving permissions for planning and implementation of these heat pumps [24].

The assessment also shed light on the points that lower SRL of heat pumps. The analyses showed that the limited knowledge and awareness of stakeholders about heat pumps and their potentials in the market is among the main factors lowering SRL of heat pumps. The stakeholders' knowledge (including governments, industrial players, customers, consumers and potential supply chain) could be enhanced on where and when heat pumps are the most efficient technology and how to perform correct and timely installations. To increase the knowledge of stakeholders, different channels, including a regional/national policy campaign, could be useful.

II.3. Wood fibre – Insulation material

Walls, roofs and external parts of buildings are responsible for most of the heat loss. Proper insulation of buildings, hence, could contribute significantly to the improvement of their energy consumption as well as energy efficiency. The largest application of insulation materials in buildings by value is in the wall (about 47%), roofs (about 37%) and floor (about 15%) [25]. Figure 13 illustrates these shares in the European market.

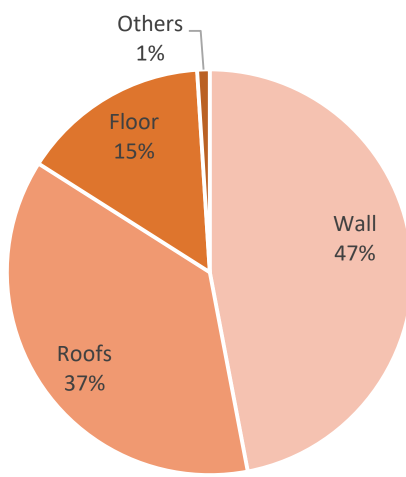


Figure 13 – Market share of insulation material in Europe by value for different buildings' components [25]

Figure 14 illustrates the expected development of the market for insulation materials in different European countries. As shown in this figure, the development rates are higher in some European countries than others. For example, this rate is higher in central and eastern Europe, especially in Germany and France [25].

Source: JRC representation with data from Visiongain, 2017.

Figure 14 – Market forecasts of thermal insulation materials for selected EU countries – values are in million USD [25, p. 7]

To improve buildings' insulation, so far different types of materials have entered the market. Figure 15 illustrates the market share of the main insulation materials used in Europe. Below a short description is provided for each of these materials.

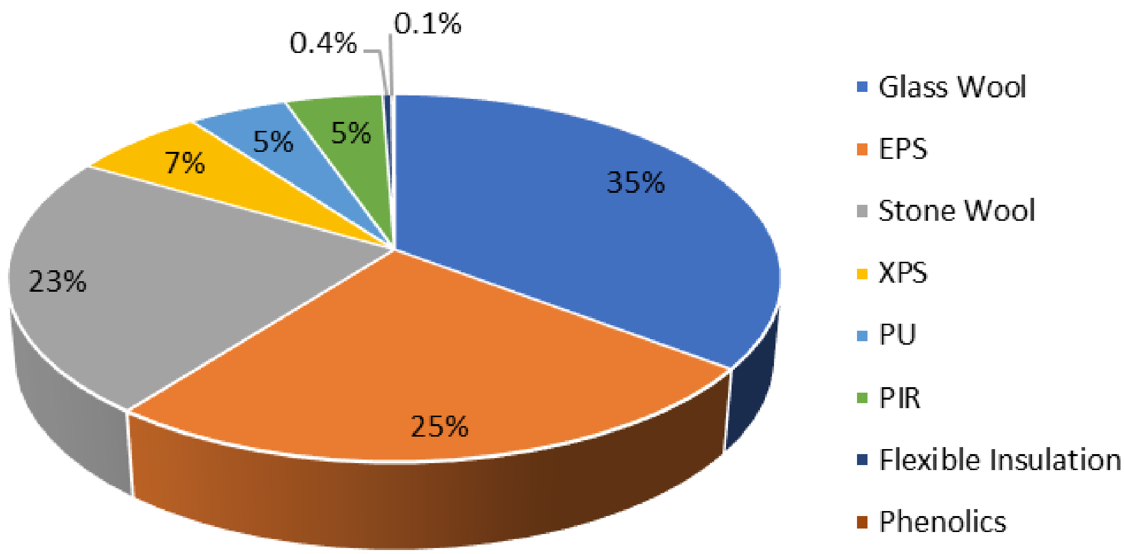


Figure 15 – European thermal insulation market by product, 2016, by volume [10]

