D8.1

Market & PESTLE Analysis

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[1] PU = Public
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Executive Summary

WEDISTRICT aims to demonstrate that District Heating and Cooling (DHC) systems can be built on a combination of renewable energy sources (RES) and waste heat recovery solutions. To achieve this, WEDISTRICT sets up four demonstration sites across Europe to showcase our success stories. Four real-scale projects are carried out in different climate zones across Europe, where there are distinctive district heating and cooling systems and construction traditions. Each demonstration site integrates two or more renewable energy technologies and draws on local resources and innovative technologies.

WEDISTRICT scope and implementation actively contributes to the European mission of decarbonization of the heating and cooling sector which accounts for approximately 50% of the final energy demand in the EU and is mainly reliant on fossil fuels [1].

The main renewable energy sources that can be integrated in DHC systems are biomass, solar thermal and geothermal and a considerable role is also represented by the use of waste heat from industry and services. The integration of this kind of heating and cooling generation units is one of the main pillars of the current evolution of DHC systems together with a more efficient functioning of the system at low temperature (both at buildings and supply network levels) and a high interoperability/integration with the energy system as a whole (management of flexible and fluctuating production).

In addition to the technological aspects, the DHC systems need to be defined also from an organizational point of view as they depend on a complex network of stakeholders directly involved from a technical and legal point of view, but also from a societal perspective. The majority of business models involves public and private players having an extended range of roles and interests. A strong effort in stakeholders' coordination and engagement is crucial during all the phases of development and implementation of the DHC projects.

The analysis of the market identifies the barriers preventing the DHC uptake that include, as major aspects, the need in a long-term planning approach from authorities able to bear the related construction, operational risks and longer payback time and the capabilities to influence negative perception-behavioural approach by communities.

The existing barriers need to be addressed by specific national strategies for energy transition and regulations introducing ad-hoc fiscal policy and facilitating all the administrative steps to be taken during the project development. DHC should be seen as a way to better exploit local RES and support the power grid management.

Starting from the countries involved in WEDISTRICT demonstrations, a general overview of the political, economic, social, technological, legal and environmental conditions impacting the deployment of DHC projects is provided. The overview on four specific European countries helps in the understanding of the current European general framework represented by countries with high amounts of district network (such as Sweden), countries with inefficient district heat infrastructures and building stock (such as Poland and Romania) and countries with no/few DHC networks (such as Spain).

This document is aligned with WEDISTRICT document *D2.3 District Heating and Cooling Stock at EU level*, where it is established the current situation for DHC in Europe, the trends identification and reasonable evolution of DHCs in Europe and, finally, the identification of inefficiencies, barriers, and improvement potentials 'lessons learned'.

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Abbreviations

Abbreviation	Description
4GDHC	4th generation of District Heating and Cooling
5GDHC	5th generation of District Heating and Cooling
ADHAC	Asociacion de Empresas de Redes de Calor y Frio
BAT	Best Available Technology
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CS	Concentrated Solar
CSP	Concentrated Solar Power
DC	District Cooling
DH	District Heating
DHC	District Heating and Cooling
EBRD	European Bank for Reconstruction and Development
EHP	Euroheat & Power
EIB	European Investment Bank
EPC	Energy Performance Contract
ETC	Evacuated Tubular Collectors
EU	European Union
FPC	Flat Plate Collectors
GHG	Greenhouse Gases
GDH	Geothermal District Heating
GDP	Gross Domestic Product
H&C	Heating & Cooling
HVAC	Heating, Ventilation and Air Conditioning
INECP	Integrated National Energy and Climate Plan
IRR	Internal Rate of Return
LCOE	Levelized Cost of Energy
LCP	Large Combustion Plants
LPWA	Low Power Wide Area
LTRS	Long Term Renovation Strategy
MFF	Multiannual Financial Framework
N/A	Not Applicable
NCBiR	National Centre for Research and Development (Poland)
NGEU	Next Generation EU
nZEB	Nearly Zero Energy Building
PBT	Pay Back Time
PESTLE	Political, Economic, Social, Technological, Legal, Environmental
PTC	Parabolic Trough Collector
PV	Photovoltaic
RES-E	RES-Electricity
RES-H	RES-Heating
RoES	Romanian Energy Strategy
ROI	Return on Investment
O&M	Operation and Maintenance
OPEX	Operational Expenditure
RES	Renewable Energy sources
TBD	To be defined
TCO	Total cost of ownership
TTO	Technology Transfer Office
WHR	Waste Heat Recovery

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1 Introduction

This report is one of the deliverables of the activity of Exploitation, Business Modelling and Market Uptake included in WEDISTRICT work plan. The scope behind this part of the action is to support the effective deployment and exploitation of viable business models for DHC systems based on RES starting from WEDISTRICT validated concepts.

To do so, as a first step, a market study has to be conducted including a PESTLE analysis. This involves the identification of Political, Economic, Social, Technological, Legal and Environmental conditions that impact on the business opportunities required to run, replicate and upscale the WEDISTRICT solutions. This is the purpose of this deliverable D8.1 Market and PESTLE Analysis.

The present report is structured as follows:

- First, we set the scene regarding 100% decarbonised DHC systems. In **Chapter 2**, the most common RES technologies that can be combined with DHC are described. The evolution from the 1st generation DHC systems towards the 5th generation are explained.
- Then, we identify the business opportunity for 100% RES DHC systems. For this, in **Chapter 3** we list the drivers to the market uptake of RES DHC, and we also identify the barriers to overcome.
- In **Chapter 4** we conduct a PESTLE analysis for RES DHC in every of the four countries which host a WEDISTRICT pilot (Poland, Spain, Romania and Sweden).
- Finally, **Chapter 5** presents the main conclusions about the sector based on our study.

This deliverable provides the overall understanding of the market conditions and framework in which DHC projects operate and supports the ongoing activity of Business Modelling (Task 8.2). This analysis is the starting point for the right comprehension of the value network of the four individual WEDISTRICT demonstration sites.

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2 DHC systems based on 100% renewable energy sources – Definition & Context

2.1 100% RES DHC – Definitions

2.1.1 What a DHC is, in few words

District Heating and Cooling (DHC) is commonly described as the system where heat and cold are produced centrally (from one or more energy sources) and are transported through a network to the final users. An insulated pipe network connects local resources to local needs.

New generation of DHC are becoming more and more technically and economically efficient in comparison with other network and far from individual based solutions. Its main contribution is to reduce primary energy consumption and local emissions in the community served. By aggregating a large number of small and variable heating and cooling demands, DHC allows energy flows and works as thermal energy storage.

2.1.2 Aiming at achieving 100% RES

Next step in DHC environment is to achieve 100% decarbonized DHC by the exclusive use of renewables (biomass, solar thermal and geothermal energy), excess and ambient heat and fossil-free generation [1]. Dependence of fossil fuels is put aside and leaves the way clean for a more sustainable energy supply. Additionally, the system does not depend on a single source of supply thanks to the integration of diverse energy sources.

In 2018, renewable energy accounted for 21.1 % of total energy use for heating and cooling in the EU. This is a significant increase from 11.7 % in 2004. Increases in industrial sectors, services and households (building sector) contributed to this growth. Aerothermal, geothermal and hydrothermal heat energy captured by heat pumps is taken into account, to the extent reported by countries. [2]

The European DHC industry is committed to fully decarbonising our networks before 2050. But what does 100% RES DHC means? It is not only the use of renewable energies, but also the optimal combination of different sources taking into account their different working temperature, flow, seasonal fluctuations, efficiencies, etc.

A 100% renewable energy district makes optimal use of locally available renewable energy sources and waste heat, enables the use of locally produced renewable energy by offering optimal flexibility, in managing consumption and providing storage capacities to the regional energy system on demand. Cost-effective and reliable DHC solutions are a closer reality.

In particular, a wide range of renewable sources can serve as alternative to fossil-based heat [3]. Shallow geothermal sources are omnipresent in Europe and they can potentially cover a quarter of total heating demand in Europe, with deeper geothermal having the potential of covering another quarter of the demand. Albeit there is some risk associated with deep geothermal solutions. Solar thermal has about the same potential as shallow and deep geothermal combined [4]. At the same time, enhancing building thermal insulation reduces both the total heat demand and the required temperature for heating buildings, while generating a substantial cooling demand. As large-scale systems benefit from economies of scale, it is advantageous to design large scale systems that are flexible enough to account for differences between buildings in space and time and to accommodate a wide variety of renewable heat sources. District heating and cooling is a proposed resilient urban energy

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infrastructure design that can supply heat and cold at required temperatures to consumers, reducing total energy demand by facilitating direct heat exchange and using renewable sources to cover residual demand.

2.1.3 State of art of most common RES used in DHC

There are different renewable sources options for being integrated in DHCs: CHP, Waste, biomass, Solar, geothermal, industrial excess, among others. WEDISTRICT projects offers information about them through the public deliverable *D2.3 District Heating and Cooling Stock at EU level* (October 2020).

According to the latest report presented by Euroheat in 2019 [6], currently, the most common three renewable sources in district heating and cooling systems to date are biomass, geothermal and solar.

2.1.3.1 Biomass

Biomass is the most widely used renewable energy for heating today, representing in 2012 some 90% of all renewable heating [5]. Only biomass is currently used as an original energy source in many European DH systems. Fuel sources are mainly forestry and agricultural waste.

Sustainable biomass use for heating/cooling production can result in a number of energy, economic, employment and environmental benefits. Biomass can be stored at times of low demand and provide dispatchable energy when needed. Depending on the type of conversion plant, biomass can thus play a role in balancing the rising share of variable renewable heat from solar in the heating system.

The main concern with biomass though is that, despite being a relatively clean alternative to more harmful fossil fuels, biomass still generates harmful pollutants that can be released into the atmosphere as it is combusted. One of the main challenges is how to reduce NOx emissions from biomass burning.

The European Commission, in their endeavour to ensure healthy air quality conditions for citizens, published Directive (EU) 2015/2193 setting emissions limits for combustion plants. From that, the objective would be to bring biomass emission figures closer to natural gas outcomes, being necessary to reduce by nearly 4 times the NOx concentration coming from biomass.

The most usual way to reduce NOx emissions is to inject ammonia (NH_4) into the furnace. Nevertheless, the chemical reaction yields very low efficiency as 50% in very good conditions of temperature and mixing. Furthermore, ammonia injection increases solid particles into flue gas stream. This increasing can wear out and harm boiler heating surfaces and bag filters. Another usual technology is to reduce NOx by using catalyst. This is a very expensive technology which can only be used on big boiler units.

Over the last years, new technologies have been developed to reduce NOx emissions from biomass and other energy sources. Above all, these technologies are based on new bag filters with embedded catalyst. This combination can deplete NOx emissions to near zero. The big issue is the investment cost to implement this solution in small and medium size biomass facilities.

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2.1.3.2 Geothermal

Geothermal energy is a renewable energy source, which can provide base-load power supply for both electricity and space heating. Near-surface geothermal energy covers drillings at depth of about 400 m and temperatures of up to 25 °C and is used solely for generating heat. Deep geothermal energy, however, uses heat originating from much deeper rock layers with a temperature possibly reaching more than 100 °C; therefore, it is also suitable for generating electricity.

The first regions to install geothermal district heating (GDH), were those with the best hydrothermal potential, however there are some new DH schemes that use shallow geothermal resources, assisted by large heat pumps [7]. The deeper the rock layer, the higher the temperature. Importantly, at a temperature of 20-40°C, it is already possible to generate heat for use in residential heating systems.

Europe is a leading global market for geothermal district heating and cooling for buildings, industry, services and agriculture. In 2019, there were 5.5 GWth of installed geothermal district heating and cooling capacity in 25 European countries, corresponding to 327 systems. The status of geothermal district heating and cooling in Europe reflects a strong interest for this renewable resource and the possibility to implement it almost everywhere in Europe. The trend of ongoing projects anticipates a rapid acceleration of this dynamics and a diversification in leading markets [8].

2.1.3.3 Solar

Integration of **solar thermal** systems into district heating networks is currently priority challenging task (mainly in Southern Europe with a lot of radiation potential, as WEDISTRICT project explores in Spain). The possible solar thermal contribution currently is very low at 0.3% of the total heat demand [10]. The extension of the solar collectors' area and use of storage allows achieving 100% solar fraction during the summer [11]. Large solar thermal systems have proven to be cost effective when combining a large solar system with long-term storage.

The cost of solar heat mainly depends on capital investment in the solar collectors and storage, as fuel costs are null and maintenance costs are insignificant. Therefore, the development of lower-cost solar technologies is crucial to facilitate their implementation and increase their competitiveness.

The most common collector types are evacuated tubular collectors (ETC) and flat plate collectors (FPC) without vacuum. The choice of collector type depends on several factors such as:

- **Price**
- **Efficiency**
- **Operating temperature and**
- **Location (available solar radiation, ambient temperatures).**

Concentrating collectors are less common in district heating systems because the temperatures needed are too low (around 100°C) to require concentrated solar systems. Nonetheless, the advantage of concentrated solar systems is that the heat output can be gradually reduced by simply defocusing the mirrors. Stagnation problems like in ETC and FPC can therefore easily be avoided. At the same time, it is easy to maintain a specific temperature even in winter compared to flat plate collectors. In this context, Concentrated Solar (CS) technology is now regarded as a technology with high potential for DHC applications.

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On the other side, solar resource can be also utilized for **solar PV** installations which could be integrated with electrical consumers in the DHC equipment in order to reduce electricity consumption, as WEDISTRICT project proposes in Poland and Romania.

2.1.4 From 1st to 4th generation DHC

The DHC market is in constant evolution and from what one can name 1st generation of DH, which was firstly installed in 1880 using steam conducted by concrete ducts as heat carrier, until the development of the 4th generation, the technology and society demands have seen great changes that have their reflect in the DHC reality.

Looking only at the technology part, the direction of development for the first three generations was to obtain lower distribution temperature, material-lean components and prefabrication.

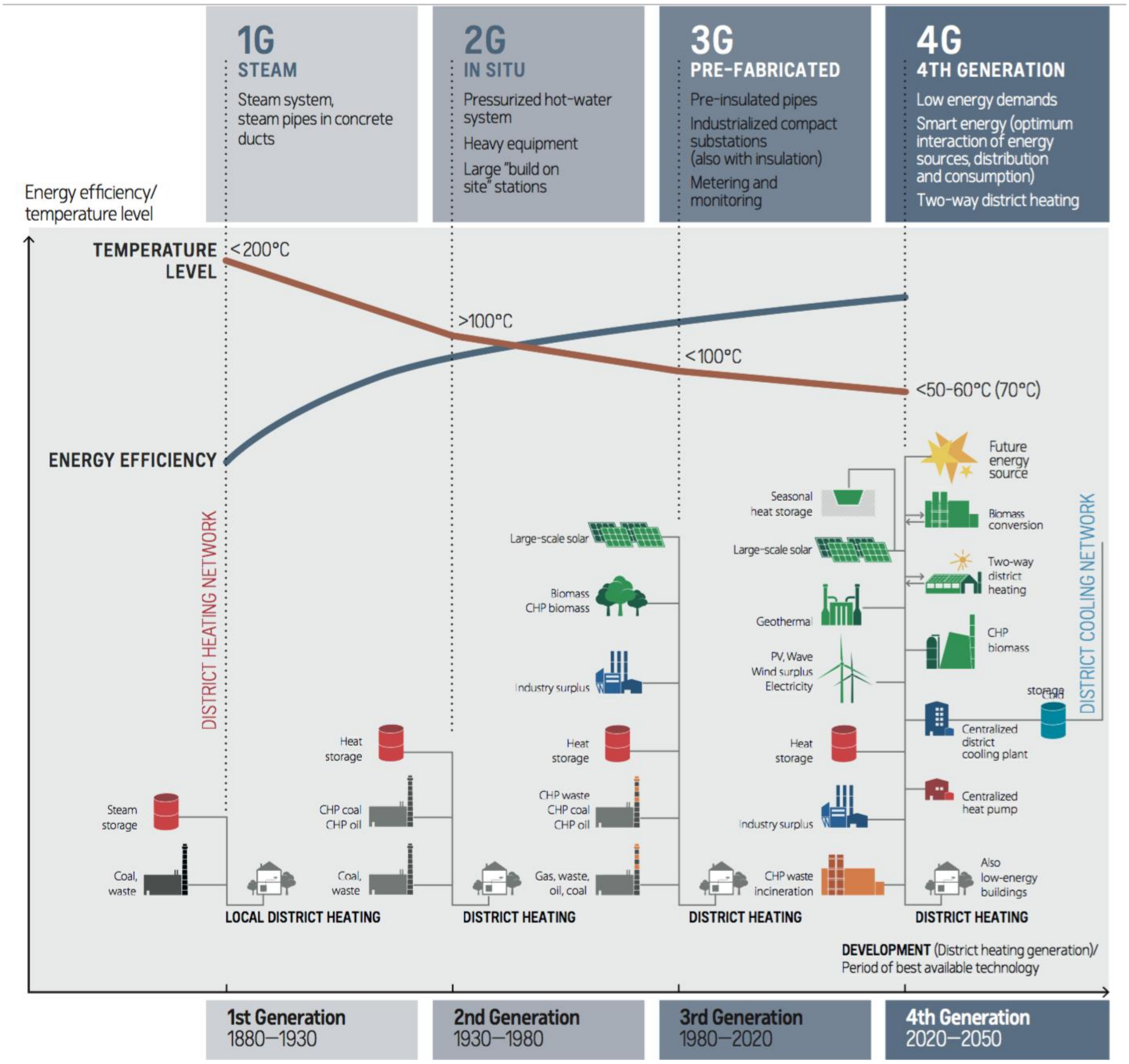

Figure 1. Illustration of the concept of 4th Generation District Heating in comparison to previous three generations [13]

According to Lund et al. (2014), future generations of district heating systems should be based on renewable energy and facilitate substantial reductions in heat demand [13]. They defined

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some properties that fourth generation district heating systems should have in order to fulfil its role in sustainable energy systems, which are:

1. **The ability to supply low temperature heat to both existing, renovated and new buildings;**
2. **Having low grid losses;**
3. **The ability to recycle heat and integrate renewable sources;**
4. **The ability to be an integrated part of a renewable multi-energy system (MES), including cooling;**
5. **Having a sound business model, also in the transition to renewable energy sources.**

The current 4th generation of district heating and cooling (4GDHC) is pushing hard to become the more widespread DHC, reaching high efficiencies by operating at low temperatures. Operation at low temperatures is both in distribution and in generation, which allows less heat loss through pipes and the use of local heat sources. At the end, this leads to CO_2 emissions savings and the development of greener local economy. In addition, the 4GDHC is based on modern measuring equipment and advanced information technology, which make the system more reliable, intelligent, and competitive.

In the heat distribution, it reduces the network heat loss, improves quality match between heat supply and heat demand, and reduces thermal stress and risk of scalding.

In the heat generation, lower network supply and return temperature helps improve the power to heat ratio of combined heat and power (CHP) plants and recover waste heat through flue gas condensation, achieves higher coefficient of performance values (efficiencies) for heat pumps, and enlarges the use of low-temperature waste heat and renewable energy.

2.1.5 The 5th generation DHC concept

In the current DHC market, the concept of 5th generation DHC (5GDHC) is now often mentioned and is frequently the subject of scientific publication. However, its definition and characterisation are still under discussion. The so called 5GDHC is still a recent and unexplored field, the know-how about this new utility distributing ambient temperature water is in the hands of few companies. No technical standards or guidelines are available for designers and there is a lack of knowledge for 5GDHC operational optimization and control [14].

The companies driving this new utility infrastructure highlights that the added value that this 5GDHC provides with respect to 4GDHC mainly lies in the distribution of a hot water temperature close to the one og the soil and thereby is. "neutral" from thermal losses point of view, has the capability to work in heating or cooling mode independently of network temperature, and bi-directional and decentralised energy flows. 5GDHC offers a way to incorporate low temperature renewable heat sources including shallow geothermal energy, as well as reduce total demand by recuperating the heat generated from cooling and the cold generated from heating.

