**Flexi-Sync**

Flexible energy system integration using
concept development, demonstration and replication

# BUSINESS MODEL AND MARKET ANALYSIS FOR THE NEW SERVICE

## VERSION 1

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ERA-Net Smart Energy Systems (ERA-Net SES) is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programs along the innovation chain provides a sustainable and service oriented joint programming platform to finance projects in thematic areas like Smart Power Grids, Regional and Local Energy Systems, Heating and Cooling Networks, Digital Energy and Smart Services, etc.

Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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## EXECUTIVE SUMMARY

In Flexi-sync project, enabling technologies such as storage solutions, control optimization, increased usage of renewable energy sources and waste heat have been included in optimization modelling and form one new service. The new service accounts both for the demand and the supply side of the district heating (DH) system allowing for unprecedented levels of flexibility in DH and electricity sectors. We analyzed different use cases in Austria and Sweden, in which the optimal operation of the supply-side system (the DH network comprising Combined Heat and Power (CHP) plant, central heat pump (HP), and heat-only boiler (HOB)) and the demand-side system (building-level HPs and thermal storage) are integrated into one system to provide flexibility to DH and electricity systems. Amongst the non-academic partners, the unprecedented combination of the demand and supply sides into one service is an important innovation that will allow increased flexibility by means of digital solutions. The new service is yet to go to market.

This report investigates how the conventional business logic does not meet the new business requirements that are brought by this new service in the DH sector.

In the case of Austria, two types of business models are proposed (the component addition and the electricity market participation business model). The first new business model adds new, cross-energy domain components (i.e., a central CHP and a HP) and therefore links the system to the electricity grid, which is not common for rural DH systems in Austria. This inclusion enables additional flexibility to the existing DH network. The second innovated business model is an extension of the first one and adds the Day-Ahead and/or the aFRR balancing electricity market participation of the CHP and HP, because their combination turns out to be a profitable option. Those business models are consolidated by the fact that the use cases of electricity market participation show increased revenues. The cases including operational or investment support for the additional generation technologies are most profitable. This indicates the additional generation technologies and possible electricity market participation are economically viable to utilize flexibility options. In DH systems, the usage of building flexibility is profitable as well (especially for DH networks without existing thermal storage tanks). And when considering network densification, flexibility via utilization of the thermal mass of buildings as a thermal storage can be economically viable. Furthermore, the business model modifications are also analyzed. The stakeholder workshops and a questionnaire are also conducted to receive feedbacks which prove to be in favor of the innovated business models.

In the case of Sweden, two representative business models are developed and elaborated, i.e., the business model of a connected product and of a performance contract. The main

difference between these two business models is the investment arrangements and operation modes of HPs. Based on this, different blocks of the Business Model Canvas are modified. Since Business Model Canvas is a widely used method to visualize existing business models for a company and create a visual roadmap of a business model's evolution. The risks perspective to business models is proposed in this analysis which is rarely considered in other studies. Trust issues between DH company, aggregator, and property owners, possible failures to respond to flexibility signals, and investment risks are proposed to DH companies before they proceed with any new business model. From a product-oriented mindset to better product offering and service-oriented mindset is the prerequisite to adapting to the changing business environment. To achieve a win-win situation, DH companies shall consider adjusting their conventional business logic, designing better offers, establishing dialogue- and trust-based customer relationships, involving new partners, developing innovative activities, channels (such as optimization solutions, installation, and maintenance) and price models.

The policy risks, technical risks, financial risks, and organizational risks are put forward to safeguard future new business models, based on the analysis of business models, policies, and regulations.

**Keywords:**

District heating, heat pump, central biomass heat-only boilers, Combined Heat and Power plant, demand side flexibility, Servitization, business model canvas, business model risks

# ACRONYMS

| | |
|---|---|
| aFRR | automated Frequency Restoration Reserve |
| BL | Balancing market |
| BMC | Business Model Canvas |
| CHP | Combined Heat and Power |
| DA | Day-Ahead |
| DH | District heating |
| DSM | Demand-side Management |
| FiT | Feed-in tariff |
| GHG | Greenhouse gas |
| GoO | Guarantees of origin |
| HOB | Heat-only boiler |
| HP | Heat pump |
| MILP | Mixed-integer linear programming |
| SVOD | Subscription Video on Demand |

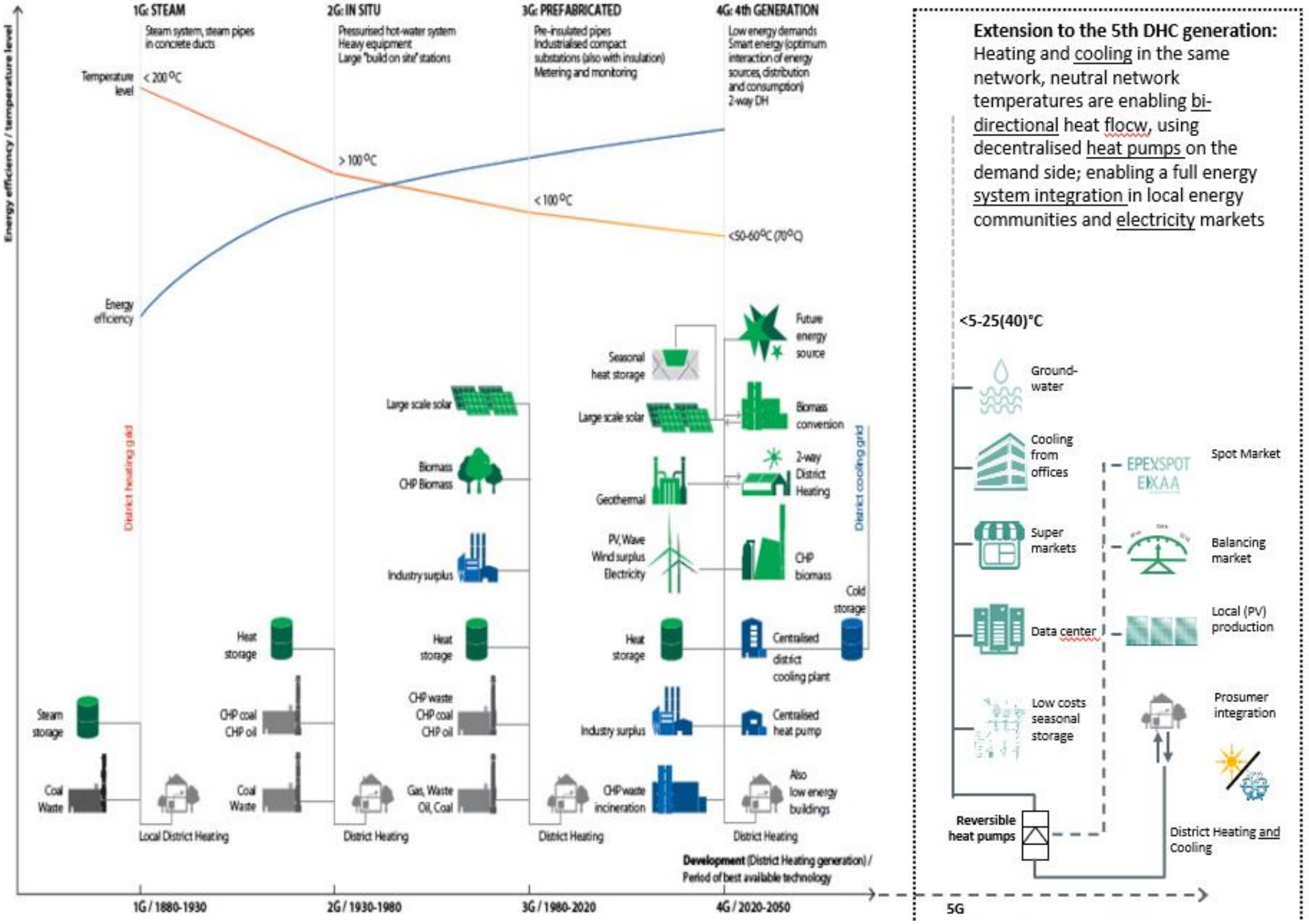
# 1 INTRODUCTION

## 1.1 Background

### 1.1.1 Development of DH networks in Europe

DH networks are experiencing ongoing development. Whereas first generation DH (developed around 1900) was mainly fueled by coal and waste and used high temperature steam as a heat carrier, second generation DH was also fueled by oil and the first Combined Heat and Power (CHP) units and used pressurized hot water as a heat carrier. Around 1970, third generation DH was developed due to oil shortage, making use of additional biomass and sometimes geothermal or solar energy. Pre-insulated pipes were utilized, and operation temperatures were just below 100°C. The fourth generation DH systems were developed to address climate change, whereas high shares of renewable energy are integrated and temperatures below 70°C are used. Network losses are minimized, and waste heat is integrated. The fifth generation of DH is including cooling, whereas heat is distributed near ambient temperatures. A bi-directional exchange of heat is enforced, thermal storages are incorporated in the networks and a demand driven control is incorporated [1]. However, there are overlapping terminologies and there is no clear distinction between fourth and fifth generation DH. In this work, we innovate business models for 3rd generation DH (see also Figure 1).

In Austria, heat generation in DH networks is mostly based on (gas-fired) CHP or – especially in rural DH networks – biomass [2] [3]. In Sweden, heating is primarily supplied through bioenergy-based district heating (DH) and heat pumps (HPs), where DH could cover the heat demands of 90% of multifamily buildings and 60% of total building [4]. It is becoming more popular that a property uses DH as heat supply and supplemented by HPs. That makes HPs as the main competitor for DH companies.



**Extension to the 5th DHC generation:** Heating and cooling in the same network, neutral network temperatures are enabling bi-directional heat flocw, using decentralised heat pumps on the demand side; enabling a full energy system integration in local energy communities and electricity markets

*Figure 1. Overview of the DH generations: Left side (up until 4th generation) by [5], right side (5th generation) by Ralf-Roman Schmidt, AIT, 2021.*

### 1.1.2 The use cases

The new service, which was developed within Flexi-Sync project, enables optimization of both the supply and consumption of energy. The new service utilizes the demand response to shave or shift heat load peaks, therefore contributing to the optimal operation of the DH system and a more flexible electricity market.

There are six demo sites in Flexi-Sync to showcase the new service, which are different in terms of design and operate on mature or less mature heat markets. In the business model related analysis, we selected four use cases that represent both the bigger (with annual demand between 300 GWh to 700 GWh respectively, in Sweden) and smaller (with annual demand of around 1.6 GWh, in Austria) DH markets. The main production units from the utility side in these four use cases include CHP plants and HOBs and the main fuels are biomass and waste. The flexibility exploitation from the end-user side is enabled by the use of HPs, thermal inertia, and storage tanks in buildings. The description of heat supply, heat demand, flexibility provision, and business visions of these four use cases are presented in Table 1. After the tests in use cases, the new service is developed into an advanced prototype and qualified for market operation.  The important new value that the new service brings is the possibility to aggregate smaller amounts of loads to provide flexibility to a bigger system. This is yet being developed and its business models are not established in the market.

*Table 1. Heat supply, heat demand, flexibility provision, and business visions of Swedish and Austrian demo sites.*

| Use cases | Heat supply side | Heat demand side | Flexibility provision | Business visions in Flexi-Sync project |
|---|---|---|---|---|
| **Borås energi och miljö**<br>**SE** | A CHP plant with both biomass and municipal waste as fuel. Annual heat supply is 600 GWh. | • Residential buildings owned by Willhem Borås AB.<br>• The HPs are today run as a base load and DH covers the peak load. | • Demand flexibility through using the thermal inertia of buildings as a thermal storage and flexible control of HPs in buildings.<br>• 37 000 $m^3$ hot water storage tank. | • The intention is to study how the DH production is affected when the customer uses the thermal capacity of their building stock and their HPs in a clever way.<br>• Operational optimization of the supply side, which also considers the identified flexibility options from demand side, will provide insights on the potential to ensure that electricity is generated during the hours with highest prices on the Day-Ahead (DA) market and electricity is consumed during the hours with the lowest prices.<br>• In addition, the balancing contribution in the electrical grid can be further enhanced through being active on the intraday and balancing markets. The optimization will in that case suggest when and how much capacity that can be offered on these markets. |
| **Mölndal energi**<br>**SE** | A biomass CHP plant with a thermal capacity of 80 MW and an electrical capacity of 26 MW. Annual heat supply is 290 GWh. | A municipality owned housing company Mölndalsbostäder AB is the owner of the buildings that offer the demand flexibility. | • Peak demand is covered by a mix of biomass and oil heat only boilers.<br>• There is no hot water storage tank in operation.<br>• Flexibility today consists of some utilization of the distribution grid as a thermal storage and trading with the neighboring grid (Göteborg Energi). | • The intention is to study how the DH production is affected when the customer uses the thermal capacity of their building stock to optimize and reduce heat production costs.<br>• The access to flexibility and the tools to best utilize it will reduce the need for fossil peak load boilers. There is also an opportunity to offer a flexibility service to the neighbor DH grid which today have limited access to flexibility. This can enable that grid to cut fossil peaks and operate CHP and HPs with a greater consideration of the situation in the electrical grid.<br>• Having access to greatly increased flexibility will enable the CHP plant to better plan electrical generation and provide balancing service to the electrical grid. This is achieved by the flexibility and generation optimization and being active on DA, intraday and/or balancing electricity markets. |

| | | | | |
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| **Eskilstuna energi och miljö**<br>**SE** | A biomass CHP plant with a thermal output of 100 MW and an electrical output of 38 MW. Annual heat supply is 700 GWh. | Some of the buildings are part of the upcoming Energy Evolution District consisting of different business, utilities, and dwellings. Other selected buildings are high-rise buildings built in the 1950s. | The current flexibility potential consists of a 25 000 m³ hot water storage tank. This flexibility will be utilized in the operational optimization together with added demand flexibility, both building thermal storage and building HPs. | • The aim is to test building side flexibility through utilizing building thermal storage and flexible operation of an exhaust air HP. This gives this demo site a very good opportunity to balance the electrical grid. This balancing potential is realized through the flexibility and generation optimization and being active on DA, intraday and/or balancing markets.<br>• One important aspect is to demonstrate replicability and scalability of the solutions tested at the other demo sites. This is to ensure that solutions developed within the project are generally applicable to many DH grids and that they can be efficiently replicated. |
| **Bioenergie NÖ Anlage Maria Laach am Jauerling**<br>**AT** | A biomass heat only boiler plant with thermal output of 800 kW. The heat demand of the DH network is approx. 2,000 MWh. | Customers are from the private living area, housing cooperatives and other property developers, public authorities, companies and churches. | Flexibility is currently provided by a central thermal storage tank of 8 m³ and two heat only boilers of 400 kW each. | • The intention is to use a broad spectrum of further flexibility options within the DH network:<br>○ Further installation of generation components (central CHP, central HP) to secure supply and enable the stabilization of the electricity grid.<br>○ Electricity market participation (DA and balancing markets) of the further generation components to enable market- (and grid-) serving operation strategies.<br>○ Usage of the thermal building mass of the connected buildings to enhance flexible operation of the generation components.<br>• Profitability (increase of revenues, reduction of costs) of the flexibility measures is calculated for all flexibility options to develop new DH utility business models. |

### 1.1.3 The new service

In Flexi-Sync project, a new digital tool was developed that combined the flexibility potential from demand-side together with heat production from supply side. This tool performed optimization considering multiple parameters and operated itself based on the cloud platform. The input data included info on the availability of production units, fuel and electricity prices, heat demands, and available flexibility, etc. Then a mixed-integer linear programming (MILP) problem with the target function to minimize operational cost was conducted. The outputs were the production plans (e.g. what production units should be run during which hours), the storage plan (e.g. how the storage tanks should be operated), and the demand flexibility plan (e.g. how the demand side flexibility should be optimally utilized). The integration of these is the new service designed within the Flexi-Sync project (Figure 2).