- **Mineral wool:**
  - **Glass wool:** this insulation material traps air in the small pockets of fibreglass which is spun into rolls, sheets or batt. The heat then is insulated using the trapped air. This material has a long lifetime and can be used in floor, ceilings and cavity walls.
  - **Stone wool:** similar to glass wool insulation, stone wool insulation material belongs to the category of mineral wool. Stone wool is made from molten stone. This material is spun to the fibre-like structure.
- **Expanded Polystyrene (EPS):** EPS is made from polymer and is impregnated with a foam creating a uniform closed cell structure when exposed to steam. This material is flexible, highly resistant to heat flow and moisture penetration. The material is light and easy to install for external wall insulation. It is used extensively in Europe due to its favourable characteristics and price. On the negative side, EPS has limited flame redundant properties [26]. EPS is widely used for pitched roof applications.
- **Polyisocyanurate (PIR)** is an efficient insulation material, which is produced as a foam. The most common types of PIR include a rigid insulation core placed between two high-performance aluminium foils. PIR is used for internal wall insulation.
- **Extruded polystyrene (XPS)** is a closed-cell foam material which absorbs very minimal quantities of moisture. XPS is in the form of foam billets with a thickness between 20 to 200 mm. In spite of its high and favourable performance, this material is not completely resistant to UV light or to rotting and ageing.

Others:

- **Wood fibre** is an insulation material which allows the production of high-quality insulation products from recyclable and sustainable materials. However, the market share of this material is still small. Wood fibre could substitute non-renewable and poorly recyclable materials as it is sustainable, breathable and has low thermal conductivity.
- **Mineral foam** is a panel made of fully mineral materials and used for the ecological type of construction. The insulating effect of mineral foam panels is somewhat less than mineral wool but it provides perfect heat insulation and resistance to flames.

The effectiveness and performance of each of these materials depend on their specific characteristics as well as the outdoor climate and the building's age and type. This means that different insulation materials are suitable for different types of application. For example, in Europe often EPS is used for sloped roofs while PIR is used for internal wall insulation. The differences between the characteristics and applications of insulation materials have made a comparison between the performances of these materials a challenge.

Currently, in the European market, mineral wools and plastic foams together possess more than 90% of the market share (see Figure 16). This high share owes to the competitive price, high performance and easy accessibility of these materials [26]. The 10% rest of the market is constituted of other insulation materials, such as wood fibre or mineral foams, which in spite of their higher prices have managed to get a small market share.

For insulation materials, the IRL assessment of this report focused on wood fibre due to its innovative dimension. This insulation material has so far, gained a small market share. Though, with raising environmental concerns, this share is expected to grow due to its promising features such as being highly recyclable or ecological. Figure 16 illustrated the IRL assessment of this technology. Overall the IRL assessment recorded score of 27.8 out of 35. The CRL and MRL were the identified dimensions with the lowest recorded readiness levels.

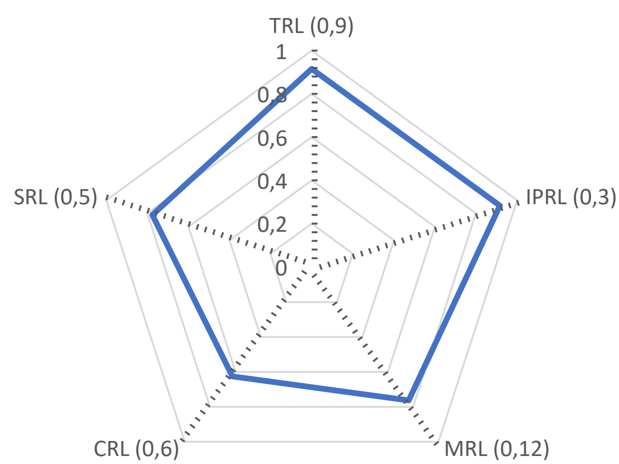


Figure 16 – IRL assessment of wood fibre insulation material

Technology Readiness Level

For wood fibre, the TRL assessment recorded the level of 8.3 out of 9. Wood fibre is a developed and fairly mature insulation material which has entered the European market about 20 years ago [27]. The basic principles of this material are understood and its performance and functionality have been tested in relevant working environments. Currently, there is a limited number of supply chain players in Europe for this material. This small number of players weaken the supply for this insulation material which is needed for large-scale production. However, currently, this is not an issue as the market share and demand for wood fibre material is small. This small market share has lowered the interest of new firms to join this market during the past years.