5GDHC does not have return flows as such, but warm and cold pipes [16]. Ideally, heat and cold demand should be of similar size to achieve an almost circular system, but still a seasonal storage is required. In principle, bi-directional decentralised DHC grids allow that each consumer can operate as a producer, so have the potential of turning each connection into a "prosumer".

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However, the energy in this ambient heat network is not enough to be of value to the buildings directly, and the temperature will need to be addressed locally via a heat pump og gas boiler to provide enough e.g. heating and domestic hot water.

A detailed feasibility needs to address advantages and disadvantages in each case and evaluate if the system is financially feasible compared to the real DHC and efficient 4GDHC with large centralised energy production via e.g. heat pumps.

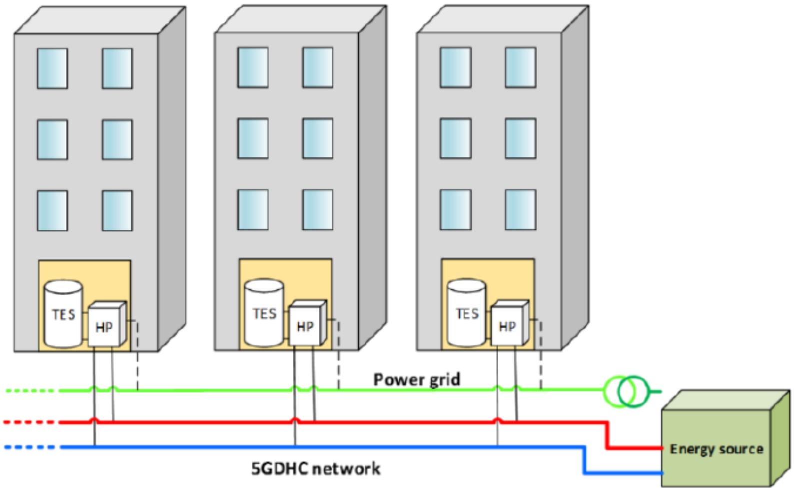

Figure 2. Scheme of a 5GDHC network concept [15]

One of the most technologically advanced examples of the so called 5GDHC in practice is Mijnwater DHC system in Heerlen, Netherlands, which is an urban smart DHC grid, incorporating several decentralized heat sources. This includes a data center, residual heat from supermarket refrigerators and from small scale industrial processes, as well as the warm return flow from space cooling in the connected buildings. The development of Mijnwater reflects the principles of 5GDHC, as it is developing from a local project engineered for an individual heat source to a modular urban-scale grid.

Based on the principles tested in Heerlen, five pilot projects for 5GDHC are being developed as part of the Interreg NWE project “D2Grids”: by a cloud of decentralized heat pumps, located at end-user accommodation, energy is exchanged on the grid, and flows are induced through customer demands. The concept allows large scale utilization of low temperature waste heat, from data centers, supermarkets, industry, etc. The project will deliver plans to create further similar developments in other sites and dedicated education and training programs for universities’ curricula [17].

2.2 Map of the involved stakeholders

2.2.1 Generic mapping of stakeholders involved in DHC systems

The business model for a district energy system is very project-specific. However, all DHC projects have a common characteristic as they deal with an extended range of stakeholders, such as investors, owners, operators, utilities/suppliers, end-consumers and municipalities. One complex scope linked to the implementation of DHC projects is to ensure that all players involved can achieve financial returns, in addition to any wider economic benefits that they seek.

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A valuable mapping process for district heating stakeholders is explained within the HNDU DPD guidance[1]. On the basis of this document of reference, anyone who has a direct or indirect interest in or could be affected by the project is included in one of the 4 groups of stakeholders are represented in Figure 3 and Table 1.

Figure 3. Stakeholders involved in DHC projects [18]

Table 1. Macro groups of DHC stakeholders

Investors	Consents
They provide the funds necessary to do the capital expenditure of the project with or without underwriting funds from financial institutions. They look for the appropriate rate of return able to cover the project development risks and/or corresponding to their profit appetite. They compare the financial attractiveness of this project vs. other kind of investments that could be of very different nature. This category could include: banks, financial institutions, local or national authorities, private companies incl. ESCOs.	These stakeholders provide the necessary permits and licenses to allow the project to proceed. This group has a mandate to undertake a particular function, which includes specific requirements and timescales. This category can include urban planning offices, environmental departments, all those government authorities linked to potential constraints in or around the area of the project; but also finance departments of the involved organizations having their internal approval procedures.
Customers	**Others**
They are the final beneficiaries provided with heat and cooling. They look for	This group includes all other interested parties actively participating to the implementation of

[1] Heat Networks Delivery Unit Detailed Project Development guidance.

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favourable savings in their bills, improvements in their energy supply and comfort, quality of air in their area. They could be private individuals, commercial, residential or industrial buildings, housing departments.	the projects (delivery partners) such as the operation and installation companies, DHC operators, heat and electricity distributors and sellers. It also includes other potential heat suppliers that could be interested in connecting to the DHC network.

The stakeholders included in the above categories can play different and multiple roles in the delivery of DHC projects. Besides, the types of roles that particular stakeholders occupy can vary drastically from project to project. The complexity of the stakeholders' map characterizing DHC projects is also confirmed by the spectrum of possible roles presented by the Heat Network Detailed Project Development Resource: Guidance on Strategic and Commercial Case, reflecting the total anatomy of a DHC project. All the following roles are not always represented in each DHC project, but this spectrum presents the full list of potential roles [19]:

Table 2. Main roles of DHC stakeholders

	Promotion - Local authorities could have this role on their own or in conjunction with others such as developers, community bodies, key anchor customers, etc. - Publicising the opportunity and communicating the benefits to key stakeholders. - Attracting developers, investors, operators and customer.
	Customer - Domestic and non-domestic buildings, local authorities purchasing heat and cooling delivered by the network.
	Governance - This role includes setting objectives, roles and responsibilities, setting overall direction for the elements of the network and overseeing performance. - This role could be taken for example by the local authority itself or an appointed board or a committee within the corporate structure of an ESCO or also an estate management company.
	Regulation - This role is focused on consumer protection and to prevent abuse of the monopoly position of a heat network. - In each legislation there are the appropriate authorities in charge of this activity which are usually independent from all other operators involved.
	Funder - They provide or arrange finance requesting security to mitigate their risk of investment.
	Asset ownership - The Asset Owner legally owns the physical assets of the network. Ownership could be split for generation assets, primary network and secondary networks). Ownership of assets may vary over the life of the project.
	Development of property - In the context of DHC networks, Developers of Property are the parties responsible for constructing or maintaining the buildings which will receive energy from the network. In some case they deliver the sites to be connected including the secondary, tertiary heat/cooling networks.

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	Land ownership - The role of the landowner is to grant leases and easements for the siting of network assets and provide rights of access for the installation, operation and maintenance of plant and equipment. This arrangement may arise where a third party with no other interest in the network lets land for the project.
	Landlordship - The Landlord role, for buildings connected to DHC networks, usually involves responsibilities for some network assets within the building, which may include the secondary and tertiary systems. This role could be covered by an estate management company or, in some cases, could coincide with the "Development of property" role.
	Installation - The installer designs and installs the DHC network and the generation units. Typically, this is the energy centre and primary network. Installers take on design and construction risk and usually retain some liability for defects in the plant and equipment for a period after completion of the network. Responsibility for delivering different parts of the network may be split between different parties and technology providers.
	Operation - An Operator is responsible for the operation and maintenance of the DHC network to ensure that heat/cooling/electricity of suitable quality and quantity can be delivered to customers. Typically, a single Operator is responsible end-to-end heat/cooling delivery, but there may be separate operators for generation plant and for secondary networks.
	Sale of heat - Depending on the National energy regulation, the sale of heat as a service can have a distinct role from the physical delivery of heat/cooling to customers. In many countries, in the electricity and gas markets there should be a mandatory separation of generation and distribution roles; this is not always applied for heat/cooling networks, for which the same organisation could be responsible for all the functions. Heat/cooling suppliers often subcontract aspects of this role, such as metering, billing and customer services, to specialist firms.
	Supplier of last resort - Depending on the National practices, there could be the role of an alternative supplier for the provision of the service to customers if the scheme's provider is unable to do so (e.g. because of insolvency or because a Concession Period ends and there is no replacement of the responsible party).

The increasing deployment of Energy Communities is currently introducing changes in the traditional business model in which the above-mentioned roles are clearly separated or always covered by the same kind of organisations: e.g. the customers take up the role of ownership of the assets from traditional operators; they can assume nowadays both the role of energy consumers and producers.

2.2.2 Involvement of public and private players

Both private and public sectors are usually involved by playing one or multiple roles amongst the categories presented above. In particular, the majority of business models for district energy involve the public sector to some degree, whether as a local policymaker, planner, regulator or consumer, or more directly through partial or full ownership of projects. Public sector involvement can be critical in coordinating multiple, diverse projects around a broader citywide vision. Even projects with a high degree of private sector control are often still facilitated or supported in some way by the public sector [20]. The degree of ownership between public and private is one the main features influencing the DHC business model: the ideal business model for a DHC project is defined by the degree of ownership that the public

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sector desires over the project and by its expected return on investment (ROI), resulting in 3 basic paradigms – wholly public / hybrid public-private / private. The local administration should have a higher involvement if the district energy project contributes to local objectives, such as local climate action plans [21].

2.2.3 Stakeholder engagement as key factor for DHC projects

Due to the complexity of roles involved and the variety of stakeholders that could directly or indirectly have an impact from DHC projects, stakeholder engagement activities represent a key factor that can influence the success of the initiative, for example, in terms of acceptance by the Community or investors backing the project.

In spite of its critical importance, the process of stakeholder engagement is often not approached with the same rigour applied to the technical, financial or legal aspects of heat network development. However, it is something that will inevitably be part of your project, whether or not it is labelled as such or treated as a distinct stream of activity [18].

The importance of the stakeholders engagement is at the core of many European and International initiatives related to DHC expansion: one of the main example is the European project CELSIUS [22], funded under the 7th Framework Programme assembling a network of 72 cities and 68 City Supporters between 2014 and 2017. One of the four sections of the Celsius toolbox, which represents a district energy knowledge resource, is dedicated to Stakeholder Engagement and provide interesting case studies of the involvement of stakeholders for the successful implementation of DHC projects.

Having a dedicated city unit or coordination mechanism to facilitate multi-stakeholder engagement actions is an example of best practice in developing and implementing a district energy strategy. Stakeholder acceptance of the vision, target, process and shared responsibility is crucial. It is important to involve stakeholders in setting goals and identifying activities in the energy plan, and to create ownership in the plan's implementation. An independent body or designated agency can provide representation for stakeholders in developing a district energy vision and build commitment to its implementation. This also provides the space for the city to understand stakeholders' positions and interests in order to negotiate common goals and activities, and can help build commitment from partners when they see the benefits that they can gain from cooperation [20].

An interesting practical methodology for stakeholder engagement is provided by Carbon Trust and includes the description of the actions and tools to use from the identification of the stakeholders involved to the engagement phase.

Furthermore, the stakeholder participation represents one of the non-technological innovation priorities reported in the report "100% Renewable Energy Districts: 2050 Vision" from DHC+ TP & HWG Districts members [23], which also stresses the importance of a fact-based and proactive communication, since social media (possibly including fake news) represents a growing challenge for municipal/regional planning processes.

A modernized heat and cooling sector, empowers local communities, small businesses and citizens, giving each citizen the possibility to take part in the energy transition as a consumer, worker, investor or even producer as a member of a community that relies on decarbonised heat supply, above all in the current framework of energy transition in cities (i.e. energy communities). Example of practical actions to reach this scope includes: the organization of public consultation procedures and consultation meetings to enhance the public participation

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in decision-making processes or the identification of enthusiastic community members acting as local/regional "ambassadors" from the beginning.

2.3 EU framework for DHC

2.3.1 Heating and cooling in the EU

The various EU countries have different stocks in DHC systems and experience different trends in the development of new systems. In some countries, the amount of produced heat and cooling is either decreasing, maintained, increasing, or there is close to none.

In general, only a few countries have taken advantage of their renewable resource potential for DHC or created policies to promote further uptake. Those with policies promoting renewable-based district heating include Denmark, Sweden and Switzerland. Denmark, with ambitious decarbonisation policies already uses high shares of renewables in DHC. Otherwise, renewable DHC still plays a modest role in most countries.

Figure 4 shows the share of energy sources (both renewable and fossil) used for heating and cooling in 2015 in the EU. Only 'District Heating' supplies heat in a collective manner, as within the other categories heat is individually supplied. 'Biomass' covers most often wood pellets, wood chips and firewood.

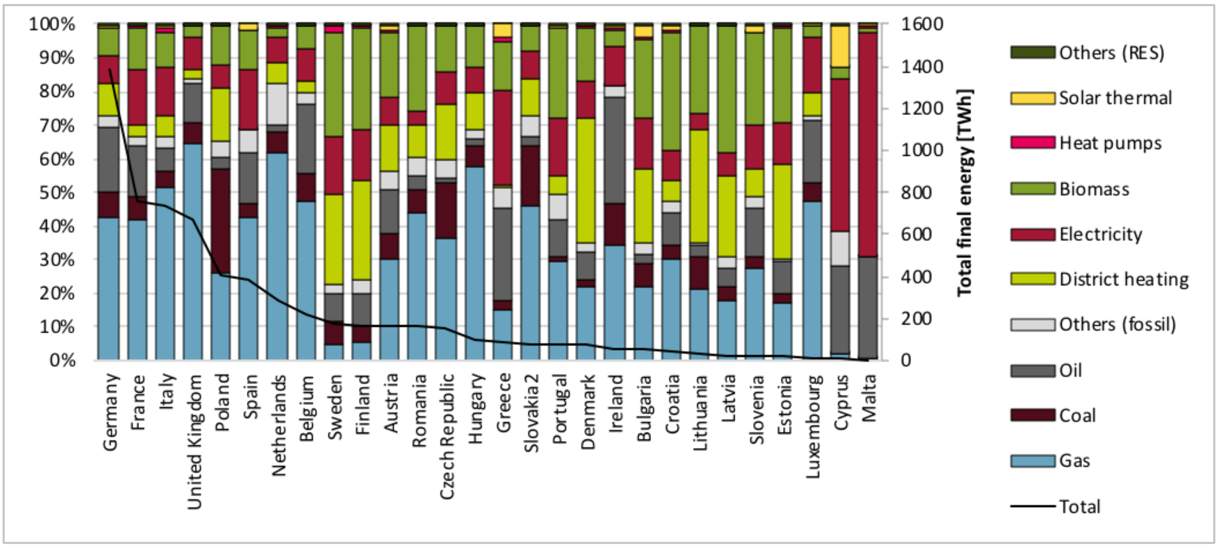

Figure 4. Share of energy carrier by country for the final heating and cooling demand for all sectors for 2015 [1]

2.3.2 District heating

EU countries use different types of fuels in their DH production. Some countries mainly use fossil fuels like oil, coal and natural gas, while other countries are increasing their use of RES, heat pumps and biomass, depending on local resources and legislations.

Generally, it can be noticed that fossil fuels (mainly natural gas and coal) covers a large share the energy supply for DH in Eastern European countries. Biomass plays a prominent role in Sweden as well as in Austria and Estonia. In Germany, most district heating systems have CHP plants. At EU level, natural gas and coal predominates on average. There is significant potential to upgrade existing systems and create new networks using solid biofuels, solar and

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geothermal technologies with significant benefits for energy security, human health and climate change mitigation.

Figure 5 shows the energy sources used to generate DH in the member countries of EuroHeat and Power in 2013 and in 2017. The general trend in these countries shows that the share of fossil fuels used for DH, such as oil and coal, is decreasing while the share of waste heat, heat pumps, biomass and other RES is increasing.

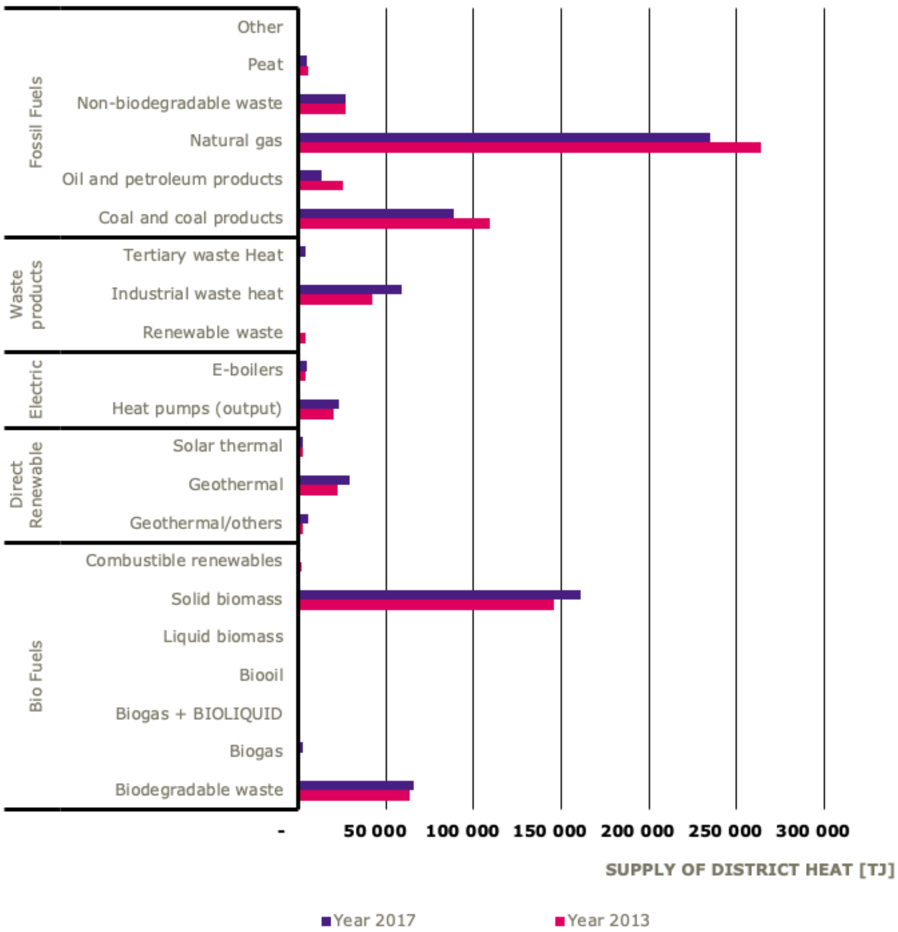

Figure 5. Sources for DH supply in the EU in district heating production from 2017 [6]

Along the same lines, Figure 6 shows for selected countries the decrease in CO_2 emissions generated for DH between 2009 and 2017.