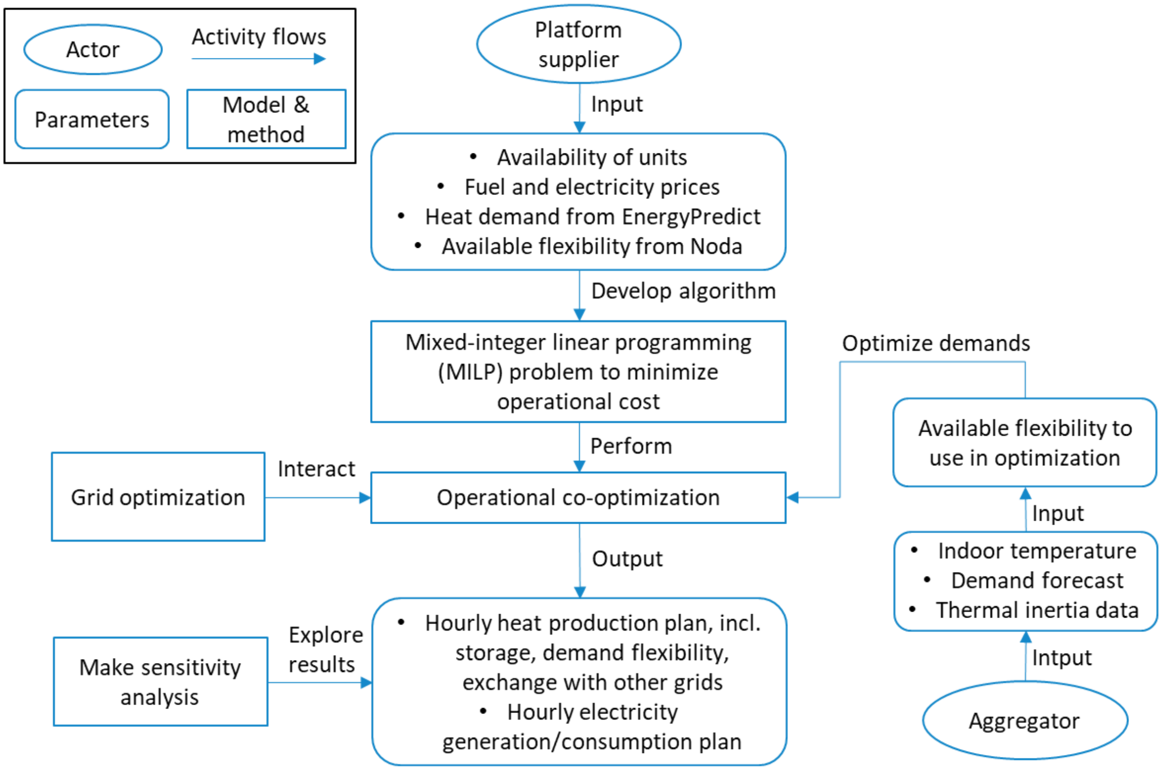

*Figure 2. The new service which was developed in Flexi-Sync project.*

To clarify, the term "digital tool" used throughout this report is perceived as the bearer of the new service. This new service was tested by real cases. For Austrian demo sites, the profitability analysis was conducted to form the basis for further business model design. For Swedish demo sites, the corresponding price models were designed for two Swedish use cases to adopt such a new service [6]. The results revealed the business potential to bring this new service from an advanced prototype to become qualified for market operation.

Figure 3 describes the conventional integrated system of DH and HP, and the new integrated system with use of the new service. The business model analysis for both Austria and Sweden were based on the new service in Figure 3. Furthermore, Austrian case analyzed the business model for an additional service, which was the potential flexibility provision to electricity market (such as the DA and balancing market). A comparison of the analysis for Swedish case and Austrian case is shown in Figure 4.

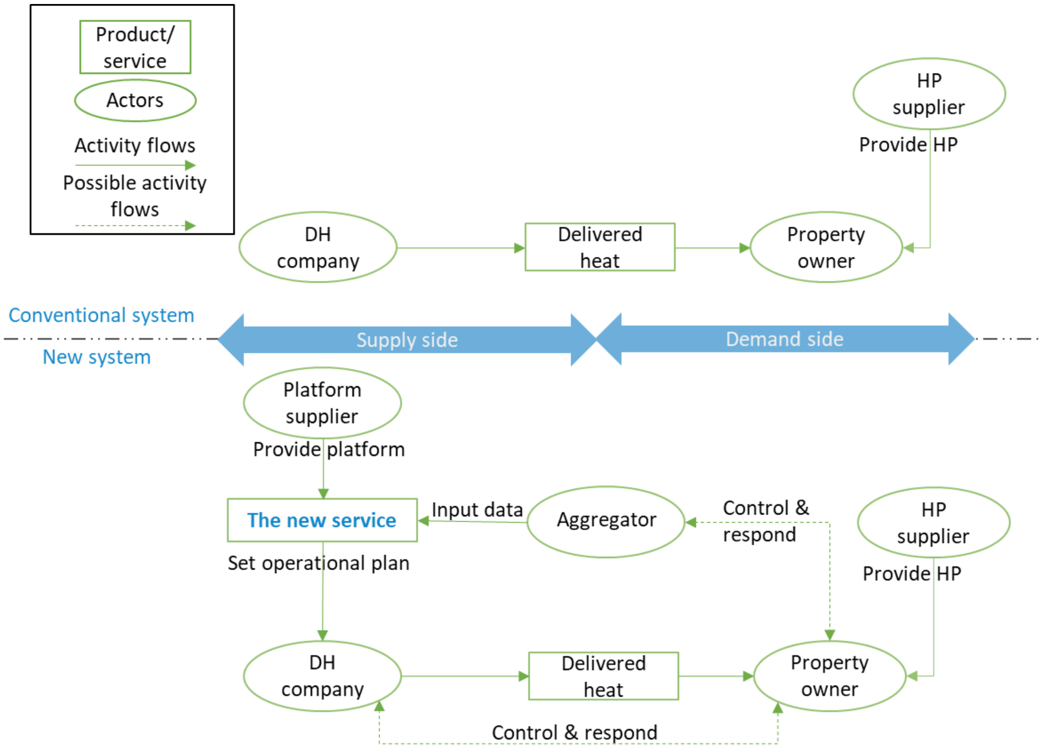

*Figure 3. The comparison between the conventional DH system and the new system with the service in use.*

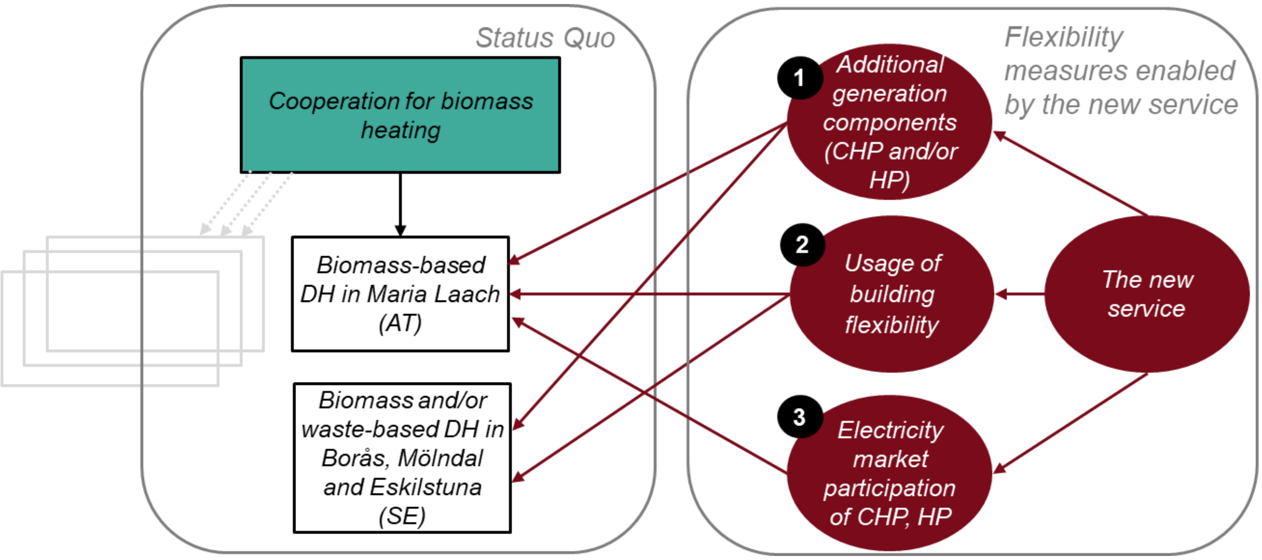

*Figure 4. Considered flexibility measures which are enabled by the new service for the Austrian and Swedish demos.*

In Swedish residential homes, HPs are usually prioritized because they usually have the lowest cost. The DH connection is used when the capacity of the demand-side HPs  is not sufficient to meet the entire heat demand. The possibilities for a DH & HP integrated system to provide flexibility lies on heat source shifting, where the shifting order depends on marginal cost of electricity and DH generation. In a study conducted by Energiforsk, a reduction of operating costs could be as high as 220-1120 kSEK/year in 81 combined DH & HP systems, if the HPs could be controlled to shift heat sources and optimize the DH grid [7]. In our previous study within Flexi-Sync, we showed that savings can be obtained by operating a load shifting heating system more efficiently by following price signals. In most cases the customer could decrease its costs of heating and the DH companies could also increase their profits by using price models that are competitive against the cost of operating HP [6]. For the convenience of the following discussion, it is necessary to clarify the settings of the new service system (Table 2). The pre-defined setting is that the HP providers will provide the HP systems to the consumers. The digital tool supplier ("Utilifeed" in the project) provides the package of the new service to the DH company (for example, "Borås energi och miljö" or "Eskilstuna energi och miljö" in Swedish cases in the project). DH company purchases and pays for such a package. The aggregator ("NODA" in the project) gathers data from the consumers and feeds them into the digital tool for optimization. Since the consumers in this project are on the building level, so they do not necessarily refer to the individual tenants. Instead, the property owner represents the consumer group. With the input from the demand side, the DH company will be able to make an operational plan for the heat generation/storage units available in the system based on the optimization performed by the digital tool. The signals of flexibility provision will be transferred either through certain market actor or the DH company itself. In the former case, certain market actor from the demand side will control the buildings to aggregate or disaggregate heat demands to respond to the DH company's production plan. This market actor could be either the aggregator or the property owner. Different business models will be analyzed for each case. In short, there are two representative business models generated from such a system in which the main difference is the investment arrangements and operation options. That is, to ask who invests in what, who operates what, what the concerns and risks are behind each scenario. With the introduction of the new service and proper business model considerations, it is foreseen that the heating system will become more service-oriented and therefore smarter and more resource efficient.

*Table 2. The business settings for the new service system.*

| Investment of the digital tool | Provision of HPs | Investment of HPs | Operation of HPs |
|---|---|---|---|
| DH company | HP provider | Could be:<br>• Property owner<br>• Aggregator<br>• DH company | Could be:<br>• Property owner<br>• Aggregator<br>• DH company |

As forementioned, the new service is applied both in the Swedish case and Austrian case. Furthermore, Austrian case develops extended service which is to use flexibility from DH sector to participate in electricity markets. In that sense, for the Austrian case, the new service also consists of additional flexibility measures for the DH network at the demo site, enabling a higher security of supply, additional revenue possibilities for the utility and possible flexible tariffs for the end-customers. The flexibility measures within the DH network are depicted in Figure 4. The additional generation components for the network are foreseen to be operated by the existing utility, whereas the flexibility is utilized using "NODA" as the control infrastructure operator (for the buildings as well as the generation components) and "Utilifeed" as the platform provider (that hosts the optimization and provides data in a standardized format).

## 1.2 Aim of the report

The goal of this report is to improve the understanding of business implications from optimized flexibility and develop new business models for the new service. To do this, the following questions are posed:

- How does the new service developed in the Flexi-Sync project challenge the traditional business logic?

- What are the possible business models for the new service?

This report is organized as follows. Chapter 2 reviews the emerging business models for exploiting flexibility in DH sector. Chapter 3 describes the methods which are used to analyze business models for Austrian cases and Swedish cases. Chapter 4 reviews the policy and regulatory framework and how they may impact business models. Chapter 5 presents the main findings and results in this report, which are the new business logics and possible business models for the new service. Chapter 6 analyzes the risks and barriers to supplement the business model design. Finally, Chapter 7 concludes the report.

# 2 BUSINESS MODELS AND THEIR ROLES IN FLEXIBILITY PROVISION

In this Chapter, Section 2.1 reviews the concepts and definitions on business models, Section 2.2 reviews the current business models for DH &HP integrated systems, and Section 2.3 reviews the current business models for DH & electricity coupled systems.

## 2.1 Business models and value chains

In the context of a business model's content-related tasks, the various definitions of business models show a homogenous picture. Many scholars describe business models as “how a firm does business” “a company's logic of earning money” [8] [9] [10], which fundamentally concern with the rationale of how an organization proposes, creates, delivers, and captures value [11] [12] [13]. Specifically, the essence of a business model is in defining how the organization delivers value to customers, entices customers to pay for value, and converts those payments to profit. It thus reflects management’s hypothesis about what customers want, how they want it, and how the enterprise can organize to best meet those needs, get paid for doing so, and make a profit [13]. It answers managerial questions such as: “who is the customer?”, “what does the customer value?”, “how do we make money in this business?”, “what is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?” [8].

Then, this broad definition is sometimes detailed through the identification of the components of the business model, which can be grouped into three building blocks: value proposition, value creation & deliver, and value capture [14]. Another widely used framework to explain business model, developed by [15], categorizes a business model activities into nine blocks, which is known as the Business Model Canvas (BMC). The detailed description of using a BMC is shown in Section 3.1. These two identifications of a business model are interrelated (Figure 5). First, the value proposition clarifies what value is embedded in the offerings of the firm. It includes the product/service offering, the customer segments, and their relationship with the business. Second, the value creation and delivery list the partners and channels through which value is produced and delivered. It includes the channels for how value is provided to customers, what key resources are needed to do so, what key activities should be conducted, and what key partnerships should be involved. Finally, the value capture is the bottom line of the business model - it translates the two dimensions in costs and revenue. Value capture describes the various revenue streams available to capture economic value through the provision of goods, services, or information. Thus, value plays a central role in business modelling, which in turn depicts the structure and activities in the value chain [16]. Comparing with the components of value proposition, value creation & delivery, and value capture, some researchers disintegrate a business model into customer value proposition, key resources, key processes, and profit formula [17]. They argue that customer value proposition is to help customers get an important job done, which means to solve a fundamental problem through the offering. Profit formula is to define how the created values could be transferred from customers' side to a company itself by considering revenue models and cost structures. Key resources and key processes describe the way of how to deliver the values to the targeted customers. To develop a good business model, one should not think about business models at all. Instead, a company should start by thinking about the opportunity to satisfy their customers. Following that, how the company could fulfill their customers' needs with profits comes into question. Different researchers may categorize the value chains in a business model in different ways by disintegrating them into interconnected and independent activities (Figure 5). However, they stand on a common ground which is the theory of values.

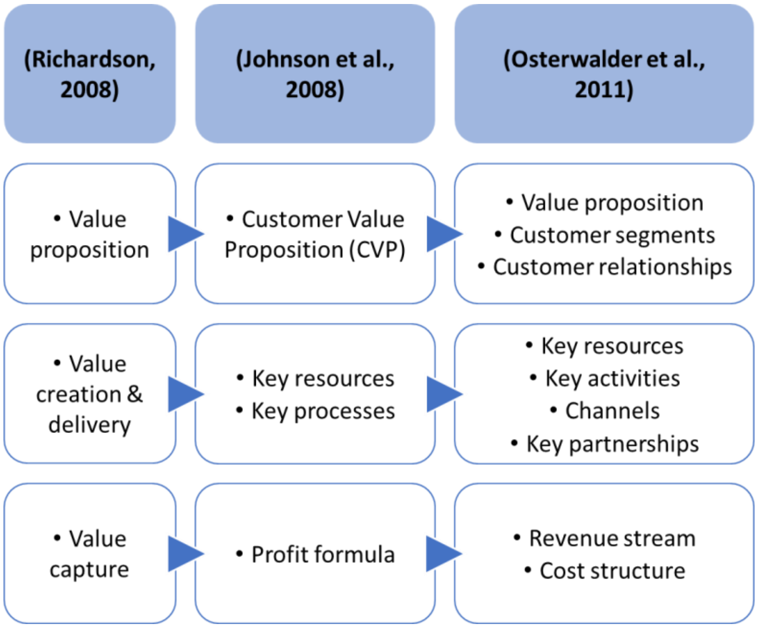

*Figure 5. Components of a business model [14] [17] [15].*

In essence, a business model is to show how a company makes a profit by transferring values. It identifies the products or services to sell, the target customers and markets, and the anticipated expenses and revenues. Some simplified questions, and a connection between value chain perspective and BMC perspective is shown in Table 3.