Wood fibre is a fully demonstrated insulation material in Europe and its success lies in its attractive environmental profile. Wood fibre has the potential to enhance buildings' insulation with low carbon footprint and using sustainable and recyclable materials [28]. Having such features, wood fibre has gained the interests of ecologists and encouraged industries or researchers to make R&D investments in this material. To illustrate, at the Technical Research Centre of Finland, there are attempts to develop wood-fibre based insulation materials and sprayable insulation foams. The objective of this research is to develop materials with the potential to replace non-renewable or poorly recyclable raw materials in the insulation market [29].

The analyses showed that what lowers the TRL of wood fibre material is primarily the high cost of this material in comparison with the alternative options. In order to enhance the position of this material in the market, there is a need to reduce costs through innovative approaches such as automating the production process of the wood fibre.

Another parameter to lower the TRL of wood fibre materials is the lack of certifications in different European countries for large-scale production of this insulation material. Currently, there are certificates assuring the compliance of the quality of wood fibre materials with EU standards. Availability of such certifications on a national level would be an enabler for further production and deployment of the wood fibre across Europe. This certification is especially important for wood fibre since their production is associated with high usage of wood, which calls for certification to assure the proper forest management.

IP Readiness Level

The IPRL recorded the level of 2.8 out of 3, indicating high progress and development made in the IP development related to wood fibre materials. Different companies develop and register IPs in order to protect their products and innovations related to them.

The assessment showed that most of the companies active in this market have a good knowledge base about the registered IPs in the field of wood fibre materials. There is good cooperation among the companies for further development of the wood fibre market. This is because companies believe there is a higher chance of market growth through cooperation rather than competition. This means, while active companies in this field may have the opportunity to slow down their competitors' progress and development through their IPs, it does not happen because companies would like to see the market of wood fibre growing. And according to them, their chances go higher through collaboration than through competition.

Market readiness Level

MRL recorded a number of 9.2 out of 12. Our analysis shows that there is a need in the market which can be met by wood fibre insulation materials. The need is to enhance the buildings energy efficiency using sustainable, recyclable and resistant insulation materials. The customers of the technology are identified and include building companies, carpenters and roof constructors, among others.

So far, there has been no policy influencing directly the wood fibre market. However, there are policies and legislations promoting energy efficiency of buildings. These policies support investments in wood fibre insulation materials as well. Social and environmental factors are in favour of investments in wood fibre for the construction of new buildings due to its positive environmental influence and sustainable characteristics. Economic factors favour investments in wood fibre insulation materials in the regions with a higher price of energy and electricity.

This is because the higher energy and electricity prices can reduce the payback time of the investments in wood fibre materials after improving buildings' insulation.

The value chain of this technology is identified and established. This value chain is scattered across Europe. For example, a company may obtain wood fibre from Poland, store them in compact products in Germany and assemble in Belgium. One identified risk associated with this scattered value chain is that importing wood waste and pallets from other countries could create issues related to accessibility and quality of the pallets.

The customers for wood fibre are identified and the main driver behind their investment's decisions is recognised. The higher comfort level and environmental concerns are the main motivation behind the investment decision of customers in this market. Projections and plans are made regarding the future market trends of this insulation material. Although the current market share of wood fibre is limited, it has shown the potential to reach about 20% in Europe.

What lowers the MRL of the wood fibre material is firstly, the high competition between this material and other alternative insulation materials. The alternative materials (e.g. mineral wools) have often an established market share, competitive price and high performance. These features threaten the position of wood fibre in the market in spite of its advantages such as being fully recyclable. Secondly, low R&D investments and lack of skilled human resources further lower the development chances of wood fibre materials [26]. Thirdly, scattered value chain and limited supply of wood fibre materials are other reasons weakening the MRL of the wood fibre. Fourthly, to access wood fibre insulation, the customers of the technology need to go through building companies because so far there are very limited and non-existence wood fibre materials which could be used as renovation materials. Finally, the lack of knowledge in the market about these materials has been noted as an issue for their deployment in the European market. Efforts are needed to assure customers about the quality and potentials of wood fibre in the market.

Consumers Readiness Level

The CRL of wood fibre insulation material recorded number of 3.8 out of 6. The utilisation of wood fibre materials is associated with a high comfort level for the consumers (end-users) and does not influence consumers' (energy consumption) routines. In the European market, there are some consumers who demand to rent or to purchase buildings that are constructed using natural materials such as wood fibre. This is due to the consumers' preferences for building materials that are fully sustainable and recyclable.

What lowers CRL of wood fibre is that in some EU countries, consumers are reluctant to invest in this material since they believe in buildings made of stone and concrete. Some consumers also favour buildings with traditional looks. Besides, as mentioned before, wood fibre materials can be used during the construction of buildings and not during renovation processes. This means private consumers *per se* cannot invest in these materials. Furthermore, due to the limited number of consumers in the market, it is difficult to engage the consumers in the process of technology development. As a result, the possibilities of improving wood fibre materials through consumers' feedback (e.g. sharing information about the actual performance of these materials) is limited. All of these parameters lower the CRL of wood fibre materials.

Society Readiness Level

The SRL of this technology recorded 3.9 out of 5. The stakeholders encourage investments in wood fibre technologies as long as their concerns are solved. The stakeholders' concerns include risks of moisture, insects, fire and others. Most of these concerns are already tackled through development and innovation of wood fibre materials during the past years.

The SRL assessment also revealed that wood fibre has a positive influence on society. It has the potential to improve the comfort level and quality of living of residents. Besides, wood fibre is made of ecological and fully recyclable materials. Due to these features, the wood fibre materials have been supported extensively by environmentalist and ecologist. However, there are also lobbying against this material by companies developing and deploying other types of insulation materials.

The assessment also identified a number of parameters lowering the SRL of wood fibre insulation material. First, in several European countries, there is a need to import essential wood. This raises questions about the wood quality and also create concerns about the wood collection methods, which if it happens without correct forest management could lead to resource scarcity. Secondly, the limited engagement of stakeholders in the process of technology development and deployment reduces the opportunities for wood fibre materials to grow through their support. This will possibly change in the future as the market share of wood fibre materials increases. Finally, since the wood fibre is still in a niche market, it has a limited chance to benefit from technology-neutral national and European policies as much as other insulation materials with a lower cost and higher deployment rate. Improvement of all these factors can enhance the SRL of wood fibre material and enhance its potential to successfully access the market.

III. Conclusion

This report assessed the potentials and risks of a selected number of technologies for enhancing the energy efficiency of buildings in Europe. It did so by using a customised version of the IRL tool, a methodology developed by InnoEnergy. The IRL tool measures innovation readiness of technology along 5 dimensions of technology readiness, IP readiness, market readiness, consumers' readiness and society readiness. The results of this report aim to extend the findings of REEEM roadmap by providing a more detailed overview of the innovation processes of selected energy technologies.

The IRL assessments of this report focused on the three energy efficiency technologies and methods, namely solar tiles, heat pump, and wood fibre insulation material. These technologies are selected from different groups of building components with varied maturity status in order to provide a more comprehensive overview of the buildings' energy efficiency market. Table 1 summarises the results of the IRL assessments on the three selected technologies. The overall objective of this report was to explore the innovation processes of these technologies and identify points in their development and deployment that can facilitate or risk their successful access to the energy efficiency market in Europe.

Table 1– Summary of the IRL assessment of the three selected technologies for energy efficiency in buildings

Technology / Dimension	Solar tile	Heat pump	Wood fibre	Maximum score
TRL	8.2	8.8	8.3	9
IPRL	2.8	2.8	2.8	3
MRL	9.4	11.0	9.2	12
CRL	4.3	5.5	3.8	6
SRL	4.5	4.3	3.9	5
IRL (SUM)	***29.1***	***32.4***	***27.8***	***35***

As shown in Table 1, the assessments recorded varied IRL scores for the studied technologies. The analyses underlined the parameters that can challenge or strengthen the successful access of these technologies to the European energy efficiency market. The findings showed several similarities and differences between these parameters. This report highlights that understanding these similarities and differences is important because it would allow us to simultaneously increase the chances of several energy efficiency technologies to successfully access the market. Below a summary of these similarities and differences is provided.

Similarities

- The assessment of the TRL showed that all the studied technologies have reached an acceptable level of technological development. Among the studied technologies, the heat pump recorded the highest TRL. Note that, a high level of TRL does not mean there is no room for further technology development, but it suggests that future technological development will probably be slower and incremental.
- The high TRL of the studied technologies suggests the development of other IRL dimensions such as MRL and CRL would be more effective in increasing their success in accessing the European market.

- The high cost of the studied technologies was among the main reason influencing both the TRL and MRL of these technologies. The assessment suggested that for successful access to the market, the cost of these technologies should be reduced in order to improve their positions in competition with other alternative options in accessing the market.
- The assessments of this report found that most of the available policies in the European markets are technology-neutral. This means these policies incentivise investments in the energy efficiency of buildings in general, rather than targeting specific technologies or markets. This is not in favour of the development and deployment of technologies that are less mature or have higher prices in the market.
- The analyses showed that the MRLs of the studied technologies were reduced based on the existing high competition between these technologies and other alternative options. This highlights the importance of the parameters which can be instrumental in enhancing the competitive advantages of the energy efficiency technologies in buildings.
- The analyses showed that the studied technologies have an established and competitive supply chain in Europe. This facilitates the accessibility of these technologies in Europe and gives Europe a chance to become a well-known and competitive player in the markets for innovative energy efficiency technologies for buildings.
- The MRL assessments identified regional climate conditions as a deterministic factor for selecting the most suitable technology for improving the energy efficiency of a building. This is due to the fact that outdoor climate influences the required amount of heating and cooling thereby put requirements on the technology for meeting harsh climate features.
- The assessments of IPRL indicated a promising level of activities related to IP development of the studied technologies. The analyses showed that several companies are active in the establishment of IPs and there is a good knowledge base available on the established IPs in the market.
- The assessment showed the importance of consumer's awareness and their choices on the development and deployment of the studied technologies. Consumers can have a direct influence on the renovation processes of a building by having a say on the choice of material, technology or supplier.
- Consumers were identified to be interested in improving their comfort level and therefore are willing to invest in energy efficiency technologies and methods to enhance the energy efficiency of their buildings.
- Households and consumers were identified to be generally open to options allowing them to enhance the energy efficiency of their buildings or houses. This is particularly true in Europe since a big part of consumers have a high level of awareness about environmental issues. Costs of energy efficiency technologies was identified to influence significantly final choices of consumers and households. This means the cost of energy efficiency technologies should be reduced in order to make these technologies a preferred option for all consumer groups.
- The assessment of SRL showed that both European and national policies could influence the deployment of energy efficiency technologies in the market. While European policies give direction, national policies enable companies to expand their market locally more effectively and smoothly.

Differences

- The analyses of this report identified somewhat remarkable differences among the parameters that influence MRL, CRL and SRL of the studied technologies.
- The assessments of this report identified different reasons behind the existing high competition between the studied technologies and other alternative options in the market. These differences highlight the need for using different approaches to improve the position of these technologies in the market. For solar tiles, this competition is high due to the existence of traditional types of roofs cheaper than solar

tiles (though less sustainable and environmentally friendly). When it comes to the heat pump, competition for this technology is high due to the availability of other competitive energy efficient heating and cooling technologies. This competition is particularly high with district heating systems. Finally, developed and deployed types of insulation materials with competitive prices and better accessibility (such as mineral wool and plastic foams) challenge the position of wood fibre insulation materials in the European energy efficiency market. This is in spite of the competitive advantages of wood fibre materials such as being fully recyclable and from sustainable sources.

- The assessments also found differences among the types and extent of societal concerns of the studied technologies. While the analyses did not record any environmental concerns associated with the development of solar tiles for roofs, they recorded concerns related to GSHPs and wood fibre materials. When it comes to GSHP, concerns were identified about the possible environmental effects of the utilised fluid in the heat pump, when it leaks or is not disposed and recycled correctly. These concerns, however, are manageable through precautionary measures. For wood fibre materials the recorded concerns were a bit more significant. Wood fibre materials need to be efficient, resistant to water, climate and stable for several decades. Besides, it is important to eliminate any risks of improper forest management associated with the production of wood fibre insulation materials.
- The analyses of this report identified the certification processes of the studied technologies in different states. For solar tiles, in different European countries, there are different certification processes. These processes impose varied criteria for solar tiles' safety or fire resistance. This report identified the differences among these certification processes as a barrier behind solar roof tiles' deployment on the European level. For heat pumps, the analyses did not find any unmanageable issues influencing the certifications of this technology. When it comes to wood fibre, the analyses suggested there are available EU certificates in the market, but the number of national certifications facilitating or hampering further development of these technologies is limited. This slows down the development and deployment of wood fibre materials in the energy efficiency market for buildings.
- The analyses of CRL showed that consumers' engagement in the markets is different for solar tiles, heat pumps or wood fibre materials. The highest level of consumers' engagement was recorded in the heat pump market, which also has the highest rate of deployment in Europe. This ranking is followed by solar tiles and wood fibre materials, respectively.

In light of the findings of this report, below a set of recommendations are provided for policymakers and industrial players on how to enhance and accelerate the development and deployment of energy efficiency technologies and methods for buildings. The recommendations are based on the findings of the IRL assessments of three energy efficiency technologies, exploring parameters and factors that are prerequisites for successful technology development and access to a market.

Insights for policymakers

- There is a need for targeted policies for each specific technology or market. This would help to exploit the potentials of technologies lower in competition with other technologies or alternative options. However, as has been highlighted in the REEEM roadmap on the energy efficiency of technologies, there is no silver bullet solution or policy that can enhance the position of all the energy efficiency technologies in the market.
- There is a need to increase the awareness of consumers about the methods and technologies, which can improve the building' energy efficiency. This, in turn, will increase the CRL of energy efficiency

technologies in the European market. This could be run through different channels, including mass media and campaigns.

- It would be beneficial to inform national and regional policymakers about the benefits of renovating of European building stocks and existing methods and approaches related to buildings' energy efficiency. In recent years, some steps have been taken in this regard. A campaign called Renovate Europe[4] has been launched in cooperation with different industrial players, civil society and national partners. The campaign focuses on building renovation and aims to enhance the awareness of politician and society on energy efficiency technologies. The campaign pushes for the renovation of European buildings to increase the share of buildings with nearly zero emission standards by 2050. Yet, there is a need for more efforts to realise the goal of renovating 100% of European buildings stocks and reducing buildings energy consumptions about 80% by 2050.

Insights for industry

- Industrial players need to understand that technological development is not the only driving factor behind successful access of technology to a market. Other parameters such as addressing social concerns, increasing the knowledge of consumers about their technologies, strengthening the competitive advantages of energy efficiency technologies in comparison with other alternative options could also improve the position of these technologies in the energy efficiency market.
- It is beneficial to increase public participation in the market through encouraging investments by different groups of people from owners and residents of the private household to building constructors and real estate companies.
- Encouraging engagement of technology stakeholders, including policy-makers, consumers and customers in the market. This can accelerate the development and deployment of energy efficiency technologies in the market. This engagement is possible through approaches such as sharing data about the actual performance of these technologies or engaging in joint projects.
- Increasing the awareness of consumers about the available energy efficient technologies and their actual influence of these technologies on energy cost or comfort level of the consumers. Providing consumers with realistic analyses and calculations on the benefits of buildings' energy efficiency measures can encourage the engagement of the consumers in this market. This, as a result, will positively influence the CRL of these technologies.
- Identifying and resolving the concerns of stakeholders about the technologies being developed and deployed in the energy efficiency market for buildings. This identification process allows companies to increase the potential of a technology or methods to successfully access this market by enhancing the technology's SRL.

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