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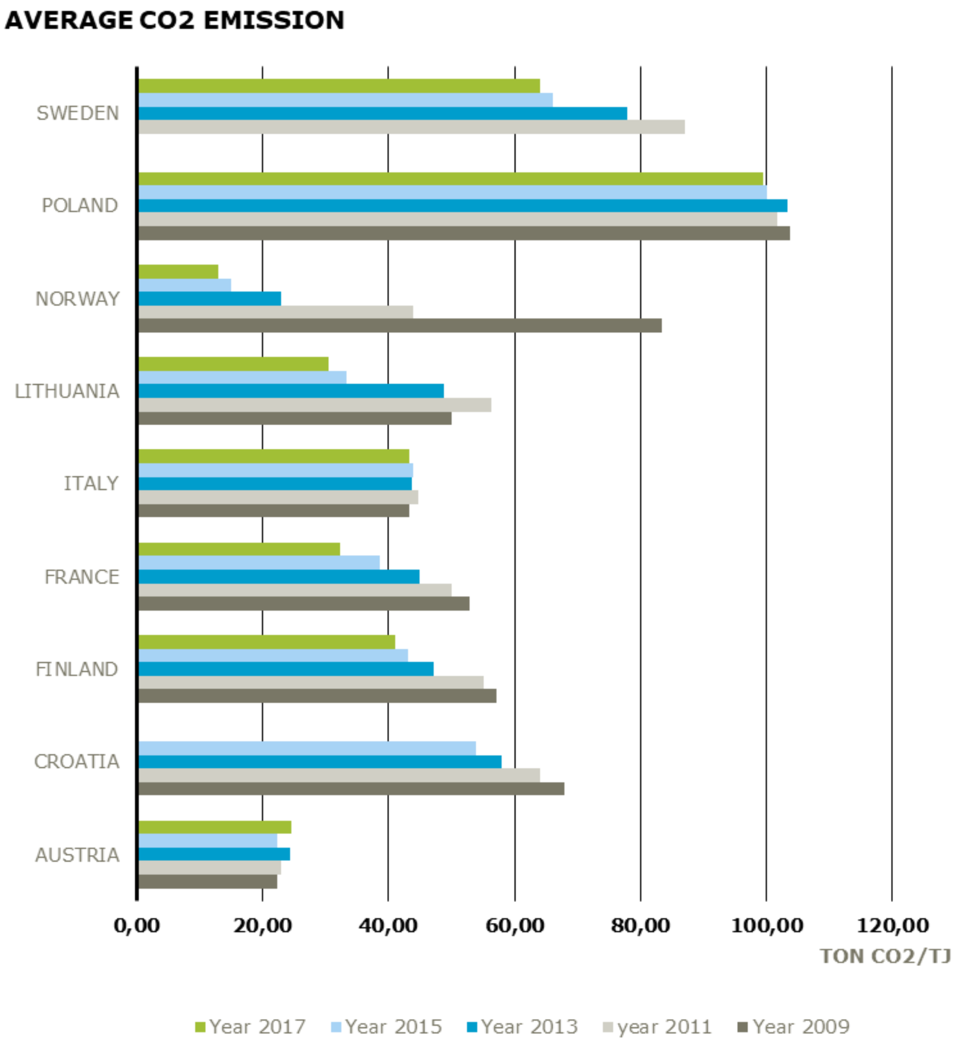

Figure 6. Average CO_2 emissions for DH production in selected European countries [6]

2.3.3 District cooling

Available data for district heating (DH) is much more comprehensive than the data for district cooling (DC). DC is not extensively used in any of the countries as this is still a new infrastructure and the demand for heating usually surpluses the cooling demand in most countries. Still, we see that in some countries the technology is gaining traction in the market as new office and commercial buildings, as well as hospitals and data centres, want more sustainable solutions for cooling. DC is mainly found in big cities, where cooling demand is dense, and is often met by the barrier that it is too expensive to establish new networks and to find sufficient cooling demands. However, there is a high potential demand for space cooling in many European countries. Table 3 shows the estimated space cooling demands in European countries as estimated by Jakubcionis et al. (2018).

Table 3: Comparison of the average, maximum and minimum potential cooling demand for the EU countries [24]

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EU country	Average potential cooling demand (TWh/a)	Maximuml potential cooling demand (TWh/a)	Minimum potential cooling demand (TWh/a)
Austria	3,4	5,1	2,1
Belgium	2,4	4,2	1,5
Bulgaria	2,7	3,7	2
Croatia	1,6	2,2	1,1
Cyprus	1,3	1,4	1,2
Czech Republic	2,8	4	1,7
Denmark	0,9	1,6	0,2
Estonia	0,2	0,4	0
Finland	0,8	1,8	0,1
France	25,5	39,7	17,1
Germany	23,2	38,2	14,4
Greece	10,5	11,7	9,4
Hungary	3,8	5,2	2,5
Ireland	0,2	0,4	0
Italy	36,4	46,4	28,4
Latvia	0,3	0,6	0,1
Lithuania	0,5	0,9	0,2
Luxembourg	0,2	0,3	0,1
Malta	0,6	0,6	0,5
Netherlands	3,6	6,5	1,9
Poland	6,2	9,5	3,3
Portugal	6,4	7,6	5,1
Romania	3,9	5,7	2,5
Slovakia	1,3	2	0,8
Slovenia	0,6	0,8	0,3
Spain	26,5	32,2	20,6
Sweden	1,2	2,3	0,1
United Kingdom	7,2	13,8	2,7
Total EU-28	**174,2**	**248,8**	**119,9**

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3 100% RES DHC – The business opportunity

3.1 Drivers to the market uptake of RES DHC

3.1.1 Policy drivers at EU level

In most countries, DHC has a role in delivering the EU 2050 climate and energy objectives. Therefore, it can be expected that the same trend will continue in the future as more RES and biomass will substitute fossil fuels in the DHC production.

The new European Green Deal sets objective for Europe to become a first climate neutral continent by 2050. As heating and cooling sector represent a high share in final energy consumption in the EU with final energy demand of 6,352 TWh in 2015 (approximately 50% of EU-28 final energy demand) [1], decarbonization of this sector is one of the EU's priorities.

The energy mix for district cooling and heating demands as presented by above Figure 4 is dominated by natural gas, while biomass is the only significant renewable energy fuel with total share of 12% 2525]. Such energy mix indicates that there is need for significant change in the heating and cooling sector in order to achieve climate neutral continent by 2050. Changes in district heating and cooling sector already occurred as coal share has decreased since 1990, while the natural gas share increased. The desired energy transition aims at significantly increasing the share of renewables and biofuels, and at the same time increasing district heating and cooling market share. A large market for renewable technologies in district heating and cooling sector is therefore expected.

District heating market is differently developed across the countries in the EU. North, Central and Eastern Europe has generally higher share of district heating than countries from other part of Europe. Most of district heating in Europe comes from CHP plants that run on fossil fuels, thus there is also potential in changing the fuel supply of CHP plants towards renewables. In order to achieve a completely decarbonized energy system by 2050, the estimated necessary district heating investments are presented in Figure 7 [26].

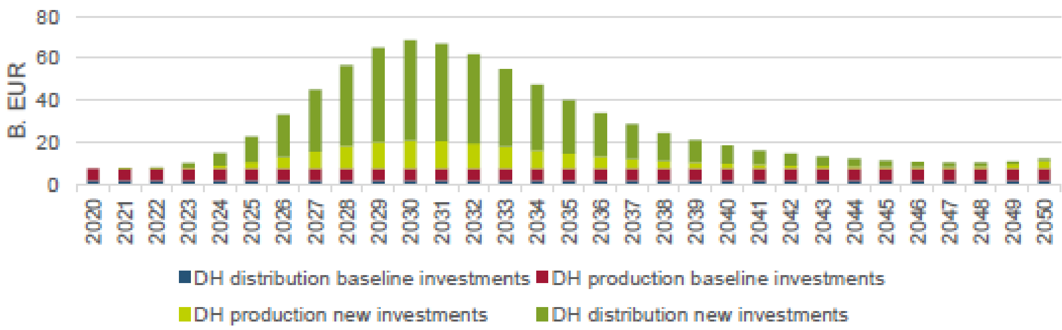

Figure 7. Estimated investments in district heating for decarbonised energy system by 2050

3.1.2 Stakeholders to be involved for market uptake at national / local level

The market uptake for DHC solutions is depending on factors that favour their implementation and factors that hinder their development, as any other set of technologies or solutions.

The uptake of renewable energy (DHC and other) depends on decisions made by various actors (companies, homeowners, cities, communities, governments, etc.). Each of them is confronted to different situations and motivations. It seems key to understand the possibilities

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that exist nowadays and the ones that will appear in the near future, in order to propose market-oriented solutions. Figure 8 shows several types of such actors [27].

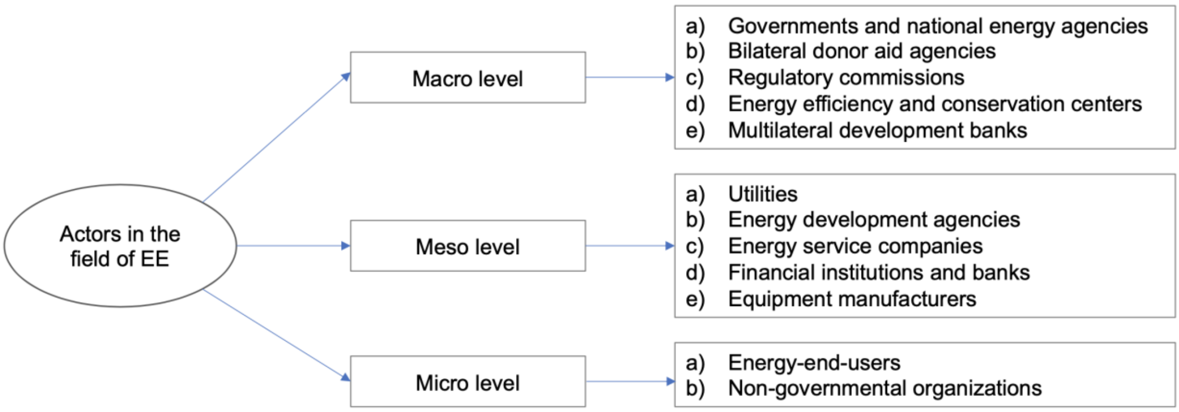

Figure 8. Actors and levels in the field of energy efficiency.

The functions of the different stakeholders in the energy efficiency (EE) market, extendible to renewable and efficient DHC, can be summarized in Table 4.

Table 4. Stakeholders in energy efficiency market [27]

Level	Actors	Functions
Micro	Consumers	Use EE technologies
	Non-governmental organizations	• Publicise good examples; • Network to make use of the latest experiences in research both in technology and applications.
Meso	Equipment manufacturers	• Provide a whole range of lighting devices to the consumers; • Cooperate on developing and later promoting EE technologies; • Make consumers understand they should not consider only purchasing but life-cycle costs.
	Business and industry enterprises	• Disseminate the achieved results; • Appeal to members to apply EE; • Negotiate with involved partners in terms of achieving EE targets, e.g. with government, foreign organizations, etc.
	Financial institutions	• Help to finance EE programmes; • Disseminate information about EETs; • Cooperate with other agencies to implement common programmes.
	Energy supply agencies	• Improve energy services – supply, transmission and distribution; • Propagate EE technologies; • Provide incentives to those who use EETs and disincentives to those who do not.
Macro	Governments	• Establish legal and institutional frameworks; • Integrate EE in decision-making in all sectors; • Support administrative efforts to enhance EE.
	EE agencies	• Collect and propagate information about activities, experiences, programs and projects; • Develop and implement EE programmes; • Put programmes together to ensure a larger market response.
	International organizations	• Develop supporting instruments for monitoring and evaluation; • Support mutual interest by adapting routines and instruments; • Serve as a forum to disseminate results; • Act as a clearing-house to establish collaborative actions.

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3.1.3 Command-and-control instruments

National strategies for energy transition are key plans to implement renewable energy as RES DHC solutions. Deployment of these strategies into new laws, norms or codes constitutes the legal basis to foster RES DHC implementation. New or enhanced regulations, as well as new agreements between tenants and landlords can help overcome investment doubts and uncertainties and thus limit the risks. Obligations for utilities to integrate renewable energy in their energy supply structure could be an important driver. In addition, obligations for new buildings and existing stock (nZEB Directive, national building codes, local regulations) can include RES obligations on large scale heating/cooling generation.

Environmental requirements can also speed renewable energy implementation in DHC. Some examples are the Kigali Agreement for Phasing down HFCs by replacing refrigerants in cooling systems, air quality national plans and local limits and local energy and climate resilience plans, or polluter taxes (for example, taxes on: CO_2, fossil fuels or pollutants such as SO_2, NO_X or $PM_{2,5}$ / PM_{10}).

3.1.4 Incentive regulation instruments

Funding, such as non-repayable grants, are powerful incentives but not stable in time as they are circumstantial. Soft loans appear to be a more robust initiative because of their stability and long-term commitment. They are becoming more and more usual and standardized. Several multilateral financial institutions banned investment support for fossil-fuel projects and redirected the investment flow towards RES. Some of them, such as EIB and EBRD, have a specific program which include RES DHC. RES and DHC are recognized within the European Green Deal Investment Plan and Just Transition Mechanism [28]. The plan for European recovery from the damages caused by the COVID-19 pandemic will support the Union’s green priorities. Climate action will be mainstreamed in policies and programmes financed under the Multiannual Financial Framework (MFF) and the Next Generation EU (NGEU). An overall climate target of 30% will apply to the total amount of expenditure from the MFF and NGEU and be reflected in appropriate targets in sectoral legislation. They shall comply with the objective of EU climate neutrality by 2050 and contribute to achieving the Union's new 2030 climate targets, which will be updated by the end of the year. As a general principle, all EU expenditure should be consistent with Paris Agreement objectives [29].

Fiscal policy, in terms of tax reduction, may be a boosting mechanism by reducing both investment and operating costs, so it is useful and feasible. Urban planning instruments are another, locally established driver. Reserve of space for RES DHC infrastructures and inclusion of the distribution network in urban planning documents establish the legal basis for implementation, encourage utilities and facilitates enormously all the administrative steps to be taken during the project development.

3.1.5 Technological drivers

RES DHC is a tool for the much-needed energy transition, as it contributes to better local RE sources management, nZEB operation, development of energy communities and positive energy districts, among other benefits. It has low technological risk, because it is usually based on a set of proven technologies. Besides, further improvement of the technology can be done over time. Low distribution temperature -4G DHC- fosters the inclusion of different renewable and/or residual energy sources which otherwise would be lost.

The current trend also points towards a convergence of thermal and electrical systems. In this sense DHC may profit during the periods of low RE electricity prices, but also providing support

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in power grid management. RES DHC may count on storage capability, including for seasonal periods, which provide additional flexibility and maximize RES usage. In this context, DHC systems could be considered as “virtual batteries” as they can serve as a cheap battery: using electricity when cheap and available and store it in thermal networks, tanks or in larger seasonal storages, for periods with higher prices and high demand for electricity [30].

3.1.6 Knowledge instruments

In order to overcome the lack of knowledge and information, almost every big European city offers energy advice services to households, public bodies, businesses and other. Networks of companies have proven efficiency in this regard too. The UN initiative “District Energy for Cities” is a good resource to deploy, as EHP Knowledge Hub or CELSIUS initiative [22]. Additionally, municipal decision makers need to be more skilled in renewable energy, so capacity building and public front runner projects need to be implemented. Participation processes are relevant to gain stakeholders and citizens acceptance. Investment in research and development for renewable energy is also needed.

Finally, activities such as awareness raising campaigns and training of professionals are crucial measures for success.

3.1.7 Market drivers

As regards technology, its suitability, performance and feasibility are very important. DHC is more suitable for climates with a high annual demand per dwelling or building. Therefore, Northern countries will have lower grid costs for heating system compared to Southern countries, and the other way around for cooling. In this sense, DHC is more likely to be adopted in more densely built areas. Both residential and tertiary / service buildings are of interest. In the service sector commercial buildings (such as shopping malls, restaurants, hotels) and office buildings should be targeted as high comfort standards are expected there.

Maintenance costs and energy tariffs influence decisively the users’ decision. The plausible cost increase in fossil fuels will lead to higher final energy prices, so renewable energy would be better positioned than fossil-based sources. In this sense, a competitive LCOE is very strong driver.

The possibility of delayed upfront cost, in terms of moving a part of CAPEX to the OPEX may also be an interesting option for reclaiming new tertiary buildings.

Emission pricing or emissions limits for both GHG and local pollutants will most probably become an important factor in market uptake. The trending wish for energy-autarchy will certainly increase the willingness to adopt local renewable energy sources. Tax reductions are a key point, thus political will have the power to foster the market.

In tertiary sector buildings, green image and public recognition can be beneficial. RES DHC contributes to environmental certifications award, such as LEED, BREEAM, etc. and to firm positioning in terms of green marketing, including corporate social responsibility.

To sum up, there is no unique solution or receipt to speed the market uptake of RES DHC. Instead, country/region specific conditions need to be well-known to deploy the most suitable tools for each case.

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3.2 Barriers to the market uptake of RES DHC

3.2.1 Introduction

There are three main types of barriers for the implementation of efficient solutions [27]:

- **Financial-economic (factors that limit financial feasibility or profitability),**
- **Institutional-structural and market oriented (factors dealing with political, legal and product related frameworks),**
- **Perceptual-behavioural (including factors as knowledge and awareness).**

At the same time, these barriers can be split into supply-side and demand-side barriers. As regards the supply-side, the factors that limit the adoption of new technologies deal with the difficulties in their implementation. On the other hand, for the demand-side the difficulties are encountered in using them. Table 5 summarizes the generic barriers for renewable heating and cooling.

Table 5.Categorisation of barriers for renewable heating and cooling [31]

Supply-Side Barriers	Demand-Side Barriers
Financial-economic	**Financial-economic**
• Development costs (transaction costs); • Initial costs (equity capital, investment prioritisation, payback time); • Operating costs (maintenance costs, taxes, regulatory costs / land use taxes).	• Initial costs (investor-user-dilemma, payback time, net-additional costs, product life cycle, opportunity costs); • Operating costs (maintenance costs, energy tariff, taxes).
Institutional-structural and market oriented	**Institutional-structural and market oriented**
• Infrastructure; • Regulations; • Technology suitability; • Policy framework (see Hollander et al. 2016); • Multi-stakeholder issues.	• Energy demand; • Building stock; • Policy framework (see Hollander et al. 2016); • Separation of expenditure and benefit; • Multi-stakeholder issues.
Perceptual-behavioural	**Perceptual-behavioural**
• Bounded rationality; • Trained workmen.	• Uncertainties; • Knowledge / awareness gaps • Trained workmen • Risk and loan aversion

In the following sections, the different barriers are briefly commented.

3.2.2 Supply side

3.2.2.1 Financial-economic

These barriers deal with the profitability of projects. Firstly, there are the initial development costs, related to examining the actual needs, elaboration of feasibility studies and acquisition of skilled partners. All this is needed for decision making.

Secondly, the initial costs are considered. These include high up-front investments, which can discourage potential investors. Capital needs to be available, so banks should be able to provide long-term credits. Institutional lenders can play a key role by ensuring credit liability, as well as more flexible internal regulations for companies. The payback time is another key parameter in decision making. Finally, the investment in heat transport and distribution also affects taking decisions. As it deals with municipal infrastructure and investment, authorities may need much time (up to decades) to be committed and undertake the implementation. Also, time factor plays an important role in the age of contemporary short-term populist driven

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decision making. Besides the fact that long-term investments mean political risk regarding the public balance sheet, there also exists the risk of preparing a successful project for the political opponents which may be in office in the future.

Also, the operating costs may represent a barrier, as they have high uncertainty. They are affected by many parameters (policies, market, fuel supply, technical performance, volatility of electricity prices, etc.). The operating costs include maintenance activities and materials and are somehow covered by the energy tariff, which may be influenced by government decisions and which determines the return of initial investment. There may be additional costs, not always foreseen, the so-called “hidden costs”, which include costs related to time loss, reduced level of service, engineering tasks and other.

As a mitigation approach vis-à-vis this kind of barriers, it should be stated that only socio-economic feasible projects should be implemented. Projects should be equally evaluated and serve a reasonable development for society, users and suppliers. This method can also showcase if DHC is the best solution or if other renewable solutions are more feasible in a given area.

3.2.2.2 Institutional-structural and market-oriented barriers

Among these barriers, infrastructure-related factors appear to be important. The density of an energy system (number of consumers served per length unit of net) influences its performance. In low density zones, the investment and distribution costs are much higher per customer. Pipes and trench dimension are a barrier in high density areas in terms of space availability and civil work needed for their implementation. Because of high investment costs, there exist a temptation to treat the market under a monopoly lens. This may encourage the energy supplier but would certainly jeopardize acceptance of users.

Regulations have a great influence on the market penetration of DHC solutions. Permissions and support from authorities are often necessary for new projects. Land use regulations can be worked to favour DHC, for example allowing the investors to purchase land or use specific planning mechanisms. Technical regulations need to consider specific needs, otherwise they can constitute a barrier. Also building law affects the installation of DHC.

As regards the administrative procedures, several barriers appear: longer procedures than for conventional energy installations, many authorities involved, lack of experience among the civil servants and other. For large scale RES systems as DHC, spatial planning and acceptance of users are key factors.

Figure 9 presents a policy decision-tree to assess options in expansion cities to develop district energy.

When dealing with solar district heating, a key lesson learned is, that, although the main legislative power is often assigned to the state governments, regional authorities do have a relevant range of action regarding regulations, authorization procedures and the framework for municipalities [32]. Regions have a relevant size but are still sufficiently close to the market actors and municipalities. It is in particular efficient to link to existing processes and structures and use them for supporting RES DH.