*Table 3. Simplified questions for a business model and categorizaiton based on value chain perspective.*

| **Simplified questions for a business model** | **From value chain perspective** |
|---|---|
| **Who invests?**<br>**Who owns?**<br>**Who operates?**<br>**Who sells?** | Set up a business: Investment, ownership, partnership, operation & maintenance, business owner, etc. |
| **Sells what?** | Value proposition |

| | |
|---|---|
| **Sells to whom?** | |
| **How to sell?** | Value creation & delivery |
| **Sells with what price, what cost, & benefit?** | Value capture |

## 2.2 Business models in DH & HP integrated systems

HP technology has been under continuous development. In Sweden, research and experimentation, involving important actors, providing subsidies and similar support schemes have promoted the deployment of HPs [18]. DH & HP integrated system increase the flexibility and security of heat supply by shifting heating loads and electricity consumption. Current business models in Swedish DH sector are product oriented. That is the DH companies sell heat directly to customers (property owners or tenants) and get paid per kWh at delivery. This business model could no longer meet the new needs of more flexible demand and supply for DH & HP combined systems. When integrating resources like HPs owned by building-owners into the DH system, DH companies need to develop additional elements of their business models. However, such a business model should ensure the use of flexibility is economically attractive and technologically feasible to use flexibility in a market-based manner.

Substantial amount of literature have made attempts to develop new business concepts and business models in DH & HP combination to capture flexibility [19] [20]. The term “prosumer” is employed to describe a customer who both uses and supplies energy [21]. In the context of DH & HP integrated system, a prosumer is a customer both consumes and produces heat, which could mean whose property is equipped with both DH and HP systems [22]. These prosumers are parts of a solution in smart energy systems through, for example, contributing to demand side management [23] [24]. The innovative ownership and operation of HPs are also discussed by introducing the third-party ownership concept or offering DH companies the right to control [25] [26]. The third party is typically a company that has a contractual agreement with the HP owner. By proposing a third-party ownership, a new actor “aggregator” is introduced which usually refers to a legal entity which is responsible for the operation of a number of demand facilities by demand aggregation [27]. Research has highlighted the involvement of aggregators in DH & HP integrated systems will enable more flexibility and more effective us of energy, meanwhile more cost savings [28]. In research [26], the authors propose a business model for DH & HP integrated systems, in which an aggregator hosts an end-user’s HP and end-user buys the heat directly from the aggregator. Furthermore, the aggregator buys electricity in the wholesale market for HP inputs and sells electrical load flexibility in ancillary market. This business model has explored a new ownership structure (i.e., the third-party ownership of HPs) and shown the economic viability in providing flexibility. In [29], the inclusion of the HP of a building into the fuel mix of a DH company is analyzed by shifting the boundary conditions between the parties.

Those attempts challenge conventional energy system designs and will constitute a paradigmatic change in business practices. The current product-oriented business logic, which predominantly focus on the amount of sold heat, need to be upgraded by a new lens of framework to incorporate flexibility provision. That also implies the need to explore new values from flexibility provisions to market actors.

## 2.3 Business models in DH & electricity coupling

The integration of electricity and DH sectors to utilize flexibility from demand responses has been widely investigated in recent years. Many researchers agree this sector coupling is proven to be efficient in terms of shaving the demand peaks [30] [31], enhancing the resilience of energy systems and integrating renewable sources [32] and reducing greenhouse gas (GHG) emission [33]. Some research such as [34] investigates the potential to make residential HPs participate in the ancillary market in Belgium. The results are very optimistic that the investigated 40,000 residential HPs could provide 70% of the current contracted number of upward reserves in winter at half of the price. Similar research [35] optimizes business economic design and operation of the DH plant against an external electricity market in Denmark. They also find positive impact of HPs. However, this research also point out the participation of residentials in ancillary market is not ready for implementation. One of the main reasons is the lack of business models.

Possible electricity market participation of HPs in DH networks also shows that HPs as flexible assets can improve profitability of DH networks, especially when participating on electricity markets. However, it is also highlighted that operators of often rural DH networks lack experience in the area of electricity markets. Additionally, the need for alternative financing models to cover the high upfront investment costs is discussed. Adequate business models are needed to promote the concept [36].

Some researchers have made the attempts to design business models for the DH sector to participate in both energy and reserve markets [37]. However, the proposed business model only considers solving a bi-level optimization problem of offering/bidding prices and quantities for DH systems. That neglects the complex layers of a business model such as different actors' interaction, business offer design and so on.

# 3 METHODOLOGICAL APPROACH

In the following, the methodological approach that is applied for the business model development is explained. The Business Model Canvas method is used for the business model development in both the Swedish and Austrian case and is therefore elaborated on in Section 3.1. The method of policy review is introduced in Section 3.2 to support business models development. In addition, the differing Austrian and Swedish approaches concerning the implementation of the new service are discussed in Sections 3.3 and 3.4, respectively.

## 3.1 Business model canvas

The so-called business model canvas (BMC) is an approach for the visualization of existing and the development of new business models. The method was introduced by Alexander Osterwalder and Yves Pigneur in 2005 and became widely known and used through the publication of their book *Business Model Generation* in 2011 [11]. The BMC consists of nine elements, namely the value proposition, customer segments, customer relationships, key partnerships, key activities, key resources, channels, cost structure, and revenue streams. Table 4 shows a template for the BMC method, which includes its nine elements as well as questions and sample characteristics that help fill out the different components. The value proposition is the most crucial component of a business model and should be the first to be elaborated on, because all other elements of a BMC are built upon it. It should answer questions such as what value is brought to the customer by the product or service, which of the customer's problems is the product/service helping to solve, or which customer needs are satisfied by the product/service. The building blocks of the BMC are the defining components of any business model and therefore, this approach is used in the here-presented case to outline the existing business models at the Swedish and Austrian demo sites.

A key benefit of the BMC method is that it is built around the value proposition visually and content-wise. As a result, it is kept in focus during the elaboration of the other components of the business model. Other advantages of using the BMC method include that it gives a quick overview of the business model, usually on a single page, and interdependencies between its elements can easily be identified. Through that, the BMC method is a way to make the business model more tangible, also because it splits it into the nine elements. Furthermore, the BMC facilitates collaboration on the business model because multiple people can contribute to the different elements, for example through using post-it notes. This also allows for more productivity, since simultaneous work on the BMC elements is possible, as well as a common understanding of the business model at hand within a team.

Even so, the BMC approach is not ideally suited for conducting business model innovation, since the nine elements can become quite confusing and they do not directly convey the core pillars of the business model, where innovation should take place. For that reason, a different approach is used for the innovation of the existing business models in this project, namely the Odyssey 3.14 method by HEC Paris [38] in the Austrian demo case and the servitization approach in the Swedish case [39].

*Table 4. Template with relevant questions for the BMC approach* [40].

<table>
<tr><th colspan="6">Business Model Canvas</th></tr>
<tr>
<td rowspan="2"><b>Key Partners</b><br>Who are our Key Partners? Who are our key suppliers? Which Key Resources are we acquiring from partners? Which Key Activities do partners perform?<br>MOTIVATIONS FOR PARTNERSHIPS: Optimization and economy, Reduction of risk and uncertainty, Acquisition of particular resources and activities</td>
<td><b>Key Activities</b><br>What Key Activities do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue streams?<br>CATEGORIES: Production, Problem Solving, Platform/Network</td>
<td colspan="2" rowspan="2"><b>Value Propositions</b><br>What value do we deliver to the customer? Which one of our customer's problems are we helping to solve? What bundles of products and services are we offering to each Customer Segment? Which customer needs are we satisfying?<br>CHARACTERISTICS: Newness, Performance, Customization, "Getting the Job Done", Design, Brand/Status, Price, Cost Reduction, Risk Reduction, Accessibility, Convenience/Usability</td>
<td><b>Customer Relationships</b><br>What type of relationship does each of our Customer Segments expect us to establish and maintain with them? Which ones have we established? How are they integrated with the rest of our business model? How costly are they?</td>
<td rowspan="2"><b>Customer Segments</b><br>For whom are we creating value? Who are our most important customers? Is our customer base a Mass Market, Niche Market, Segmented, Diversified, Multi-sided Platform</td>
</tr>
<tr>
<td><b>Key Resources</b><br>What Key Resources do our Value Propositions require? Our Distribution Channels? Customer Relationships Revenue Streams?<br>TYPES OF RESOURCES: Physical, Intellectual (brand patents, copyrights, data), Human, Financial</td>
<td><b>Channels</b><br>Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-efficient? How are we integrating them with customer routines?</td>
</tr>
<tr>
<td colspan="3"><b>Cost Structure</b><br>What are the most important costs inherent in our business model? Which Key Resources are most expensive? Which Key Activities are most expensive?<br>IS YOUR BUSINESS MORE: Cost Driven (leanest cost structure, low price value proposition, maximum automation, extensive outsourcing), Value Driven (focused on value creation, premium value proposition).</td>
<td colspan="3"><b>Revenue Streams</b><br>For what value are our customers really willing to pay? For what do they currently pay? How are they currently paying? How would they prefer to pay? How much does each Revenue Stream contribute to overall revenues?<br>TYPES: Asset sale, Usage fee, Subscription Fees, Lending/Renting/Leasing, Licensing, Brokerage fees, Advertising<br>FIXED PRICING: List Price, Product feature dependent, Customer segment dependent, Volume dependent</td>
</tr>
</table>

| | |
|---|---|
| SAMPLE CHARACTERISTICS: Fixed Costs (salaries, rents, utilities), Variable costs, Economies of scale, Economies of scope | DYNAMIC PRICING: Negotiation (bargaining), Yield Management, Real-time-Market |
| Designed by: The Business Model Foundry (www.businessmodelgeneration.com/canvas). Word implementation by: Neos Chronos Limited (https://neoschronos.com). License: CC BY-SA 3.0 | |

## 3.2 Policy review

As an important aspect of business model development or innovation, the legal and regulatory framework needs to be examined to ensure applicability of the developed services. For this, relevant legal documents are analyzed. EU policy, such as the Clean Energy Package and the European Green Deal, as well as Austrian and Swedish legislation (energy strategies, laws, and regulations) are examined. The national policies include, amongst others, the Austrian Climate and Energy Strategy, Austria's Integrated National Energy and Climate Plan, the Austrian Government's Program of 2020, the Green Electricity Act, the Renewable Expansion Act, the Heating and Cooling Pipeline Expansion Act, the Price Act, The Heating and Cooling Costs Settlement Act and the Consumer Protection Act. For the Sweden-specific policy review, legislation such as the District Heating Act, the Municipal Act, the Planning and Buildings Act and the Environmental Code were examined.

In a following step, regulatory barriers are identified which form the basis for the business model innovation process and recommendations for action. The policy review process is shown in Figure 6.

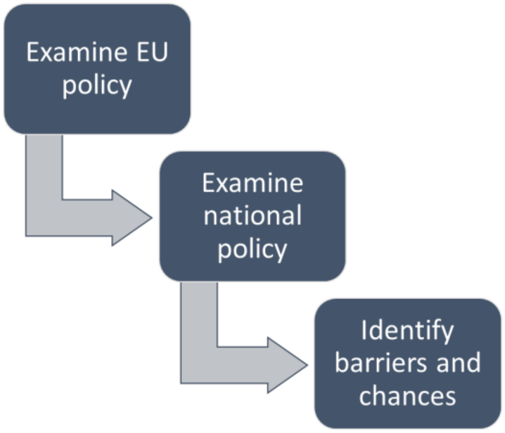

*Figure 6. Policy review process as basis for the business model development and innovation of the service.*

## 3.3 Austrian approach

For the business model innovation of the DH utility company of the Austrian demo site, a gradual approach is adopted. The legal and regulatory feasibility of the developed use cases is examined (Section 3.2) and the profitability of different additional flexibility measures is determined (see Section 3.3.1). As a following step, different tools for the actual business model innovation are considered (Section 3.3.2).

### 3.3.1 Profitability of flexibility measures for the utility company

To guarantee applicability of the developed business models, profitability of the flexibility-providing measures needs to be ensured. For this, a cost-optimization model with the objective of maximizing profits is developed specifically for the Austrian DH demo site of Maria Laach. Flexibility measures such as Demand-side Management (DSM) (usage of customers' buildings as thermal storages), the expansion of the central heat generation facilities, utilization of the existing central thermal storage tank and additional electricity market participation are evaluated. The parameters of the DH network (status quo and additional installations) are depicted in Table 10 in Appendix A.

Various use cases have been investigated with the developed optimization model and can be seen in Table 5. Thereby, demand side flexibility as utilization of the thermal storage mass of the buildings connected to the DH network is evaluated (see last column). Furthermore, the installation of additional components (HP and CHP) and their operation with different support mechanisms (feed-in tariffs (FiTs) and investment support for the additional generation components) is considered. In a further step, the electricity market participation of the additional components on DA and balancing markets (BL, aFRR[1]) as a supplementary flexibility measure is evaluated. To validate the electricity market participation, their operation is compared to that with a fixed tariff based on the average DA price ("Avg. DA tariff").

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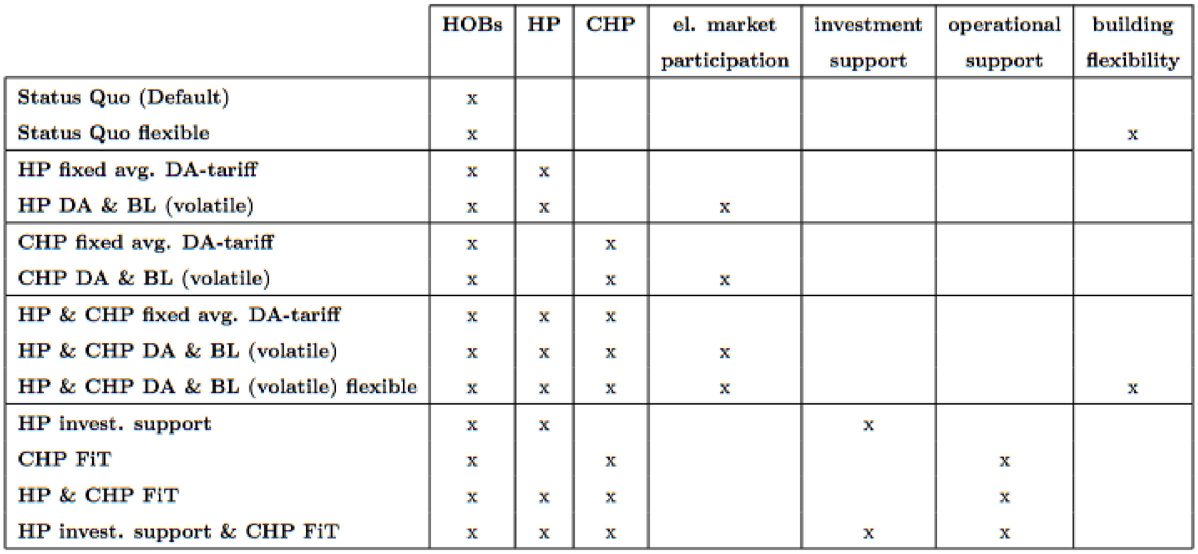
[1] Automated Frequency Restoration Reserve, formerly known as secondary reserve

*Table 5. Overview of the considered use cases for the Austrian DH demo site.*



| | HOBs | HP | CHP | el. market participation | investment support | operational support | building flexibility |
|---|---|---|---|---|---|---|---|
| Status Quo (Default) | x | | | | | | |
| Status Quo flexible | x | | | | | | x |
| HP fixed avg. DA-tariff | x | x | | | | | |
| HP DA & BL (volatile) | x | x | | x | | | |
| CHP fixed avg. DA-tariff | x | | x | | | | |
| CHP DA & BL (volatile) | x | | x | x | | | |
| HP & CHP fixed avg. DA-tariff | x | x | x | | | | |
| HP & CHP DA & BL (volatile) | x | x | x | x | | | |
| HP & CHP DA & BL (volatile) flexible | x | x | x | x | | | x |
| HP invest. support | x | x | | | x | | |
| CHP FiT | x | | x | | | x | |
| HP & CHP FiT | x | x | x | | | x | |
| HP invest. support & CHP FiT | x | x | x | | x | x | |

### Status Quo

In the Status Quo use case, the DH network includes two HOBs and is equipped with a central storage tank which already serves as a flexibility measure for the network. The use case depicts the status quo of the currently existing DH demo network in Austria. Profitability as net revenue for the utility is examined.

### Additional generation technologies and possible market participation as flexibility options

As additional flexibility, supplementary generation technologies (HP and/or CHP) are investigated within the optimization. Thereby and as a first step, the HP is powered by electricity from the grid with a fixed electricity tariff (as an average DA market price of 4.58 ct/kWh for 2018) and the CHP has a fixed FiT.

These fixed tariffs are compared to electricity market participation on Day-Ahead and balancing markets (aFRR). Thereby, the electricity to power the HP can be bought on the DA market and negative balancing energy can be provided, whereas the electricity that is generated by the CHP can be sold on the DA market or positive balancing services can be offered. In comparison to fixed electricity tariffs for the additional generation components, flexible heat demand of 6 of the connected buildings is investigated as well for these use cases.

### Additional generation technologies and investment/operational support

Furthermore, a subsidized FiT for the CHP and/or investment support for the HP are investigated. For the FiT of the CHP, a tariff of 18.97 ct/kWh is used[2], whereas for the investment support of the HP, 20% funding of the investment costs is assumed (see Appendix A).

### Building flexibility

To evaluate economic viability of using the thermal mass of 6 of the 35 connected buildings as a storage, further use cases are depicted. In comparison to a static heat demand of the buildings, within the "flex" use cases, heat demand of 6 connected buildings (42% of the total heat demand within the network) can be shifted in time. This measure can be used for heat load peak-shifting or to enable a more flexible electricity trade within the market participation use cases.

### Profitability

For all use cases, the profitability as net revenues ($R_{net}$) for the utility company – considering operational costs (fuel, startup, maintenance) ($OPEX$), investment costs (as annuities) ($A_{CAPEX}$) and income (heat and partly electricity sale) ($R_{heat} + R_{electricity}$) – is determined for one year.

$$R_{net} = R_{heat} + R_{electricity} - A_{CAPEX} - OPEX$$

The operational and investment costs and income parameters have been assumed, whereas data is taken from the DH demo site and the project heat portfolio [41] (see Table 11 in Appendix A).

This profitability analysis forms the basis for the further business model innovation at the Austrian demo site, whereas new possibilities to generate income are elaborated for the utility and are explained in detail in the following section. Overall profitability of the use cases for the utility is important, however, the BMC can as a following approach define how this revenue and cost streams can be embedded within a company structure.

### 3.3.2 Business model innovation

In addition to the BMC method explained in Section 3.1, the Odyssey 3.14 approach is applied to reinvent the current business model through the integration of flexibility measures. The current business model is to be innovated, as the components are already close to the end of their service life and coupling with the power system can offer further flexibility, security of supply, grid stability and additional sources of income. In the following,

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[2] Thereby, the tariff of 18.97 ct/kWh constitutes the subsidized FiT for biogas CHPs in Austria for the year 2018.

the characteristics of this Odyssey 3.14 method for business model innovation and its advantages are discussed.

The Odyssey 3.14 approach was developed at HEC Paris by Laurence Lehmann-Ortega, Hélène Musikas, and Jean-Marc Schoettl and is especially useful for business model description and the innovation of an existing business model. They published the approach through a Coursera course [42] as well as in their book *(Re)invent your business model: With the Odyssée 3.14 method* [38] in 2022. The Odyssey 3.14 method is based on the BMC, but it combines the nine elements of the BMC into three focus points: the value proposition, the value architecture, and the profit equation, as illustrated in Figure 7. The reason for this simplification is that the creators find it more understandable and less overwhelming than the BMC. In addition, they endorse using a top-down approach for business model development and innovation, which is facilitated by first focusing on the three most important pillars of the business model and then working out the details from them. Furthermore, the different aspects of the business model turn out to be more harmonized when first experimenting with and finally defining the three main aspects of the business model, according to them. Another difference of the Odyssey 3.14 approach and the BMC method is that in the former, the profit equation does not only consider the costs and revenues, but also the so-called capital employed, which is a company's working capital as well as the assets it needs for its operation. The creators of the Odyssey 3.14 approach believe that the capital employed significantly impacts the cost structure in a business model, which is the reason for adding it [38], [42].

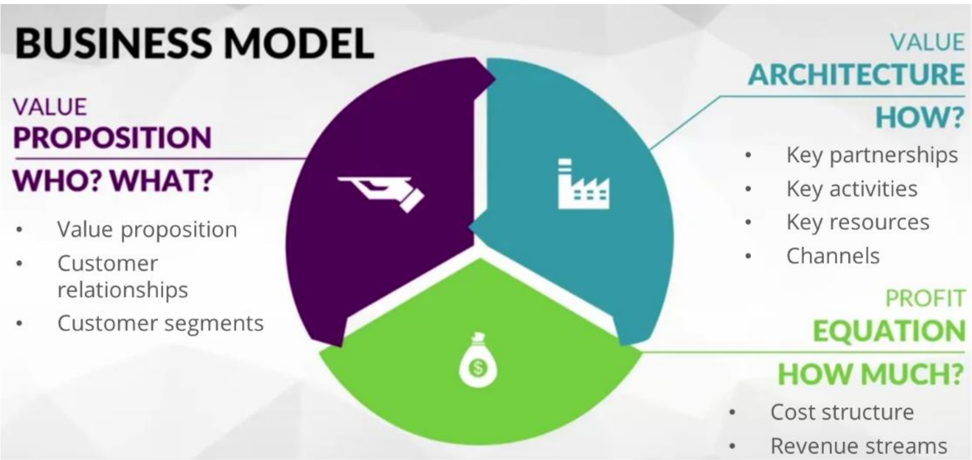


*Figure 7. Illustration of the Odyssey 3.14 approach, showing which elements of the BMC translate to which pillars of the Odyssey 3.14 method [42].*

The components of the Odyssey 3.14 method can furthermore be supplemented by the so-called value curve and value chain. The former illustrates the value attributes of the proposed innovated business model and the level of offer for each of them, i. e., how much of each value attribute is offered by the suggested innovation. The latter has the capacity to visualize the value architecture of a business model by showing the set of activities that a business has to execute for the market delivery of its products or services. The concept of the value curve originates from the book *Blue Ocean Strategy* [43] by W. Chan Kim and Renee Mauborgne, while the value chain and its use in business model development was introduced by Michael Porter in his book *Competitive Advantage, Creating and Sustaining Superior Performance* [44].

In the here-presented case, a combination of the Odyssey 3.14 approach and the BMC method is applied to conduct business model innovation, thereby uniting the benefits of both approaches. In a first step, the current business model is displayed in a BMC template. After that, it is innovated by using the Odyssey 3.14 method. As a last step, the innovated business models are translated back to a BMC template. This approach makes it possible to directly compare the current and the innovated business models and facilitates the identification of the modifications that were made in the new business models.

As a further step to reinventing the business model, the developed business models are validated. This validation is conducted via stakeholder workshops and questionnaires. One workshop is organized with local stakeholders at the DH demo site, another workshop is arranged with operators, manufacturers, service companies, and researchers, and another group meeting of a biomass association is used to receive valuable input. Furthermore, questionnaires (during and detached from the workshops) complete the validation. The results of the consultations are included in the developed business models.

## 3.4 Swedish approach

### 3.4.1 The servitization in business models

The servitization concept emerged from manufacturing industry when a shift from selling products to providing solutions occurred. It is featured by the addition of service elements in the business models [45]. Therefore, the value propositions, which is the core of a business model, of a servitized company transform to user-oriented and result-oriented and create advanced forms of market relations [46]. This is in line with the findings of Alvarez et al., who highlighted the relationships among stakeholders in the value chain by perceiving servitization as an evolutionary process [47]. Basically, all components of a business model is challenged by servitization [45]. Annarelli et al. summarized the four criteria for an organization’s servitization level, in which the relationship based value basis of activities instead of transactional based, asset utilization instead of asset ownership, total service integration instead of physical product plus extra services, and mass customization instead of mass production are considered at higher servitization levels [48].

In energy sector, the process of servitization is ongoing as well. Many companies have made valuable attempts to add advanced services to their product offering or sell the usage or performance of their product. This is a strategic organizational transformation in a way that it requires fundamental changes in viewing value propositions, value creation and delivery, and value capture in business practices. Especially, the transformation of multiple service offering and the relationship with customers is important to acknowledge. Much trial-and-error learning is needed to explore this new path. To explain different levels of complexity in servitization process, the servitization pyramid model is employed [39] (Figure 8). On the horizontal dimension of this model, the distinction between product focus and customer process focus is made. On the vertical dimension, we borrow three types of value propositions from manufacturers offerings: providing customers with a certain input, a performance agreement, or a guaranteed result. They oriented towards customers "who want to do it themselves", "who want us to do it with them" and "who want us to do it for them" respectively [49]. In district energy sector, all value offerings could be categorized in this servitization pyramid [19].

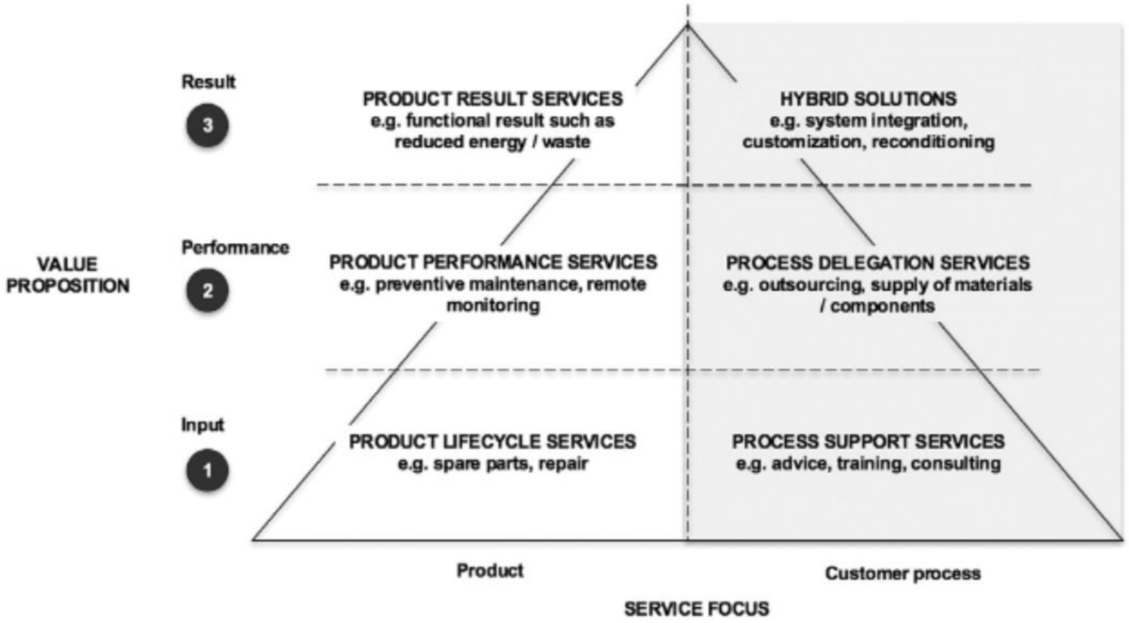


*Figure 8. The servitizaiton pyramid [39].*

# 4 POLICY ANALYSIS AND REGULATORY FRAMEWORK

DH plays a vital role in contributing to the decarbonization goals. Both the EU, as well as national and local policies set the framework for this development. In the following, the most relevant policies are outlined and barriers, especially for the implementation of flexibility and sector coupling, are discussed. The policy analysis is crucial for the development and innovation of business models in the DH sector, since the legal framework can either hamper or enhance further development of business models.

## 4.1 EU legislation

In 2016, the EU formulated its *Heating and Cooling Strategy*. It identifies areas where policy adaption is crucial to deliver for the *Energy Union* goals from 2015, which are security of supply, sustainability, and competitiveness [50]. It aims at decarbonizing highly fossil-fuel dependent DH networks, as well as also highlights the importance of linking heating and cooling to the electricity sector [51]. The Energy Union goals set the basis for the direction of DH business models, whereas supply-security and the inclusion of renewable energy sources is the focus. However, DH in the EU, and in Austria and Sweden in particular, is not operated in a highly competitive manner. This is due to DH systems constituting natural monopolies.

The *Clean Energy for all Europeans package* (2018/2019) consists of 8 legislative acts and overhauled the overall EU energy policy framework. The *Renewable Energy Directive*, the *Energy Efficiency Directive* and the *Energy performance in buildings Directive* set directions for sustainable heating, whereas the *Electricity Market Directive* and the *Electricity Market Regulation* set out consumer empowerment in the electricity sector [52].

The *European Green Deal*, published at the end of 2019, aims at transforming all sectors to reach carbon neutrality by 2050 [53]. It puts pressure on DH systems that include heat generation from fossil fuels and enhances investments in renewable generation. As part of the European Green Deal, the *EU strategy for energy system integration* came into place (July 2020) which aims for a more circular economy and sets out the goal to increase biomass utilization and accelerate the use of renewable electricity [54]. To meet GHG reduction target, the EU published its *Fit for 55 package*. [55]. It also proposes to further amend, among others, the *Energy Efficiency Directive* and the *Renewable Energy Directive* to meet the targeted goals.

The draft of the Renewable Energy Directive (RED III), aims at making EU energy systems more flexible, making it easier to integrate renewables [56]. It also provides sustainability criteria for bioenergy, which can have major impact on current DH networks. The aim is to prevent distortions in the commodity market and damage to biodiversity caused by bioenergy. The draft provides for the introduction of the cascade principle for woody biomass, which stipulates that wood is to be used for (1) wood products, which are to be (2) extended in their useful life, (3) re-used, (4) recycled and only then made available for (5) bioenergy use before they are (6) disposed. This draft therefore puts pressure on biomass-based DH networks and could stipulate a shift in generation technologies and fuel utilization. In addition, the draft proposes that pure electricity generation from biomass is no longer to be subsidized in the EU from 2026. GHG minimization is also planned for biomass plants.

In the EU, approximately 52% of DH is used for space heating, 30% for process heating and 10% for domestic hot water. The average percentage of residential heat supply from DH was 24.5% in 2018 [57]. A member state comparison of DH usage in the EU member states is displayed in Figure 9.

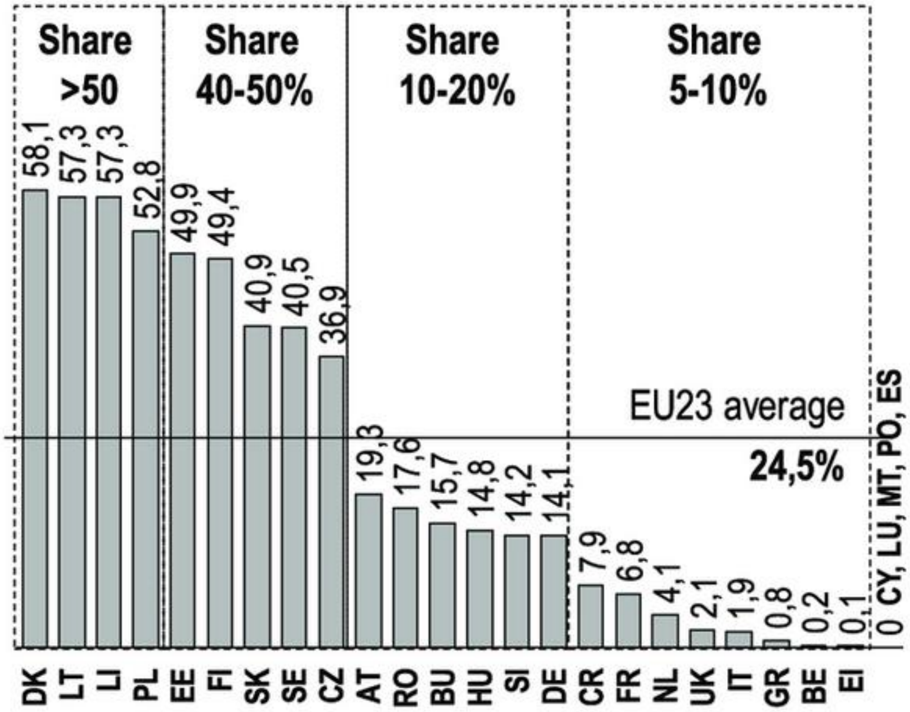


*Figure 9. Share of residential DH supply in EU countries [57].*

The technology generation mix for DH in Austria and Sweden can be seen in Figure 10. Sweden has a higher share in renewable CHP production and less fossil-based production within the DH sector [58] [59] [60].

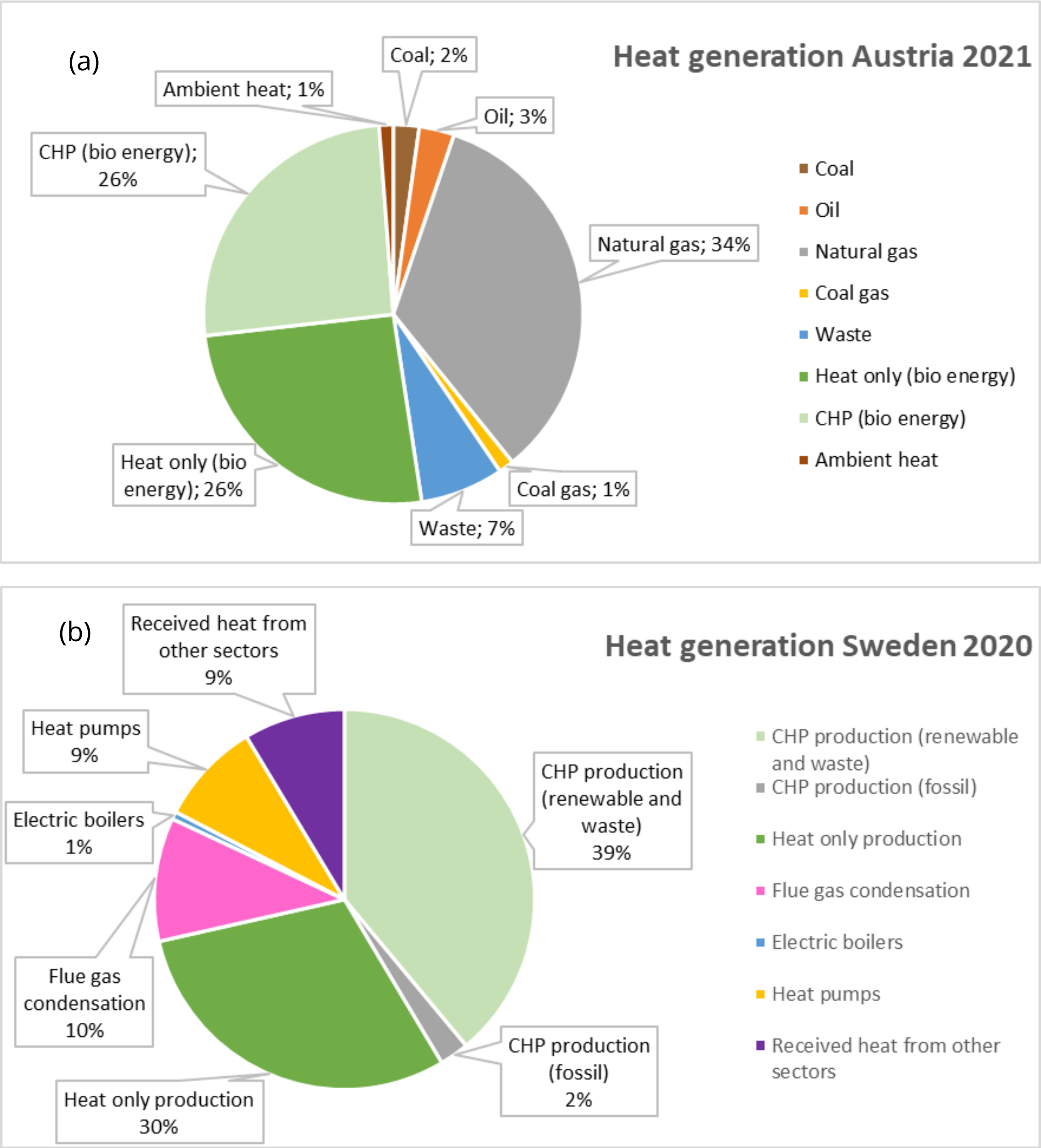


*Figure 10. Share of generated energy for DH in Austria (2021) (a) and Sweden (2020) (b) [58] [59] [60].*

Currently, biomass for energy remains to be the main renewable energy source in the EU with a share of nearly 60%. Heating and cooling constitute the biggest sector, using 75% of all bioenergy. Thereby, forest products remain the main source of biomass (logging residues, wood-processing residues, fuelwood, etc.). In 2018, 49% of biomass for heating in the EU was used in the residential sector and 17% for DH. However, 79% of energy sources used for heating and cooling in the EU still came from fossil fuels. Nevertheless, the market for biomass has been growing by 3% yearly since 2000 [61] [62]. The ongoing development of EU policies show a trend of utilizing renewable energy sources for DH, whereas woody biomass might only be used for energy generation as their second life application. Additionally, sector coupling is a focus, enhancing the development of business models in that direction.

## 4.2 Austrian legislation

In Austria, 30 % of the total final energy consumption is used for heating (including warm water and air conditioning). The market share of (local) DH in Austria's total heating demand (including warm water) was about 24 % in 2015 and has roughly tripled since 1990. The use of highly efficient CHP plants for DH in urban areas has succeeded in significantly reducing Austria's $CO_2$ emissions. However, currently, these plants are under severe economic pressure due to the development of gas and electricity prices [63]. Austria is one of the largest bioenergy consumers per capita in the EU [61]. As of September 2021, more than one million households in Austria use DH, and around 50 of Austria's 100 largest cities are supplied with DH. According to calculations, around 50% more DH customers could be supplied by 2050 - provided that the right framework conditions continue to apply [64]. This constitutes a prosperous outlook for DH business. However, the current share of renewable energy in DH constitutes just nearly 50% in Austria [65]. Additionally, bioenergy is the biggest renewable energy sector in Austria with currently 53.10% [66].

In 2018, the *Austrian Climate and Energy Strategy* (#mission2030) was decided. To reduce the dependence on fossil fuels, biomass, solar thermal and ambient heat should be further expanded until 2030. The details are to still be defined in a national heat strategy together with the federal states of Austria. Additionally and according to the strategy, biomass should also play a vital role in the achievement of 100% renewable electricity [67].

Austria's *Integrated National Energy and Climate Plan* (*Ger. integrierter Nationaler Energie- und Klimaplan (NEKP)*) aims at, e.g., the successive displacement of fossil fuels by renewable forms of energy for heating, hot water and cooling and the expansion of agricultural and forestry bioenergy production [68] [69] [70].

The Austrian *Government's Program* of 2020 envisages climate neutrality for Austria earlier than targeted by the EU, already by 2040. This means that DH is foreseen to be fully decarbonized by 2040. The program also sets the target for 100% renewable electricity in 2030, for which measures are defined in the *Renewable Expansion Act* [71]. Furthermore, concerning heating of buildings, oil and coal heating systems shall be forbidden for new buildings by 2020 and forbidden when changing the heating system in existing buildings by 2021. Furthermore, there will be a compulsory replacement of oil and coal heating systems older than 25 years from 2025 and the replacement of all oil and coal heating systems by 2035 at the latest. From 2025, no gas heating systems will be allowed in new buildings [72]. The federal and state governments are currently negotiating a *Renewable Heat Act* (*Ger. Erneuerbares-Wärme Gesetz EWG*). This act shall guarantee a renewable heat supply in Austria by 2040 through a gradual phase-out of fossil energy, called *Austrian Heat Strategy* (*Ger. Österreichische Wärmestrategie*), whereas the current draft is depicted in Figure 11. Furthermore, it shall enable the expansion of DH systems in urban areas and trigger decarbonization. The cornerstones of reducing energy consumption in this sector consist of enhancing thermal-energetic refurbishment, efficient use of energy for space heating and hot water and the establishment of cooling without or with low energy demand [73] [74].

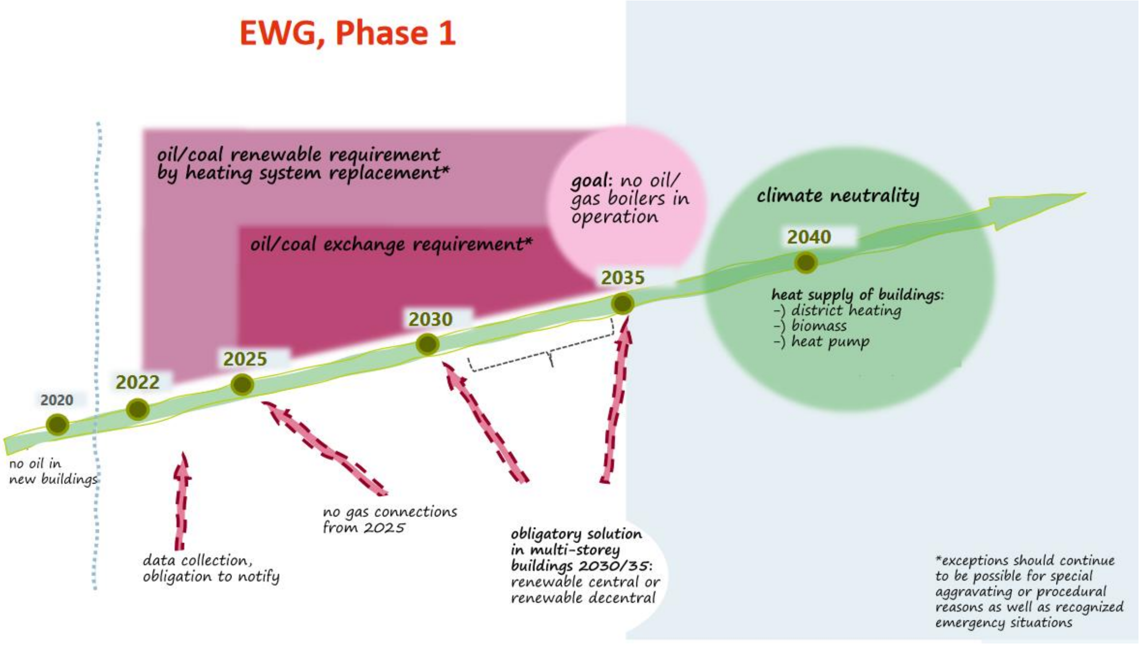


*Figure 11. Planned key points in the Austrian Renewable Heat Act (Ger. Erneuerbaren-Wärme Gesetz EWG), adapted from [73].*

This foreseen replacement of fossil-fueled (mostly decentral) heating systems is putting pressure on DH operators in terms of network densification and promotes the installation of new (renewable) DH systems. Furthermore, the aspect of low-energy buildings (new construction and refurbishments) is an important aspect, since current DH business models in Austria focus on delivering high temperature heat to customers.

The newly enacted *Renewable Expansion Act* (*Ger. Erneuerbaren-Ausbau-Gesetz EAG*, in force since July 2021) replaces the *Green Electricity Act* (*Ger. Ökostromgesetz ÖSG*) as the basic legal document for defining subsidies for all green electricity generation technologies, including biomass and biogas CHPs. Furthermore, the Renewable Expansion Act defines that operators of DH or district cooling plants with more than 250 customers or 3 GWh of heat sales per year must publish on their website at the end of each year a breakdown of the type of fuels they use in heating and CHP plants as well as the share of waste heat or cooling fed into the grid [75] [76]. This part of the law imposes a significant certification burden, but it also provides transparency regarding the extend of renewable energy inclusion in DH.

With the help of subsidies under the *Heating and Cooling Pipeline Expansion Act* (*Ger. Wärme- und Kälteleitungsausbaugesetz*), the expansion of the infrastructure is stimulated [63]. Amongst other key points, the act focuses on the integration of renewable energy sources for the expansion of small-scale regional heat supply in rural areas. This shall be achieved through promotion by means of investment subsidies. In this context, the additional expansion of heating and cooling networks may only be subsidized if the additional generation demonstrably leads to less use of primary energy sources and causes fewer $CO_2$ emissions. The subsidy amounts to a maximum of 35% of the total investment costs [77].

Support for DH systems and heat generation plants in general is an important driver for business innovations. However, the support regime needs to provide long-term stability and changing support mechanisms can hamper instead of trigger investments. The current funding possibilities for DH and generation plants for Austria are listed in Appendix B.

The DH prices for end-users are subject to the *Price Act* (*Ger. Preisgesetz*) in Austria. The law states that the Austrian Federal Minister of Economics and Labor may, by ordinance, lay down tariff principles and tariff structures to ensure that DH utilities operate in an economic, cost-oriented manner that is aimed at the best possible utilization of capacity [78]. The *Heating and Cooling Costs Settlement Act* (*Ger. Heiz- und Kältekostenabrechnungsgesetz*) additionally defines the allocation of heating (and cooling) costs in multi-apartment buildings. For the economical use of energy in buildings with at least four apartments that are supplied by a common supply system, the heating, hot water, and cooling costs are to be settled predominantly based on the actual consumption. Therefore, fixed costs should be calculated based on the respective heated areas in relation to the total area, whereas the variable costs are to be determined via calibrated meters [79]. In addition, DH contracts are, by their very nature, subject to the *Consumer Protection Act* (*Ger. Konsumentenschutzgesetz*), especially if consumers are private individuals. Therefore, it must be possible to terminate a DH contract after the first year [80] [81] [82]. These restrictions to price setting need to be considered by DH utilities. They significantly influence possible business models. However, as defined by the respective policies, DH pricing in Austria is not rigorously regulated and gives opportunity for new pricing mechanisms, e.g., for enhancing flexibility provision.

In addition to national regulations, federal state- and municipality-specific legal requirements also come into play. Especially spatial planning (*Ger. Raumordnung*) can make an important contribution to the use of sustainable heat generation systems. Within spatial planning, zoning (*Ger. Flächenwidmung*) is the basis for the generation and distribution of renewable energy. Vienna, for example, as a federal state, issues its own spatial energy plans (*Ger. Energieraumpläne*), which serve the sustainable development of energy provision and use of heating and hot water generation systems in Vienna (see Vienna Building Code [83]). Spatial energy planning is also seen to play a vital role in the Austrian Heat Strategy, especially for grid-bound energy sources such as DH. Both spatial planning and building regulations (*Ger. Bauordnungen*) are not the responsibility of the Austrian national government [84] [83].

Renewable heat generation within DH need to be enhanced in Austria, whereas the strong dependency on biomass, especially on boilers generating only heat, is to be questioned to guarantee business success. However, as can be seen in recent Austrian policies, biomass is still seen as a major energy resource for DH, although possible changes (as outlined within the EU draft on the Renewable Energy Directive) can be expected.

## 4.3 Swedish legislation

Currently, Sweden's energy policy is built upon three pillars: ecological sustainability, competitiveness, and security of supply, in line with the IEA and EU formulation of the energy trilemma. Concerning energy policy targets, Sweden aims for 100% renewable energy by 2040, no net GHG emissions by 2045, and a 50% more efficient use of energy by 2030. Sweden's share of renewables in all sectors surpassed the national goal of 50% and the EU RED's target of 49% already in 2013 and for heating and cooling, it reached 65% in 2018. [85]

### History of and drivers for DH in Sweden

The first DH systems in Sweden were established in the 1950s and more and more were added up to the 1990s, often in conjunction with newly built housing areas. In addition, the heavy expansion of nuclear energy in the 1970s and 1980s led to an increase in the use of electricity for heating in individual housing and in DH systems. The oil crisis in the 1970s and air quality concerns in cities represent other important drivers of the expansion of DH systems and the transition away from individual heating systems such as oil boilers. [85]

In more recent years, sustainability and efficiency concerns have been the strongest drivers for DH: After the nuclear power plant accident in Chernobyl in 1986, it was decided to phase out nuclear power in Sweden until 2010. In addition, investment programs for DH were established during that time. To foster the transition towards more sustainable energy systems, a carbon dioxide tax was introduced in Sweden in 1991. Furthermore, an environmental code as well as other environmental goals were also introduced in the 1990s. This led to the use of biomass instead of coal or peat as the primary energy source for DH. Moreover, Sweden joined the EU in 1995, which resulted in additional energy efficiency, renewables, and climate obligations. Additionally, some investment programs were replaced by green certificate schemes. [85]

After the economic slump in the early 1990s, the Swedish electricity and, as a consequence, also DH markets were deregulated in 1996. A contentious market design and the DH Act followed in 2008, which increased transparency and continued innovation. Furthermore, HP competition and the fossil fuel free targets were introduced at that time. [85], [86]

### Market shares

Because of the aforementioned drivers for DH implementation in Sweden, its market share for heat supply in residential and service sector buildings has continually increased since the 1950s, currently making up about 60%. Furthermore, HPs have emerged in the 1990s and their market share has continued to grow since then. The share of firewood and natural gas decreased until the late 1970s and has since then remained relatively stable. As opposed to that, the share of fuel oil has decreased since the oil crisis in the 1970s and the share of electric heating has decreased starting from the 1990s. [85]

Concerning the energy sources for Sweden's heat supply, biomass and waste heat currently dominate, while excess heat, ambient heat, fossil sources, electricity, recovered gases, and peat make up smaller shares. [85]

### Ownership models in the market

Currently, there are about 500 DH networks in Sweden. The market organization concerning the establishment of new networks is quite open, therefore there is a large array of ownership models for them. Even so, about 60% of DH networks in Sweden are still owned by municipal companies. The rest are owned by public, private, or state-owned companies or by joint ventures. [85]

### Regulatory framework

The most important regulatory framework document for DH in Sweden is the District Heating Act (SFS 2008:263), which was passed in 2008. Its main objective is more transparency concerning pricing and costs, a mediation of the same, and the clarification of the DH operators' responsibilities towards customers. These include topics such as minimum terms for customer agreements, provision for vulnerable customers, obligations relating to interruption in services, compensation, third party access, and reporting obligations [87], [85].

The DH Act is based on a 2005 report on DH by the District Heating Commission, which was in operation between 2002 and 2005, called “District heating and cogeneration in the future” (SOU 2005:33). Within it, among others, matters such as a discussion of the advantages and disadvantages of third-party access to DH networks and a reevaluation of the concession obligations for building and using pipes for the transport of DH were attended to. The findings of the evaluations within the report resulted in the following recommendations, among others: No introduction of third parties except for the use of surplus heat, such as industrial waste heat and heat from refuse incineration; removal of the concession obligation for DH pipes; and possible exemption from the municipal siting principle in the Local Government Act, which comprises DH operation beyond the municipal boundaries, if the municipality’s goal is to achieve a more efficient DH operation. The Swedish government adopted these proposals in the 2008 DH Act [87].

In addition to the DH Act, other regulations such as the Municipal Act, which regulates DH network operation as part of a municipality’s activities, the Planning and Buildings Act, the Environmental Code, and multiple EU regulations exist [87], [85].

### Institutional setup

The Energy Markets Inspectorate is the regulator for electricity and natural gas markets in Sweden, but they are also responsible for the DH market. Their main task is to ensure the DH network companies’ compliance with the DH Act. In addition, they monitor the development of the DH market and if necessary, recommend regulatory changes. However, they do not attend to DH prices. Furthermore, since DH companies are natural monopolies in their area of operation, the Swedish Competition Authority is responsible for preventing abuse of dominant position. Moreover, the DH industry has a self-regulatory program via the District Heating Board, called the Price Dialogue, where DH operators and customers negotiate prices and condition. Even so, no binding decisions for either party can be made this way. In addition, there is an industry association, which represents companies that produce, distribute, sell, and store electricity, heat, and cooling, called the association for energy companies in Sweden [85], [87].

### Policy-based incentives for DH

To incentivize DH, the government in Sweden has implemented an array of policy measures to support DH and its transition towards more sustainability. One of the most important of these policy measures is the taxation of energy and carbon, which has proven to be successful in transforming the markets towards more renewables and a more efficient use of energy. The carbon tax in Sweden, which was already established in 1991, was widely accepted by the population. The reason for their acceptance of this tax is, that a so-called “green tax shift” was implemented simultaneously. This comprised lowering the tax on income while establishing the carbon tax. In addition, investment grants for biobased CHP and conversion grants for property owners to transition away from oil and electric heating have also been strong drivers towards more DH implementation and sustainability. Furthermore, Sweden’s Landfill Ban resulted in less than one percent of remissible waste in its landfills and the creation of close to 40 waste incineration plants coupled to DH [85].

# 5 BUSINESS MODEL DEVELOPMENT

To enable the usage of flexibilities and push energy-as-a-service in the DH sector, new business models need to be developed and existing ones need to be innovated. The following Sections highlights the results of the business model development/innovation for the DH demo cases of Austria and Sweden.

## 5.1 Austria

In the following, profitability of flexibilization measures within the DH network of Maria Laach in Austria is presented, on which the business model adaptations are rooted (see Section 5.1.1). The business model adaptations are further validated by stakeholders through involvement in workshops and questionnaires. The results of the business model innovation process and the validations thereof are presented in Section 5.1.2.

### 5.1.1 Profitability of DH network demo site

Based on a developed cost optimization tool for Austria, profitability of different flexibility measures within the DH network for the year 2018 is investigated. Here, the main results that are of relevance to the business model adaptations are outlined.

**Additional generation technologies and possible market participation as flexibility options**

Results for the analysis of the year 2018 show that the flexibility measure of including central CHPs and HPs as additional generation components is profitable for some cases. The most profitable case constitutes the installation of both a CHP and a HP unit within the existing DH network of HOBs (and a central storage tank), by including investment and/or operational support for the additional generation technologies. However, it can be shown that the use cases of electricity market participation prove to increase revenues (in comparison to a fixed average DA tariff of 4.58 ct/kWh). This comparison to a flat energy tariff for electricity purchase (for the HP) and sale (for the CHP) – as would be typical for contracts with an electricity supplier – shows that market participation is economically viable. Figure 12 shows profitability of the different examined use cases for an additional HP, CHP or a combined HP & CHP installation and for the use cases considering support mechanisms. It can be seen that the cases including operational or investment support for the additional generation technologies are most profitable. It needs to be stated that the newly enacted support mechanism of market premiums in Austria (expected to be in operation in Q4 2022) actually enables electricity market participation while receiving support, which constitutes a profitable business model outlook for the future.

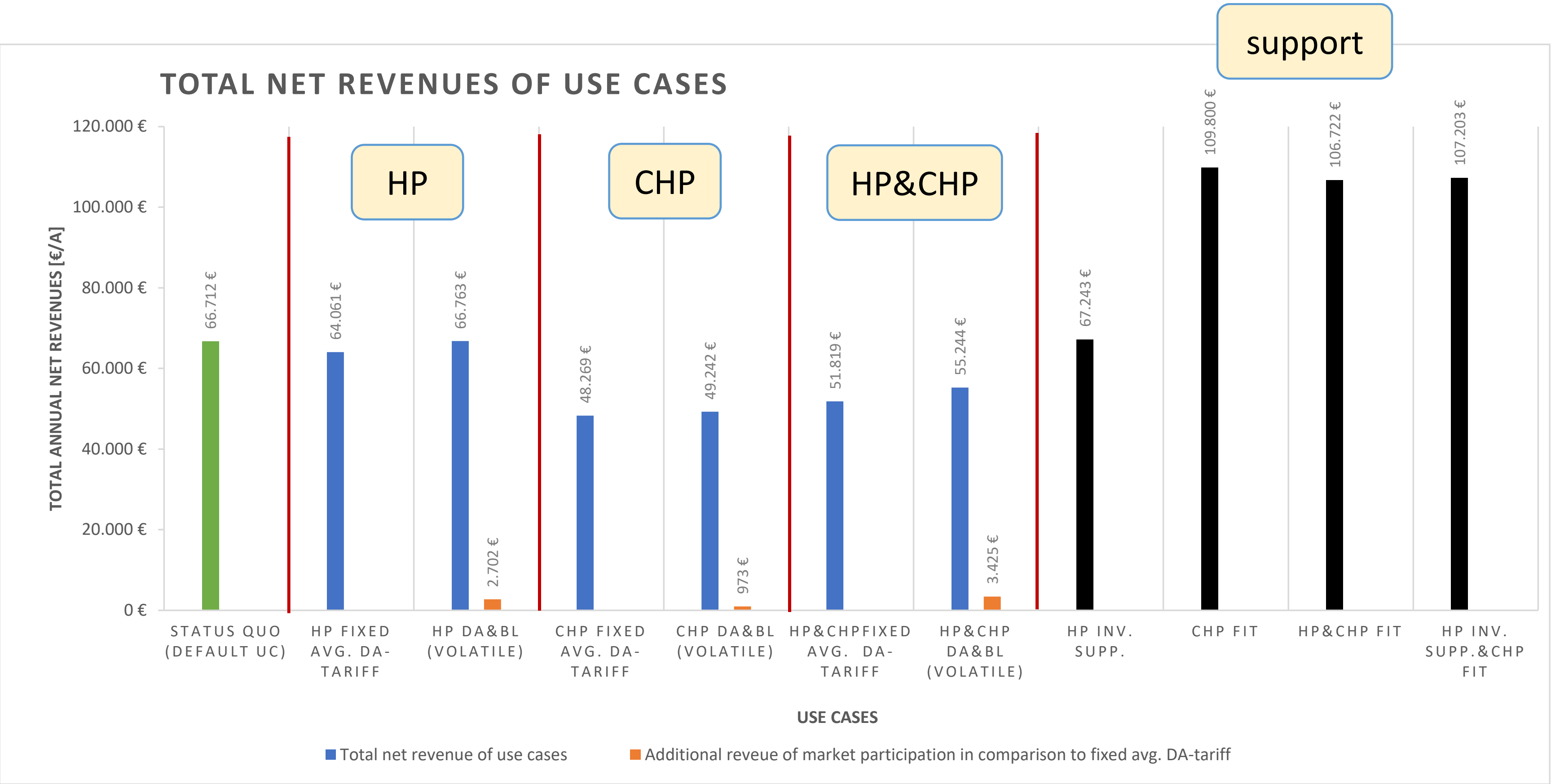


*Figure 12. Annual net revenue of electricity market participation for al central CHP and HP in addition to the existing HOBs in the Austrian demo DH network.*

## Building flexibility

Furthermore, the value of building flexibility (using the thermal mass of 6 of the connected 30 buildings as storage mass) is examined. Results show that for the Status Quo use case of HOBs only, 5% of the total heat demand in the DH network could be shifted in time by peak-shifting. This DSM measure can reduce heat load peaks and therefore save startup costs (of e.g., additional generation components) and improve efficiency. Figure 13 shows a heat load profile for buildings in case without and with the DSM measure for the first week of January. Within this period the maximum hourly peak load of 2211 kW without shifting could be reduced by 26% with peak-shifting. Concerning revenues, only approximately 2% of additional income can be generated in the Status Quo use case through building flexibility in six buildings. This rather low value of revenue increase results from the already existing central storage tank within the DH system. However, it needs to be stated that for DH networks without existing thermal storage tanks, the usage of building flexibility is assumed to be more profitable. Additionally, when considering network densification, flexibility from the thermal storage mass of buildings can be economically viable.

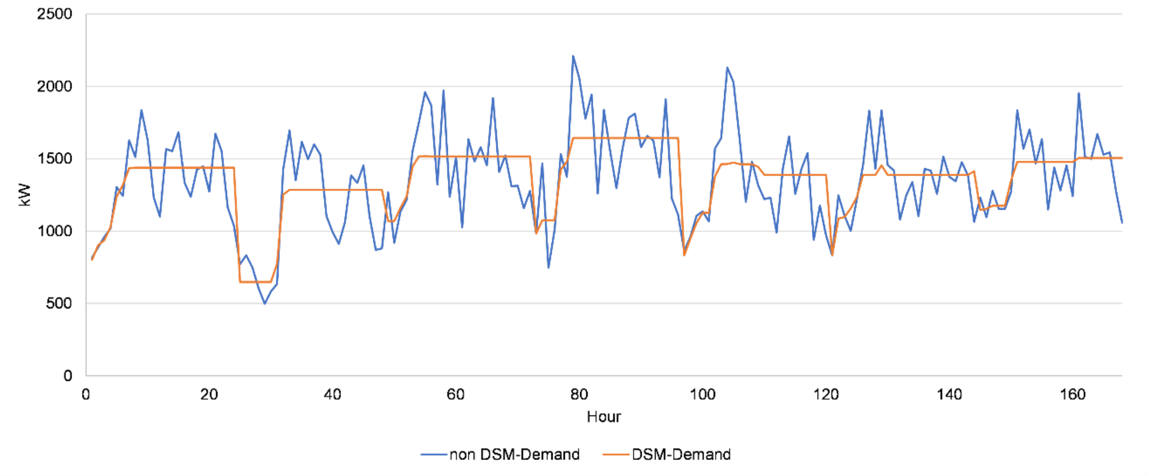


*Figure 13. Hourly heat load of flexible buildings with and without peak shaving as a DSM measure for the first week of January.*

## Input of profitability analysis for business model adaptations

The results from the profitability analysis are used as input for the following business model adaptation process. Thereby, the profitability analysis shows that the installation of additional central generation components (e.g., a CHP and HP) can be profitable, as well as their electricity market participation (at least in limited cases). Furthermore, DSM measures within the connected buildings (usage of the thermal storage mass) is especially profitable for DH networks not already equipped with a lot of flexibility options – as it is the case in the Austrian demo, where a central storage tank and two HOBs already exist.

### 5.1.2 Business model adaptations

As explained in Section 3.3, the Odyssey 3.14 method is used to innovate the current business model.

Table 6 illustrates how it is applied by summarizing sample questions that are explored to make adaptions to the current business model. Two new business models are developed this way and the results of the profitability analysis form their basis. To illustrate where the current business model was innovated, the new business models are moreover re-translated into the components of the BMC and displayed together with the current business model. Through that, it becomes obvious where changes or additions to the current business model were made. As a further step, inputs collected during two stakeholder workshops are discussed to validate the new business models.

*Table 6. Selected questions from the Odyssey 3.14 approach that are explored to innovate the existing business model.*

| | Direction | Question | Ideas |
|---|---|---|---|
| **Selected questions from value proposition side** | 1 | Can you pare down your offer in such a way as to lower your costs and therefore, the price for the client? | Additional electricity generation could reduce heat costs, a combined product (heat and electricity) or flexibility measures (DSM) could reduce costs. |
| | 2 | Which products or services do clients use in addition to your own? What are the complications your clients come across whilst using your products or services? | Electricity could be offered (energy community or as ESCo), wood (e.g., for tiled stoves). Some potential customers are outside the supply area (could heat with local electricity); a reduction of high heating costs reduction could be accomplished by flexible tariffs (heat and/or electricity). |
| | 4 | Is your product or service essentially functional or emotional? | Functional and emotional product/service. Sustainable value creation from region. |
| | 6 | Could you identify other stakeholders that could be interested by a contact with your current customers? | Interested stakeholders: Utility companies, telephone and internet providers, installers. |
| | 7 | Could you invoice your clients differently?<br>Does your offer allow your clients to save or generate income? | Billing could be changed such to incorporate flexible tariffs. Additional income could be generated by building flexibility (DSM) and in the future by forming an energy community (utility could buy electricity – or offer free/reduced heat for their electricity – from private persons/companies to operate their central HP. |
| | | | |

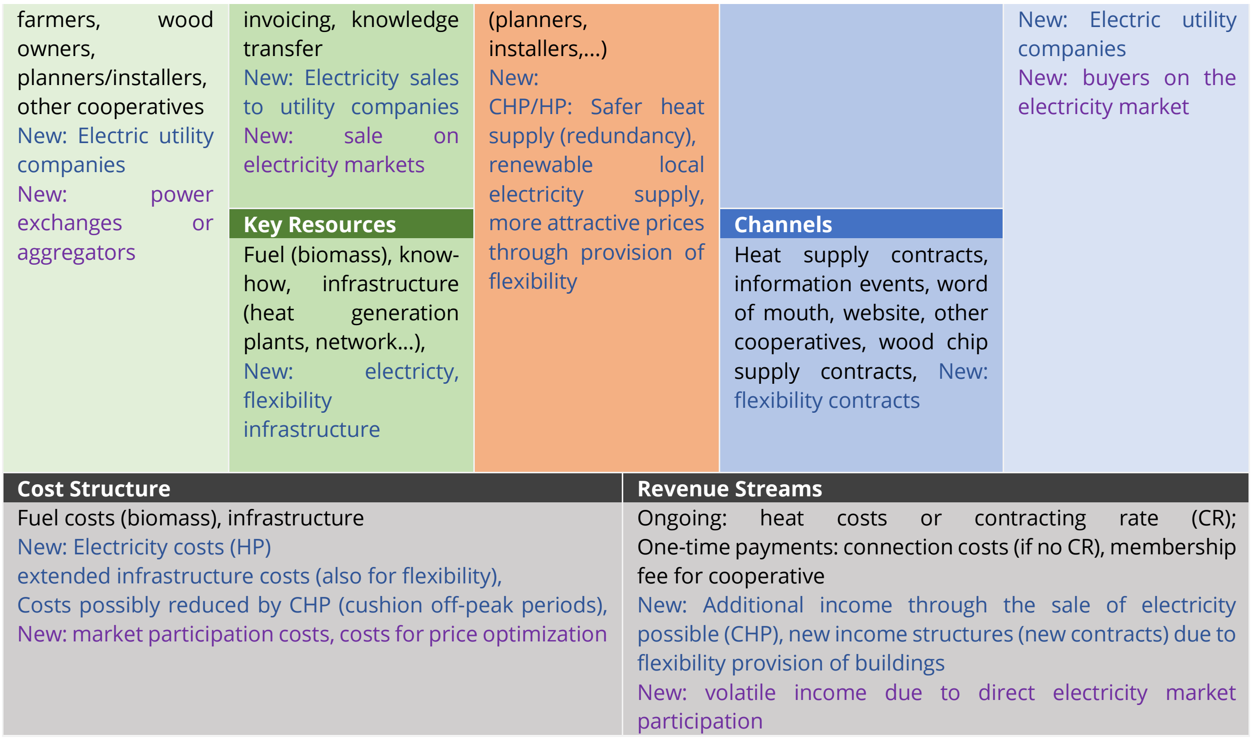
| | | | |
|---|---|---|---|
| **Selected questions from value architecture side** | 8 | Do your competitors use a technology you could integrate? | Besides biomass, competitors use other generation technologies (CHP, HP, thermal power plants, waste incineration, solar thermal, etc.). |
| | 11 | What are the strategic resources and competencies? Have you developed know-how that could be of interest to other companies? | Financing know how could also be of interest for other companies. In addition, knowledge on how to best utilize flexible components could be offered through consulting. |
| | 12 | Who are your competitors?<br>What are their strong points and their strategic resources?<br>How are these advantages or resources complementary to yours? | Mainly large ESCOs that operate DH networks, but also installers that want to install HPs. Utility could form alliances with big ESCOs for knowledge transfer (especially in electricity sector). Utility could involve installers in workshops or possibly introduce a brokerage fee so that they also generate profits from DH connections. |
| | 14 | What resources could you source outside the company? | Flexibility infrastructure provision and electricity market participation (e.g., via aggregator) could be outsourced. By using contracting, the installation and financing of RES power plants could be outsourced. |

The first new business model adds to the current business model through the addition of flexibility measures that additionally use or produce electricity, achieved by the inclusion of new components, namely a CHP and a HP. They are used to provide additional flexibility to the existing DH network. The second innovated business model is an extension of the first one and comprises the DA and/or on the aFRR balancing electricity market participation of the CHP and HP, because their combination has turned out to be a profitable option according to Section 5.1.1.

The BMC displaying the current business model in black, additions made by the first innovated business model in blue, and further alterations due to the second innovated business model in purple is shown in Table 7. The elements of the BMC describing the current business model were developed during the Stratego project [3].

*Table 7. BMC showing the current and the two innovated business models.*

| Key Partners | Key Activities | Value Propositions | Customer Relationships | Customer Segments |
|---|---|---|---|---|
| Chamber of Agriculture, forest associations, biomass associations, auditing associations, machine ring, | Contracting (plant and energy saving), construction of the systems, support & maintenance, repairs, local fuel procurement, accounting & | Local heat supply, technical solutions/services, know-how transfer between plants, good price for biomass, workshops for users | Local, renewable experts for heat supply with a focus on integrating local value creation | Customers from the private living area, housing cooperatives and other property developers, public authorities, companies, churches |



| | | | | |
|---|---|---|---|---|
| farmers, wood owners, planners/installers, other cooperatives<br>New: Electric utility companies<br>New: power exchanges or aggregators | invoicing, knowledge transfer<br>New: Electricity sales to utility companies<br>New: sale on electricity markets | (planners, installers,...)<br>New:<br>CHP/HP: Safer heat supply (redundancy), renewable local electricity supply, more attractive prices through provision of flexibility | | New: Electric utility companies<br>New: buyers on the electricity market |
| | **Key Resources** | | **Channels** | |
| | Fuel (biomass), know-how, infrastructure (heat generation plants, network...),<br>New: electricity, flexibility infrastructure | | Heat supply contracts, information events, word of mouth, website, other cooperatives, wood chip supply contracts, New: flexibility contracts | |

| **Cost Structure** | **Revenue Streams** |
|---|---|
| Fuel costs (biomass), infrastructure<br>New: Electricity costs (HP)<br>extended infrastructure costs (also for flexibility),<br>Costs possibly reduced by CHP (cushion off-peak periods),<br>New: market participation costs, costs for price optimization | Ongoing: heat costs or contracting rate (CR); One-time payments: connection costs (if no CR), membership fee for cooperative<br>New: Additional income through the sale of electricity possible (CHP), new income structures (new contracts) due to flexibility provision of buildings<br>New: volatile income due to direct electricity market participation |

The new business models both add to the value proposition by being able to provide a safer supply due to the redundancy of the HP and CHP. In addition, it is possible to generate renewable electricity locally with the CHP. An energy community would be an attractive option to use the produced electricity. Another extension of the value proposition due to the addition of the new components is, that it may result in lower prices for customers.

Utility companies are new key partners in the first innovated business case. In the second one, power exchanges or aggregators are added. Concerning the key activities, electricity sales to utility companies are possible by both new business models. The generated electricity and the flexibility infrastructure are added key resources by the innovated business models. The customer segments are extended only by the second new business model by buyers on the electricity market. Moreover, new channels for both innovated business models are flexibility contracts.

The cost structure is changed by the added electricity costs. Furthermore, costs for the extended infrastructure for the provision of flexibility and the added components make up further costs in both innovated business models. The second innovated business model moreover adds to cost structure because of the market participation costs and the optional costs for price optimization. However, there is a potential for cost savings due to the CHP. The reason for that is, that it can cushion off-peak periods. The sale of electricity with the

CHP represents a new revenue stream. In addition, the provision of flexibility calls for new contracts, which represent new income structures.

The innovations made for the new business models can also be observed in the value chain, which is illustrated for the current and innovated business models in Figure 14. The primary activities that are needed to introduce the new business models to the market are the installation of the additional components, the procurement of additional electricity supply from energy communities or energy markets and providing additional electricity supply to them.

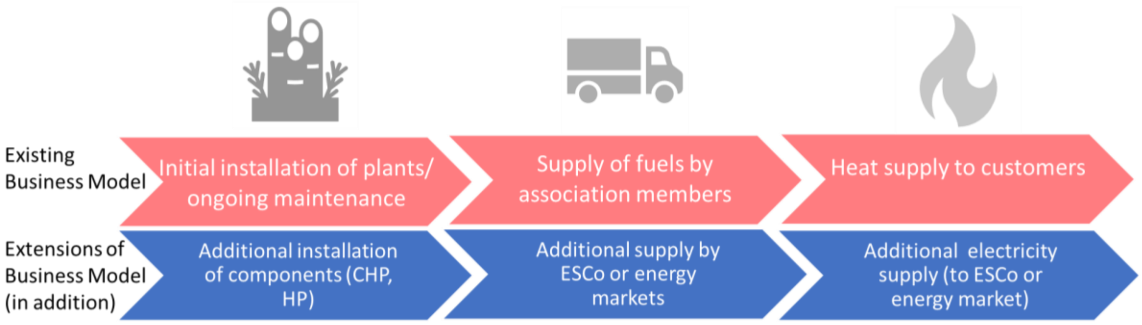


*Figure 14. Value chain of the existing and innovated business model for the Austrian DH demo site.*

Figure 15 shows the value curves of the existing and the innovated business models. Thereby, the curve shows which parameters of the existing DH network are improved (+) or worsened (-) by the extensions. The parameters are formulated such that a high value can be seen as positive (see e.g., 'uncomplicated regulatory framework'). The added components and the flexibility and security of supply they enable are their main additions to the value of the current business model. Other high value attributes of the new business models are the provision of system support (as stabilization of the electricity grid) and monetary incentives for new customers. The second new business model results in a higher exposure to price volatility, because of the participation in the electricity markets, but can provide extended system support and bring higher monetary incentives for new customers. Both innovated business models entail a complicated regulatory framework and complex new contracts as opposed to the current business model and therefore show up as lower value attributes in the value curve. However, Figure 15 shows that the new business models overall add value compared to the current business model.

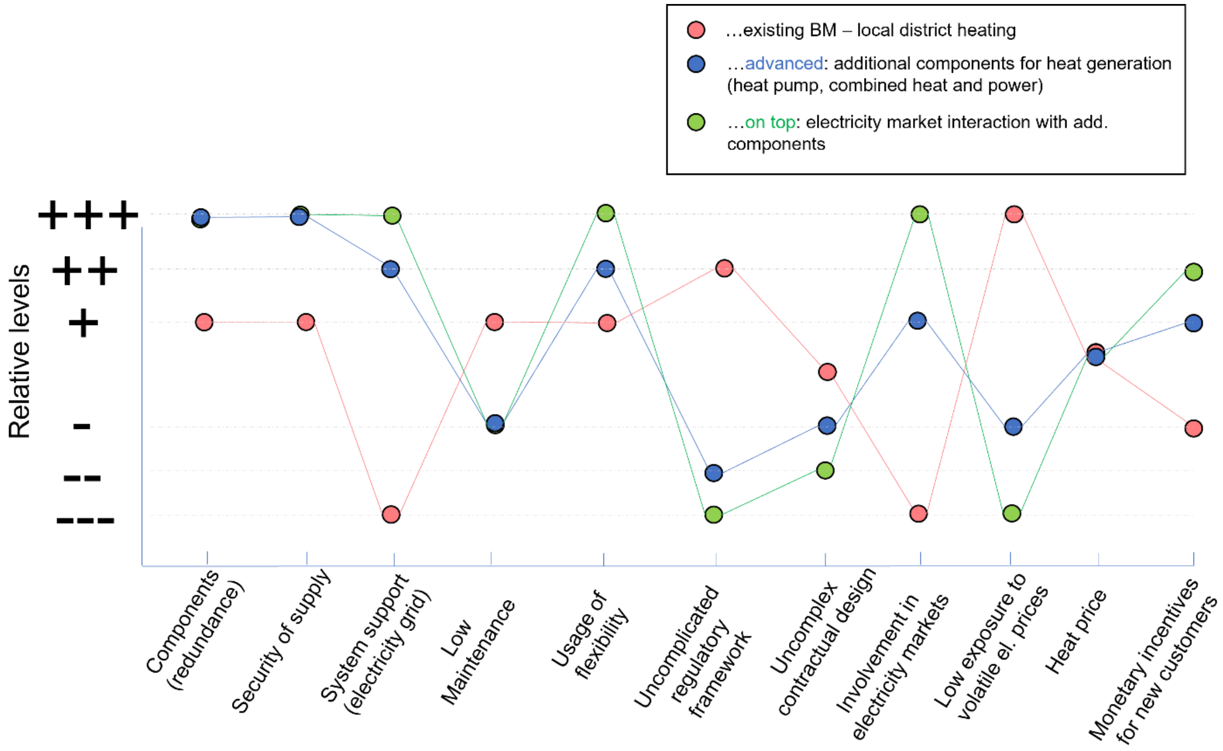


*Figure 15. Value curves of the existing and innovated business models for the Austrian DH demo site.*

### *Validation of the business models*

Input from stakeholders such as biomass producers and consumers, DH technology manufacturers, and utility companies was collected in two stakeholder workshops. Furthermore, a questionnaire was sent out to stakeholders such as the aforementioned ones, as well as to technology and consulting providers in the heating sector. Through that, the innovated business models could be validated and challenges for their implementation could be identified.

The first key takeaway from the two workshops is, that the stakeholders identify the coupling of the power and heating sectors as an interesting new business model. Moreover, they expect growth of sector coupling and the use of flexible components in the future, for example by using them for the reduction of peak loads and aiding the optimal integration of fluctuating renewables into the energy system. The questionnaire added to this aspect by showing that in rural DH networks, HOBs and their combination with HPs and CHPs are seen being the most relevant technologies in the future. These outcomes support the here-developed innovated business models.

However, in the workshops it was stated that the participants are concerned about the lack of information on topics such as subsidies, contracts, flexibility technology options for existing DH networks, prequalification requirements for balancing energy provision, and energy community participation. The questionnaire supported these concerns and furthermore identified regulatory as well as economical aspects as being the greatest barriers for future HP and CHP integration. These issues should be considered during business model development and innovation because they could result in new business opportunities and represent challenges for their implementation.

A need for support in the financing of the installation of new components was identified in the workshops as well as supported by the questionnaire, where investment costs for HPs and CHPs were identified as barriers for their implementation. New business opportunities that arise from that could be, for example, the provision of contracting services or offering consulting on financing options.

Producing renewable electricity by flexible components in DH networks is seen as an important part of new business models in the future. For example, it was voiced that free roof surfaces should be used to install PV. Moreover, an interest in the participation in energy communities was identified. However, the limitation was made that it needs to be possible for multiple generation plants to participate. In the questionnaire, a strong potential for the participation of heat consumers in energy communities was stated.

The representatives of the utility companies that attended the workshops endorsed the use of flexibilities in DH networks. Moreover, they voiced that they are willing to discuss monetary bonusses for benefits brought by the flexible components like for peak load reduction. For the utility companies, new business models could stem from their expertise on electricity market participation and contracts, among others and providing consulting services on these topics. Furthermore, they could act as partners for energy communities.

In conclusion, the results of the profitability analysis and the feedback collected during the stakeholder workshops and in the questionnaire are in favor of the innovated business models. However, concerns voiced by the stakeholders and other obstacles such as the complex regulatory framework represent challenges, which should be resolved prior to their implementation.

## 5.2 Sweden

### 5.2.1 Product-oriented BM and service-oriented BM

Business logic defines the structural context of a company and explains the evolutionary conditions of its business model. The business model is the description of certain critical success factors [7]. Conventionally, the business logic of DH companies is the sale of heat to their customers and thus get paid by delivering a certain amount of heat. The objective of such business models is to install more DH systems by extending pipes or substations and acquire more revenues by increasing the number of customers or increasing the amount of consumption. Essentially, that indicates scale in production and distribution. The connection between DH and customers is relatively weak since DH business has been characterized as a local monopoly by its nature. Thus, the interests of customer engagements have not been strong enough to impact decision-makings.

This business logic is challenged by the addition of the new service to utilize flexibility, even the core product, which is the delivered heat, has been homogeneous. In this process, DH companies alter their business role from providing a single product (which has been certain kWh of heat) to providing system solutions (which is to optimize production plans, minimize the whole system costs, and maximize customers' experience). Naturally, their business offers need to be re-designed and the connections with their customers need to be strengthened. All these changes could be contextualized in BMC. The introduced new changes to the business models or the transition from product-oriented to service-oriented business logics could be hindered by DH companies themselves. Because they are, to some degree, locked into the current business and reluctant to change due to vested interests. Also, they usually hold conservative mindsets due to their local monopoly status.

The first business model is named a connected product model or a product-oriented model in essence, which focuses on the optimized use of the service (as a "product" itself). Compared to the conventional business models of DH company, in simple words, this proposed business model is "do something similar but much better". This business model could be conceptually related to the "Razor and blades model" where one item ("razor" vs "digital tool") is sold at an inexpensive price (or even free of charge) to increase sales of another good ("blades" vs "heat"). The optimization package, including hardware and software, could be offered to the customer with an installation fee (or free of charge), and heat is delivered in an optimized way every month based on that. Two sub-BMs are developed based on the choices from real cases. Being discussed above, either the aggregator or the property owner could respond to the flexibility signals by controlling the heat demands, which means, by turning on and off the HPs. The motivations behind an aggregator controlling HPs are that it will be able to extend its business from only extracting data and optimizing demands to becoming part of the system operation. That is, from passive technology business to active influencer of energy consumption. The motivations behind a property owner controlling HPs are self-evident, that it needs to oversee the day-to-day operations of real estates. Scenarios on investment arrangements and the operation options of HPs are listed in Table 8. For scenarios from BM1-1 to BM1-3, it is the aggregator that controls the operation of HP. Property owners, aggregators, or DH companies may be investors of HPs. Correspondingly, there are some concerns and business risks identified in each scenario. In a similar way, BM1-4, BM1-5, and BM1-6 are listed with possibilities and risks, in which the property owner responds to the flexibility signals.

The first business model considers a situation where the DH company does not operate the HPs. The first major risk from this is that flexibility signals are not correctly responded to by the property owners or aggregators (low risk when the aggregators operate the HP, higher risk when the property owners operate the HP) (scenarios from BM1-1 to BM1-6). This can be caused either by the technical error of the system, not being willing/motivated to respond, or other human mistakes. This risk can be too high to allow certain business model scenarios to happen, such as scenarios BM1-4, BM1-5, and BM1-6. The second major risk is that the introduction of aggregators to operate HP may bring complaints from the end-users or insufficient trust from property owners, especially in the scenarios BM1-1, BM1-2, and BM1-3. The entrust of controlling HP from the property owners to aggregators may bring concerns to property owners. Since the property owners do not want to lose control over their tenants. The third major risk is the investment risk from different stakeholders (DH companies, aggregators, or property owners), which exists in all business model scenarios except for scenario BM1-4 (since in scenario BM1-4 it is the property owners both invest and operate the HP, which represents the current situation).

*Table 8. The investment arrangements and operation options of HP in the product-oriented BM.*

| Scenarios | Investment of the digital tool | Investment of HP | Operation of HP | Business model risks for DH company (DH companies' customers= property owners) |
|---|---|---|---|---|
| BM1-1 | DH company | Property owner | Aggregator | • Customer does not trust aggregator<br>• Customer may feel the control over tenant comfort is jeopardized and thus must handle complains<br>• Customer' motivation for high investment on HP without controlling them |
| BM1-2 | DH company | Aggregator | Aggregator | • Customer does not trust aggregator<br>• Customer may feel the control over tenant comfort is jeopardized and thus must handle complains<br>• Business partner (aggregator) may find it not motivated for high investment on HP unless very convinced about its profitability potential |
| BM1-3 | DH company | DH company | Aggregator | • Customer does not trust aggregator<br>• Customer may feel the control over tenant comfort is jeopardized and thus must handle complains |

| | | | | |
|---|---|---|---|---|
| | | | | • Investment risk if the customer decides to withdraw from the supply/demand balancing service |
| BM1-4 | DH company | Property owner | Property owner | • Customer does not respond to flexibility signal |
| BM1-5 | DH company | Aggregator | Property owner | • Customer does not respond to flexibility signal<br>• Business partner (aggregator) almost is not motivated for high investment |
| BM1-6 | DH company | DH company | Property owner | • Customer does not respond to flexibility signal<br>• Investment risk if the customer decides to withdraw from the supply/demand balancing service |

In a performance contract model (in some literature, it is also referred to as "heat-as-a service"). Compared to the conventional business models of DH company, in simple words, this proposed business model is "do something completely different". This business model could be conceptually related to the "Subscription Video on Demand (SVOD) model" where the customer pays a recurring payment on a monthly basis or another specified timeframe for access to a service or product. Such as Netflix's customers pay for a monthly plan and are given access to a vast library of media at anytime and anywhere to satisfy customers' needs. In comparison, DH companies sell heat as a packaged service which means the customers buy an agreed level of warmth rather than units of fuel. This package could be offered with a monthly subscription fee and give full access to heat to the customers, and guarantee a certain level of satisfaction. It is important that this performance contract should ensure the customers are satisfied both with the provided comfort level and the heating bills. Since customers care more about the heating outcomes rather than what kind of system delivers the heat or how the system delivers the heat. This business model is receiving increased attention. The corresponding investment arrangements and operation options are shown in Table 9.

The second business model considers a situation that the DH company operates the HPs. It is in the interest of the DH companies that they operate the HP well for the heating system to work as efficiently as possible (scenario BM2-1, BM2-2, and BM2-3). This also mitigates the risks of a response failure as mentioned above in the first business model. It is also possible that DH companies would be willing to invest in HPs if they could take full control over the HPs (scenario BM2-3). But the major risk is the trust issues against DH companies (scenario BM2-1, BM2-2, and BM2-3). Since the property owners have no control right over HP, they must fully rely on DH companies' service to maintain the satisfaction level of their tenants.

In this business model situation, a dialogue-based and more interactive relationship between DH companies and their customers are of vital importance. The second major risk is similar to the first business model which is the investment risks from different stakeholders. Especially for the aggregators, it should be difficult to motivate their investments if they do not operate the invested system (i.e., HPs) (scenario BM2-2).

*Table 9. The investment arrangements and operation options of HP in the service-oriented BM.*

| Scenarios | Investment of the digital tool | Investment of HP | Operation of HP | Business model risks (DH companies' customers= property owners) |
|---|---|---|---|---|
| BM2-1 | DH company | Property owner | DH company | • Customer does not trust DH company<br>• Customer may feel the control over tenant comfort is jeopardized and thus must handle complains<br>• Customer' motivation for high investment on HP without controlling them |
| BM2-2 | DH company | Aggregator | DH company | • Customer does not trust DH company<br>• Customer may feel the control over tenant comfort is jeopardized and thus must handle complains<br>• Business partner (aggregator) may find it not motivated for high investment on HP unless very convinced about its profitability potential |
| BM2-3 | DH company | DH company | DH company | • Customer does not trust DH company<br>• Customer may feel the control over tenant comfort is jeopardized and thus must handle complains<br>• Investment risk if the customer decides to withdraw from the supply/demand balancing service |

For any of the new business models, DH companies' selling points should prioritize the achievable economic savings each month for the customers and guarantee a higher level of customer satisfaction. Further selling points could be customers directly supporting energy efficiency measures and contributing to the decarbonization of societies since the total fuel for heat production is lowered.

### 5.2.2 Business model canvas adaptations

The new business models, represented by the two main categories, pose challenges to all blocks in a business models canvas. Figure 16 describes the common modifications of BMC of both the connected product BM and the contract performance BM. Despite its seeming simplicity, its power lies in the complex interdependencies among its parts. Any significant change in any of these elements affects the other elements and the whole.

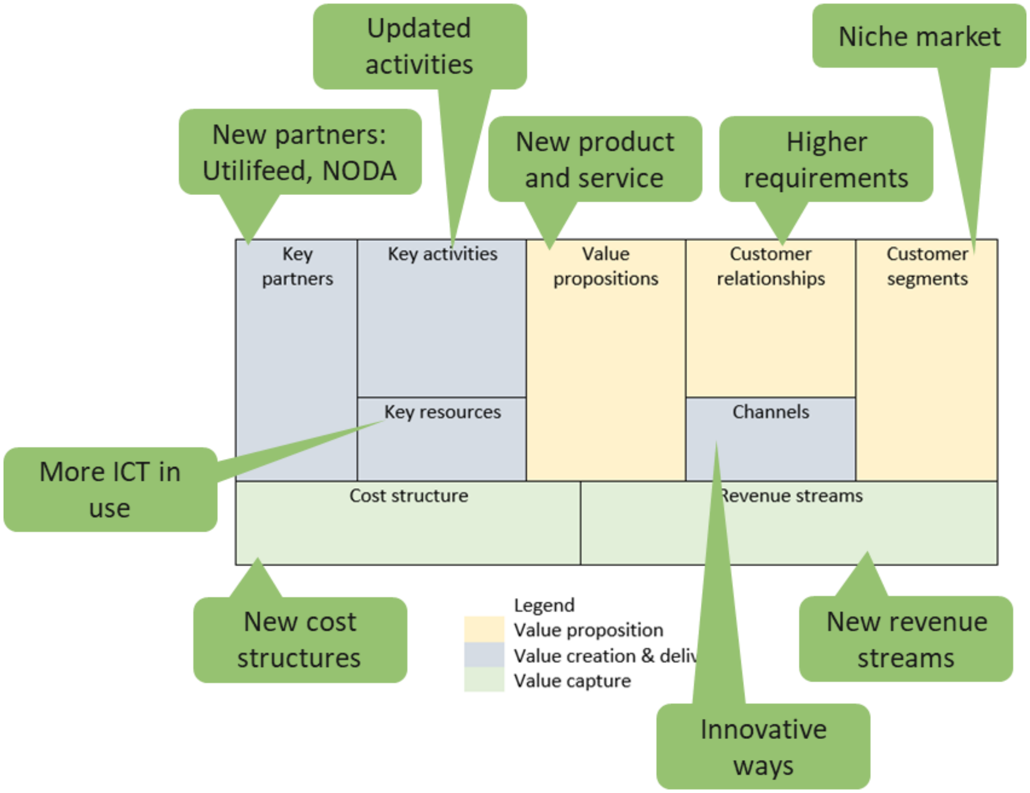


*Figure 16. The modification of BMC based on the new business model designs.*

In the product-oriented BM, the DH company sends a control signal, meanwhile, the property owner or aggregator decides how to operate (i.e., decides if and when to switch hourly). For the modified value proposition, DH company offers the customer a packaged optimization solution, including hardware and software, that connects the customer's HP and DH substation to a control interface. And DH company aims to maintain and maximize the performance of an installed product. The customer segments could be technical customers who would actively engage with DH company or customers who have a contract with an aggregator with specialized knowledge about controlling. It requires a customer relationship of being long-term, interactive, and engaging. The new key partners should include the digital tool developer and the aggregator. The modified key activities and channels should naturally include new optimization solutions, installation, and maintenance activities. These are enabled by the key resources, which are flexibility control signals and ICT infrastructure, e.g., smart heat meter. The cost structures may add new components due to the changing business activities, such as hardware costs including purchasing supply-side platforms and software costs including optimization service, training personnel for operation, more regular system maintenance, HP investment (depending on different business model scenarios presented above), and possible costs from customers failing to respond to flexibility signals. Correspondingly, the revenue streams include the reduction of heat peaks (therefore, savings), providing possible flexibility to electricity grids (therefore, remunerations), product installation income, product monthly subscription income (depending on the pricing strategies), and so on. In addition to the risks analyzed above (Table 8), DH company may face the challenge of handling a huge amount of hourly optimization and data, which in turn poses challenges to ICT infrastructure.

In the performance contract BM, HP becomes an integrated part of the production system of the DH company and should be operated in the same way as a large-scale central HP. Thus, all responsibility to operate HP and respond to flexibility signal is shifted to the DH company. The modified value proposition from DH company is that DH company guarantees an optimal indoor temperature to the customer’s building rather than simply delivering the produced heat. DH company aims to deliver comfort to meet the temperature requirement at a lower internal cost through a functional contract. DH company’s customers could be both non-technical and technical customers. Similar to BM1, customer relationships should reach a higher level of trust and transparency by establishing dialogue- and interaction-based relationships. The new key partners should also include the digital tool developer and the aggregator. The modified key activities and channels will be not only new optimization solutions, installation, and maintenance activities, but also the operation of customers' heating systems in buildings. Therefore, it requires very efficient integration of the building into the larger DH grid and supporting ICT infrastructure, e.g., smart heat meter. The modified cost structure and revenue streams are quite similar to BM1, while the difference for BM2 is that it may include service yearly subscription income, and operation and maintenance income (depending on the pricing strategies) as part of the revenues. In addition to the risks analyzed above (Table 9), there are certain risks such as not well-established regulations on heating comfort contracts, pricing strategies, and protection of customers’ data. Furthermore, DH company needs to make strategic changes in its business models, since its business logic is thoroughly changed by this proposed business model.

# 6 RISKS AND BARRIERS

This Section describes risks and barriers for DH operators when introducing flexibility measures within their networks, especially by introducing the business models outlined in this work. These risks need to be considered to guarantee broad applicability of the developed business models and services.

Section 6.1 presents risks and barriers concerning the regulatory and policy framework, Section 6.2 outlines technical implications, Section 6.3 focuses on financial hurdles and Section 6.4 highlights risks of organizational nature.

## 6.1 Policy risks and barriers

In the following, policy barriers for Austria and for Sweden, as well as combined implications on developing new services are discussed.

### 6.1.1 Policy barriers in Austria

In Austria, according to a study on behalf of the Chamber of Labor (Ger. Arbeiterkammer), many DH customers criticize the lack of transparency in pricing and billing, the weak price controls, the lack of consumer protection provisions under consumer protection law, and the lack of legal protection options. The lack of competition and the sometimes-impossible switch to a different heat supply technology are cited. However, unbundling network operation and heat supply is not an option due to technical circumstances. The Price Act does, according to the study, provide a control function, but since responsibility for this has been delegated to the provincial governors, this option is currently only exercised in three provinces (as of 2016: Vienna, Styria and Upper Austria). Moreover, unlike the *Electricity Industry and Organization Act* (*Ger. Elektrizitätswirtschafts- und organisationsgesetz ElWOG*) and the Gas Industry Act (*Ger. Gaswirtschaftsgesetz GWG*), there are no special consumer protection provisions in the Heating and Cooling Cost Settlement Act [88] [89] [90] [91]. In the past years, connection costs for district and local heating supply have often be viewed as high compared to decentralized heating technologies. However, the current price uncertainty and price increases are leading to the need for network densification in many local and DH networks. A barrier for customers also constitutes the unavailability of information on the existence of and the proximity to local or DH networks in the area.

Furthermore, although legal documents such as the #mission2030 as well as the EAG promote flexibility (e.g., on the building's side), studies show that residents of buildings prefer to be in control over their room temperature and set acceptable room temperature variations by themselves [92]. Additionally, and due to the long-term nature of local heating supply contracts, price incentives for e.g. flexibility measures are difficult to implement, especially for existing customers.

On the side of the heat providers, changing legal requirements, slow processes and difficult planning capability are hindering factors for the integration of flexibility. For example, the changing landscape concerning subsidies (especially operational subsidies for CHP electricity) impede realizations. The slow implementation of the subsidies within the Renewable Expansion Act (Ger. Erneuerbaren-Ausbau-Gesetz EAG) further unsettle operators willing to increase flexibility within their heating networks. Additionally, including HPs or especially CHP plants within heating networks results in multiple additional legal requirements concerned with electricity. According to the Electricity Industry and Organization Act (Ger. Elektrizitätswirtschafts- und -organisationsgesetz ElWOG), operators of CHP plants have certain reporting obligations as well as must deal with their guarantees of origin (GoOs). Additionally, and based on the to be enforced parts of the EAG, electricity from CHP must be sold on wholesale electricity markets (i.e. directly sold) if market premiums are earned and not administered by a third-party company.  Furthermore, the mandatory energy mix breakdown of larger DH providers results in a certification burden. