

STRATEGIC REPORT ON

**IMPLEMENTATION OF RESEARCH AND INNOVATION PRIORITIES** AND DEPLOYMENT TRENDS OF THE RENEWABLE HEATING AND **COOLING TECHNOLOGIES** 

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A special thanks to the members of the Horizontal Working Groups on Buildings, Districts, Cities and Industries, Technology Panels members, as well as all other stakeholders (listed in Annex I), who contributed to the data collection process and by providing ideas and feedback for the final version of this report.

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Manuscript completed in October 2021 Brussels, © RHC-Platform, 2021

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The European Technology and Innovation Platform on Renewable Heating and Cooling (RHC-ETIP) is officially endorsed by the European Commission and its activities are supported by the Horizon 2020 research and innovation programme (GA N° 825998).

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### THE DIR IN A NUTSHELL

### Thanks to this valuable work, the trio of policy documents published by RHC-ETIP in the last three years is now complete



Marco Calderoni
Chair of the RHC-ETIP

Working on the strategic report focusing on deployment and implementation of RHC technologies was a unique opportunity to discuss with the Renewable Heating and Cooling community about how research, development, and innovation activities are being carried out in our sector. The outcomes of this long process showed that the RHC Strategic Research and Innovation Agenda (RHC SRIA), published in October 2020, captured well the main RD&I trends in RHC. The added value of this work was not only the opportunity to discuss with many stakeholders who participated in the online survey and in the successive workshops, but also the feedback

received about some ongoing RD&I activities which had not been worked out in the RHC SRIA. Thanks to this valuable work, the trio of policy documents published by RHC-ETIP in the last three years is now complete. We strongly feel that the RHC Vision, the RHC SRIA, and now the Strategic Report on Deployment and Implementation of RHC Technologies very well represent the RHC sector and provide clear messages on how the renewable heating and cooling technologies can and should contribute to the future renewable energy system.

This report offers an insight into the Renewable Heating and Cooling (RHC) community's research, development, and innovation activities and trends. Its findings indicate that priorities identified in the previously published RHC SRIA<sup>(1)</sup> are well aligned with the RD&I priorities of the RHC stakeholders and are to a large extent being implemented.

The report indicates a clear trend towards cross-cutting technologies, sector coupling, and integrated or hybrid systems, which would increase optimisation and efficiency. Findings also showed a trend towards a greater inclusion of and cooperation with other renewable technologies, particularly hydrogen-based renewable energy systems but also encompassing waste heat recovery,

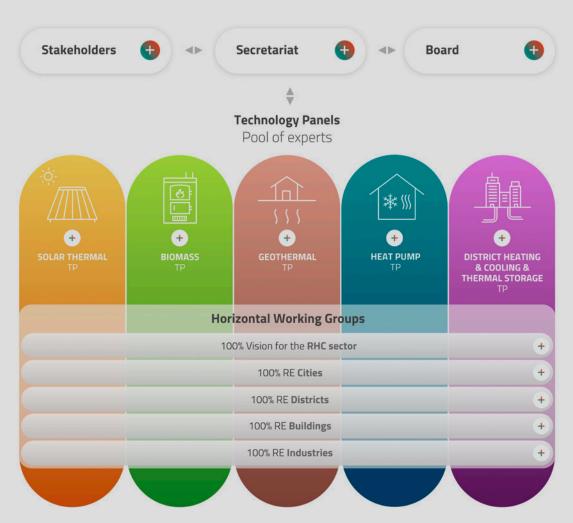
district heating (DH) and district cooling (DC), and thermal energy storage. Finally, RHC sectors are looking to increase the digitalisation of their technologies, such as through smart control distribution systems.

In terms of RHC stakeholders' R&D spending, there appears to be a trend towards investing a greater amount of revenue into RD&I activities in RHC. The findings of this report point towards either an increase in funding or a stagnation over the past 3-5 years. Funding amounts seem to remain the same or increase further in the next few years.

### EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM ON RENEWABLE HEATING AND COOLING IN A NUTSHELL

The European Commission (EC) has supported RHC-ETIP since 2008. The Platform is a forum where European industry and research stakeholders can define technological research needs and set strategic priorities to increase the use of renewable energy sources (RES) for heating and cooling. RHC-ETIP employs mixed structure, utilising Technology Panels and Horizontal Working Groups (HWGs), which were created to bring together interested experts from different technologies directly related to heating and cooling from renewables (below) to think synergistically about how to tackle high-level challenges.

The RHC-ETIP takes a holistic view of research and innovation priorities related to renewable heating and cooling technologies, providing strategic insight into market opportunities and needs. It reaches almost 900 stakeholders from industry, research organisations, and the public sector from all over Europe, and represents trusted and competent advisor to policymakers. The RHC-ETIP has been instrumental in raising the profile of the renewable heating and cooling sectors through its recommendations for research priorities and project ideas.



Structure of the RHC-Platform

### **GLOSSARY** (1/2)

<b>»</b>	AI	Artificial Intelligence			
<b>»</b>	BTES	Borehole Thermal Energy Storage			
<b>»</b>	CO <sub>2</sub>	Carbon Dioxide			
<b>»</b>	ccs	Carbon Capture and Storage			
<b>»</b>	СНР	Combined Heat and Power			
<b>»</b>	CHPC/CCHP	Combined Heat, Power & Cooling			
<b>»</b>	CSP	Concentrated Solar Power			
<b>»</b>	DC	District Cooling			
<b>»</b>	DH	District Heating			
<b>»</b>	DHC	District Heating and Cooling			
<b>»</b>	DHW	Domestic Hot Water			
<b>»</b>	DIR	Deployment & Implementation Report			
<b>»</b>	EC	European Commission			
<b>»</b>	EMS	Energy Management Systems			
<b>»</b>	EPBD	Energy Performance of Buildings Directive			
<b>»</b>	EPC	Energy Performance Contracting			
<b>»</b>	ERP	Energy-related Products			
<b>»</b>	ESCO	Energy Services Company			
<b>»</b>	ETIP	European Technology and Innovation Platform			
<b>»</b>	EU	European Union			
<b>»</b>	F-gas	Fluorinated Gas			
<b>»</b>	GHG	Greenhouse Gases			
<b>»</b>	GSHP	Ground Source Heat Pump			
<b>»</b>	GWP	Global Warming Potential			
<b>»</b>	H2	Hydrogen			
<b>»</b>	H&C	Heating and Cooling			
<b>»</b>	HP	Heat Pump			
<b>»</b>	НРА	Heat Purchase Agreement			
<b>»</b>	HVAC	Heating, Ventilation and Air Conditioning			
<b>»</b>	IoT	Internet of Things			

Information Technology

IT

### **GLOSSARY** (2/2)

<b>»</b>	LCA	Life-Cycle Assessment		
<b>»</b>	LCOH	Levelized Cost of Heat		
<b>»</b>	LCOH2	Levelized Cost of Hydrogen		
<b>»</b>	LoRaWAN	Long Range Wide Area Network		
<b>»</b>	LTDH	Low-Temperature District Heating		
<b>»</b>	MPC	Model Predictive Control		
<b>»</b>	MW	Megawatt		
<b>»</b>	NH3	Ammonia		
<b>»</b>	OPEX	Operating Expenses		
<b>&gt;&gt;</b>	PCM	Phase Change Material		
<b>&gt;&gt;</b>	PEF	Primary Energy Factor		
<b>&gt;&gt;</b>	PV	Photovoltaics		
<b>&gt;&gt;</b>	PVT	Photovoltaic Thermal		
<b>&gt;&gt;</b>	RD&I	Research, Development & Innovation		
<b>»</b>	RE	Renewable Energy		
<b>»</b>	RES	Renewable Energy Sources		
<b>&gt;&gt;</b>	RESCO	Renewable Energy Service Company		
<b>»</b>	RHC	Renewable Heating and Cooling		
<b>»</b>	RHC-ETIP	European Technology and Innovation Platform on Renewable Heating and Cooling		
<b>»</b>	sCO <sub>2</sub>	Supercritical Carbon Dioxide		
<b>»</b>	SHC	Solar Heating and Cooling		
<b>»</b>	SHIP	Solar Heat for Industrial Processes		
<b>»</b>	SRIA	Strategic Research and Innovation Agenda		
<b>»</b>	ST	Solar Thermal		
<b>»</b>	TES	Thermal Energy Storage		
<b>»</b>	TRL	Technology Readiness Level		
<b>»</b>	ULT	Ultra-Low Temperature		
<b>»</b>	UTES	Underground Thermal Energy Storage		
<b>»</b>	VIP	Vacuum Insulation Panels		

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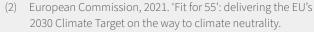


The RHC-ETIP has been instrumental in raising the profile of the renewable heating and cooling sectors through its recommendations for research priorities and project ideas

### Introduction

Decarbonising the heating and cooling sector will be key to achieve the European Green Deal goals<sup>(2)</sup> and making Europe a climate-neutral economy by 2050. The recast of the Renewable Energy Directive increases the current EU-level target of "at least 32% of renewable energy sources in the overall energy to at least 40% by 2030".<sup>(3)</sup> Specific targets are proposed for renewable energy use in heating and cooling, among other sectors. To meet both our climate and environmental goals, the momentum for deploying renewable H&C (RHC) technologies has never been stronger.

Understanding the RHC RD&I landscape and forecasting its future development is crucial for preparing the right policies and coordinating investment decisions and budget priorities. Within this context, it is important to understand the deployment of RD&I actions previously identified by RHC-ETIP, what RD&I activities are being implemented as well as overall trends in terms of RD&I funding, cooperation, policy frameworks affecting RHC RD&I, and barriers affecting the uptake of RHC technologies. This will contribute to the policymaking and maximise the returns on investment for RHC stakeholders in a context of limited resources and competing priorities.



<sup>(3)</sup> European Commission, 2021. Commission presents Renewable Energy Directive revision.



### **Scope and Objectives**

The objectives of this strategic report are to:

**Analyse the RHC industrial RD&I**, particularly with regard to identifying and understanding the trends in the R&D operations of the companies active in RHC (i.e. the current status and future scenarios).

**Monitor the implementation of the RHC SRIA** (4) **priorities**, particularly regarding what extent the RHC SRIA is being implemented and by which stakeholders.

To meet these objectives, a set of research questions were addressed throughout the report, as shown in Table 1.1.

Research questions				
RQ1	To what extent is the RHC SRIA being implemented?			
RQ2	What are the gaps in the current RHC SRIA (i.e. areas not covered in RHC SRIA or vice-versa by the industry stakeholders active in RHC)?			
RQ3	How are the topics changing? What are the reasons behind these changes? Are these changes in line with the SRIA?			
RQ4	How is RHC stakeholders' R&D budget being spent and how are these amounts changing looking in the recent past and near future?			

Table 1-1 Research questions

This report is a sequel to the RHC SRIA, published in October 2020, which outlined the directions of technological and organisational changes that need to be converted into specific research activities over the next years, starting from Horizon Europe (2021-2027). Furthermore, it aimed to facilitate the coordination of other research programmes in and between member states. Already in the RHC SRIA, it was articulated that as market growth to a great extent depends on major technological advances, the implementation of the RHC SRIA, along with appropriate market conditions, is crucial to realising the shift to a renewable energy system in which European citizens can enjoy affordable and sustainable heating and cooling services. The current report focuses on the technological advances and factors affecting their implementation.

The report has been prepared by the RHC-Platform's Horizontal Working Group on Deployment and Implementation Report. It was edited and coordinated by the Secretariat of the RHC-Platform and ultimately approved by the Board of the RHC-Platform. Horizontal Working Groups on 100 % RE buildings, 100 % RE districts, 100 % RE cities and 100 % RE industries, consisting of numerous experts, provided essential input and insight, notably in the data gathering process. This publication was made possible thanks to the support of the European Commission through the Horizon 2020 Research and Innovation Programme (Grant Agreement n. 825998).

<sup>(4)</sup> RHC-ETIP, 2020a.



### **Methodology and limitations**

To address the RQs listed above, a range of activities was conducted to gather data. This report used a qualitative assessment and verification of data analysis method to achieve its objectives. The process comprised of:

- 1. An extensive online survey, targeted at members of the RHC-ETIP platform and Secretariat partners' members, to provide an EU-wide view of the implementation of RHC technologies and overall trends in terms of RD&I funding, cooperation, policy, challenges, and barriers. The survey consisted of 4 main parts:(5)
  - a) General information;
  - b) Monitoring the implementation of the RHC Strategic Research and Innovation Agenda priorities;

- c) RD&I trends among RHC stakeholders;
- d) Policy and miscellaneous.
- 2. Semi-structured interviews, (6) targeted at stakeholders not covered by the survey and aligned with its structure. This served to gather additional inputs on the RD&I activities and associated current and future trends.
- **3. Co-creation workshop**, (7) gathering stakeholders across the different RHC technologies aimed at validating data collected via survey and interviews. This provided space to further discuss current trends in the RHC sector and deployment of RHC technologies in Europe.

Activity	Online survey	Interviews	Co-creation workshop
No. of inputs (i.e. participants)	94	14	82

Table 1-2 Overview of data gathering activities and related number of participants

Based on the data gathering activities, the editing team synthesised all data captured and conducted in-depth analysis to pinpoint past, present and future trends related to RHC stakeholders and their RD&I activities.

Data gathered during the preparation of the report generated possible areas for future work and intervention.

<sup>(5)</sup> Annex II presents the survey template with all the parts and questions.

<sup>(6)</sup> Annex III presents the interview template with questions and topics covered.

<sup>(7)</sup> Annex IV presents the co-creation workshop concept and template used.

#### **Limitations**

Producing this report entailed the challenging exercise of collecting scattered data and extrapolating greater industry trends based on the microcosm of contributing stakeholders. A number of caveats, limitations, and assumptions should be considered in relation to the findings of this report. Firstly, the H&C sector is highly heterogenous, encompassing stakeholders across the value chain, while this report draws on insights from a limited number of stakeholders. However, this limitation was countered by cross-checking collected data with the collected inputs across different stakeholder engagement and data gathering activities. Secondly, trends in the RHC sector are inherently tied to national (and supranational) policies and regulations which are impossible to predict with cer-

tainty. Nevertheless, the findings presented here should not be interpreted as predictions of specific future scenarios, rather should offer insights into the main trends, challenges, and opportunities of the RHC sector. In this way, relevant decision-makers are better able to design forward-looking policies and investment strategies. Thirdly, the quality and quantity of the data submitted through the RHC stakeholder survey is dependent on the time and effort stakeholders could devote to its completion. This occasionally led to brief explanations for qualitative questions or more concise responses to complex aspects of the RHC sector, related technologies, and associated RD&I activities.

### **Structure of this report**

Beyond this introductory chapter, this document features three additional chapters:

#### Chapter 2

Monitoring the implementation of RHC SRIA priorities analyses the implementation level of the RHC SRIA priorities across the Horizontal division

#### Chapter 3

RD&I trends among RHC stakeholders – presents key findings and identified RD&I trends among RHC stakeholders

#### **Chapter 4**

Recommendations & conclusions – presents key recommendations based on the findings and identified trends, formulating policy options for consideration by EU stakeholders and institutions

The core report is accompanied by four technical annexes:

#### Annex I

Provides a list of stakeholders who contributed to the strategic report

#### Annex II

Provides a detailed overview of the survey process and template used

#### **Annex III**

Provides a detailed overview of the interview template with questions and topics covered

### **Annex IV**

Provides a detailed overview of the co-creation template with questions covered



# This chapter offers an analysis of the implementation of the RHC SRIA priorities across five groups: cross-sectoral, buildings, districts, cities and industries

#### Context

This chapter offers an analysis of the implementation of the RHC SRIA priorities across five groups: cross-sectoral, buildings, districts, cities and industries. For each group, it is highlighted whether the RHC SRIA priorities are being implemented, to what level, whether a priority is deemed important<sup>(8)</sup> or not and whether there are any RD&I priorities missing in the RHC SRIA.

The Strategic Research and Innovation Agenda for Climate-Neutral Heating and Cooling in Europe, <sup>(9)</sup> published in 2020, responded to the need to boost the market uptake of RHC technologies and thereby realise the Platform's 2017 Vision for H&C carbon neutrality by 2050<sup>(10)</sup> at the latest. It presented the main R&I priorities to overcome current and imminent societal, technological and industrial challenges facing RHC.

The document identified R&I priorities to boost the market uptake of RHC technologies needed at buildings, industry, cities and districts level, by focusing on deployment environments (i.e. market-pull) rather than technologies individually (i.e. technology-push). This means its priorities are wide-ranging and consider the interaction between technologies and the surrounding environment.

### **Implementation - key findings**

### **Cross-cutting priorities**

### Technologies of heat and cold storage and distribution

This topic concerns thermal energy storage (TES), (11) which has potential to be a key enabler for the deployment of RHC in cities, districts, industries, and buildings, at small or large scale. An integrated approach implies better exploitation of TES. The cost-effectiveness of all types of TES, including combined storage, long-term and seasonal solutions, should be identified and unlocked for heat and cold.

### **57** applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, namely:

- » Achieving greater use of RES thanks to the use of thermal storage;
- » Adaptable storage cycles (daily, weekly, monthly or seasonal), if adaptability is required to optimize the storage's contribution to the system;

<sup>(8)</sup> The importance of priorities is relative to the number of surveyed stakeholders. Important to note is that in all cases, the difference between combined percentage of very relevant and moderately relevant stands predominantly for stakeholders who did not answer the specific section. I.e. low combined percentage of very relevant and moderately relevant does not equal high percentage of not relevant.

<sup>(9)</sup> RHC-ETIP, 2020a.

<sup>(10)</sup> RHC-ETIP, 2020b.

<sup>(11)</sup> RHC-ETIP, 2020a, Section 3.1.



- » Residual heat integration in CHP systems, to increase the energy utilisation factor;
- » Cost reduction;
- » High temperature thermal energy storage up to 1000°C developed at TRL 4-6;
- Thermal energy storage and grid balancing through phase-change materials and slurries for industrial cooling or air conditioning of buildings.

Activities being realised (as reported) include:

- » DHC thermal storage applications ranging from short / seasonal storage for daily peak cutting and large DH and DC systems respectively (at least two different stakeholders indicated focus on this activity); high density storage solutions for H&C at building and district level; to storage of heat in pipelines for district heating by combination of rising delivery temperature with storage in water tanks.
- Thermal storage tanks applications ranging from heating systems for detached houses based on medium sized (i.e. 1000 litres) heating water tanks; increasing the efficiency of these water storage systems (i.e. decreasing the dimensions and volume of the storages without the loss of storage capacity); PCM storage with parabolic trough collectors; to improved thermal storage design and fabrication using 3D technology of a low-cost hot water storage cylinder, with a high capacity of stratification, flow management, and storage capacity, suitable for domestic Installations.

- Thermal storage with CHP applications ranging from providing flexibility to (biomass) CHP production by adding (large) scale thermal storage (at least two different stakeholders indicated focus on this activity); to latent heat storage with thermoacoustic transformation, making use of thermal storage for both heating and cooling as a solution to decrease energy needed, with cogeneration as the key driver.
- » Solar thermal storage applications ranging from solar thermal DHC with seasonal storage (at least two different stakeholders indicated focus on this activity) and/or large absorption heat pump to investigation of a PVT pilot plant with electrical and thermal storage.
- » Heat storage at high temperature applications ranging from heat storage at high temperature (>250°C) and up to ~300°C.

One of the common denominators for accelerating an implementation of these activities is the availability of more funding options, including for fundamental and/or experimental research for innovative concepts and pilot project subsidies.

One major surveyed stakeholder reported that the focus of the company's activities has been on increased use of RES in heat production for DH including integration of excess heat resources and heat storage which provides much needed flexibility when using more RES. Drivers for realisation of the RD&I activities in this case have been the company's strategy (i.e. becoming fossil free within one generation), meeting customer requirements, and being one of the front runners of the energy transition.



### **Policy and social innovation**

This topic concerns RD&I related to policy and social innovation in the use of RHC technologies. (12) The scope of the topic includes better understanding of consumer behaviour, the role of RE in alleviating energy poverty, social innovation, local energy markets for heating & cooling, coupling of the thermal and electrical grid and others.

### 44 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, namely finding and understanding:

- » Consumer behaviour enabling effective marketing, information campaigns and sales tools for people in the RE sales chain
- » If energy-as-a-service works in practise and showcasing good examples
- » Political pathways describing precise policy measures on local and regional level to improve regulatory frameworks for DHC

- The sustained awareness created in public and policy which will lead to investments in the transformation of the DHC sector contributing to 100% fossil-free supply
- » Funding/market models for local participation in RHC

- » Legislation, strategy and guidelines activities, ranging from developing strategy for greening of heating supply; building business based on Heat Purchase Agreements similar to PPAs well known in the power industry; to various technology specific activities, such as:
  - development of a national code of practice for domestic heat pumps;
  - legislation in support of shallow geothermal energy for heating and cooling;
  - promotion of the installation of solar thermal systems in businesses (i.e. process heat) and replacement in households;
  - promotion of automation in solar thermal systems:
  - promoting installation of solar thermal systems being mandatory for the building's construction (Energy Performance Requirements under EPBD); and
  - capacity building in support of transition to RES in existing DH & DC systems.

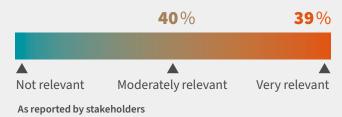


- » Social innovation focusing on end users' activities ranging from development of barometer for end user; to employing reuse and observing change in attitude of end users engaged in reuse.
- Awareness raising activities ranging from foundation of a collaborative project platform to enable the engagement and awareness of available sustainable solutions in the sector of RE for built environment; working with cities and district heating companies and making them recognise city sewage as a widely available heat source for large heat pumps; continuous writing about SHC technologies on solarthermalworld.org and gathering real project cost data to increase the awareness of commercial solar heat that reached cost reductions over the last ten years; discussions with stakeholders, contacts with national representatives and providing consultancy in law and regulatory issues; to stakeholder engagement by informing authorities about the geothermal potential, the available technologies, the advantages of developing geothermal HC applications and proposing support measures.
- » Market development activities ranging from GSHP market development in the EU to development of local energy markets, including across different energy vectors.
- Training activities ranging from focusing on professionals to addressing stakeholders in specific target groups to combine all relevant knowledge on a regional level as well as providing capacity building and training for local politicians, decision makers, consultancies and advisers about the benefits of sustainable district energy solutions.
- Combining energy vectors ranging from research on integrated multi-energy vector systems (using clean cluster concepts); to solutions for off-grid locations where the combined heat and electricity make a business advantage. Solutions where the combined heat and electricity make a business advantage, e.g. with solar and biomass inputs, whereas heat is stored for only 24 hours and biomass is used on days without sunlight.

### Digitalisation, operation and system flexibility

This topic concerns digitalisation, operation and system flexibility for large scale adoption of RHC applications for all RHC technologies. (13) The scope of the topic includes generation of digital twins and autonomy, digital twins and optimisation, controller-in-the-loop testing, IoT, AI & cloud services, short term forecasting, sector coupling and flexibility, interface between different control layers, and others.

### 37 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, namely:

In case of applications for DHC, surveyed stakeholders were asked to identify at which level their activities are focused:

- » Production level ca. 24%
- » Design and planning ca. 20%
- » Sector coupling and integration of multiple sources ca. 17%
- » Building level ca. 15%
- » Distribution level ca. 13%
- » Consumption level ca. 12%
- » Asset management ca. 6%

- » Digital twins and AI ranging from digital twins, IoT, AI, short term forecasting driven by the increased share of renewables in the energy supply for buildings; to development of artificial intelligence methods combined with statistical design of experiments methods for optimised design and operation of a power system.
- » Digitalisation, optimisation and operation ranging from smart home, product digitalisation, net digitalisation; activities focusing on reliable operation; flexibility use of electricity in heat pumps; increase in efficiency, optimisation of system use, district heating costs for customers; digitalisation in solar fields; to raising solar fraction, demand matching and higher efficiency.
- Control platforms ranging from the use of opensource software and control platforms to provide a low-cost method of optimising RE applications and providing support processes to RE installations, to ensure the foundation of trust and knowledge of the use/advantages of RE applications in buildings; improved controls to boost efficiency and the share of RES as well as the use of residual heat; to dedicated electronic controller to optimise cooling and heating sources.
- Connectivity ranging from connectivity for home appliances; pre-packaged heating solutions to minimise issues associated with integration and installation; to automatic cleaning system and plant output management
- » Monitoring and predictive control ranging from control of complex cooling system using predictive model control; innovative controls (model predictive control); EMS - energy management systems for example for the whole district heating network including renewables; system integration by model predictive control; to providing advanced monitoring solutions for customers with predictive maintenance, OPEX optimisation and energy reduction.

<sup>(13)</sup> RHC-ETIP, 2020a, Section 3.3.

### Innovative financing schemes and new business models

This topic concerns innovative financing schemes and new business models supporting the efforts to undertake sustainable energy programmes and infrastructure projects in RHC. (14) The topic includes alternative financing schemes, energy as a service, use of blockchain, securitisation, leasing or contracting, green public funds, bartering, blending finance, and others.

### 26 applications

44 %

A A
Not relevant Moderately relevant Very relevant

As reported by stakeholders

The activities being realised are aligned with the desired results indicated in the RHC SRIA, namely:

- » Successful green financing systems to gain interest among investors
- » Investment pathways for local communities wanting to invest in their local heat infrastructure: creating a new heat network, expansion, decarbonisation of supply
- » Efficient contractual forms and business models
- » New schemes that will help in a greater deployment of investments to green energy for industry
- » New business models that open more flexible options at lower risk to deploy renewable energy supply for industries

- New business models (e.g. heat as a service) ranging from unlocking investment in larger scale RHC systems by using heat as a service model and energy service contracts in general (e.g. heat, cold, electricity); building business on Heat Purchase Agreements (HPA), similar to PPAs well known in the power industry, reaching all the way to building HPA Fund structures; to RE ESCO project financing and even selling electricity, heat and cold to industries or utilities instead of the installations; turnkey installations, which stay in the ownership of the ESCO.
  - **New financing schemes** ranging from implementation of green taxation; support financing/grant schemes with sector specific focus (e.g. hotel sector, dairy industry, pharmaceutical industry etc.); to industry grants and lean project financing.
- » Investment pathways for local communities ranging from participation models for customers of the municipal utilities; to PV installations on private and public buildings for the benefit of end users.
- » Contracting ranging from energy sharing contracting to excess heat utilisation, specifically contract and business models.
- » Deployment of RE supply for industry ranging from practical application of reuse of waste energy produced by machines; industrial heat; to biomass drying.

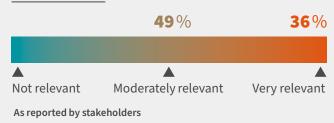


### Other activities reported included activities related to the sustainability of RHC products, such as LCA or investigations into products' environmental footprint

### **Circularity**

This topic concerns circularity in the context of RHC production, i.e. as many components and products need to be designed for re-use, repair, and recycling. (15) However, the topic goes beyond materials, to include efficient use of low-temperature or excess (waste) heat from industrial processes and commercial buildings (e.g. data centres and other urban infrastructure, such as sewage processing plants, that are currently in large part dissipated in the atmosphere or water) and residential buildings.

### 27 applications



The activities being realised are aligned with some of the desired results indicated in the RHC SRIA, namely:

- » Adopt standardisation procedures and a quality label for components (such as geothermal pipes, collectors, pumps, etc). This measure is essential to improve the confidence of consumers and legal authorities in the sustainability of RHC products
- » Support research and innovation projects that will develop new technologies for waste and water management
- » Create exergy-optimised hybrid concepts Develop cryogenic recycling of waste for circular energy technologies

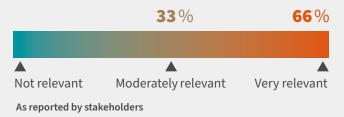
- Utilising waste heat ranging from recovering waste heat from industries and active flue gas condensation; use of industrial waste heat as UTES thermal storage associated with heat pumps; using waste heat from cooling processes for driving drying processes; cooling by using waste heat (i.e. sorptive cooling), upgrading waste heat (i.e. heat transformation), storage of waste heat and conversion to power; district heating using waste heat; identification of unutilised and non-traditional excess heat sources and their use; to energy storage facilitating use of waste heat primarily without heat pumps.
- Geothermal energy in circular use activities ranging from BTES, coupling buildings with different functions to exchange thermal flows, sector coupling; Underground thermal energy storage and heat pumps (UTES) systems and direct renewable heat technologies; through usage of geothermal energy, integration of urban excess heat resources (e.g. sewage, subway, IT-centres), seasonal storage, sustainable heating and cooling for tertiary sector (offices, hospitals, etc.); to geothermal energy for H&C with power production and mineral extraction.
- Hybrid concepts ranging from the implementation of synergistic technologies to provide cost effective low carbon heating; solar energy systems including large absorption heat pumps and large seasonal storages; EMS development; CO<sub>2</sub> capture and storage using pyrolysis; third generation PVT system that would fit to the ultra-low temperature heating strategy of EU; to installation for cryotherapy with air cycle refrigeration system that has ZERO GWP where heat recovery is implemented to heat up the premise without using additional energy.
- » Other activities reported included activities related to the sustainability of RHC products, such as LCA or investigations into products' environmental footprint.

### 100% RHC in Buildings

### RE H&C technologies and systems for costeffective retrofitting of building stock

The topic concerns developments in systems and technologies supporting the deployment of energy-efficient heating and cooling through retrofitting of building stock. (16)

### 26 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, namely:

- » Available technologies, especially easy to install renovation kits for serial renovation of buildings
- » Highly efficient HP systems with new refrigerants and low GWP for heating and cooling
- » Optimised system architectures for combination with new hybrid RE sources for tri-generation of electricity, heat and cold (CCHP) and availability of geothermal sources for co-generation of heat and cold for single buildings, and districts
- » Smart, energy-efficient and renewable air-conditioning technologies

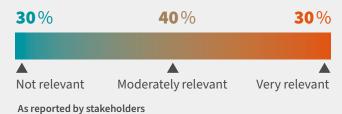
- easy to install renovation kits ranging from developing RES solutions easily adaptable to existing buildings; retrofitting of dwellings with a focus on building greening (e.g. with a focus on green roofs, ventilated roofs and facades) (multiple similar activities reported); architecturally slim products with flexible sizes; insulating existing homes to decrease fuel poverty; to applications for solar thermal in existing buildings identifying the widest range of applications, developing technical solutions to suit the variety of buildings that exist, developing versions of solar heat that can be more optimised for different applications; and cost effective retrofitting solutions including solar thermal preheating or waste heat recovery.
- Highly efficient HP systems for heating and cooling ranging from replacement of existing space/water heating appliances with high-efficient (and renewable) technologies as hybrid units (heat pump + boiler), thermally driven heat pumps, heat pump water heaters; ground source heat pumps for heating and cooling and tailored for retrofitting operations; hybrid heat pumps and storages for integration in buildings; compact solutions with efficiency in line with latest ERP and F-Gas developments; to heat pumps for high temperature production to replace boilers in radiator systems.
- » Smart, energy-efficient and renewable air-conditioning technologies ranging from sorptive cooling systems; to heat recovery on ventilation.
- » Co-generation of heat and cold for single buildings and districts; and solar thermal combi systems for heating and DHW.



## RE H&C technologies and systems for cost-effective retrofitting of historic and special buildings

This topic concerns the mapping of historic buildings, characterisation of their H&C needs in order to explore the possibility for easy but effective integration of RES, as long as the development of solutions for integration of RE systems in historic and special buildings does not compromise the value of the building in terms of aesthetics and lifetime, especially when some of the components of the RHC systems need to use the building façade to capture energy. (17)

12 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA fulfilling the desired results of reducing energy demand of the buildings due to energy efficiency measures, raising percentage of integra-

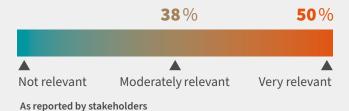
tion of RE for H&C in historic and special buildings, and raising acceptance by stakeholders to the integration of RE for H&C in historic buildings.

- Integration of RE for H&C in historic buildings ranging from cost effective and sympathetic retrofit of solar heat solutions to older buildings; PVT systems coupled with low-temperature heating equipment coupled with heat pipes to form the most feasible option for retrofitting historic buildings with minimum modifications and building loads; to fully RES-based DH system in historic centre of Bruges combining new and old.
- Raising stakeholders' acceptance to the integration of RE for H&C in historic buildings ranging from technology based on the concept of replacing the existing heating source with a renewable energy unit to keep retrofit works to a minimum; speeding up retrofitting by removing the machine from external environments; ground source (i.e. geothermal) heat pumps for heating and cooling; to sustainable post-earthquake recovery of Zagreb's historic centre.
- Energy efficiency measures characterised by high efficient but thin insulation (e.g. VIP).

## RE sources, technologies and systems for new buildings and their integration and external connectivity

This topic concerns development of a wide range of sustainable RHC technologies and combinations of technologies for buildings built according to modern building standards by, for example, further integrating RE systems (solar thermal and PV or PVT) in the building envelope (façade), and new system architectures for using PVT collectors for the generation of electricity, heating, and cooling. (18)

#### 21 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, namely:

- » 100% RE coverage solutions adapted to local possibilities and regulations
- » Maximised solar contribution to heat, electricity and cold needs
- » Maximised ambient aerothermal and geothermal contribution to additional heat and cold needs
- » Highly efficient, cost-effective and sustainable RE systems
- » Heating and cooling storage on daily and seasonal basis to increase system efficiency and providing energy security as well as electricity storage grid-balancing services

The focus of activities being realised (as reported) spans:

» Maximised solar contribution to heating, electric-

**ity and cooling needs** ranging from solar hot water heating system; solar steam generation system; sustainable heating and cooling solutions, sector coupling with heat electricity, e-mobility; PVT and PV combined with heat pumps; to ground source heat pumps for heating and cooling.

- High-efficiency RE systems ranging from management of HVAC systems; low emission housing; to streamlining the process of installing renewable technologies in new construction, increasing acceptance of new technologies by the construction industry, achieving cost effectiveness without compromising on quality, which can damage reputation of renewable solutions.
- Solutions adapted to local possibilities and regulations ranging from improving and increasing products' connectivity; LoRaWAN connectivity of home energy systems; to providing an innovative RESCO Model in a residential block of apartments in Cascais Portugal - granting the owner of a Building refurbishment Development a method of off-setting the investment costs of the centralised RE building services and systems, space heating/cooling & DHW, solar thermal assisted heat pump (combi-system), district heating/ cooling metering, centralised ventilation, grey water recycling, 48v DC microgrid & 40% of the infrastructure building distribution load. All these utilities will be available (sub-metered) to the future apartment occupants, yielding a revenue stream, to enable on-going maintenance and the repayment to the initial Investor consortium, that allowed for the ESCO installation to be built.
- » Aerothermal/geothermal contribution to additional heat and cold needs ranging from heat pumps and air ventilation systems; MPC & hybridGEOTABS; to using free cooling systems.
- » H/C storage ranging from high performance insulation, highly innovative energy capture and storage technologies (phase change materials, photoisomeric process, hybrid collectors, sector coupling, lowex-systems, ice-storage-systems); to developing RES solutions, using hybrid energy storage with enough flexibility to connect with external energy grids.



This topic concerns the development and demonstration of CHP and CHPC technologies to ensure secure, reliable, and efficient power and heat & cold supply for old/historical and new buildings. These technologies may be fully integrated with other RE technologies: they can use storable RES (biomass, biogas, underground storage, renewable hydrogen etc.) to produce on-demand electricity and storable heating and cooling, while reducing GHG emissions and increasing the primary energy savings. (19)

### 7 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA fulfilling the desired results of achieving CHP/CHPC technologies and systems that are well suited for cost-effective inclusion in RE packages for different types and sizes of buildings.

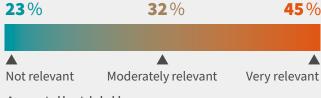
The focus of activities reported as being realised spans:

- » CHP based renewables supporting low-PEF-solutions
- » Sorptive cooling systems
- » Cogeneration with renewable energy systems, hydrogen production and fuel cell generation
- » Decarbonisation of energy system in a castle

### **Energy systems, education, training and** certification for different building categories

This topic concerns education, training, and certification for different building categories to enhance competitiveness and technical skills of the installers of fossil-fuelled heating equipment, as well as to train RHC system designers. (20)

### 16 applications



As reported by stakeholders

The activities being realised are somewhat aligned with the desired results indicated in the RHC SRIA by developing various training programmes for experts and installers, EU information strategy and certification system for RE installers.

- Training ranging from the training of experts of the national energy certification system of buildings (EPC system) in the national energy agency, construction skills and heat pump skills; the education and training of professionals for solar thermal systems and PVT; the training programme for heat pump installers, PV, and refrigeration engineers; Master's degree programmes in energy conversion systems and technologies; to the education of planners and installers.
- » Certification.
- » **Information strategy** creating exergy-aware design and control algorithms for nearly-complete decarbonisation towards the Paris agreement goals.

<sup>(19)</sup> RHC-ETIP, 2020a, Section 4.4.

<sup>(20)</sup> RHC-ETIP, 2020a, Section 4.5.



### MISSING TOPICS/PRIORITIES FOR 100% RE BUILDINGS

Below, topics/priorities that have been indicated as missing among the RHC SRIA priorities by survey stakeholders are listed and put in perspective, as some of these have been referenced in the RHC SRIA, and others are either very general or very specific.

#### **Topics/priorities missing:**

### Waste heat recovery especially for hydrogen generating systems

This topic is missing from the previously identified priorities for 100% RE Buildings (i.e. dealing with individual buildings, not connected to a district heating or gas grid). This is due to little focus being placed on hydrogen in 100% RE Buildings. Overall, waste heat recovery in general is a central and important topic in the RES H&C sector to maximise resource utilisation and energy efficiency in RES energy systems and is extensively mentioned in the RHC SRIA.

#### **Topics/priorities with too little focus:**

#### Use of hydrogen for H&C

Use of hydrogen for H&C is mentioned in Topic 4 for 100% RE Buildings<sup>(21)</sup> as one of several storable RES. Even though it might have a significant potential in the individual buildings in the future, the opinions on the use of

H2 for heating and/or cooling buildings are diverging. The uses of hydrogen in industry and as a supplement in green gas networks were considered to have a higher priority and are mentioned in the RHC SRIA.

### **Ensuring optimal control of modern technologies to avoid operation beyond best point**

Control is mentioned in several of the topics for 100 % RE Buildings, while control is more extensively treated in the transversal topic Digitalisation, operation and system flexibility. (22)

### Development of green gases market in substitution of fossil fuels for residential heating

Green gases were not intended as a topic in 100% RE Buildings, which are assumed not to be connected to a gas grid. However, green gas is mentioned in the RHC SRIA with respect to phasing in green gas in the gas grid.

### Harvesting urban excess heat in combination with seasonal heat storages

Seasonal heat storage is mentioned in Topic 3 for 100% RE Buildings<sup>(23)</sup> as well as several other places in the RHC SRIA, while heat storage is more extensively treated in the transversal topic Technologies of Heat and Cold Storage and Distribution.<sup>(24)</sup>

<sup>(21)</sup> RHC-ETIP, 2020a, Section 4 – Topic 4.

<sup>(22)</sup> RHC-ETIP, 2020a, Section 3.3.

<sup>(23)</sup> RHC-ETIP, 2020a, Section 4 – Topic 3.

<sup>(24)</sup> RHC-ETIP, 2020a, Section 3.1.

#### Topics/priorities missing and/or that are very general:

### Heat to electricity conversion and full circular design applied generally

Heat to electricity conversion is a very general topic, as well as full circular design. Topic 4 for 100% RE Buildings<sup>(25)</sup> is also about converting heat to electricity, while circularity is a transversal topic in the RHC SRIA. Circular design, as in designing a specific component or system to maximise material circularity, is a more specific topic and has been mentioned in the transversal topic Circularity.<sup>(26)</sup>

#### **Thermal cooling technologies**

Thermal cooling is mentioned in Topic 1 for 100% RE Buildings<sup>(27)</sup> but could have been elaborated more on in other topics. However, Technologies of Heat and Cold Storage and Distribution is a transversal topic in the RHC SRIA.<sup>(28)</sup>

#### **Location and user-centred solutions**

Centred solutions are mentioned within the transversal topic Policy and social innovation<sup>(29)</sup> and is implicitly a natural part of many solutions, but the topic could have been more specifically elaborated upon in the RHC SRIA.

#### Heat exchange for heating and cooling

This is a very general topic and an implicit part of any H&C system. Optimising the heat exchange naturally contributes to increased energy efficiency and increased utilisation of the RES.

### Production and material technologies, including standardisation and certification for hybrid systems

Production of RES components and systems and the choice of materials to use in these are important with regard to many aspects, including lifetime and costs. Materials are mentioned in Topic 4 for 100 % RE Buildings (30) as well as in a number of the transversal topics.

#### **Topics priorities that are very specific:**

A study involving a significant number of systems (combining different RHC technologies such as solar thermal and solar PV to support heat pumps) with different set-ups for comparison to prove the cases and inform policy

Such a study would be interesting as a future recommendation, as would other dealing with different RES system combinations. Therefore, the topic could be broadened from its current specific focus.

Ensuring optimisation of heat pump controllers for buildings in which they are installed to avoid operation on default parameters (e.g. heating curve, DHW, production strategy, etc.)

Heat pumps have been mentioned for 100% RE Buildings and broadly in the RHC SRIA, and control is also mentioned. The optimisation of heat pump controllers for the system installed in a specific building is a specific topic which could have been elaborated.

Low-temperature heating system with little or no parasitic power demand and high temperature cooling

This topic could be seen as either very general or rather specific. A system that enables low-temperature heating when it is colder and high temperature cooling when it is warm is certainly interesting, particularly if it is able to do this without providing work based on electricity.

For the RHC SRIA, it was decided to describe common topics for the different horizontal working groups in so-called transversal topics. While this was appropriate, it could also lead to more missing topics being reported for the individual horizontal working groups, as indicated in the comments in this section.

<sup>(25)</sup> RHC-ETIP, 2020a, Section 4 – Topic 4.

<sup>(26)</sup> RHC-ETIP, 2020a, Section 3.5.

<sup>(27)</sup> RHC-ETIP, 2020a, Section 4 – Topic 1.

<sup>(28)</sup> RHC-ETIP, 2020a, Section 3.1.

<sup>(29)</sup> RHC-ETIP, 2020a, Section 3.2.

<sup>(30)</sup> RHC-ETIP, 2020a, Section 4 - Topic 4.

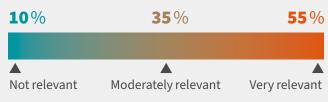


### 100% RHC in Districts

### **Energy system integration at district-level**

This topic concerns identifying measures, technologies, and strategies to lower network temperature in order to decrease heat losses while widening the range of renewable heating and waste heat source integration. (31) The research areas may include low temperature networks, innovative substations, return temperatures, and others.

### 18 applications



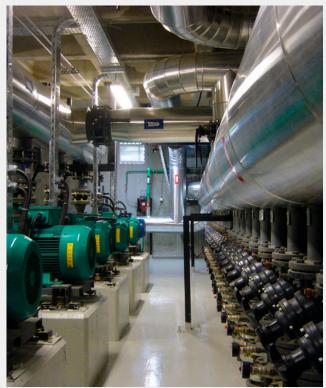
As reported by stakeholders

The activities being realised are somewhat aligned with the desired results indicated in the RHC SRIA with focus on wide-scale rollout of LTDH systems in Europe significantly boosting the integration of renewables and low temperature waste heat covering a significant portion of heat demand; and unconventional urban excess heat sources alone covering more than 10 % of the EU's total energy demand for heat and hot water.

- Solar energy such as solar district heating, solar process heating and cooling – both including longterm and short-term storages and/or heat pumps; combining PVT with ST in district heating; and integrating solar heat as a supplement while relying on large scale storage or more dispatchable fuels such as biomass-driven CHP or renewable gases for ensuring security of supply.
- Excess heat ranging from heat recovery from industry; to use of excess heat from non-industrial urban sources, sector coupling heat pumps, and PtX surplus heat in municipal system.
- » LTDH and district cooling ranging from cold district heating, LowEx; utilisation of waste cold from heat pumps; to integration of an ice storage in a cooling network for saving energy by operating chillers under beneficial conditions; and implementation of an energy management system for improve RE use.

<sup>(31)</sup> RHC-ETIP, 2020a, Section 5 – Topic 1.





### Distribution temperature reduction in heat networks at district-level

This topic concerns smart sector integration referring to the interaction between different sectors (buildings, services, transport, and industry) and energy carriers (electricity, heat, gas) including storage, leading to energy system optimisation. (32)

### 16 applications



The activities being realised are somewhat aligned with the desired results indicated in the RHC SRIA, although they are largely aligned with the previous priority. They focus on options to integrate heat pumps for DHC (DC) powered by "green electricity" and thermal energy storage.

- Integrating heat pumps for DHC ranging from integration of heat from solar thermal and heat pumps; development of decentralised heat pumps; district heating and cooling by GSHPs; to a reduction of distribution temperatures in heat networks.
- Lowering the temperature in heat networks and beyond ranging from district heating system with 40°C heating supply temperature with pure solar energy with minimum pumping demand project; district heating with low-enthalpy geothermal with ORC optimum share; lowering the flow and return temperatures in existing and new district heating networks; lowering the flow temperature to reduce heat losses, low temperature local heating and cooling grids; distribution temperatures reduction in heat networks using absorption exchangers and decreasing fouling of these exchangers; change temperature need by the customer as requirement for low temperature in the grid; 5<sup>th</sup> generation thermal network planned at university campus; to developing a replicable test for balancing water flows in existing central heating radiators.



### Decarbonisation – scenario evaluation and decarbonisation strategies at district-level

This topic concerns identifying and implementing future sustainable technology scenarios to decarbonise the heating and cooling sector, especially the 100% decarbonisation of DH systems by 2050 with maximum integration of locally available renewable sources (including waste heat). (33)

### **20** applications

11%
25%
64%

Not relevant Moderately relevant Very relevant

As reported by stakeholders

The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on:

- » 100% decarbonised system positive impact on health
- » Waste heat utilisation as circularity principle
- » Technological pathways describing precise decarbonised systems, which are economically feasible, affordable, reliable and enhance user's comfort
- » Identify synergies regions in which demand and renewable/waste heat sources coexist

- Technology scenarios for DHC networks with a focus on maximising the share of local renewable and emission-free energy resources ranging from development of specific individual heat pump technology, which interacts with the DH network; district cooling using free cooling from water bodies; very large renewable systems (e.g. 100,000 m² solar thermal); activities aiming for CO₂ neutral heating and cooling via waste-to-energy combined with CCS; decarbonising heat and power supply to social rented homes; and identifying solutions to decarbonise the local district heating system.
- » Mapping for decarbonisation of DHC by utilising clean cluster concepts.
- » Maximising the use of waste heat sources by increasing the regenerative share of heat generation.
- Other activities reported included those related to the 100% commercial hydrogen boilers and burners; change of generating plants; investigating the CO<sub>2</sub>emissions due to exergy destruction – investigating solutions and the direct relation between exergy destructions and CO<sub>2</sub> emission responsibilities.



### MISSING TOPICS/PRIORITIES FOR 100% RE DISTRICTS

Below, topics/priorities that have been indicated as missing among the RHC SRIA priorities by survey stakeholders are listed and put in perspective, as some of these have been touched upon in the RHC SRIA, and as some of these are either very general or very specific.

#### **Topics/priorities missing:**

#### **Directories of competent actors in the sector**

This topic is not mentioned in the RHC SRIA, but it could be a transversal topic applicable to other HWG.

#### **Topics/priorities with too little focus:**

#### **District cooling and cold storage**

This topic is mentioned in the RHC SRIA section on Districts only as "Options to integrate heat pumps for DHC (DC) powered by green electricity and through thermal storage". (34)

### Selection criteria for complex system designs (i.e. tools)

This topic is mentioned in the RHC SRIA as a Transversal Topics and in the section on Cities with focus on energy planning. However, it is also applicable to Districts.

The role of ownership in the regulatory aspects of RHC and avoiding profit to private ownership of DHC systems and/or securing non-profit ownership

This topic is mentioned in the RHC SRIA as a Transversal Topic related to social innovation under the "participation of communities in the ownership of the grids". (35) No specific priority is included in the section on 100% RE Districts.

Development of the policy and directives related to the influence of exergy destructions on global warming and developing new design principles in the RHC sector for minimising exergy destructions

Exergy destruction is mentioned in the RHC SRIA only in the section on  $100\,\%$  RE Industry and not in the one on  $100\,\%$  RE Districts.

For the RHC SRIA, it was decided to describe common topics for the different horizontal working groups in so-called transversal topics. While this was appropriate, it could also lead to more missing topics being reported for the individual horizontal working groups, as indicated in the comments in this section.

<sup>(34)</sup> RHC-ETIP, 2020a, Section 5 - Topic 2.

<sup>(35)</sup> RHC-ETIP, 2020a, Section 3.2.

#### 100% RHC in Cities (36)

### Technologies for integrated system solutions of decarbonised energy systems of cities

This topic concerns, but is not limited to, R&I actions aiming to increase the modularity as well as the physical and digital connectivity of all energy components and sub-systems needed for decarbonised energy systems of cities in the field of generation, distribution, conversion, storage and consumption of heat, cold, and electricity from renewable energy sources and waste energy; as well as R&I actions aiming to develop platform solutions for integrated energy systems, e.g. for district energy systems with a multi-source DHC system coupled with local renewable electricity generation, which not only enable the integration of components from different producers, but also guarantee a high system efficiency by optimised design and operation. (37)

The focus of activities reported as being realised are:

- » Combination of different energy sources for district heating, e.g. solar thermal, geothermal, CHP, power to heat, boilers and photovoltaics
- Identifying feasible technologies
- Low CO<sub>2</sub> production and new systems for long-term storages
- Heat island effect at local place of generation to reward owners at point of heat generation and investigate how to engage or change them
- » Software platform for increased data-overview and optimisation of DH systems

#### 6 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on increased share of integrated energy system solutions, increased system efficiency of the energy systems and increased share of self-supply consumption with renewable and waste energy sources.



<sup>(36)</sup> There is a blurry line between where districts sector ends and cities sector begins. Accordingly, the rather small amount of data in this sub-section is caused by a reoccurring issue with collecting inputs on RD&I priorities for 100% RE Cities, whereas many stakeholders consider themselves working either at the building- or district-level.

<sup>(37)</sup> RHC-ETIP, 2020a, Section 6.1.



### Tools and guidelines for the planning of climate-neutral energy systems for cities

This topic concerns, but is not limited to, R&I actions aiming to develop planning tools which allow for the identification of the optimised design for decarbonised energy systems for cities and guidelines for energy planning in cities. (38) The energy system planning tools should be based on existing tools but allow for an integrated multi-domain optimisation and should reflect the complexity and dynamic of the decarbonised energy system. It should be usable by local energy experts and should use modern digitalisation methods, e.g. making use of open data pools and using artificial intelligence methods for optimisation. The guidelines for energy planning in cities should consider energy system optimisation by using the energy planning tool (see R&I action above), improved interdisciplinary planning procedures as well as the other dimensions of the planning process.

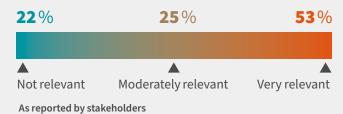
The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on new planning tools and guidelines, which are usable by local actors, allowing decision makers in cities to take decisions on the energy system transformation on a reliable and sound basis.

The focus of activities reported as being realised are:

- » Planning of heating and cooling systems
- » Data-assisted energy planning in cities
- » Development of guidelines for decarbonisation of the local district heating systems

It was also indicated by a stakeholder that this will be more important topic in a few years based on the energy mix in a specific DHC system.

### 6 applications



(38) RHC-ETIP, 2020a, Section 6.2.



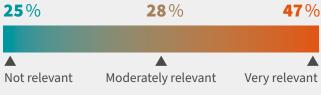
# Tools and guidelines for the development of transformation strategies and roadmaps to achieve decarbonised energy systems of cities

This topic concerns, but is not limited to, R&I action aiming to develop methodologies and related tools which help cities to develop transformation strategies and related roadmap to decarbonise their energy systems by 2030 or 2040.<sup>(39)</sup>

The focus of activities reported as being realised are:

- » Developing carbon-neutral smart cities supplied with 100% RES
- » Developing guidelines for decarbonisation of the local district heating

### 4 applications



As reported by stakeholders

The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on methodologies, guidelines and tools for the development of strategies and roadmaps to decarbonise the energy system of a city, which can be used by European cities to plan and implement the transformation of their energy systems.

<sup>(39)</sup> RHC-ETIP, 2020a, Section 6.3.

### MISSING TOPICS/PRIORITIES FOR 100% RE CITIES

Below, topics/priorities that have been indicated as missing among the RHC SRIA priorities by survey stakeholders are listed and put in perspective, as some of these have been referenced in the RHC SRIA, and others are either very general or very specific.

#### **Topics/priorities missing:**

### Methods, tools, and guidelines to influence and increase the acceptance of inhabitants

The development of tools and guidelines which include "Methods and models which are enhanced with respect to non-technical aspects, e.g. public acceptance, transition dynamics, stakeholder interactions" are mentioned in the RHC SRIA. (40) Studies on consumer behaviour are mentioned as well in the RHC SRIA. (41) However, methods, tools, and guidelines to increase the acceptance based on the findings are not mentioned yet.

### Effects of climate change localised on city level and linked necessary changes to RHC

The impact of climate change must be considered in the projection of heating and cooling demand development as input data of the planning tools, which should be developed according the RHC SRIA. (42) However, the specific influence of climate change on heating and cooling could become a stand-alone research topic.

### Pico grid energy and CO<sub>2</sub> counting in low-data rates system to enable digitalisation of the district

Data platforms for monitoring and optimised operation of sustainable energy systems in cities are mentioned in the RHC SRIA. (43) A concept to minimise the data volume is not mentioned there and should be a goal for the platform development.

### **Topics/priorities with too little focus:**

### **Trading and sharing heat in energy communities**

With increasing expansion of local heating networks in cities, the exchange of heat between members of Renewable Energy Communities (RECs) will become important. The development of RECs centred around renewable heating

and cooling is mentioned in the RHC SRIA. (44) However, targeted business model development is useful.

### **Development of GHG monitoring tools and energy balancing tools**

GHG monitoring and energy balancing are part of the tool development mentioned in the RHC SRIA, (45) but are not explicitly mentioned.

### Long-term transformation strategy to guide cities' decision makers

The RHC SRIA already identified the need to develop methodologies and related tools which help cities to develop transformation strategies and related roadmap to decarbonise their energy systems by 2030 or 2040. (46)

#### Planning tools specifically to assess heating infrastructure investments

Tools and guidelines for the planning of climate-neutral energy systems for cities are mentioned in the RHC SRIA<sup>(47)</sup> with the objective to optimise the entire energy system including the heating infrastructure. Specific tools focused specifically on the heating infrastructure must be addressed e.g. in the district heating section.

For the RHC SRIA, it was decided to describe common topics for the different horizontal working groups in so-called transversal topics. While this was appropriate, it could also lead to more missing topics being reported for the individual horizontal working groups, as indicated in the comments in this section.

### **Topics priorities that are very specific:**

### Transparency in energy performance of households

Household data should become a part of the data platforms for monitoring and optimised operation of sustainable energy systems in cities, which are mentioned in the RHC SRIA. (48)

<sup>(40)</sup> RHC-ETIP, 2020a, Section 6.2.

<sup>(41)</sup> RHC-ETIP, 2020a, Section 3.2.

<sup>(42)</sup> RHC-ETIP, 2020a, Section 6.2.

<sup>(43)</sup> RHC-ETIP, 2020a, Section 3.3.

<sup>(44)</sup> RHC-ETIP, 2020a, Section 3.2.

<sup>(45)</sup> RHC-ETIP, 2020a, Section 6.2 and 6.3.

<sup>(46)</sup> RHC-ETIP, 2020a, Section 6.3.

<sup>(47)</sup> RHC-ETIP, 2020a, Section 6.2.

<sup>(48)</sup> RHC-ETIP, 2020a, Section 3.3.

### Stakeholders indicated that measures needed to make

RES interesting for them include financing schemes

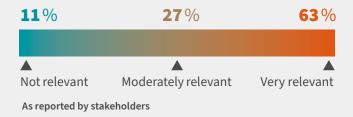
for RES, lower payback, higher TRL, awareness of the possibilities at stakeholders and utilities, and quickly installed and low-cost technologies

### 100% RHC in Industries

### Hybridisation of renewable energy systems

This topic concerns combination of RES and existing (conventional) technologies towards optimised operational parameters aligned to industrial needs, paving the way towards commercialisation; development of hybrid solutions to integrate in industry specific energy streams; innovative applications in the industry (e.g. cement, chemicals, food & beverages, etc.) contributing to swift decarbonisation of the heating and cooling sectors. (49)

21 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on:

- » Development of hybrid solutions including adapted and newly developed combinations of RES available for implementation in industrial processes to significantly increase the share of RES and meet the specific needs of industrial processes
- » Solar thermal process heat above 150°C in combination with other energy supply technologies like heat pump and geothermal technologies
- » Greenhouse production based on the combination of deep geothermal medium temperature systems with other available bio and heat-based RES sources

Stakeholders' responses to the survey indicated that measures needed to make RES interesting for them include:

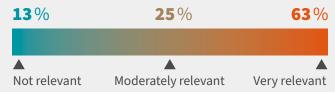
- » Financing schemes for RES
- » Lower payback
- » Higher TRL
- » Others: awareness of the possibilities at stakeholders and utilities; quickly installed and low-cost technologies

- » Solar thermal processes ranging from integrating solar thermal as pressurised hot water or steam into industrial processes; integration solar heating and cooling systems in different industry sectors like food industry, textile and metal surface industry; developing parts of solar systems (e.g. collectors, controllers); to solar process heat.
- » Greenhouse production such as greenhouse heating & cooling dehumidifying (i.e. biomass/geothermal drying).
- Integration of RES in industrial processes ranging from optimum integration of RES in industrial processes as well as recovery and use of waste heat (specially at high temperatures); total containment of heat and cold and accurate reuse or conversion of energies not used; energy saving and renewable energy applications in the agro-food industry; to maximising RE fraction with available space.

### Innovative technologies for optimised system integration of renewable energies

This topic concerns development of new technologies integrating different RES to provide reliable and on demand energy for industrial processes. (50)





As reported by stakeholders

The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on the development of new energy supply technologies (TRL 2-4) which are using a combination of RES to provide reliable energy to industrial processes.

Stakeholders' responses to the survey indicated that what they expect from RE technology include:

- » Reliability
- » Predictability of performance/output
- » Reaching certain temperature including high temperatures from 150°C to 1100°C and very low like for refrigeration and ultra-low temperatures
- » Others: For customers and investors having reliability concerning the performance of their investment

is key; Affordable cost; Noticeable comfort and energy savings with minimal input from user; Storage of heat; Some degree of variability of output (which is acceptable, as DH is a flexible technology that can accommodate this); To have a roadmap towards unsubsidised cost-competitiveness vis-a-vis fossil fuels; Cover a high share of demand by using thermal storage; CO<sub>2</sub> free and same performance as fossil fuel based sources.

- Development of new energy supply technologies which are using a combination of RES to provide reliable energy to industrial processes ranging from TES based on adsorption system with a reliable high temperature thermal storage with a high thermal energy density aimed to increase the share of SHIP decoupling the generation and use of thermal energy; development of Carnot batteries; demonstration of high temperature heat pumps in drying processes; absorption heat pumps for heating and cooling (reversible systems); solar thermal process for heat/cold for industry purposes; CSP systems for process heat; to heat pumps couples with solar thermal and/or other RES.
- » Optimised system integration of renewable energies from controls point of view ranging from improved controls and smart sensors to boost efficiency and the share of RES; development of a digital controller to maximise the efficiency of heat pump and natural gas combined in a hybrid system; designing systems with integrated absorption machines; to calculating part load behaviour data.

<sup>(50)</sup> RHC-ETIP, 2020a, Section 7.2.

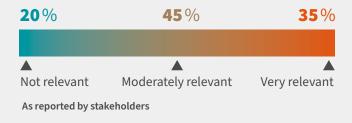
## More than two thirds of surveyed stakeholders indicated that they would be willing to use/adapt their technology

towards supplying new process technology concepts

#### Developing new process technology concepts being supplied by renewable energy

This topic concerns new technologies allowing for cost-effective RES integration. The development of innovative technology concepts for production process will involve different sectors in a new, energy efficient, and low-exergy way. (51)

#### 18 applications



The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on new process technologies allowing for cost-effective RES integration.

Stakeholders that responded to the survey were asked whether they would be willing to use/adapt their technology towards supplying new process technology concepts. More than two thirds of surveyed stakeholders indicated that they would be willing to use/adapt their technology towards supplying new process technology concepts. In addition, about half of the stakeholders indicated they are addressing industrial process between 80°C - 100°C; one fourth indicated they are addressing industrial processes

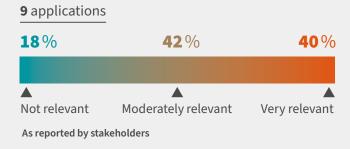
between 100°C - 180°C; and one fourth indicated they are addressing industrial processes above 180°C.

Stakeholders also reported in which way they would be willing to use/adapt their technology:

- Integration in different processes, investigating new energy storages, especially for high temperatures (new storage materials) and steam
- » Supply of heat
- » Supplying low, medium and high temperature needs and producing electricity in the industry
- » Data centre applications with certain quantity of heat reuse; cooling and heating distribution networks with localised booster to reach different building needs
- » Refrigeration compressors adapted to use for high pressure heat pump applications
- » New applications for solar thermal adapted to provide higher or lower temperatures, or higher kWh at lower cost

#### New concepts for awareness dissemination

This topic concerns awareness raising related to the use of renewable heating and cooling in the industrial sector on the industrial stakeholder level, policy level, as well as citizens level. (52)



The activities being realised are aligned with the desired results indicated in the RHC SRIA, with focus on information materials/tools targeting Industry owners, energy managers and industrial facilities planners; policymakers; citizens to build a community of experts and engineers in process industry in combination with energy use.

Almost nine out of then survey participants indicated they would be opened to disseminate experiences on B2B level and information on innovative business models.

Stakeholders were also asked to indicate which functionalities a tool should have or which information material should provide in order to offer them an added value:

- » Showcase successful quantifiable projects.
- » Be user friendly and simple, introduce technology and its benefits in brief, perform pre-feasibility analysis.
- » Technical capability in comparison with conventional sources.

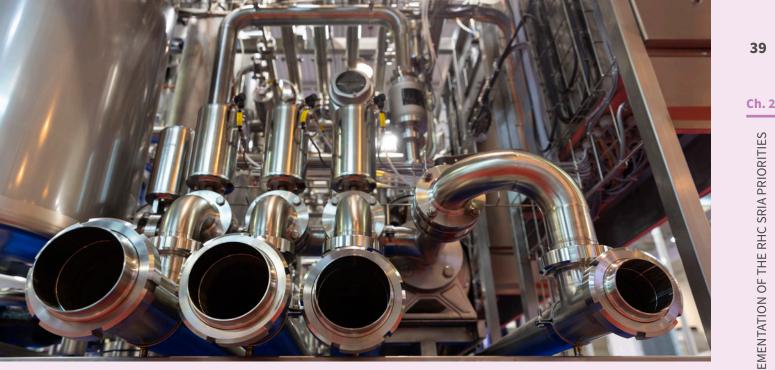
- » Financial feasibility.
- » Impact of RES on CO<sub>2</sub> emissions.
- » Database of all renewable heating and cooling installations in Europe.
- » Calculate and communicate costs based on LCOH, (53) not MW capacity, as this is not relevant as long as supply isn't stable (i.e. capacity can only be met in optimal scenarios which rarely occurs), €/m² (as this doesn't make sense to anyone outside the solar industry), nor W/m² (same reason), etc.
- » An up-to-date list of (potential) solutions for industrial processes, with links to information sources and providers. This would act as a tool to force cooperation, where R&D efforts are prioritised and concentrated. All efforts today are too diluted and lack planning.

The focus of activities reported as being realised spans:

- » Awareness focused research projects, including training and webinars.
- » Workshops about absorption technologies (open to public or closed groups with special topics).
- » Creating awareness and confidence in the technology and introducing a product.
- » Amplify heat as a service; circular application of all energy to contain and control waste emissions; or integration of solar thermal driven adsorption heat pump for cooling using self correcting intelligent-building energy management system.

<sup>(52)</sup> RHC-ETIP, 2020a, Section 7.4.

<sup>(53)</sup> Point mentioned by multiple stakeholders.



#### MISSING TOPICS/PRIORITIES FOR 100% RE INDUSTRIES

Below, topics/priorities that have been indicated as missing among the RHC SRIA priorities by survey stakeholders are listed and put in perspective, as some of these have been referenced in the RHC SRIA, and others are either very general or very specific.

#### **Topics/priorities with too little focus:**

Hybrid mixed systems for high temperature heat (e.g. electricity enhanced solar thermal)

This topic is covered in the RHC SRIA under topic Hybridisation of renewable energy systems. (54)

#### Steam storage — up to 200° C

This topic is covered in the RHC SRIA under topic Hybridisation of renewable energy systems. (55)

#### Topics that are too specific:

- Liquid lead storage
- Waste heat recovery for polygeneration (sCO<sub>2</sub>, ORC)
- Hybrid absorption system with solar thermal plants, thermal storage, and/or harnessing waste heat

These topics are very specific, but partly covered within the RHC SRIA under topic Developing new process technology concepts being supplied by renewable energy. (56)

For the RHC SRIA, it was decided to describe common topics for the different horizontal working groups in socalled transversal topics. While this was appropriate, it could also lead to more missing topics being reported for the individual horizontal working groups, as indicated in the comments in this section.

One upcoming important topic for industry is missing. The technology is in a very early stage and needs for sure several years for further development:

#### Solar thermal energy and photos for Hydrogen production

The photo-electrochemical in combination with thermochemical reactions splitting of water by direct use of sunlight offers a promising possibility to produce hydrogen. Its process efficiency can be increased by using wastewater, since pollutants and waste substances contained in wastewater (e.g. microplastics) serve as an additional "source" of hydrogen (sacrificial substances) in the broadest sense. The advantage - at the same time as H2 is produced, a significant elimination of pollutants and thus purification of the wastewater takes place. Based on new catalyst the reactions can be performed at low temperatures. The research is in early stage.

<sup>(54)</sup> RHC-ETIP, 2020a, Section 7.1.

<sup>(55)</sup> RHC-ETIP. 2020a, Section 7.1.

<sup>(56)</sup> RHC-ETIP, 2020a, Section 7.3.



The aim is to find out on what RD&I activities stakeholders are currently working; what the objective of their RD&I activities is and what affects formulation of their RD&I activities; and what the budget for these RD&I activities is and whether it is increasing or decreasing

This chapter offers an overview of findings and identified RD&I trends among RHC stakeholders. The aim is to find out on what RD&I activities stakeholders are currently working; what the objective of their RD&I activities is and what affects formulation of their RD&I activities; and what the budget for these RD&I activities is and whether it is increasing or decreasing.

#### 3.1. Key findings

### Funding going towards RD&I and the overall trend

A key aspect of RHC RD&I is adequate financing through funding opportunities. To streamline this process, companies tend to operate through internal RD&I activities, and often have a dedicated RD&I or sustainability department to handle internal projects. Despite the perceived importance of RD&I activities, annual revenue is unevenly divided. The survey showed that barely one-fourth of surveyed companies contribute more than 40% of their revenue towards RD&I activities, while one-fourth contribute less than 10%.

There does appear to be **a trend towards investing a greater amount of revenue into RD&I activities in RHC**. The survey noted either an increase in funding (ca. 34 % of participants) or a stagnation (ca. 36 %) over the past 3-5 years. In any case, funding for RD&I does not appear to be dwindling; rather, funding amounts were predicted to remain the same or increase further in the next few years.

Even companies without a dedicated R&D department value research. For instance, Austrian solar energy company SOLID's revenue is split between 20%-25% of revenue for R&D, and 75-80% for operations. However, both are linked, and the company has several hybrids that work on both sides. This allows for an exchange and learning from real life projects, which feeds back into R&D.

#### **Sources of funding**

Stakeholders' feedback indicates that sources of funding for internal RHC RD&I activities can vary widely. However, the most prominent sources of funding stem from government aid programs - either from the national governments, the EU or regional governments (in order of prevalence). In countries where national funding to RD&I is limited, EU programmes are the first source of funding. The German government, for example, has dictated that geothermal energy should be the focus for H&C, while electrical heating is perceived as a bridge technology until coal is phased out. This indicates that strong national leadership and policy have a significant impact on RD&I through their funding programmes. Other sources of funding include financial contributions from other companies and equity. Private funding, including internal company resources, is valuable because it means that RD&I can be done on an accelerated basis, without waiting for the bureaucratic application and approval processes of national governments or the EU.

External funding opportunities such as bank loans and reimbursable advances from governments are, according to the collected feedback, noticeably less prominent sources of funding. Importantly, sources of funding have generally not changed in the past several years – though the competitiveness of the EU's funding application process has meant that some projects have received reduced aid from the EU. The increasing competition for public funding could be somewhat mitigated through the large scope of initiatives such as the European Green Deal, though the increased amount of funding is complemented by an increased number of participants applying for funding. The evaluators of funding programmes thus have a good amount of control over where money is allocated.

Due to the long approval and enactment period of EU funding programmes, Dutch company IF Technology noted a tendency toward implementing commercial projects rather than research ones. By focusing on commercial activities, IF Technology could focus on direct implementation more effectively and economically.



#### TRL, RD&I objectives and the overall trend

The umbrella of RHC RD&I activities is wide and spans all technology readiness levels (TRL). (57) The spectrum of TRL suggests that **the continuous nature of RD&I has contributed to a natural flow and progression in relevant technologies from the development stage to deployment and production and market introduction phases.** The wide span of TRL indicates the previous years of funding and research, as well as future capacity for technology and innovation in the market.

Stakeholders noted that RHC RD&I activities are primarily confined to two divisions: improving existing products and services and developing new products and services. Within these divisions, RD&I activities focus on certain objectives. One of the most important objectives is **addressing environmental issues through sustainable energy systems**. Sustainability is a cornerstone of RHC RD&I, and surveyed individuals remarked upon a growing focus on the development of efficient renewable energy technologies such as thermal energy, photovoltaic energy, heat pumps and hybrid systems. This focus seems stable as main internal RHC-related RD&I activities will not change in the next 3-5 years but could expand in scope depending on market preferences.

For future trends and objectives, European RHC sectors will likely centre around increasing the RHC sector's scale, reliability, affordability and efficiency. A stronger focus on

cross-cutting technologies, sector coupling and integrated or hybrid systems could increase optimisation and efficiency. Building up capacity is also key. Future trends will likely also include greater inclusion of and cooperation with other renewable technologies, particularly hydrogen-based renewable energy systems but also encompassing waste heat recovery, district heating (DH) and district cooling (DC) and effective heat storage measures. Finally, RHC sectors are looking to increase the digitalisation of their technologies, such as through smart control distribution systems.

#### RD&I cooperation and the overall trend

**Technical cooperation is prevalent in RD&I projects in various ways**. Companies generally cooperate with third parties on RD&I projects, either by developing technology knowledge to influence R&D activities or by exchanging technological knowledge resulting from previously conducted R&D activities. This cooperation is also not confined to a single country; in fact, a majority of companies cooperate across EU countries or are planning future cooperation with the EU. Cooperation also encompasses data sharing. Certain renewable energy systems such as district heating and cooling can use AI on a large scale to predict and improve its flexibility. However, acquisition of this data can lead to privacy issues, particularly on the side of the client.

Technological cooperation is invaluable for numerous reasons. By fostering knowledge transfer, the learning curve



The most prominent sources of funding stem from government aid programs – either from the national governments, the EU or regional governments (in order of prevalence)

is shortened, allowing R&D to be advanced faster and with increased efficiency. It is vital that this cooperation is nurtured and expanded in the future to create accelerated and effective development in European RHC solutions. Furthermore, cooperation allows for greater implementation of technologies across different European administrative and financial climates. The cooperation with other EU countries must be aimed at finding synergies between the separate energy systems and infrastructures, seasonal climate, varied needs and diversified regulatory systems.

### Policy frameworks affecting RD&I and the overall trend

Policy frameworks can beneficially or detrimentally affect RD&I and its overall trend – this is exemplified in the fact that **a vast majority of companies follow policy developments at the EU level**. The concrete impact the EU has on RD&I is not clear; from the survey, a majority found that EU policy does affect company activities, though a strong minority (40%) disagreed. This division is perhaps explained by the diverse priorities and areas of research for individual companies.

According to RHC stakeholders, **policy seems to have the strongest impact in terms of funding opportunities**. EU policies can target certain renewable energy technologies, leaving alternative technologies underfunded. In this way, EU policies and complementary objectives can shape RD&I research. Incentive policies such as those based on capital expenses or through specific government ministries are particularly important. The influence of EU policy therefore extends beyond specific EU mandates and

funding programmes; EU regulation impacts the scope of research and innovation, and EU policy acts as an umbrella policy for national policy, shaping Europe's long term and strategic direction for RHC research. By creating more unified strategic direction for RHC RD&I, EU policy can also promote the circular economy, energy communities, and greater sector integration regarding renewable energies.

Other framework conditions such as political conditions, legal conditions, market conditions, research conditions, social conditions and financial conditions have a less clear impact on RHC uptake, according to stakeholders. Market conditions and research conditions are generally perceived as favourable, political conditions and legal conditions are divided and social conditions and financial conditions are generally perceived less favourably.

French company Dual Sun's RHC-related RD&I activities are certainly related to market conditions. The company explained that the types of PV technology which they produce are chosen to better address the market. Their focus on tertiary buildings is also linked to a future market need: France's mandatory regulation to install solar systems that cover 30% of the roof area.

Both political and legal conditions will vary depending on the country and political conditions are also naturally affected by the level of politics. In Germany, there is a trend towards clustering renewable energy projects into regional networks to reduce redundancy, promote cooperation and increase outreach. France legally requires all public entities to prioritise renewable energies over fossil fuels.

#### 3.2. Challenges and obstacles

#### Internal/external factors affecting RD&I

There are several internal and external challenges which affect RD&I activities, the largest of which is the availability of public funding. EU funding is key and would be beneficial for RHC solutions, but the process to access EU funding is complex and competitive. Funding measures also target more economically viable and high performing solutions.

Stakeholders such as Italian residential heating company Palazetti Lelio SPA emphasised the importance of funding programs, which direct RHC-related RD&I activities. The company noted the need for the European RHC sector to more clearly define market trends and organise consortia to receive EU funding.

Other important factors to RD&I activities are **insufficient cash flow** and insufficient staffing. Interestingly, although the availability of EU funding is a challenge, the survey showed that EU regulations are not perceived as a major hindrance. In fact, certain regulations such as CO<sub>2</sub> taxation cause greater emphasis on decarbonisation of heating and cooling technologies. Nevertheless, permits and regulations can slow the R&D process.

Geothermal company Vulcan Energie Ressourcen GmbH described how the permitting process for one request of 17 pages took 2 years for review. German company EWE even admitted that certain projects were cancelled due to excessive bureaucratic hurdles. Considering the rapid development of technology and the state of the climate crisis, making permits and approval procedures more efficient would only accelerate the market uptake of renewable heating and cooling technologies and solve the climate crisis.

There are also factors which prove beneficial to the uptake of RHC solutions and thereby increase RD&I. Education and training, cooperation between companies and strong national policies facilitates greater support for RD&I. Most prominently, there is strong support from users and consumers to access renewable energy systems.

German RHC development company Ritter Energie noted that the "collective mind is changing" and there is a "change in common consciousness" with regard to the renewable energy transition, specifically referencing Fridays for Future.

#### **Barriers affecting the update of RHC**

Numerous barriers can affect the uptake of RHC solutions and impede further innovation. The strongest barriers to RHC uptake centre around **a lack of clear information and communication**, including insufficient information about the benefits of RHC solutions; uncertainty around the performance of RHC technologies; and uncertainty of regulations. Other barriers stem from more concrete external factors, such as a lack of policy support; high installation costs; and higher competitiveness of traditional solutions.

Stakeholders highlighted certain areas where the EU or national governments could pursue stronger policy: sharply reducing the use of fossil fuel and creating incentives to push renewable technologies against fossil fuel technologies. With stronger decision-making from government leaders, renewable technologies would receive greater support.

A central theme is **cost** – which naturally reflects the need for adequate funding. There are **high upfront costs for research and applications' installation**, and fossil energy is in turn quite cheap. Barriers therefore stem from the cost to switch to renewables, both from companies and consumers. Certain policy initiatives such as CO<sub>2</sub> taxes can help alleviate those barriers. Lack of information is also barrier, particularly in terms of experienced and skilled installers. There is a combination of relative ignorance of the customers of the benefits of RHC, the relative inability of the supply chain to deliver and the relative lack of public policy to incentivise the right solution. There are also some technical challenges to overcome, such as finding adequate storage capacity.

The fact that **uncertainty of regulations and lack of policy support** are both strong barriers indicate that the EU and national governments must do more to support RHC RD&I. Survey participants specifically referenced a lack of support from authorities, the lack of a long-term vision, and lack of adequate funding – particularly in the face of competition from fossil fuels. Other barriers to RHC solutions include volatility in energy provision from renewables; an unclear legal situation for consumers, tenants and landlords; and lack of skilled personnel for installing RHC solutions and providing support.

The strongest barriers to RHC uptake centre around a lack of clear information and communication, including insufficient information about the benefits of RHC solutions; uncertainty around the performance of RHC technologies; and uncertainty of regulations



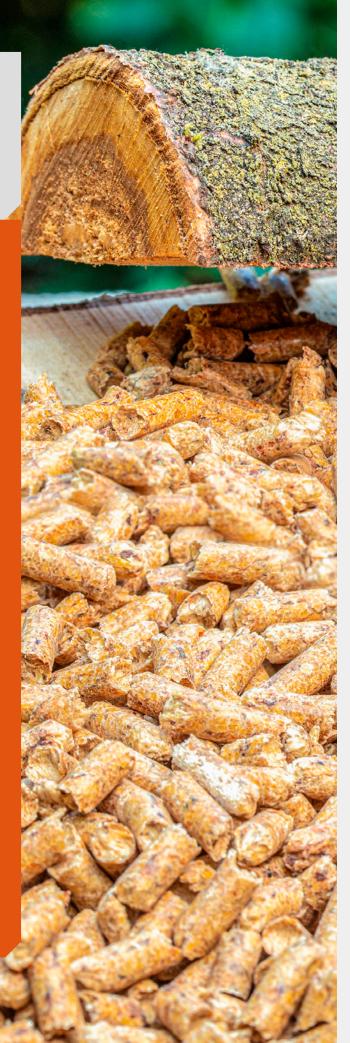
CHAPTER 4
RECOMMENDATIONS
& CONCLUSIONS

#### Recommendations concerning the further implementation of **RHC SRIA priorities**

In the course of collecting data for the purposes of this report, stakeholders provided suggestions and recommendations concerning the speeding up of their RD&I activities and what specific steps would accelerate market deployment of their RHC technologies. These are listed here and classified according to the RHC SRIA priorities.

#### **Technologies of heat and cold** storage and distribution

TES is a major aspect of successful RHC implementation and requires adequate support and funding to increase the market and upscale the solution - particularly as large-scale heat demand cannot be cost-efficiently accommodated by electrification. Currently, innovators have reportedly demonstrated a low-cost 1.5 MWh storage. However, energy storage is an important aspect of future renewable energy capacity. Stakeholders have thus recommended greater technical assistance for the preparation of investment projects, more awareness from investors and decision-makers about existing installations, and strong cooperative measures with research centres and other industry organisations. Competing solutions also help to build awareness and to build sector coupling and more efficient system integration; current solutions use high-temperatures in order to increase turbine efficiency for electricity production without capitalising on opportunities of the lower temperature market. For existing networks, incentives should be enacted for customers to convert the heating systems to low temperatures; in new heating networks, renewable technology (equated with cogeneration technology) should be the basis of operations. Legal measures could also be employed to order a reduction of distribution temperatures at a district level.





## Digitalisation, operation and system flexibility

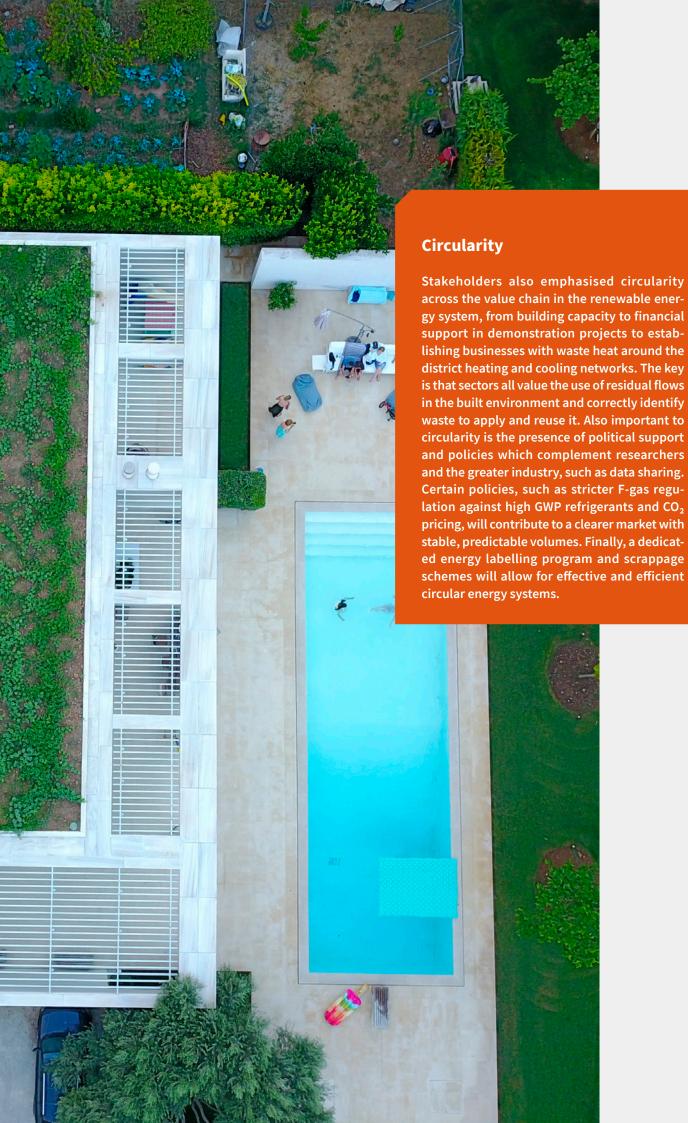
Digitalisation is also an important focus area for stakeholders, who support the engagement/dissemination of the use of open-source platforms to reduce the cost of secure, advanced control strategies for RE systems in buildings. Ideally, this would lead to the mandatory digitalisation of the power grid and demand-based electricity prices, as well as the standardisation of protocols. These protocols should be transparent to users, and control systems should include a self-learning adaptation for optimisation. Stakeholders also recommended monitoring publicly subsidised installed technology for at least 5 years, with the flexibility of further improvements.

For energy systems to operate effectively and efficiently, there are also important cooperative methods which must be adopted. Inherent is better cooperation and communication between research (simulations) and industry – which includes data sharing. Open-source model libraries, for example, would stimulate greater collaboration and would allow for easy public access to relevant consumption and production data. Cooperation also includes other sectors of the economy, such as marketing renewables and bringing more awareness to PVT benefits.

Another key aspect of operation is funding systems. Approval procedures should be simplified, bureaucracy reduced, taxes enacted on non-renewable energy (stakeholders suggested a "heavy hour by hour CO<sub>2</sub> tax on electricity that is not green") and launch greater funding measures for development of EMS (energy management systems) which target digitalisation issues for renewable heating and cooling.











#### 100% RHC in Districts

Stakeholders stressed the need for energy efficiency, sustainability, and circularity. On a district level, RHC planning is essential. District heating and cooling should integrate large-scale heat pumps, including those using geothermal and other low-temperature resources, and energy storage systems. Districts also imply a greater recognition of the importance of dynamic simulations, digitalisation solutions (artificial intelligence, smart control and monitoring), and integration with the wider energy system. For example, districts could implement energy efficiency investments or deep renovation in buildings in coordination with temperature reduction. Such advances on a district level would have a domino effect, build capacity, and result in significant impact.

Successful RHC integration in districts also requires support on a variety of levels. Local authorities must first want to implement RHC technologies, and government should regulate district heating. There should also be support for new research proposals and funding for renewables, including specific research and innovation funds and financial support for RHC projects. Financial support should also extend to the energy transition of existing district heating systems and incentives for new area development (both on a private household level and on a greater industrial level). District governments should also create a legislative and normative framework to consider as self-consumption the decentralized consumption of electric energy produced in the area of the DHC network.

Finally, successful RHC integration on a district level requires greater data and information. More data on decarbonisation strategies and scenario evaluations at the district level, which remain scarce and roughly estimated, as well as better European heat consumer data would improve RHC implementation. To aid the current data shortage, open-source model libraries, open innovation practices, and directories of competent actors on the DHC sector would lead to greater data-sharing and subsequent innovation and development. Continued involvement from stakeholders, such as through stakeholder groups and data sharing, would create more focus on RHC impact and implementation.

#### 100% RHC in Cities

Stakeholders emphasized the importance of long-term storage facilities and the accompanying R&D needed to develop that capacity. Cities also require circularity, the interconnection of the renewable energy process to integrate all energies, prevent waste, and bring down total energy use. RHC integration in cities also requires local government support, not only through adequate economic support such as funding measures but also administrative support, including simplified approval procedures and reduction of bureaucracy. Governments should also allow for easy public access to relevant consumption and production data as well as public visualisation tools (e.g. based on mapping of EPC results), which would lead to greater awareness and choices for people to make decisions.

Stakeholders acknowledged that cities and districts within them cannot enforce an immediate transition to fully renewable energies. Solutions must be found which continue to use the benefits of fossil fuels until adequate alternatives are developed and implemented. Nevertheless, CO<sub>2</sub> taxes or other fossil fuel taxes should be enacted to offset the price for green technologies. Electricity prices should also give an economic motivation to sector coupling.



#### 100% RHC in Industries

Stakeholder feedback is essential for RHC integration across the wider industry. A prominent topic for stakeholders is absorption. Firstly, stakeholders requested more publication about absorption machines, which can be used successfully with waste heat to provide cooling. Having the possibility to use a large amount of solar in summer for cooling would enable for a higher solar fraction to be achieved at lower cost by reducing the mismatch between summer generation and the traditional load of winter heating. However, development is needed to reduce the driving temperatures of absorption and/or to increase achievable heat from solar and improve the control and integration. Nevertheless, with greater perception and interest in absorption technology, the European market could better capitalise on its potential. Stakeholders also stressed the importance of funding, such as for pure dissemination projects including utilities partners.

#### **CLOSING REMARKS**

A major contribution from all renewable heating and cooling technologies will be needed for Europe to achieve climate neutrality by 2050. Despite the obvious huge impact and benefits of these technologies, their importance is often neglected and only slowly moves onto policy makers' and national energy agendas. This has been also substantiated by IRENA, IEA, and REN21, which reported that only a small number of countries —mostly within the EU — had national targets for renewable heating and cooling at the end of 2019. <sup>(58)</sup>

This report builds to a large extent on the previously published RHC SRIA and the Vision and represents an inquiry into the RHC community's RD&I activities, related challenges, and priorities. It has been confirmed that the Vision and associated set of ambitious objectives presented in the RHC SRIA are to a great extent being realised and implemented.

With this report, the RD&I activities, related challenges, and overall priorities of RHC stakeholders are presented and put into perspective with the previously identified objectives.

This report can provide insight and further guidance for:

- » Representatives of the European Institutions, for the definition and strategic planning of the Horizon Europe programme and other funding instruments for Research and Innovation
- » Representatives of national governments working in the fields related to the RD&I and development of the renewable heating and cooling sectors
- » RHC companies and industries in their internal R&D strategies, joint initiatives, and collaborative projects
- » Representatives from associations in other connected sectors such as: buildings, electricity, transport, and citizen organisations, as well as environmental NGOs and think tanks

# ANNEX I Stakeholders Contributing to this Strategic Report

#### **Contributing to the survey:**

- » Glayx
- » Tekniker
- » Riello S.p.A.
- » North-West Croatia Regional Energy Agency
- » Rioglass Solar
- » Vattenfall Wärme Berlin AG
- » Fiera Group and Heat Plus Pump
- » University of Catania
- » StepsAhead Energiesysteme GmbH
- » EEI Energy Technologies
- » Northern Ireland Housing Executive
- » Terawatt Ireland
- » CRES Centre for Renewable Energy Sources and Saving
- » netgreen.eu
- » Swegon
- » GEA GmbH
- » Institute of Energy Systems and Environment, Riga Technical University
- » Polytechnic Institute of Setúbal
- » SPIUG (Association of Heating Appliances Producers and Importers in Poland)
- » Mirai Intex
- » Stiebel Eltron
- » THERMOWATT Kft.
- » UGI
- » Limerick Institute of technology
- » ENGIE
- » Colterm Timisoara SA
- » SOLRICO
- » Cyprus Union of Solar Thermal Industrialists

- » Ingenieurbüro solar energie information
- » PLEION SRL
- » ASIT
- » Tangente
- » AES Solar
- » Creaspin
- » University of Cordoba
- » Czech Technical University
- » ZAE Bayern
- » Technische Universität Berlin
- » AIT Austrian Institute of Technology GmbH
- » MG SUSTAINABLE ENGINEERING AB
- » Absolicon Solar Collector AB
- » Stadtwerke Kempen GmbH
- » Consiglio Nazionale delle Ricerche Istituto di Tecnologie Avanzate per l'Energia (CNR ITAE)
- » Dr. Jakob energy research GmbH & Co. KG
- » Ecotherm Austria GmbH
- » GREENoneTEC
- » CREVER research group/ Universitat Rovira i Virgili
- » Prime Laser Technology
- » SOLID Solar Energy Systems GmbH
- » PlanEnergi
- » LaSalDeLaTierra, S.L.
- » Technical University of Denmark
- » TVP Solar
- » Heliac
- » TEKNIKER
- » ENERGAID S.R.L.
- » University of Bologna
- » Chalmers university of technology
- » Clin

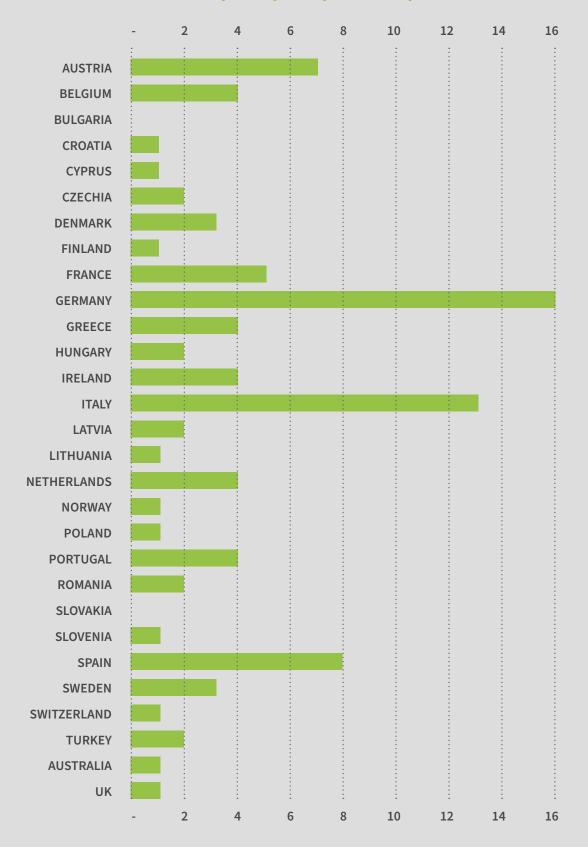
- » Conversio GmbH
- » Technical University of Cluj-Napoca
- » CEE-Engineering

#### **Contributing to the interviews:**

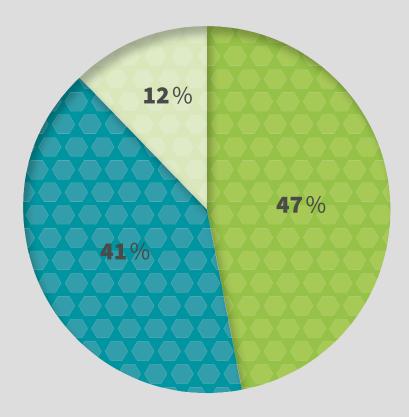
- » Easy Smart Grid (DE)
- » INEGI Institute of Science and Innovation in Mechanical and Industrial Engineering (PT)
- » Dalkia (EDF) (FR)
- » EWE (DE)
- » Fjernvarme (NOR)
- » SOLID (AT)
- » MegaWatt Solutions Nordic AB (SWE)
- » Vulcan Energie Ressourcen GmbH (DE)
- » IF Technology (NL)
- » GPC INSTRUMENTATION PROCESS (GPC IP) (FR)
- » COMPTE. R Biomass Boilers (FR)
- » PALAZZETTI LELIO SPA (IT)
- » Ritter Energie (DE)
- » Dual Sun (FR)

## ANNEX II **Survey insights**

#### Number of participants per country



#### Share of participants per sector

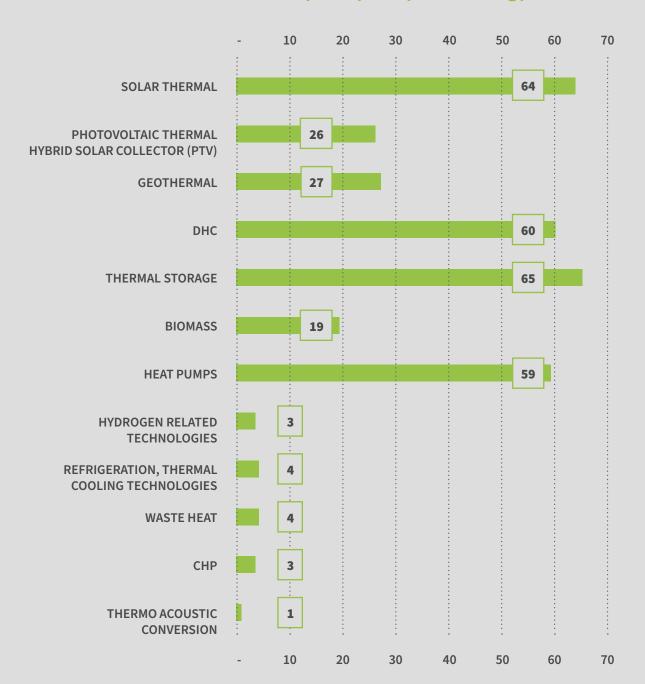


Selling / developing RHC technologies

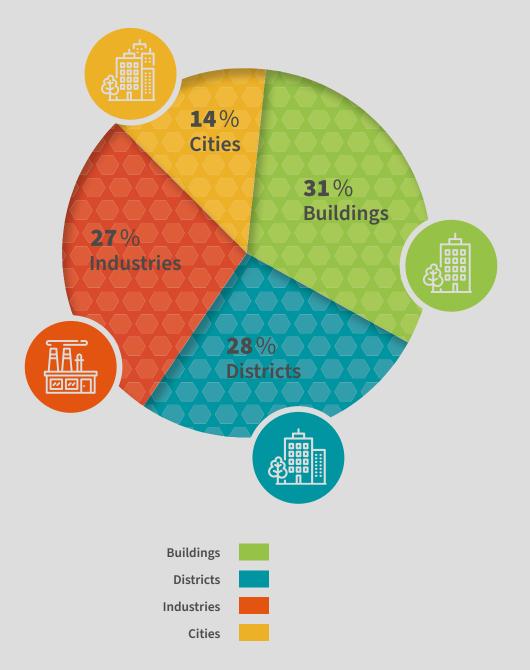
Purchasing / using RHC technologies

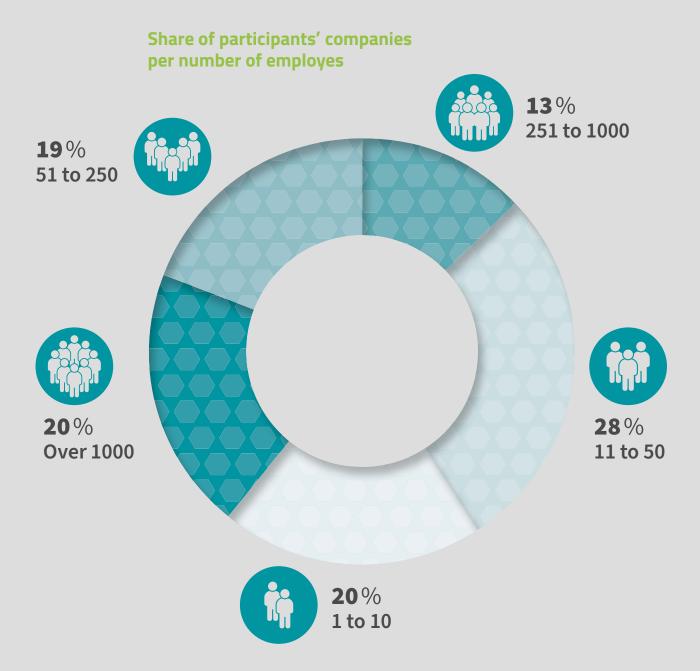
Other

#### Share of participants per technology

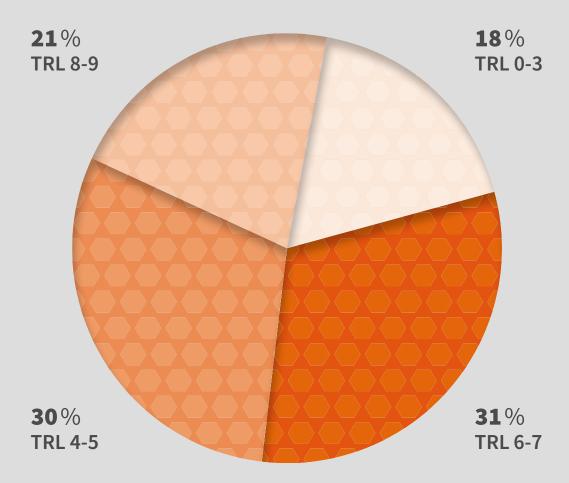


#### Share of participants per horizontal sector





## TRL levels of RHC RD&I activities conducted in 2020 (as reported)



#### **ANNEX III**

#### Interviews template

#### **Country**

#### Respondent is ...

- » Selling/developing RHC technologies
- » Purchasing/using RHC technologies
- » Other (please specify below)

Indicate under which horizontal RHC sector(s) would you categorise the activities of the respondent (you can choose more than one):

- » Buildings
- » Districts
- » Cities
- » Industries

What percentage of respondent's current production/development/use can be characterise as falling under renewable heating and/or cooling category?

%

#### **Company name:**

Respondent wishes the name of the company to be listed in the final report among other entities that completed this survey.

□ Yes □ No

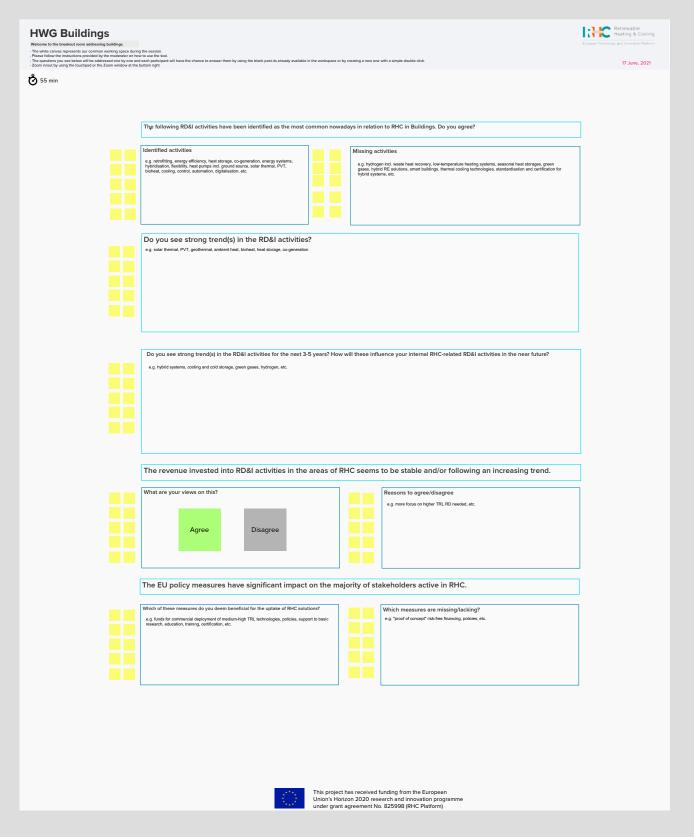
Number of employees (estimate):

**Respondent's e-mail address** (if they wish to disclose and receive the final report)

Is the respondent a member of the European Technology and Innovation Platform on Renewable Heating and Cooling (RHC-ETIP)?

□ Yes □ No

## ANNEX IV Co-creation Workshop Template



#### References

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European Commission, 2021.'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality. COM (2021) 550 final. [online] Brussels: European Commission. Available at: <a href="https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN">https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN</a>

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## PARTNERS OF THE SECRETARIAT OF THE RHC ETIP



EUREC and BIOENERGY EUROPE coordinate the Secretariat of the European Technology and Innovation Platform on Renewable Heating and Cooling



Bioenergy Europe coordinates coordinates the Biomass Technology Panel & the 100 % RE Buildings Horizontal Working Group



EGEC coordinates the Geothermal Technology Panel & the 100% RE Cities Horizontal Working Group



EHPA coordinates the Heat Pump Technology Panel



Euroheat & Power coordinates the District Heating and Cooling and Thermal Energy Storage Technology Panel & the 100 % RE Districts Horizontal Working Group



Solar Heat Europe coordinates the Solar Thermal Technology Panel & the 100 % RE Industries Horizontal Working Group



The Secretariat of the European Technology and Innovation Platform on Renewable Heating and Cooling is a project that has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement N°825998.



info@rhc-platform.org

Join us today and shape the future of RHC in Europe!