As regards technology, its suitability, performance and feasibility are very important. DHC is more suitable for climates with a high annual demand per dwelling or building. Therefore, Northern countries will have lower grid costs for heating system compared to Southern countries, and the other way around for cooling. In this sense, DHC is more likely to be adopted

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in more densely built areas. Low demand density becomes an evident barrier for economic feasibility achievement.

According to the renewable energy source and technology, different needs (probably barriers) may arise, such as space needs, closeness of the users to the energy source, air quality protection, noise protection, etc. Some regulations applying to technology can constitute a barrier too. Contracts between energy supplier and final user may hinder RES adoption, because both of them may be refusing to take risks.

When considering market share, renewable energy is gaining competitiveness and market share in the energy supply. However, the uptake is slower than desired, especially for heating and cooling technologies, where policy challenges persist. Diffusion of RES could be increased by growing competitiveness and supporting policies for their investment. The trend in the building sector, in line with decreasing the energy demand, is to become fully electric. This is mainly related to the increasing penetration rate of heat pumps [33], which are seen as a cost-effective mean to decarbonize the European building sector [34].

Governmental decisions such as the European Performance of Buildings Directive [35] pushed this trend, obliging to only build net-zero energy buildings (nZEBs) from 2020. The nZeb framework [36] is based on the principles of reducing the energy use of the building while providing the remaining with renewable sources, aiming to achieve an annual zero energy balance. So far, the most promising nZEBs seem to be all-electrical, with a photovoltaic system for the production of the renewable energy part, and a heat pump for the heating or cooling supply (or alternatively biomass) [37] hence this is the most implemented solution in real cases. [38,39].

This tendency may become a reality depending on the climate, availability of resources, capacity of building upgrade, local policies, and other. Furthermore, there is seeming competition between DHC and low energy houses. However, DH systems are more efficient and allow better RES integration when demand is at low temperature, therefore they are not incompatible with low-consumption buildings.

Generally speaking, bringing the relevant stakeholders together to take a shared decision is a challenge.

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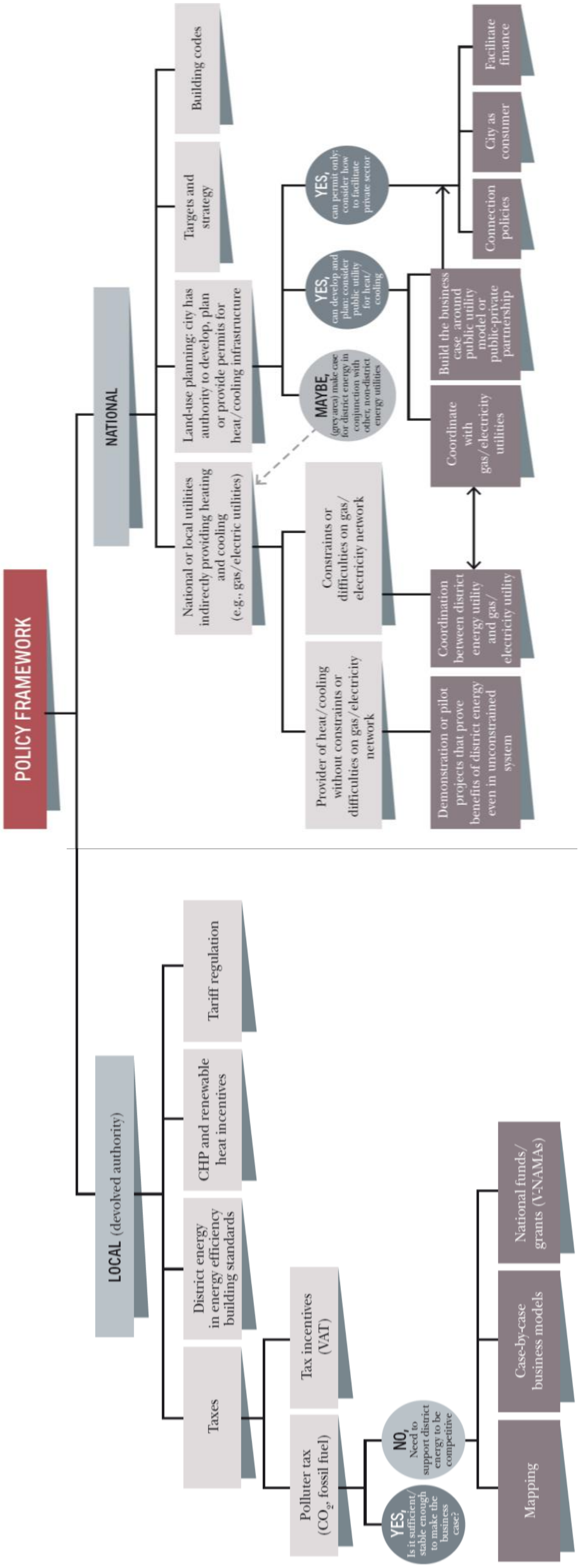

Figure 9. Assessing options in expansion cities to develop district energy based on the national and local regulatory framework [20]

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3.2.2.3 Perceptual-behavioural barriers

Most business models assume consumers take rational decisions. However, rationality is bounded, and the supply side behaviour is not that predicable. Financial issues may not be the only factor influencing the decision to invest. Seen from the demand side, bounded rationality could be both a barrier and a driver for renewable energy in general but also its integration in DHC.

RES DHC may be subjected to the NIMBY (“not in my backyard”) effect which occurs when the local population is not in favour of a common good and advocates only for its own, frequently ill-understood, welfare.

To install a large-scale heating and/or cooling plant, trained work craft is needed. Trained plumbers and heating system engineers are needed but usually hard to find. New technologies need to be accompanied by training efforts for engineers and selling teams.

3.2.3 Demand side

Demand side includes all type of users that can benefit from DHC supply. Space heating and cooling demands depend on several factors, being the climate, the kind of space use and the type of construction among the dominant ones. The media, NGOs and other opinion makers influence the market, by communicating certain messages about needs of the consumers or suitability of determined infrastructures or energy sources.

3.2.3.1 Financial-economic

One important barrier is that initial costs are faced by parties that will not directly benefit from the savings. A typical example is the owner-tenant dilemma, in which the owner should invest for the benefit of the tenant. Other complex situations are communities that could invest but are not actually aligned in the objective and/or manner. Energy efficiency investments have long payback times for users, and this discourages them because they are usually seeking short-term benefits. In addition, most users are not willing to invest in new technologies while the current installation is still performing well enough. According to Progress Heat Project [31], with scarce resources such as capital, time, management attention, or other key factors, consumers do not assess every opportunity in detail and tend to turn to “core business” (e.g., for companies to increase production or for households to improve comfort). The time needed to research new technologies could be a barrier and produces the need for a higher value of a new technology.

It is often the case for buildings that investment and operating costs are managed separately. This affects the decision process, as it may cause internal conflicts of interests.

3.2.3.2 Institutional-structural and market-oriented barriers

Energy demand affects the feasibility of RES DHC. As regards the residential sector, energy demand is strongly connected to climatic conditions, whereas the heating and cooling demand for the non-residential sector depends on the type of activity and it is generally higher than for households. The building stock is very diverse across Europe. Buildings in Europe are considered to have tremendous energy savings potential, mainly within the heating demand. RES DHC could be more favourable when higher demands are concentrated in limited urban land, as well as when interventions to highly decrease fossil energy consumption of existing buildings encounter limitations. Also, the cooling demand is increasing in Europe, due to climate change, the increasing use of electronic equipment and higher comfort expectations.

Regulation framework can be a barrier to refurbish historic buildings, thus energy performance upgrade is limited. This could favour the interest of RES DHC. On the other hand, historic

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buildings tend to be located in city centres and implementation of DHC may face other barriers as lack of space for plants or for substations or difficulties in deployment of network.

The EU targets and current trend to increase energy efficiency, especially in the building stock, may decrease energy intensity and may impact feasibility of certain DHC projects. Nevertheless, because of high energy performance targets, which prioritize on-site renewable energy production, in some circumstances RES DHC can offer feasible opportunities. A multi-parameter analysis should be done on a case-by-case approach in order to push further feasibility studies or re-focus the objectives.

In any case, the challenge is to have flexible and adaptive generation capacities.

In general, multi-stakeholder issues are also challenging. Matching all the motivations from the supply side with the expectations of the demand side in order to facilitate the investment requires strenuous efforts.

Specific barriers exist when it comes to the effort and cost for connecting existing buildings. Namely, HVAC installations in some buildings are directly compatible with connecting to a DHC system via a proper substation, while in some buildings a complete reengineering of the HVAC system is required. In the latter case both direct equipment costs but also the interruption in building normal operation represents a barrier.

3.2.3.3 Perceptual-behavioural barriers

Uncertainties at different levels arise often due to lack of long-term continuity for policies that promote renewable energy. These uncertainties are about the future situation for households and companies, changes in regulations, energy prices evolution, technology performance, etc.

Lack of knowledge and misinformation of the public are barriers to decide in favour of renewable energy, thus RES DHC. Also, technology possibilities may not be enough known and explained to the potential beneficiaries.

As for the supply side, trained local professionals are needed and are actually scarce.

Finally, the shift to renewable energy DHC may be perceived as risky by users when comparing to existing mature business as usual fossil-based solutions, such as the commonly widespread individual boilers.

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4 PESTLE analysis at country level

4.1 Introduction

Within the next sections, a PESTLE analysis is presented for RES DHC in every of the four countries which host a WEDISTRICT pilot. Within a first part, the positive and negative impacts of Political, Economic, Social, Technological, Environmental and Legal factors are briefly presented and evaluated on a scale from very negative to very positive. Then, within a second part, each of those factors are described.

4.2 Poland

4.2.1 Summary of the factors and their impact

Table 6 Main factors from the PESTLE analysis for Poland

	Very negative	Negative	Positive	Very positive
Political		• Policy low efficiency. • Polish government and RES supporting organizations do not clearly show support for DHC.	• Stable and favourable policy towards energy efficiency and thermal upgrades. • High budget for R+D+I actions from governmental organizations. • Polish regions have launched innovative policies to increase rate and depth of thermal renovation.	• Big financial support for selected RES sources (PV, biomass) from Polish government organizations (NFOŚiGW). • Torrefied Biomass as a fuel – in Polish RES Act (Warszawa, 29 czerwca 2018 r. P.1276).
Economic	• Weak health, social and environmental rankings (cancer). • Worrying rise of the Private Debt.	• Fiscal incentives low efficiency. • High prices for energy devices such as: Heat Pumps, Innovative Cooling Devices and HVAC systems.	• High employment rate. • Poland in 2020 is among the fastest-growing economies in the European Union. • Low interest rates and the execution of EU funds–related investments - sustain Poland's economic growth prospects in the near term.	
Social	• Polish people are not ready to use services based entirely on web platform	• Energy poverty in Polish small and medium municipalities (all citizens' groups) and in some big cities (people above 60 years) due to the low salaries.	• Growing concern and awareness of climate change. • Growing social knowledge in the area of "Green Technologies" thanks to new NFOŚiGW training programs ("Human Capital" 2014-2020). • Increasing number of engineers with	• Rising number of Technical Universities in Poland (<12 from 16) with Faculties providing higher education in sector: Energy and Renewable Energy Sources.

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			specialization in RES (PV, Biomass, Wind, Heat Pumps, Solar Collectors etc.). • Increasing number of managers with technical background in Energy Sector with RES as main specialization.	
Techno.		• Lack of highly qualified Heat Pump services.	• Quality (certification) mark for renovation. • Market available cheap PV deliverers.	• New torrefied biomass pellet producers. • New medium power biomass boilers producers.
Environmental	• Adverse impact of renovations: embedded energy, material.	• New family houses with very low energy demand thanks to good thermal insulations, not prioritizing additional investment in different energy solution.	• Old building stock with high energy consumption. • Adaptability to climate change impacts. • Problems with low quality fuel in small municipalities and low emission problems during heating period.	• Existing need to face very big problems with smog and emission in big cities (Kraków, Katowice, Zabrze, Gliwice, Wrocław, Zakopane – South Poland and, Warszawa, Łódź, Częstochowa, Kielce – Central Poland).
Legal		• Long term since 2014 amendments to the RES Act.	• On the basis of BAT, emission limits are determined, which must take into account the technical characteristics of the installation, its geographical location and local environmental conditions. • Circular Economy: construction products reuse. • Obligation to connect to DH under specific conditions.	• Regulations concerning biomass fuels. • Thermal regulation for existing buildings. • Regulations concerning PV installations.

4.2.2 Description of the factors

4.2.2.1 Political factors

Stable policy towards energy efficiency and thermal renovation is supported by national programs such as NFOŚiGW National Fund for Environmental Protection and Water Management – “Clean Air”, “My Electrical Energy”). The innovation in this area is also supported by governmental institutions such as National Centre for Research and Development (NCBiR) which delivers programs such as “Fast Tract to Innovations” for “Heating Devices”.

There are also policies at local and regional level, such as the resolution in Śląskie voivodship – where Kuźnia Raciborska is located. This resolution focuses on decreasing smog and forces to change the old, inefficient, highly polluting heating sources in favour of new, low-emission solutions.

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Additionally, the Polish RES Act supports innovative biofuels such as biochar as stated in the Art. 1.4b). On the other hand, support to DHC is not specifically developed, either by polish government or RES supporting organizations.

4.2.2.2 Economic factors

As calculated by Central Statistical Office (“GUS”), Poland has very low unemployment level, despite the COVID-19 pandemic. For years 2018-2020, the unemployment level has varied between 5.1% and 6.4% [41].

According to pre-pandemic forecast, Poland has one of fastest-growing economies in the European Union, after Malta, Romania and Ireland. GDP growth was predicted to be 3.3% and inflation level in 2020 to be 2.7 %. Although, according to Summer 2020 Economic Forecast, a recession caused by COVID-19 pandemic will cause GDP fall by 4.6 % in 2020 and no change to inflation. In 2021 the GDP should be positive again (4.3%). As in other countries, interest rates are low with a reference rate at 0.1% as set by the National Bank of Poland (and remained the same during COVID-19 pandemic) [40].

Polish economy growth is supported and maintained by EU funds related investments as well. The overall economic context seems favourable for National investments including energy transition investments that could face the social issue of energy poverty.

One negative item linked to the Polish economy which probably has an indirect impact on DHC development can also be mentioned: the rise of the Private Debt is worrying. In 2018 it amounts to 48.9% of GDP, but in 2020 it may rise to 56 % (EU forecast), or even 65 % – dependent on source [42,43]. Constitutional level in Poland is 60 % and 55 % is cautionary threshold.

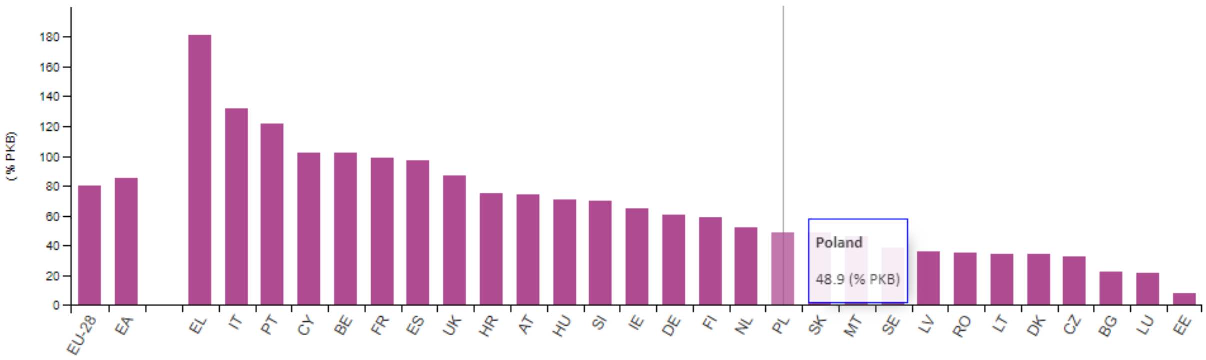

Figure 10. Private Debt in 2018 [42]

Another negative aspect concerns the fiscal incentives system. Polish policy lacks efficient fiscal incentives associated with RES and DHC. Energy devices such as heat pumps, innovative cooling devices and HVAC systems are also very expensive in Poland. Such devices are produced in Poland in very small numbers – majority of them are imported.

4.2.2.3 Social factors

First of all, more and more people in Poland are associated with Power Engineering and RES. The number of technical universities with such faculties increases and so does the number of engineers with such specialization. Managers with technical background in RES technologies also increases.

Social knowledge in the area of green technologies and RES grows as well. Many national programs such as new NFOŚiGW training program “Human Capital” 2014-2020 are available.

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On the other hand, small and medium municipalities often experience energy poverty – in all age groups, what is considered as negative aspect. In some big cities this negative phenomenon sometimes occurs for people above 60 years due to low salaries [46].

Another very negative aspect is that generally Polish people are not ready to use services based entirely on web platforms – especially people after age of 60. According to certain reports, 87 % of people 65 – 74 years old have never used internet network [47].

4.2.2.4 Technological factors

Of all the renewable energy sources, biomass is a CO_2 neutral biofuel which is used for big-scale heat and electrical energy production, but it can be also used for distributed energy systems and as other bio-based products. A very positive aspect is the biomass fuel availability and processing. According to 2012 data, Poland is one of the EU leaders in biomass fuel production – after Germany, France, Sweden and Finland (Polish potential of biomass for fuel is distributed equally: 50% is in woody biomass from forests and 50% in biomass coming from agriculture). At national level, around 30% of the land is occupied by forests. This percentage varies from region to region with the Lubuskie voivodship having the highest percentage (49.2%) and Lodzkie having the lowest (21.3%) [48].

Coniferous species dominate 68.7% of the forest area in Poland. Of the coniferous species, pine occupies 58% of the forest area of all ownership forms. This is an excellent biomass for DH purposes.

One of the greatest global problems is increasing energy consumption. Combined with the need to limit the use of fossil fuels, it forces the development of crops that will produce the maximum yield of biomass which could be converted into energy fuel using modern technologies. Additionally, Poland is one of pioneers of torrefied biomass in Europe. Compared with other RES, biomass provides continuous electricity generation, and is the only widespread source of renewable heat. Biomass co-firing and biomass combustion will contribute to the reduction of CO_2 and SO_2 emissions and increase energy security and regeneration of rural areas, due to the increase of forestry and agricultural activity and the provision of small-scale heat and electrical energy production schemes. Polish developers of boilers also provide medium-size power plants adapted to such fuel.

According to the 2030 energy strategy for Poland, bioenergy plays a particularly important role in sectors that are difficult to electrify, such as shipping, aviation and industry - both for heat production process and for direct use. Meanwhile, traditional uses of bioenergy for heating purposes, which covers a large part of today's demand for bioenergy, must be replaced by innovative options – like torrefied biomass in small and medium size CHP.

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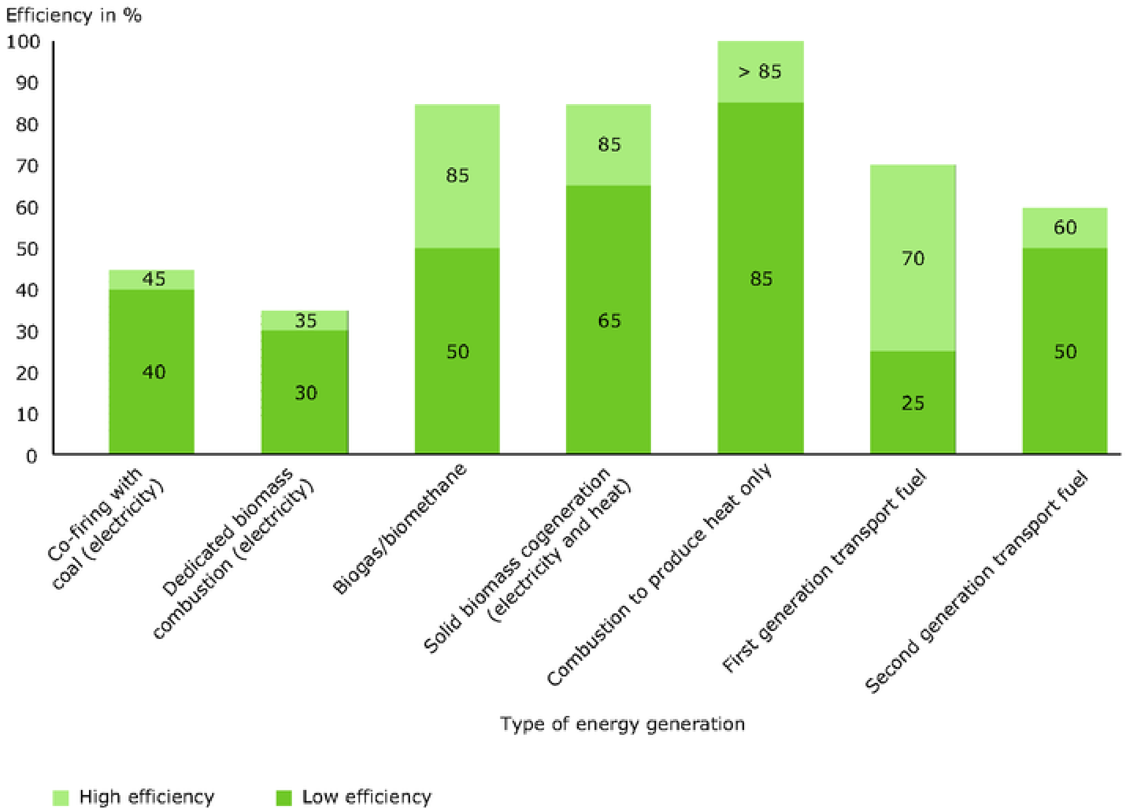

Figure 11. Overview of the relative efficiency of different types of bioenergy. Data represent net efficiencies taking into account results of life-cycle analysis [51]

Another positive aspect is availability of cheap PV. Polish distribution market is fully developed and prices reasonable.

Negative technological aspect is the lack of highly qualified heat pump services. Generally, the level of development of manufacturing of these devices is quite low in Poland.

4.2.2.5 Environmental factors

Very positive aspect of the WEDISTRICT project is the fact that as RES project it will improve situation with air pollution and advertise such measures. Poland is the European country with the worst air pollution [45]. Figure 12 shows the population-weighted concentration field of annual mean Benzo(a)pyrene (BaP) in 2012.

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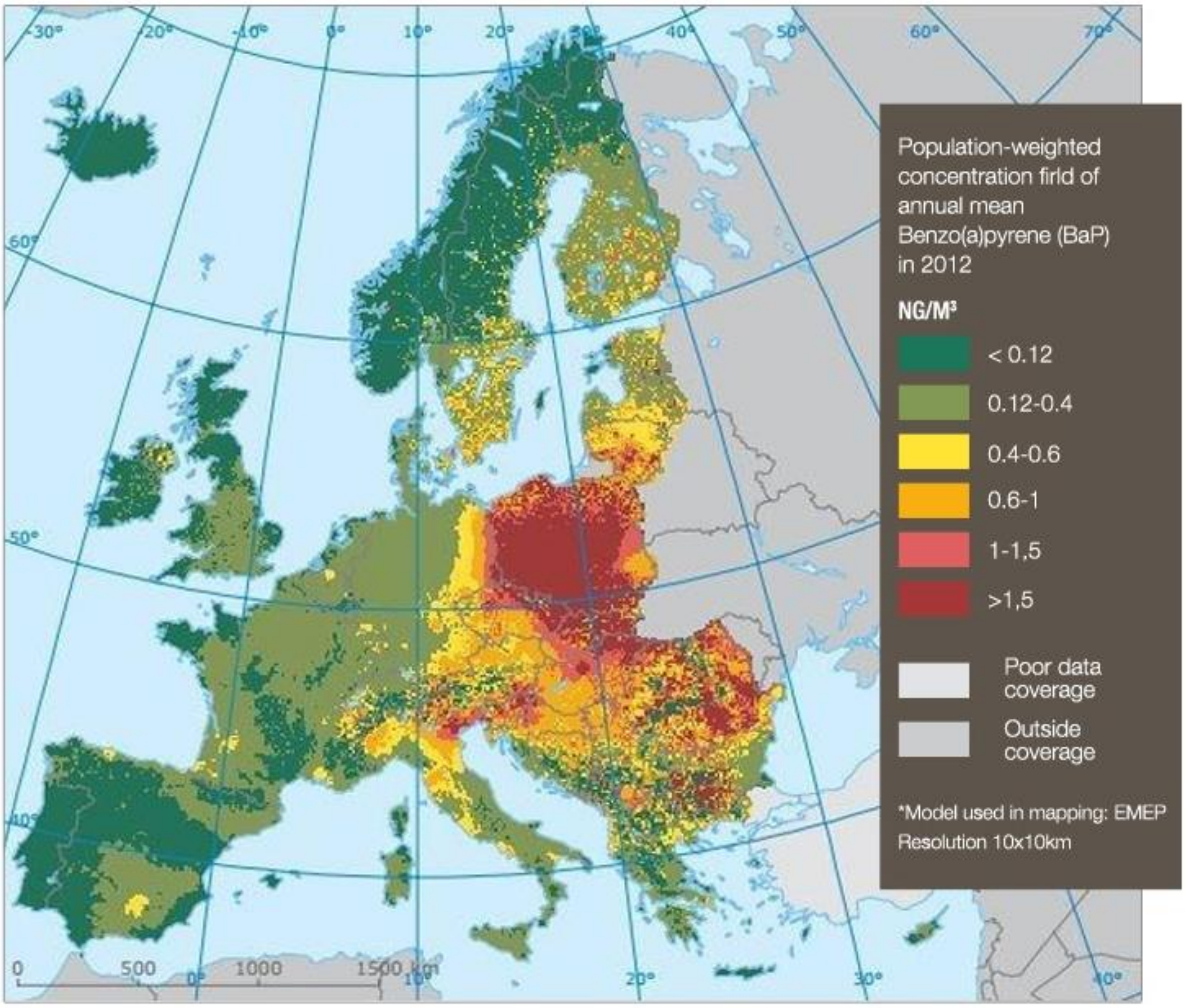

Figure 12. Population-weighted concentration field of annual mean Benzo(a)pyrene (BaP) in 2012 [45]

Unfortunately, Polish cities are leaders in PM 2.5 dust air pollution as well. Table 7 includes European cities with the highest average pollution in μm/m^3 in 2017. Only one city (Bogumin) is not located in Poland.

Table 7. Cities with highest average pollution in μm/m^3 in European Union in 2017

City name	Average PM 2.5 pollution in 2017 [μm/m^3]
Kraków	40.10
Sosnowiec	39.26
Nowy Sącz	34.95
Gliwice	33.26
(Czech Republic) Bogumin	32.68
Łódź	32.21
Piotrków Trybunalski	31.92
Bielsko-Biała	31.55
Katowice	31.21

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An additional aspect that WEDISTRICT may improve is fuel quality in small municipalities. In such places in Poland, the most common fuel is low-quality coal. The experience gained in Kuźnia Raciborska, which is a small municipality, will contribute solve this problem.

On the other hand, there is a risk that general renovation of thermal plant might be unprofitable. Some elements might be oversized. Heat prices must be much higher then and consumers would select another supplier. Additionally, buildings' thermal renovation and construction of energy-efficient buildings do not favour district heating in general. However, in Kuźnia Raciborska many buildings are outdated – both connected to DH and to be connected.

4.2.2.6 Legal factors

Due to the central planning history, 40% of the population is connected to 20,000 km district heating networks [49]. Poland has taken many steps to modernize its DH systems, which face challenges such as high CO_2 emissions (because the use of coal), poor quality of the networks and high loss of heat. Most of the DH companies are managed by municipalities, but in large cities like Warsaw, Poznan, Lodz or Wroclaw they are managed by private or foreign operators. Poland's energy regulation office (URE) approves tariffs to cover all justified costs but also the justified ROI expected by the heat companies and bad financial state of municipalities has limited their investment capacity, therefore the DH enhancements has performed slower than anticipated.

Polish RES Act supports innovative biofuels such as stated in the Art. 1. 4b) biochar (see in above section about political factors) [51].

In 2021, a new thermal regulation for newly built buildings will come into force [52]. The maximum thermal transmittance for standard space dividers (such as windows, doors and walls) is defined. Additionally, the primary energy factor is lowered from 95 kWh/m^2 to 70 kWh/m^2. An efficient way to meet this requirement is by applying RES, which is a very positive aspect for the WEDISTRICT solutions.

The RES Law introduces the prosumer concept for PV [53]. It defines who can be prosumer, describes tax reliefs and discounts for PV installations, removes connection fees and considers only net price of electricity. It is another very positive aspect for WEDISTRICT solutions.

Another positive aspect is BAT conclusions from 28 April 2017 for LCP [54]. It introduces new emission limits for plants, which have 4 years to modernise installations to meet the requirements included. The experience gained in the WEDISTRICT project will certainly make a positive impact on other thermal plants.

Art. 7b of Energy Law introduces an obligation to connect newly built facilities to existing DH under specific conditions. If any of the following is met, there is no such obligation:

- DH or local heat source is already installed;
- There is no technical condition to connect to DH;
- Heat price in DH is higher than or equal to the average price defined by the Energy Regulatory Office;
- Non-renewable primary energy factor does not exceed 0.8 for heat produced in the building;
- Heat pump or electrical heating is used;
- DH is not efficient (DH is considered efficient if 50 % of heat comes from RES, or 50 % of heat comes from waste, or 75 % of heat comes from CHP).

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Since the thermal plant in Kuźnia Raciborska will have efficient DH status after modernization, such law is a positive aspect for whole WEDISTRICT project.

On the other hand, despite many laws have positive impact on WEDISTRICT project, some of them were not amended for a long time – RES Acts is practically unmodified since 2014, especially regarding biomass. It might be a negative aspect for WEDISTRICT project.

4.3 Spain

4.3.1 Summary of the factors and their impact

Table 8 Summary of main factors from the PESTLE analysis for Spain

	Very negative	Negative	Positive	Very positive
Political		• Heating knowledge about buildings still minimal, then there is a poor representation of DH requirements.	• National INECP includes specific measures to increase DHC by 2030.	• Spanish roadmap for DHC deployment at quite an advance stage.
Economic	• Uncertainty over the outlook for the Spanish economy due to COVID-19 impacts.	• Share of DHC out of the total consumption very low (0.15% in 2017).		• High level of investments is foreseen in the INECP for the energy transition.
Social	• Unknown technology for most of Spanish people • Most people used to have their own boiler at home, instead in dwellings • Perception of Energy Plants as pollutant elements (nimby effect)	• Older population, more resistant to changes • No direct relation between savings in heating and Health • Lack of confidence in government	• Good perception of RES	• 74% of population living in cities and 67% in flats, generates better profitability • 45% of young people living in rental housing, allows real estate companies to connect buildings to DH
Technological		• Storage system innovation applied in DHC is low. Water tanks seems to be only applied. • Low experience in in integrating solar thermal technologies in DHC.	• Growing trend of DHC installation in Spain since 2011.	• Business opportunity to insert solar technology and innovative storage system exists thanks to the specific Spanish climate.
Environmental		• Old building stock with high energy consumption	• Growing attention to climate change mitigation actions. • Increasing energy demand could be a driver for new DHC development.	• Increasing requirements for greenhouse gas emission abatement • Urban air pollution to be tackled.

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	Very negative	Negative	Positive	Very positive
Legal		• No specific regulation related to DHC implementation	• the DHC Spanish Association was incorporated as Spanish representative member at Euroheat & Power.	• Upcoming Law on Climate Change and Energy Transition.

4.3.2 Description of the factors

4.3.2.1 Political aspects

Over the last few years, the fuel use for DHC in Spain has shifted from a deep reliance on fossil fuels in 2013 to the predominance of biomass in 2017, which is the result of the development of DHC in small and medium-sized municipalities that have chosen centralized heat and cold generation over individual generation as a tool to produce heat and cold in a more affordable, efficient and environmentally-friendly way. The Spanish DHC market has grown steadily over the last five years, both in the number of networks and installed capacity, as reported in chapter 4.3.2.4 based on the yearly monitor on DHC networks published by ADHAC (the Spanish Business Association for DHC) [55].

DH potential depends on climate, population density, urban planning and the built environment. Since the cost of DH pipes depends on the spatial distribution of the demands, cost curves must be developed to reflect each regional potential, especially relevant for DHC since the infrastructure costs represent a large part of the investment.

Enhancement of Spanish roadmap for DHC requires the usage of data, methodologies, knowledge and approaches and a detailed spatial analysis to understand the local nature of heating and cooling and infrastructure costs. Furthermore, an in-depth understanding of the thermal sector and thermal demands is required for different climate conditions present in Spain. Because heating knowledge about buildings is minimal, there is a poor representation of DH requirements. Cooling requirements are typically hidden within the electricity sector. This forms the base of any strategic heating and cooling development and underlies an understanding of the possible energy savings.

On the country level, action and implementation plans should include and develop adjustment efforts in order to consider approaches to 1) end-user savings, 2) thermal infrastructure expansion, 3) excess heat utilisation and heat production units, and 4) individual heat pumps outside urban areas. These are the main technologies that contribute to the efficiency, decarbonisation, and affordability of the heating and cooling sector [25].

Framework for the development of thermal renewable energies

Energy consumption for thermal uses in Spain in 2015 accounted for more than 33% of the total final energy consumption. In the same year, the contribution of renewable energies to consumption for heating and cooling was around 16.8%. Therefore, it will be necessary to double this contribution by 2030 in order to achieve the objectives of INECP, the Integrated National Energy and Climate Plan (presented in the following paragraph).

The Renewable Energy Directive provides that Member States must implement the necessary measures to increase renewable energy quotas for consumption for heating and cooling by 1.3% annually from the value achieved in 2020 (1.1% if residual heat is not included).

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With regard to heating and cooling networks, according to the statistics reported in the framework of Article 24(6) of Directive 2012/27/EU, the final energy consumption in heating and cooling networks in Spain in 2017 was 1,777 TJ (approx. 42 ktoe). Since the final energy consumption in the heating and cooling sector was 28,905 ktoe, the share of heating and cooling networks out of the total consumption in the heating and cooling sector was 0.15% (i.e. well below the 2% set out in Article 24(10)(a) of Directive 2018/2001 on the promotion of the use of energy from renewable sources).

However, and given the potential for developing district heating and cooling identified, INECP considers specific measures, both regulatory and on financial support, to enable district heating and cooling using renewable fuels to play a much more significant role by 2030 [3]. The responsible bodies for implementing these measures are the General State Administration (MITECO, Ministry of Finance and MITMA), and local and autonomous regional administrations.

- Assessment of the potential of energy from renewable sources and of the use of waste heat and cold and other uses, in the framework of Article 14 of Directive 2012/27/EU and Article 15 of Directive 2018/2001/EU. This assessment will be available by 31 December 2020 at the latest.
- Specific mechanisms related to the building sector: Aid programmes (loans and subsidies). Aid schemes for installations in buildings or heating networks, depending on the characteristics, potential and cost of each technology and the potential impact on improving the carbon footprint.
- Mechanisms related to the promotion of heating and cooling networks
    - To annually collect the information needed to fulfil the statistical obligations on heating and cooling networks, both existing and new, including at least the installed capacity, technology used, fuel used, energy produced and whether the installation meets the definition of ‘efficient district heating and cooling’ in the Energy Efficiency Directive (at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat).
    - Moreover, mechanisms will be put in place to ensure that information is provided to final consumers about energy efficiency and the share of renewable energy in the heat networks to which they are connected.
    - Evaluation of the potential of these networks in new urban development projects.
    - Development of renewable energy communities linked to climate control networks, including technical training at the municipal level.
    - Ensuring that a cost-benefit analysis is conducted for each new urban development.
    - Legislative analysis and implementation of measures for potential users.

4.3.2.2 Economic factors

Current economic situation in Spain

The macroeconomic projections of the Spanish economy for the period 2020-2022 have varied greatly during the current year. The COVID-19 pandemic has given rise to much uncertainty over the outlook both for the Spanish economy and the Euro area. In order to reflect the extraordinary level of uncertainty at present, *Banco de España* has been formulated several alternative scenarios [56]. The scenarios are: a so-called “early recovery” scenario, and another “gradual recovery” scenario. The decline in GDP is more marked in 2020 in both

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scenarios, but in one of the scenarios the exit from recession is swifter and the loss in output in the medium term is smaller.

Spanish GDP would decline under the early recovery scenario by 9% this year, before rebounding by 7.7% and 2.4%, respectively, in 2021 and 2022 (see Figure 13). Under the gradual recovery scenario, the rebound in the economy would be later, meaning that the decline in output this year would be 11.6%.

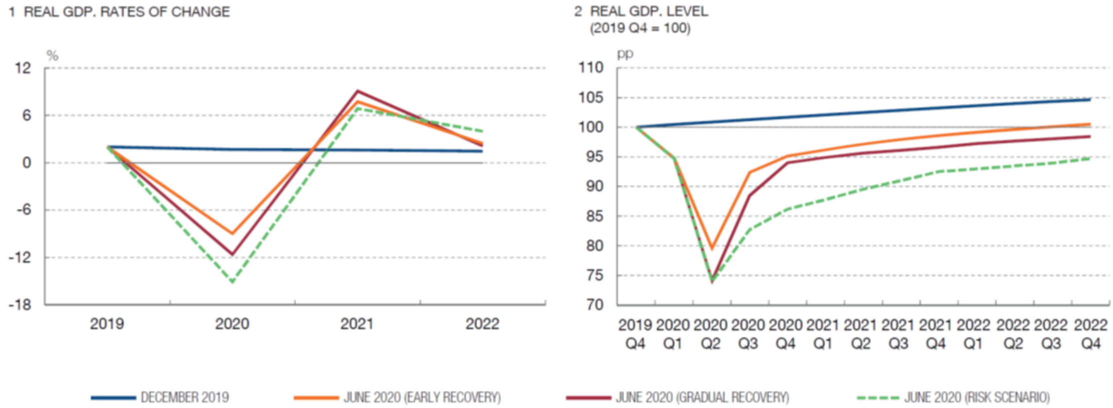

Figure 13. Spanish GDP under the different forecasting scenarios [57]

Energy and climate planning in Spain

The energy and climate policy framework in Spain are determined by the EU, which is acting in line with the requirements of the Paris Agreement reached in 2015 to provide a coordinated international response to the climate change challenge. For this reason, the EU requires each Member State to prepare an Integrated National Energy and Climate Plan 2021-2030 (INECP) [58].

The measures provided in the INECP will allow the following results to be achieved in 2030:

- **40% reduction in greenhouse gas (GHG) emissions compared to 1990;**
- **32% share of renewable energy in total gross final energy consumption;**
- **32.5% improvement in energy efficiency;**
- **15% electricity interconnection between the Member States.**

The energy transition set out in INECP represents an important economic and employment opportunity for Spain [58]. The total investments to achieve the objectives of the Plan will amount to EUR 241 billion between 2021 and 2030. Of this amount, EUR 196 billion are additional investments compared to the Baseline Scenario (without additional policies). The total investments are distributed between:

- **Saving and efficiency: 35% (€83 bn)**
- **Renewable energy: 38% (€92 bn)**
- **Networks and electrification: 24% (€59 bn)**
- **Other measures: 3% (€8 bn)**

With regard to the source of the investments, a substantial proportion of the total investment will be made by the private sector (80% of the total) and the rest of the investment by the public sector (20% of the total).

Specific funds for the development of energy saving projects are: REBECA (Low Carbon Economy Network for the period 2014-2020) [59]; GIT PROGRAMME (Financing of pre-

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qualified companies for Large Thermal Installations in buildings, based on renewable sources) [60].

4.3.2.3 Social factors

Population and Age distribution. Spanish population is 47,3 million people with a minimal growth the last years. Population between 15 and 64 years has been almost stable, around 65%, during the last 30 years, but people older than 65 years represent an increasing share, larger than those younger than 15 years, coming up to 20%. This means that Spanish population is getting older every year (Figure 14) [62].

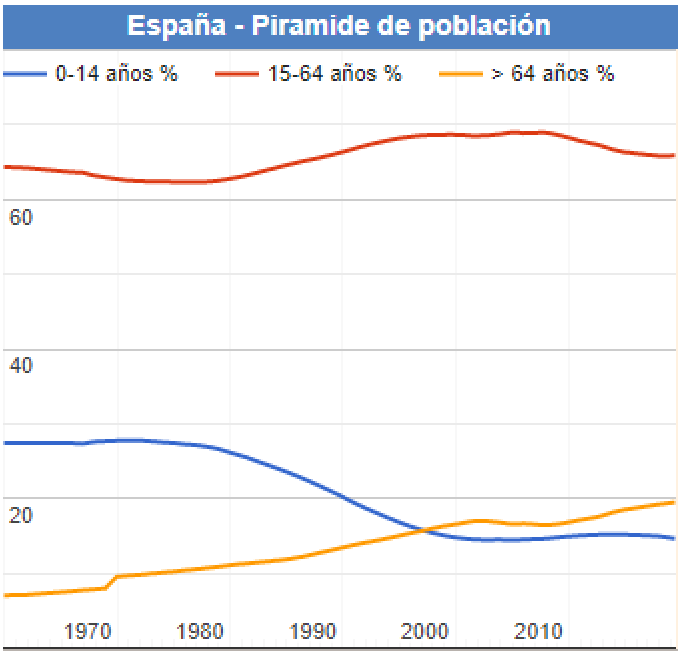

Figure 14. Spanish population is getting older each year.

In Spain, DH is not a traditional infrastructure, except in some cities. In fact, it is an unknown concept for most of the population. Therefore, since older people use to be more resistant to changes, the fact that Spanish populations becomes older every year will not help in DH development in Spanish cities.

Territorial distribution of population and building typologies. In Spain, 50% of population lives in cities, 24% in towns or suburban areas and only 26% in rural areas, quite close to the average EU-28. Moreover, and perhaps related to the previous, only 33% of population lives in houses, while 67% lives in collective buildings [63]. The average EU-28 for houses is 58%, almost double.

Despite of the weather diversity existing in Spain, in general heating loads are lower than they are in northern countries with a huge development of DH networks. Therefore, the “load density” is a key issue to DH profitability in Spain. Regarding offices buildings, most of cities have developed specific areas for offices, generating high density pools of cooling demand. The referred figures are indicative of optimal conditions to develop DH networks in Spanish cities as they are.

Real Estate Property Structure and BAU in domestic hot water (DHW) and space heating (SH). Regarding real estate market structure, it’s important to take into account that Spanish share of rental housing have been historically under 30%, while in Germany it is above 80%.

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During the last years it has increased above 40% in average, but close to 45% for people younger than 34 years [64].

Moreover, a main social issue is the fact that the standard DHW&SH system in most cities of Spain is the individual boiler per dwelling.

The decision to connect a building to a DH network has always been an issue for real estate companies, due to the apprehension to potential customers rejection to this “innovative” system, that gets out of the standard solution. So, on the one hand, the traditional way of owned housing with individual boilers represents an important barrier, but the current transition to a rental housing market may ease the transition also to DH connected buildings, due to the minor interest and less capacity of customers to condition the election of the thermal system. In the case of office buildings, the market has moved faster in the last years and the property structure mainly avoids these barriers, making easier the decision to connect a new or an existing building to DH network.

Health consciousness. Unless health is an issue in the present Spanish society, in general people does not link health with the use of thermal system, due to the massive use of natural gas, with friendly image, instead of coal or wood, as it was in the past. Conversely, the collective imaginary related to a thermal plant includes pollution, noise, explosion risk, etc. even if the system includes the best available filters technology.

Adding both factors, while energy plant looks like an “industry” and specially if it includes a chimney, health consciousness will play against DH.

Ethical concerns and attitudes towards saving. Nevertheless, Spanish society has developed in the recent years an environmental awareness, that may lead many people to choose a green option (based on RES) instead of a conventional one if there is no extra cost; certain very conscious people would do it even if there is an extra cost.

If DH is perceived as a “green” technology, this factor will push its development.

Attitude towards government. Spanish people are used to live under a welfare state structure, which has generated a relation that in general may be summarized in a lack of confidence accompanied by a high level of criticism but also of delegation, expecting many things just to be done.

This dynamics makes it difficult to find popular or cooperative initiatives to develop DH systems (with some exceptions) but also to assume by the people a public initiative in this way, due to the lack of trust in it just for coming from the public sector, thinking that perhaps it won’t work or that eventually they will have to pay more for their energy or will lose some freedom as customers.

4.3.2.4 Technological factors

Current situation

There are 414 identified networks in Spain in 2019, according to the yearly monitor on District Heating and Cooling networks published by the Spanish Business Association of DHC – ADHAC [65]. More than 5,340 buildings are connected to these networks and the installed total capacity is 1,576 MW.

Among the identified networks, 374 provide heat only (90%), 36 provide both heat and cold (9%) and only 4 of them provide cold only (1%).

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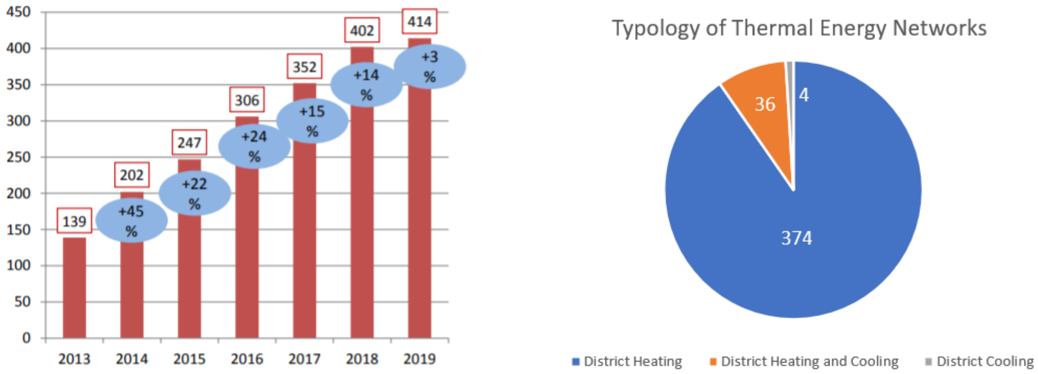

Figure 15. District Heating and Cooling networks in Spain

The 75% of these networks in Spain use biomass exclusively or in combination with another energy source. Around 80% include renewable sources in their energy mix.

A business opportunity linked to the introduction of other renewable energy sources, different from biomass, into DHC system exists. In particular for:

- **Solar technology**

Until now, in Spain the solar thermal technology has not been used to increase the renewable energy mix in new and existing DHCs since the conventional solar thermal panels do not have a high-performance efficiency for temperatures higher than 70ºC. This required temperature is due to the existing heating systems inside the residential buildings in Spain (waterborne systems). WEDISTRICT project aims at providing a technical solution supplying cooling based on renewable energy, which is produced in absorption chillers that need a hot source with a temperature above 90ºC to provide cooling energy at 7ºC.

These two reasons make the three solar technologies (Parabolic Trough, Fresnel and Low Concentration Flat Collectors) suitable for the DHC solutions.

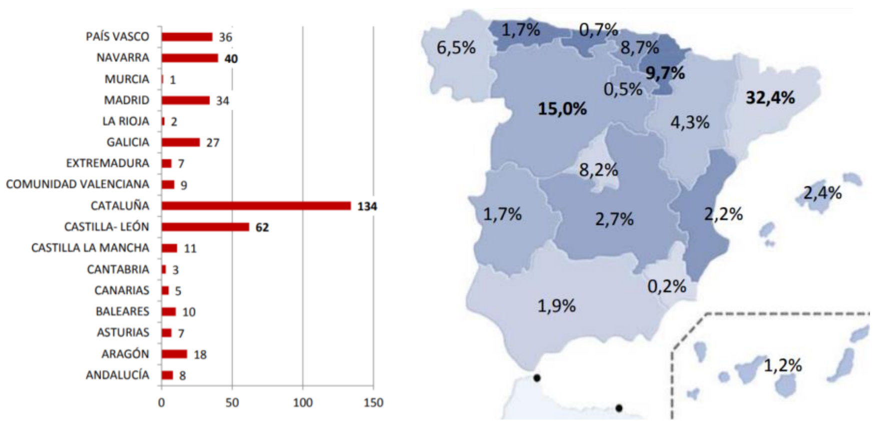

Figure 16. District Heating and Cooling networks by Autonomous Community

Even if that Spain is one of the hottest countries in Europe (specially the southern half), there are very few DHC networks connected to solar technologies. For instance, referring to the concentrated solar power (CSP) technology, there are almost 50 solar thermal power plants based on CSP in Spain, but this technology has not been practically used for heating or cooling in Spain (only some cases, among which no DHCs).

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- **Storage solutions**

The main and practically the only storage system that is installed in the DHC networks in Spain is based on water tanks with a maximum temperature of <100ºC. The storage solution based on molten salt to be installed in Alcalá DHC gives a new perspective compared to the current technological solution. In these existing networks, the tank stores the thermal energy at the same temperature that the DH provides heating energy to the connected buildings.

The WEDISTRICT solution separates hydraulically the primary and secondary circuits, each one working at different temperatures. Thus, the biomass boiler provides temperature above 100ºC (in Alcalá at 215ºC) and the PTC and Fresnel technologies also work at 215ºC in order to charge, from these three sources, the molten salt storage tank at the same temperature (and maintain perfectly the stratification inside the tank). These separate circuits (with different temperatures) allow the DHC to work in different scenarios (DH, DC and DHC) without changing the operating parameters of the biomass boiler and taking maximum advantage of the installed solar power.

However, some technological barriers exist vis-à-vis this business opportunity. These include some specific aspects such as: i) a solar field is needed close to the power plant. If not, the installation cost (CAPEX) and the operation costs due to heat losses (OPEX) increase. Besides, the fluid that connects the solar field with the power plant is thermal oil, which has legal and technical requirements that make preferable to install it closer. Then space availability must be carefully managed and designed. ii) There is a lack of expert knowledge to design, procure and implement salt molten storage tanks.

WEDISTRICT project validation and dissemination actions will prove the feasibility of specific solution overcoming the above-mentioned barriers and will show how additional RES technology could be integrated: e.g. the biomass boiler working at higher pressure (to achieve 215ºC) than in a conventional DH network, advanced filter installation, advanced absorption chiller and Desiccant Indirect Evaporative Renewable Cooling Unit.

4.3.2.5 Environmental factors

Climate change. The need for climate change mitigation can make some developers restrict environmental concerns to emissions. Although renewable energy technologies have potential to reduce emissions, their implementation can have local environmental impacts. Renewable DH can contribute to climate change mitigation reducing non-renewable sources consumption and concentrating small emitters (i.e. residential gas boilers) into a big focus (i.e. biomass boiler stack) that can be controlled more efficiently.

Urban air pollution. The combustion of fossil fuels in urban centres is devastating because the impact of air pollution is felt more in places with high population densities. This is exacerbated by inefficient heat generators in many cities of the developing world. Emission targets at municipal level are the primary driver for many of the transformations from old DH to renewable DH. Renewable DH has the potential to reduce part of pollutants in urban centres.

Greenhouse gas emission abatement. Given that it is larger scale than individual heating and cooling facilities, renewable DH allows faster and cheaper greenhouse gas emissions reduction. Conventional municipal coal-fired CHP plants or similar can be substituted by renewables technologies, cleaner, with reduced or without greenhouse gas emissions.

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Increasing energy demand. The increase of municipal energy demand can be an opportunity, but it is necessary to validate the convenience of DHC based on renewable sources rather than other systems based on fossil fuels.

Old building stock with high energy consumption. Old buildings are in general less energy efficient than new ones; this implies that, even if the energy source changes to a renewable one, the system will be inefficient, and the consumption figures will be maintained and not reduced. Then, DH installation in old buildings can be tricky, and the cost can be unjustified without mandatory obligations.

4.3.2.6 Legal factors

Firstly, it is important to point out that in Spain, DHC development is quite new in terms of system penetration in the market and there is no specific regulation related to DHC implementation. ADHAC (the DHC Spanish Association) was incorporated as Spanish representative member at Euroheat & Power in 2012 with the objectives, amongst many others, to i) develop a Legal Framework that regulates the activities of associated DHC companies; ii) to manage and distribute the funds assigned to train the personnel involved in the field of DHC networks; iii) to promote social dialogue and search for valid dialogue channels with the public administrations.

The main actions performed by ADHAC include, for instance, the modification of DHC legislation to adapt it to the EU framework; the support to Local Entities in the development of district heating & cooling projects ; participation in the Working Group in charge of drafting the UNE 216701 standard "Classification of energy service providers".

Although there is a lack of specific regulation for DHC networks, the Spanish Council of Ministers submitted to the Cortes, in May 2020, the draft Law on Climate Change and Energy Transition, which is perfectly aligned with the benefits that a RES DHC system may provide.

This new Spanish law responds to the commitment assumed by Spain in the international and European sphere and presents an opportunity from the economic point of view and the modernization of the country, as well as from the social point of view, facilitating the equitable distribution of wealth in the decarbonization process. In this way, the law puts the fight against climate change and the energy transition at the centre of political action, as a key vector of the economy and society to build the future and generate new socio-economic opportunities.

Two new fundamental figures are being created to determine the framework for action against climate change. These are the two main tools for climate and energy governance established in Regulation 2018/1999 of the European Parliament and of the Council, of December 11, 2018, on the governance of the Energy Union and Climate Action: The National Integrated Energy and Climate Plans and the Decarbonization Strategy to 2050. Both tools must be coherent with each other, since there is no other way to ensure, in a reliable, inclusive, transparent and predictable way, the achievement of the objectives and goals for the year 2030 and for the long term.

This law consists of thirty-six articles distributed in nine Titles, four additional provisions, two transitory provisions, a single derogatory provision, and thirteen final provisions. Table 9 summarizes the main contents of each Title of the Draft Law (developing the sections where RES DHC penetration could be boosted).

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Table 9. Main contents of each Title of the Draft Law.

Title	Description
I	National objectives for the reduction of greenhouse gas emissions, renewable energies and energy efficiency of the Spanish economy for the years 2030 and 2050: the emissions of the Spanish economy as a whole in 2030 must be reduced by at least 20% compared to the year 1990 and climate neutrality must be achieved no later than 2050. In addition, in 2030 a penetration of renewable energy sources must be achieved in the final energy consumption of at least 35%, an electrical system with at least 70% generation from renewable energy sources and improve energy efficiency by reducing primary energy consumption by at least 35% compared to the baseline according to community regulations. On the other hand, the law includes as planning instruments to address the energy transition the Integrated National Energy and Climate Plans and the Decarbonisation Strategy to 2050 of the Spanish Economy.
II	Provisions regarding the generation of electricity with energy from renewable sources and energy efficiency.
III	Measures related to the energy transition and fuels.
IV	Emission-free mobility and transport issues.
V	Adaptation measures against the impacts of climate change.
VI	Measures in the area of "fare transition".
VII	Signs for resource mobilization in the fight against climate change and the energy transition. Firstly, the law provides, with the exceptions established therein, that at least a percentage of the General State Budgets, equivalent to that agreed in the Multi-annual Financial Framework of the European Union, must have a positive impact in the fight against climate change, establishing, secondly, that the Government, at the joint proposal of the Ministry for the Ecological Transition and the Demographic Challenge and the Ministry of Finance, will review this percentage upward before 2025. Third, the use of revenues from greenhouse gas emission rights auctions is defined. On the other hand, a series of measures related to public procurement will be included, such as the inclusion as specific technical requirements in the procurement documents of emission reduction and carbon footprint criteria specifically aimed at the fight against climate change. The inclusion of award criteria is also contemplated.
VIII	Issues of essential importance for the involvement of Spanish society in responses to climate change and the promotion of the energy transition, such as education and training for sustainable development and climate care, and research, development and innovation.
IX	It regulates in a new way the governance of climate change and energy transition in Spain. First, the Committee of Experts on Climate Change and Energy Transition is created as the body responsible for evaluating and making recommendations on energy and climate change policies and measures, including regulations. The autonomous communities must inform the Climate Change Policy Coordination Commission of the energy and climate plans as of December 31, 2021. Finally, the law contemplates an article on greenhouse gas policies, measures, inventories and projections, so that coordination is strengthened when responding to the obligations of information assumed in the framework of national, community and international regulations.

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4.4 Romania

4.4.1 Summary of the factors and their impact

Table 10 Summary of the main factors from the PESTLE analysis for Romania

	Very negative	Negative	Positive	Very positive
Political	• Weak government strategies. More administrative cooperation is needed to renew infrastructures and equipment.	• The main documents (RoES and LTRS) that must guide and support the national energy policy are not officially approved.	• The political framework includes directions for development the efficient RES H&C to reach the 2030 national targets.	
Economic	• Low purchasing power. • Lack of internal economic measures for RES-DHS implementation.	• Inflation above EU mean value • National currency rates.	• Favourable energy prices as compared to EU. • Financial mechanisms for industry. • National financial support only for small and individual RES-H investments	• Declining unemployment rates.
Social	• Limited knowledge of the benefits of buildings rehabilitation or energy system reconfiguration. • Current legislative framework has an excessive bureaucracy	• High rate of energy poverty vs. EU average • Lack of skilled workers in technologies for EE and RES.		• There is an opportunity for the energy sector to essentially contribute to Romania's development.
Techno.	• Low budget/investments. • Low manufacturing capacity.	• Low research & development in private sector. • Low-energy building technologies. • Innovation and technology upgrades.	• Accessibility to European grants for research & development. • Dynamicity of scientific and technological progression.	• High level of accessibility to information. • Increasing Adoption of Technologies. • Expansion of Smartphone and Internet Penetration.
Environ-mental	• Management of urban and industrial waste.	• Lack of information on environmental penalties.	• Growing awareness of climate change. • EU and national fund used as support, for co-financing low emission investments.	• Energy potential and raw materials.
Legal		• Delays in the application of the provisions of the law. • Incoherent methodologies for energy efficiency legislation.	• Energy policy of Romania consistent with EU requirements.	• Adoption of Law No 184/2018 regulating the prosumers' status.

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4.4.2 Description of the factors

4.4.2.1 Political factors

Romania's energy policy showed an increasing focus on renewable sources mainly in relation to the green energy commitments and EU targets and to the interest of investors.

The energy sector has an essential contribution to Romania's development, with strong influence on economic competitiveness, life quality and the environment. To meet consumers' expectations in the long run, the Romanian energy sector must become cleaner, more economically robust and technologically advanced. The Romanian energy policy encourages the development of the investment based on RES, mostly RES-E.

Romania recorded positive progress towards most of its national targets of the Europe 2020 strategy [66], such as in national greenhouse gas emissions, renewable-energy levels and energy efficiency. Romania has already met its European commitment for 2020 to increase the RES share to 24% of gross final energy consumption.

The general policy framework in the energy field is guided by a series of national strategies and plans. Up to now, the main strategies – "Romanian Energy Strategy 2019-2030, with an outlook to 2050" (RoES) and "Long-term Renovation Strategy" (LTRS) are only in draft forms, there have not been officially approved. The main key areas of strategic intervention from RoES concern the improvement of RES-H objectives and transformation from individual sources to the new RES DH systems. In the same way, after implementation of the LTRS, a framework for developing both RES-E and RES-H&C will be created. This strategy involves the energy renovation of buildings and the adoption of RES technologies, such as installation of heat solar panels, photovoltaic panels and heat pumps, which will contribute to the achievement of the RES-E and RES-H&C targets for 2030.

ANRSC approves local prices and tariffs for the operators supplying or providing public services of heat supply, excluding cogeneration heat, as well as local prices and tariffs for public institutions and economic operators. Local prices of heat invoiced to the population are approved by the local authorities and they can approve lower prices by covering the difference from the local budgets.

GD No 1215/2009 defines the criteria and conditions required for the implementation and promotion of high-efficiency cogeneration based on the demand of useful heat as well as scheme applicable to the producers having units with installed electric capacity above 1 MW. Promotion was made through regulated prices and the obligation for suppliers to buy energy from producers and household consumers with low power cogeneration units or micro-cogeneration units. This was approved by the European Commission.

Several administrative bodies share responsibilities in the building sector, which makes it difficult to develop a common national strategy on deployment of sustainable energy technologies and solutions. Cooperation is needed to agree on a strategic appraisal of the barriers, concerted efforts for building renovation, design of a policy framework, provision of information to building owners and investors, incentives and capability to perform the renewal of the involved infrastructures and equipment.

The EU has set binding climate and energy targets for 2030: reduce GHG emissions by at least 40%, increase energy efficiency by at least 32.5%, increase the share of RES to at least 32% of EU energy use and guaranteeing at least 15% electricity inter-connection levels between neighbouring Member States (Clean Energy Package, 2019). An overview of

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Romania's objectives, targets and contributions have recently been published (2019) in the draft National Energy and Climate Plan 2021-2030 (Figure 17) [68]. The ambition level presented in the draft appears very low, by comparison with the EU 2030 targets and other Member States.

National targets and contributions	Latest available data	2020	2030	Assessment of 2030 ambition level
Binding target for greenhouse gas emissions compared to 2005 under the Effort Sharing Regulation (ESR) (%)	-2	+19	-2	As in ESR
National target/contribution for renewable energy:				
Share of energy from renewable sources in gross final consumption of energy (%)	24.5	24	27.9	Below 34 % (result of RES formula)
National contribution for energy efficiency:				
Primary energy consumption (Mtoe)	32.4	43	36.7	Very low
Final energy consumption (Mtoe)	23.2	30.3	27.5	Very low
Level of electricity interconnectivity (%)	7	>9[7]	Not provided	N/A

Sources: EU Commission, ENERGY STATISTICS, Energy datasheets: EU28 countries; SWD(2018)453; European Semester by country[8]; COM/2017/718; Romanian draft NECP.

Figure 17. Overview of Romania's objectives, targets and contributions 2019.

The implementation of the WEDISTRICT project in Bucharest will strengthen the actions in relation with building an energy efficiency sector set in: the draft National Energy and Climate Plan 2021-2030; implementation of the projects included in the Energy Strategy of Romania 2019-2030, with perspective of 2050; Law No 121/2014 on energy efficiency; Government Decision No 129/2017 (laying down the criteria and conditions required for the implementation of the support scheme for promoting high-efficiency cogeneration based on the useful heat demand; Gazette No 192/17 March 2017 and Government Emergency Order No 24/2017 amending (establishing the system for promoting energy production from renewable energy sources and amending certain legislative acts).

4.4.2.2 Economic factors

The Romanian mean equivalised net income has increased by 19% since 2010, reaching RON 11,884 (EUR 2,622) in 2015, giving households a larger purchasing power. However, the housing cost overburden rate was at 14.4% in 2016, above the EU-28 average of 11.1%, highlighting housing affordability issues. The housing quality is low. The overcrowding rate is 48.4%, the worst in the EU. Similarly, the severe housing deprivation rate reached 19.8% in 2016, the worst in the EU [69].To address these issues, the government introduced the First Home Programme with a budget of RON 2 billion (EUR 428.8 million) for 2018, which provides state guarantees of up to 50% of the value of the mortgage. Moreover, the part of population

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unable to keep home adequately warm can be explained by low purchasing power but also by low energy efficiency standards of residential buildings [70].

In 2016, Romanian electricity prices were below the EU average, while the gas market concentration was at the same level than the EU average. Since 2015, gas prices for non-households are fully liberalized. Moreover, households' electricity prices were below the EU average. In the same year, the share of taxes and levies in household's electricity prices were at around 8 p.p. below the EU average. With regard to the energy affordability the share of energy in total household expenditure of the lowest quintile of population is among the highest in the EU, i.e. at around 15% as comparing to 8.6% at the EU average [70].

Since 2016, the unemployment rate in Romania remained at 5.9%, being 2.5% lower than the EU-28 average. The share of renewable energy related employment in total employment of the economy in Romania was at about 0.21%. Employment was particularly high in biomass, small hydro, wind and photovoltaic industries [69].

With regard to the energy and building efficiency sector, there is a significant job creation potential linked to energy savings. The use of revenues from market-based instruments (MBIs) to offset other taxes or to finance investment in energy-saving equipment could have positive economic, social and/or labour market benefit [71].

The WEDISTRICT project can boost the interests on energy and building efficiency related jobs, complying also with the targets set in the National Strategy for Green Jobs 2018-2025.

4.4.2.3 Social factors

Most of the Romanian energy end-users have limited knowledge of the benefits of buildings rehabilitation or energy system reconfiguration that could conduct to better performances and effectiveness [72]. This is correlated with:

i) Government and public authorities' difficulties in providing the necessary funds;
ii) If the financial opportunities exist, the current legislative framework has an excessive bureaucracy that discourages both owners, builders and thus energy suppliers [73];
iii) The latter is related to the lack of standards in project development and documents, which makes it difficult for banks and investors to trust that the energy savings generated will be a reliable source of revenue [74];
iv) The lack of qualified personnel and workforce in the sustainable energy sector and of specific information or awareness-raising regarding the energy performance of buildings, except for the promotion of national thermal rehabilitation programmes and projects with a limited impact (particularly European). There are limited information actions performed by associations of municipalities, cities, etc.

In Romania, the ESCO market and the application of EPC (energy performance contract) are not developed yet and need to be stimulated at local and central level. The first step to be developed is to align the current and future Romanian framework to the European standards [74]. These can boost both consumers' confidence and investment sector.

Fuel or energy poverty is considered one the most negative social impact resulting from the inefficiency of the domestic sector [75]. It can be considered both a cause and a symptom of poverty [71]. The fuel poverty effects, due to inadequately heated homes, include thermal discomfort that can lead to welfare losses and adverse impact on occupants' physical and mental health [76]. As stated above, in 2017 Romania was occupying the second rank in EU-28 rank with a rate of 35.7% at risk of poverty or social exclusion [77]. According to BPIE report:

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"A large proportion of Romania's population is not able – in general and in normal conditions – to provide itself with sufficient levels of thermal comfort in their home, because of the high cost of heating energy relative to their income"[78].

In the data provided by the EU Energy Poverty Observatory (EPOV), it is mentioned that in Romania all household-reported performance indicators are below EU average (Figure 18) [77].

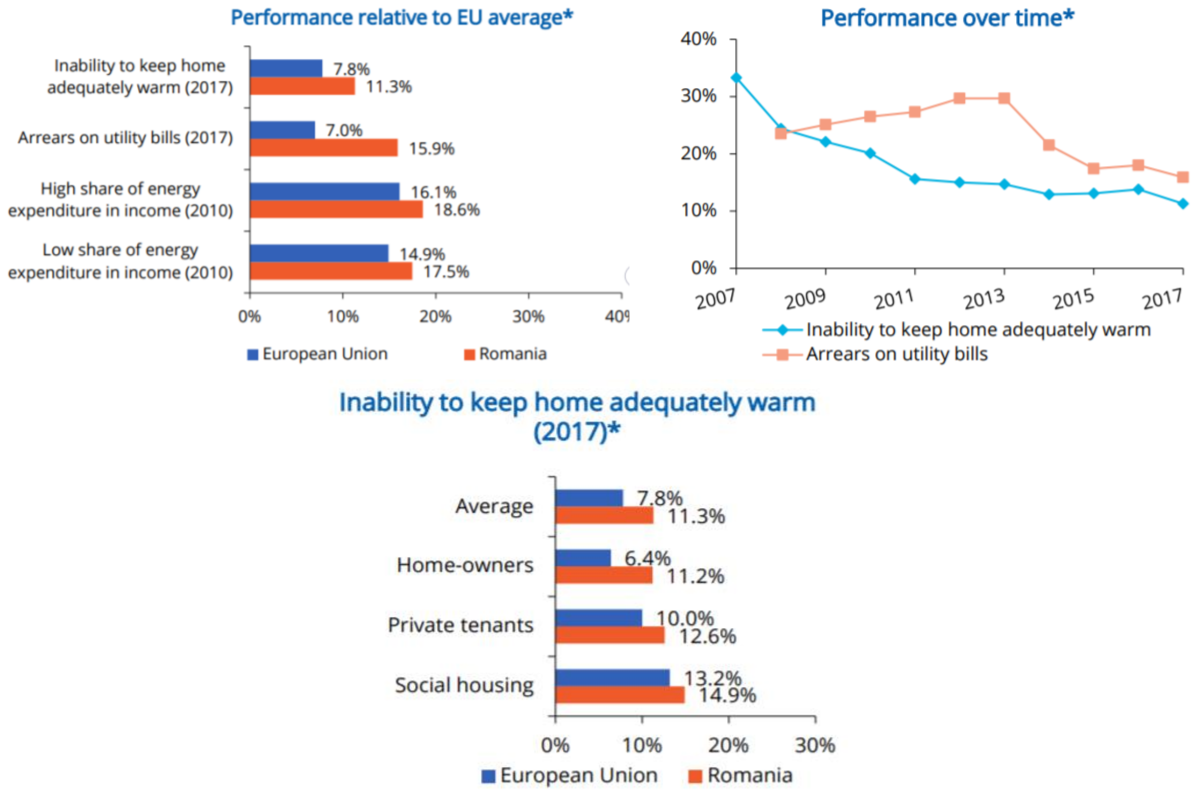

Figure 18. Romania household reported performance indicators 2017.

However, it is estimated that in Romania, 60% of the costs of investments in thermal retrofitting may be recovered during property transactions. This reality supports the argument for taking into consideration the added value due to energy performance when the financial analysis within the energy audit is performed [79].

Due to the lack of awareness, it is important to promote the benefits of energy efficiency in buildings among stakeholders, end-consumers and policymakers. This can be achieved through mass-media channels. Nevertheless, the latter will require the creation of specialised capacities for providing information, support and guidance instruments for system reconfiguration for nearly-zero energy buildings (nZEB). The promotion of the WEDISTRICT project will raise awareness among the players in this sector.

In Romania, there is still a lack of skilled workers or low levels of training in the use of new technologies designed for Energy Efficiency and Renewable Energy Sources. The implementation of the WEDISTRICT project in the University Politehnica of Bucharest will generate state-of-the-art knowledge transfer opportunities to the interested stakeholders (students, workers, renewable energy engineers, professors, energy auditors etc.) allowing their upskilling.

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Positive outcomes are greatly possible considering the development of energy efficiency education programs based on the WEDISTRICT project findings on a real-case establishment. Such an integrated approach represents a long-term endeavour, towards the development of green jobs, social inclusion, poverty reduction and thus environmental sustainability.

4.4.2.4 Technological

Romania has done improvements in many areas including science and technology. However, according to the World Economic Forum Global Competitiveness Report, which ranked the country in 53rd position and classified it in the efficiency-driven economy category, its strengths include education at all levels, macroeconomic environment and market size, and technological readiness [80].

A few start-up success stories are emerging from Romanian entrepreneurial ecosystems. Prominent success stories do not seem to have benefited significantly from either university programmes or incubators. Here comes 15 technological and business incubators and the four scientific and technological parks which are members of the national network for innovation and technological transfer (ReNITT). Furthermore, most of these success stories have at least partly moved their offices, if not their headquarters, abroad and have benefitted from foreign investors.

Manufacturing Production in Romania decreased by 3.1 % in February 2020 compared to previous year (Figure 19).

Actual	Previous	Highest	Lowest	Dates	Unit	Frequency	
-3.10	-2.10	21.70	-17.80	2001 - 2020	percent	Monthly	SA, WDA

Romania Business	Last	Previous	Highest	Lowest	Unit	
Industrial Production	-2.60	-2.70	17.90	-14.30	percent	[+]

Figure 19. Manufacturing Production in Romania, 2019 continuing with 2020.

The creation of a stimulating environment for private sector initiatives, the reaching of the necessary critical mass of researchers, the development of performing research organisations are some of the 2014-2020 national objectives for Research and Innovation. They have been designed to reduce Romania's current gap compared to both its potential and the EU average. They assume that by the end of 2020, public spending for Research and Innovation will gradually grow up to 1% of the National GDP, incremental to the indirect support to be provided for the private sector [68].

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In order to develop the know-how and in maintaining close contact with similar researches in EU Member States, the stimulation of new techniques and technologies for the construction of buildings with low energy consumption or 'active/positive buildings' (buildings that generate more renewable energy than the energy they consume) has a primary role.

Many initiatives seem to be focused on the building sector: measures for boosting the level of compliance in constructions were taken since 2017, when significant introduction of training and qualification programmes in 'low-energy building' technologies for workers in the building sector has started.

More closely to the DHC sector, it is interesting to quote that the climate conditions in Romania make the cooling demand relevant only for 3 months per year; therefore, in residential buildings cooling energy needed is ensured through split-type air conditioning devices, powered by electricity, mounted individually by each consumer. In the non-residential sector, old buildings use a similar approach as residentials, but new buildings are equipped with district chiller-type cooling facilities.

Around 22% of all cities and towns in Romania (320 cities and towns) use a district heating system but there is a continuous trend of decrease in the number of localities connected to district heating (e.g. from 1997 to 2003, 40 % of district heating in urban areas were removed) leading to a 10% annual decrease in localities connected to district heating services, mainly in smaller towns and cities. The reason behind this disconnection process is linked to the poor management of local district heating network prior to 2007 (before joining EU). Therefore, many citizens opted to disconnect from DH and to use a small heating system, usually individual gas fired central heating system, resulting in a poor economic use of energy. It is to be noted that in last couple of years this trend is decreasing because the DH companies are retrofitting and expanding the networks.

The investments in DHC systems don't seem to be a priority amongst other lively business opportunities existing in the country in other sectors. According to the Financial Times, Romania has become a popular tech destination. And Quartz considers it could very well be EU's next tech-start-up hub, while TechCrunch called it the Silicon Valley of Transylvania. Romania closed 2017 with a total of $53M investment in tech companies. According to the State of European Tech, 2017, report produced by Atomico [81], this value is three times higher than in 2016 and four times higher than in 2015. This is 0.27% of the $19B invested in tech companies across Europe which is to say there is still plenty room for growth.

But, considering the innovation, in the EU 2018 Innovation Scoreboard Romania is listed in the Modest Innovators category (countries with a level of performance below 50% of the EU average). The country shares the category with Bulgaria and remains last in the EU on its innovation performance. The innovation performance of Romania has been decreasing since 2010 by 14%. Alongside Cyprus, with performance declining by 9%, Romania is among the two Members States with the quota of performance that declined by more than 5 percentage points.

In Romania, changes took place at the level of authorities. For example, in 2016, the government set up another body – the National Council for Innovation and Entrepreneurship (NIAC). The NIAC 's mission was to *"support the National Authority for Scientific Research in the exercise of its powers in implementing the National Strategy for RDI 2014-2020 and to ensure the consultation to stimulate the absorption of innovation, technological harmonisation by identifying and promoting synergies and complementarities in funding technological development and innovation" [82].*

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The adoption of the advanced technologies will conduct to the achievement of the 2030 RES target through: development of solar and wind power plants, development of storage capacities and digitalisation of the energy system.

Scientific research in the RES area and the fostering of investments in the development of these solutions will contribute to the achievement of the target proposed for 2030.

Technology transfer represents a relatively recent activity in universities, although the major universities have developed their own technology transfer offices (TTOs). Twelve TTOs are members of the Romanian network for innovation and technology transfer, ReNITT, together with 12 centres for technological information. Overall, technology transfer activities in Romania unfound slowly. In terms of patenting in Romania, very few European or international patents originate from Romania. Eurostat data show that there were less than 10 EU patents granted per year during the period 2008-2012. International patenting is a standard outcome and measure of technology transfer activities. The low level of patenting demonstrates the weakness of the technology transfer system at universities.

Since 2013, Innovation Labs has been held in five university centres – Bucharest, Cluj, Sibiu, Timișoara and Iași, since 2017. Since it has begun, 206 teams comprising 1,040 young participants have taken part in the programme. Throughout Innovation Labs 2013-2016, 305 technology product ideas were hatched, developed and pitched; 120 mentors gave their time, energy and know-how; and 85 Demo Day minimum viable products (MVP)s were pitched in front of investors and media [83].

In terms of human resources, the lowest shares (of less than one quarter) of people working in science and technology occupations were recorded in Romania (20.3%) [84].

Big Data services build on technologies and innovations that facilitate the collection, transfer, storage and analysis of huge amounts of data. The continuous development of these enablers give rise to new services and business opportunities but also pose new challenges as technologies and standards continue to evolve.

Connected technologies such as low power wide area (LPWA), Zigbee, WiFi, and additional wireless sensor technologies enable to efficiently plan and execute various operations in energy efficiency process. Different policies and measures have been taken in Romania to adopt advanced technologies in the energy sector by attracting private investments, supporting scientific research and developing strategic partnerships.

In order to keep up to date about the latest development in their own field, people are increasingly reliant on smartphones and other intelligent mediums. They become depend upon broadband and other wireless networks to stay updated and participate in specific industry directed knowledge sharing initiatives. Collection and sharing of data are becoming more and more accessible.

4.4.2.5 Environmental factors

The Romanian Environmental Implementation Review 2019 report [85] shows that resources and waste management is still a key challenge. Resource efficiency, nature conservation, waste management, air quality is still low if compared with the foreseen improvement targets, while the circular economy remains underdeveloped. In this light, there is a risk of non-compliance with the 2020 municipal waste recycling target of 50 % and 70% of the waste from construction [85]. Most of the construction and demolition waste is abandoned and/or stored in an uncontrolled way on both intra- and extra-urban land [86].

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The EU Roadmap for moving to a competitive low carbon economy in 2050, identifies the necessity to reduce the carbon emission resulted from buildings sector by 88%-91% by 2050, compared to 1990 levels [87]. The Energy Roadmap 2050 strategy strengthen aforementioned data where higher energy efficiency potential in new and existing buildings is key in reaching a sustainable energy future and contributing significantly to reduced energy demand, increased security of energy supply and increased competitiveness [88]. Moreover, the value of environmental benefits brought about by the renovation of buildings can be around 10% of the savings in energy costs. "The savings made under the maximum load of the energy systems following the energy renovation of buildings, including energy self-generation, have about the same value as savings in energy costs''. It is estimated that the renovation of the Romanian building stock could reduce the CO_2 emissions by up to 80% [66].

Some of Romanian key priorities regarding energy usage and potential are:

- Decreasing the use of coal for domestic heating. This measure will limit air pollutants emissions. The action can be supported through "Coal regions in transition" EU initiative.
- Restructuring of the energy and domestic heating system (facilitating the integration of renewable, shifting to gas, district heating and pollution controls).
- Aligning with the current framework on energy efficiency, eco-design, energy from renewable source and energy performance of buildings presented in the next table.

Table 11. Romania current framework on Energy efficiency, eco-design, energy from renewable sources and energy performance of buildings.

<table>
<tr><th>Directive 2012/27/EU on energy efficiency (EED)</th><th>Ecodesign Directive 2009/125/EC (recast)</th><th>Energy Labelling Directive 2010/30/EU</th><th>Directive 2009/28/EC on the promotion of the use of energy from renewable sources</th><th>Directive 2010/31/EU on the energy performance of buildings (recast)</th></tr>
<tr><td>National strategies</td><td rowspan="3">EC declaration of conformity of energy-related products</td><td rowspan="6">Labelling of energy-related products</td><td rowspan="10">Setting of minimum levels of energy from renewable sources in new buildings and existing buildings undergoing renovation</td><td rowspan="2">Nearly zero-energy buildings</td></tr>
<tr><td rowspan="3">Energy saving targets</td></tr>
<tr><td rowspan="3">Energy performance certificates</td></tr>
<tr><td rowspan="4">Minimum requirements</td></tr>
<tr><td rowspan="3">Supplier obligations</td></tr>
<tr><td rowspan="2">Cost optimality</td></tr>
<tr><td rowspan="4">Complementing the Ecodesign Directive</td></tr>
<tr><td>Reporting requirements</td><td rowspan="3">Product regulations</td><td rowspan="3">HVAC inspections</td></tr>
<tr><td>Energy audits</td></tr>
<tr><td>Energy savings</td></tr>
</table>

According to Energy Performance of Buildings Directive, all Member States have to ensure that all new buildings are nearly zero-energy buildings (nZEBs) by 31 December 2020, and new buildings occupied and owned by public authorities are nZEBs after 31 December 2018. It is made mandatory that an energy performance certificate is issued every time a unit is sold or rented, and that energy audits for large companies are made at least once every four years.

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Since 2017, in Romania, the ministry amends the current general format and content of building and building unit Energy Performance Contracting (EPCs) by introducing the primary energy conversion factors used for determining primary energy use. Moreover, in order to reduce energy consumption and limit CO_2 emissions, inspections of heating systems are carried out regularly and inspection reports are issued by certified technical experts (Law no. 372/2005 (recast 2016)). Up to date there is no information available on penalties or use of enforcement and impact assessment of inspections [67].

Romania is committed to fighting climate change and pursuing low carbon development. Therefore, the Government of Romania, through the Ministry of Environment and Climate Change (MECC), has requested the World Bank to provide advisory services to help meet this commitment [89].

The development of new electricity production capacities by 2030 is important, particularly considering that 80 % of the existing heat units are outdated as well as the fact that, in 2017, the energy sector generated over 66 % of the GHG emissions, as accounted at national level. Romania thus plans to replace a significant capacity based on high-carbon sources with new gas, nuclear energy and RES efficient low-carbon plants. This will be achieved also for heating in SACET district heating systems by transit of energy through National Energy System (NES) and the use of heat pumps at source level, also relying on electricity market mechanisms.

A part of the revenues pertaining to the EU-ETS Mechanism (Modernization Fund) and of the Structural Funds pertaining to the new 2021-2027 Multiannual Financial Framework, and those of the Just Transition mechanism, will be committed to co-fund RES projects or to create financial instruments to guarantee loans used in the implementation of such projects.

The concept of best available techniques (BAT) concerns the most efficient and advanced stage of development of activities and how to perform them, indicating particular techniques that may be used in order to mitigate emissions generated by these activities to the maximum extent possible (and thus these activities having a minimum impact on the environment).

Through this, mitigation and adaptation actions will be integrated into Romania's national strategies, policies and programs. This will be a critical step in shifting its development path towards a climate-resilient, low-carbon and green economy.

So, the Program implemented by Romania together World Bank and MECC will help Romania to advance towards attaining the "Europe 2020 Strategy" objective which provides EU Member States a framework and means for moving towards a greener and more competitive low-carbon economy that makes efficient use of resources and is resilient to climate risk.

4.4.2.6 Legal factors

Although in Romania the legislative framework on energy efficiency is still under improvement and alignment with EU requirements, in the last years' notable steps have been done towards meeting the national targets under Europe 2020 strategy. Even though the country is on the track to reduce energy consumption by 19% by 2020, this figure is low [66].

From the energy usage perspective, 70% of the consumption of a residential building comes from heating and hot water usage. By implementing efficient heating solutions and thermal insulation, the energy consumption of a building can be can reduce by up to 40% [90]. Starting from 2020, all the EU Member States will have to construct only nearly Zero Energy Buildings (nZEBs) [78]. The EU Energy Performance of Buildings Directive (2018/844/EU) has new requirements that promote the electro-mobility infrastructures by installing equipment for

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charging electric vehicles, the smart technologies in buildings by installing systems for automation and control of energy consumption, with the purpose for better public health and quality of life of the building's users.

Overall, the thermal rehabilitation of residential buildings is challenging because the government and public authorities are unable to provide the necessary funds, and the legislative framework has created an excessive bureaucracy that has discouraged both owners and builders [91].

The adoption of Law No 184/2018 establishing the system for promoting production of renewable energy was a step forward in the regulation of prosumers' status in Romania. The new law provides for a series of advantages for prosumers, as follows:

- The scheme is applied to prosumers owning renewable energy production units with installed capacity of not more than 27 kW per consumption place in individual households, residential blocks, residential, commercial or industrial areas etc.
- The electricity distribution operators must connect prosumers in accordance with the specific regulations issued by the regulatory authority in this respect.
- Prosumers have the possibility of selling electricity to suppliers with whom they have concluded electricity supply contracts at a price equalling the weighted average price recorded on the day-ahead market in the previous year; suppliers having a contract with prosumers must take over the energy at the former's request.
- Prosumers are exempted from the payment of excise duties for electricity produced from renewable sources for self-consumption, and the excess production sold to suppliers.
- Prosumers as natural persons are exempted from the obligation of purchasing green certificates annually and quarterly for the electricity produced and used for own final consumption, other than own technological consumption of power plants.
- Prosumers are provided with the service of regularisation between the value of electricity delivered and the value of electricity consumed in the grid by the electricity suppliers with whom they have concluded electricity supply contracts the service.

The aim of these measures is to increase the amount of electricity from renewable resources, which is produced by prosumers. Furthermore, the barriers to the development of this sector (administrative barriers as a priority) must be removed; a first step in this direction is the implementation of Directive (EU) 2018/2001.

In 2016, the European Commission published the ''Clean Energy for All Europeans'' package which aims for the EU to assign a prime role to energy efficiency and become the global leader in renewable by providing consumers with a fair solution. In this context the sets of measures will diminish the energy poverty by increasing the affordability of expenses incurred by household consumers. This legislative framework supports the eco-design concepts on energy efficiency, renewable energy, electricity market, security of electricity supply and governance rules for the Energy Union.

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4.5 Sweden

4.5.1 Summary of the factors and their impact

The use of DHC in Sweden is mature, so the following analysis is looking at the provision of third-party heat by WHR from other processes, those that are derived from RES. The focus on data centers for WHR is of direct interest and very topical as it is a fast-growing sector and they are known to convert a significant proportion (>80%) of their electrical consumption into heat. The analysis makes the assumption that future urban (edge-style) data centers will invest in continuous flow batteries in the form of fuel cells to address availability of the services and therefore, the WEDISTRICT solution aims to capitalize on the access to WHR from both the data center and the fuel cells rather than the state-of-the-art that requires investment in heat pumps.

Table 12 Summary of the main factors of the PESTLE analysis for Sweden

	Very negative	Negative	Positive	Very positive
Political		• Third Party Access issues in connecting WHR to DHC		• Supports the goal to be net zero CO2 by 2045
Economic		• Could increase the capital construction costs of data centers, but FCs have the advantage as prime power for urban data centers, which are perceived to grow.	• The potential to reduce DH energy prices to the consumer. • Urban data center operational costs could be reduced with sustainable WHR solutions in urban areas.	
Social			• Raises awareness of cloud services end users that their digital footprint contributes to supplying the DH grid. • Local DHC grids already provide a good level of sustainable living.	• Reduces competition on urban electricity supply to use fuel cells as prime power
Technological	• Geographical issues for WHR from FCs since access to fuel and a local DH is not available.	• New concept / Lack of experience with integrating FC, DC and heat recovery	• Can help reduce overhead energy consumption in data centers	• Very local WHR using FCs offers other sectors access to >75C hot water.
Legal	• Current legislation is inhibiting the growth of DH supply to new buildings.	• No framework for third party access to the DHC grid		• Strong movements that could become law for data centers to recover their heat
Environmental		• Lack of synergy in using WHR with DH gird could be counterproductive without holistic integration.	• Potential for a regional circular economy by turning urban waste into biogas. • The evolution of DH networks supports sustainable living.	• Great opportunities for WHR solutions

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4.5.2 Description of the factors

4.5.2.1 Political

Swedish DH systems can be characterised as high security of supply, low carbon dioxide emissions, and efficient use of available heat sources, expertise that has led the way for introduction and deployment of district heating systems [61]. Sweden's well-established district heating system has the goal of being completely carbon neutral 2045. The demonstrator being built in this project could potentially help Sweden (and other countries) on their way towards carbon neutral societies, supporting the goal to be net zero CO2 by 2045.

The major driving forces for district heating were the municipal interest in CHP-plants alternatives to electricity purchase from the major power suppliers, homes program for one million new apartments and single-family houses immediately connected to district heating systems, giving significantly higher heat sales, the international oil crises that supported a governmental oil substitution programme, and climate change debate that introduces several climate change policies. But the Swedish parliament never introduced a dedicated district heating policy, district heating systems are tools for reaching efficient thermal power supply, decent residential houses, higher security of energy supply and mitigation of climate change.
Originally, the municipal ownership was associated with non-profit pricing according to the Municipal Act, but the deregulation of the electricity market leads to an increased price for heating/cooling services and currently Swedish district heating price level is higher than the average European price level, but below the highest national price levels (Denmark, Slovakia and Germany).
The Municipal Act regulated all municipal activities, including district heating systems until the removal of the non-profit pricing principle for municipal district heating systems, made citizen request a special legislation for district heating systems; therefore government prepared a special district heating legislation and set up the District Heating Commission leading to the identification nine different issues and proposals for a special district heating legislation were delivered covering legal issues like unbundling, third party access, economic transparency, price regulation, and heat theft.
A District Heating Board was also set up for complaints concerning prices and other delivery conditions as a mediator during negotiations regarding the terms and conditions for district heating services between companies and customers.

Even if the political framework is favourable to the sector, third party access issues exist. Third party access to district heating grids for heat producers is not included in the District heating act. To meet the many disappointments from market actors, a Third-Party Commission was set up in 2009, which gave their proposals for revision of the District Heating Act in one governmental official report. However, the only revision of the act became finally a possible regulated access since the local district heating company should not suffer an economic damage from the access. Therefore, district heating companies are only obliged to offer a remuneration corresponding to the avoided variable costs. This remuneration principle is very close to the established practice conditions for industrial excess heat recovery. The fundamental principle of full third-party access for district heating was then rejected for the second time [61]. This means that the integration of data center waste heat into district heating should be done in close collaboration with the local district heating system owners, to avoid complications and counterproductive results.

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4.5.2.2 Economic

Given that WEDISTRICT demo site in Sweden is focused on waste heat recovery from an existing data center, the analysis of the economic factors is also linked to this kind of system and include:

- **Data center economic construction constraints**
  Capital investment in data centers is complex and therefore any integration of systems or approaches that recovers the waste heat from the data center and/or on-site power provision will inevitably increase construction costs from the data center perspective. The economic cost must be weighed up against the reduced environmental impact within the financial constraints of any data center construction project. Fuel cells are proving themselves to be a worthy investment for data centers in the US, not because of the WHR potential, but for operational advantages. Such data center projects could be considered in Europe with WHR and no need for extra plant and operational energy consumption as is the case with heat pumps.
  Looking at the WEDISTRICT demonstration project in Sweden, the chosen configuration incorporating fuel cells may be more expensive than the tried and tested approach of heat pumps (more competitive and fully validated nationally and abroad, e.g. Denmark) as other benefits have been prioritized, such as saving on the use of primary energy. However, this is looking at the data center purely as a WHR source, but there are stronger arguments for data centers to invest on FCs rather than HPs because of the prime focus of the data center business. Bringing FCs to data centers opens up the opportunity for a more effective WHR rather than using HPs.
- **End user economic benefits**
  The consumer could potentially benefit from price reductions of heat when waste heat is recovered from systems and processes that produce excess heat. Although basing prices on primary energy sources is likely to level the playing field, the reduction in emissions by offsetting the primary energy source should be considered as having economic value.
- **Economic benefits for data center operations**
  The proposed solution to operate small data centers in urban locations on biogas (or in the future on hydrogen) for primary energy sources is driven by the business requirements of the data center and could benefit both the data center's operational cost and performance when the waste heat is recovered for direct use in district heating networks, or for more local use in hospitals, hotels or laundries since the sustainability angle and energy reduction operational and capital costs associated with the cooling of the data center white space are likely to reduce the operational costs, benefiting all stakeholders. For small installations (as for the WEDISTRICT demonstration), there is a risk of sub-optimisation in terms of cost effectiveness from the WHR perspective, however the WEDISTRICT piloting activity will be an important reference focused on the use of renewable electricity in a sustainable manner in data centers and could be the showcase for future upscaling or opportunities for data centers that will focus on FCs for prime power in the future.

4.5.2.3 Social

The following social factors have been identified:

Public awareness: Most urban dwellers consume cloud services through the apps that run on their devices that demand digital storage and remote digital processing over high throughput digital networks. The end user is oblivious to the end use energy demand of these

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services, but with clear messaging end users should become more aware of the relationship of their digital footprint and thermal energy recovered and provided to the DH grid that they benefit from directly.

Improved sustainable living: Where there are currently local DHC grids there is already a good appreciation of citizens that their level of sustainable living is augmented by the existence of such networks. Recovering waste heat from a system that they are reliant on will increase their appreciation of and their access to sustainable living standards.

Enabling reduced congestion on the urban electricity supply: The roll out of data centers in urban areas to support the increased digital demands of the urban citizens has always put an increased strain on an already congested power grid. The use of fuel cells running on natural gas, or better still biogas (created from the urban waste), or later hydrogen, to produce prime power for urban data centers with direct waste heat recovery has the obvious advantage of reducing power grid congestion and at the same time reducing the heat island effect common to dense urban living.

4.5.2.4 Technological

Constructing data centres in urban areas are challenged by power availability, noise limitations, environmental and thermal constraints, and in some cases the effects of climate change. Fuel cells have been identified as a solution that can alleviate demands on the urban power distribution since they operate on natural gas, biogas, hydrogen or propane (LPG) that can be transported and distributed over existing gas networks. Fuel cells can provide energy-efficient on-site power generation, which scales up and down with modularity to the end-use application without any degradation in energy efficiency due to size. The modularity, energy efficiency, low emissions, low noise, steady electrical demand and ability to operate on renewable sources of fuel, such as renewable hydrogen or biogas, make fuel cells ideal as the prime power source for resilient data centres in populated areas. Data centre availability usually depends on having two electrical feeds, an A and B, which in some rare instances may come from different electrical grids. In practice the B feed is connected to a series of back-up generators, which themselves are undesirable to have located in urban areas and are also subjected to increasingly stringent emissions regulations. Using fuel cells as the prime power, the so-called A feed, with modularity provides reliable on-site generation with lower electrical losses and the electrical grid can then be used as backup, but even then the gas supply does not necessarily become the single point of failure as fuel can be safely stored on-site.

Fuel cells require large amounts of a continuous fuel supply to be used as the prime power generation for a medium sized data center. This means that the data center needs to be directly connected to a stable fuel source, like a gas grid. This heavily decreases the flexibility of where a fuel cell powered data center can be located geographically. Also, there must be a district heating system with large enough pipes nearby to enable connection of the waste heat. These are more infrastructural issues that could disqualify the technological approach at several locations.

The concept of using fuel cells as the prime power source in combination with data centers has been done before (e.g. by Equinix), however, to our knowledge never in combination with heat recovery for district heating supply. The lack of experience in operating fuel cells,

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especially with heat recovery demands, has the strong potential to slow down the envisaged growth of the concept.

By using very energy efficient fuel cells (>55%), the primary power used will in many cases be reduced compared to buying grid power in many urban areas, that for instance is produced by more carbon intensive electrical production approaches, and which is distributed over long distances causing additional distribution losses. Also, the concept of integrating the fuel cell and data center as a CHP will enable an even higher overall fuel efficiency as the heat can be used in the district heating system, without further "processing".

4.5.2.5 Legal

Current legislation is inhibiting the growth of DH supply to new buildings as, in Sweden, they need to fulfil certain demands of energy efficiency. In practice, it means that only a certain amount of purchased energy is allowed per square meter per year of the building.
This incentivizes the use of local heat pumps, since depending on the average Coefficient of Performance (COP) over the year, the end customer might only need to buy one third of the energy that is actually needed to heat the building, vs. if district heating were to be used, then all energy required for heating must be purchased.
There is currently a move towards a primary energy view on this "problem", to include the advantage of using recovered heat (thermal power) from industries and other heat sources, since the CO_2 emissions related to the use of recovered heat should not be equalized to the CO_2 related to using electrical power.
This concept of "purchased" energy has impacted the continued growth of district heating in Sweden, but hopefully the legislation is expected to soon change, so the continued district heating expansion will again be financially viable.

Since the third-party access to district heating networks currently needs to be agreed with the district heating network owners, it could potentially prohibit heat recovery from good heat sources. However, it is anticipated believe and support the idea that a systemwide analysis always needs to be made in collaboration with the DH network owner, to achieve the best possible heat recovery integration.

There are strong movements within Sweden (and the rest of Europe) to push for heat recovery from data centers. These ideas could be transferred into laws and legislation soon. To have efficient solutions for heat recovery validated, and even operational could be a big competitive advantage if these heat recovery laws becomes reality. To transfer the heat into existing district heating systems is an appealing idea, as massive amount of heat theoretically can be received by the DH grids. However, there are also technological system challenges with adding new heat sources to an existing, and well-functioning DH system.

4.5.2.6 Environmental

Amongst the environmental factors, it is important to report that the lack of synergy in using WHR with DH grid, could be counterproductive without holistic integration.
There is a risk with adding new waste heat sources to a district heating network, since, for example, it might reduce heavily invested and existing CHP-plants the possibility to use the DH network as a "heat sink", meaning that either a lower amount of electrical power can be produced, or that heat from CHP plant needs to be dumped into rivers of vented off into the

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air. This could mean that more electricity is produced in e.g. coal fired power plants (with or without heat recovery) that would lead to a significantly higher CO_2 emission per produced MWh. Therefore, it is very important to understand the impact of how a new heat source might affect the district heating systems, and the systems it interacts with. Having a full understanding of how the local district heating system is heated is very important before any decisions of where and how new heat recovery sources should be connected. A good intention could have a knock-on effect on the district heating systems overall efficiency and CO2 emissions. This is the reason why it will be very difficult to propose general guidelines of introducing WHR solutions into existing district heating systems, it must be done system by system.

There is a potential for a regional circular economy by turning urban waste into biogas. Today there are huge amounts of biological waste produced in urban societies, this waste can be transformed into biogas by various technologies. By using this biogas to operate efficient fuel cells, for example in a setup demonstrated by the WEDISTRICT, a regional, environmentally friendly circular economy could be achieved. Where the urban waste is used to empower data centers, which houses cloud- and other digital services simultaneously as heating the houses of these “digital customers” is provided through a district heating system.

District heating is one key element to Sweden’s success of keeping its CO_2 per capita down over the last ~70 years. It has proven to be a success factor in the thrive of sustainable societies and living. WEDISTRICT shows how large-scale digital systems, can be integrated with the latest fuel cell technology to support the future development and deployment of district heating.

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5 Conclusions

The European vision for 2050 is clear: *"in low-carbon district networks, heat is produced from heat pumps, biomass, biogas or Synthetic Natural Gas (SNG)-powered boilers. Smart district heating and cooling grids improve the management of energy demand. Such networks can be optimised in real-time with digital heat meters and control of heat sub-stations (heat exchangers). In 2050, waste heat recovery solutions are deployed for most buildings in the commercial and tertiary sectors." [92]*

District Heating and Cooling networks have a high potential to save carbon, save money, generate revenue, reduce fuel poverty and support economic development in all European countries. This transition to renewable energy systems implies large investments in new renewable supply technologies and, in order to achieve an economic optimal transition, these investments in new production capacity must be coordinated with investments in reduced demand in buildings. One of the main driver for the increase in development of 100% renewable DHC is represented by the shared will of local authorities, building investors or local communities to opt for sustainable heating and cooling solutions, coupled with the capability to invest/have access to considerable funds (EU estimate: annualised investment costs in district heating supply and in distribution infrastructure should reach around 16 B EUR/year and 20 B EUR/ year in 2020-2030 corresponding to about 8,700 new systems [26]. Certainly, optimized/new business models for DHC sector needs to be applied, in particular, for multi-utilities companies and excess heat providers accompanied by an appropriate dedicated regulation which is still missing in most of the European countries (e.g. on third party access rights).
Pioneering countries usually from Northern Europe (such as Germany, Switzerland and Denmark) provide interesting successful examples to take as reference for the deployment of 4th and 5th generation DHC [73] and demonstration projects like WEDISTRICT further contributes in validating the practical implementation locally and in extending the knowledge repository supporting policy makers, energy planners and industrial players both on technological aspects and on the importance of raising awareness amongst communities.

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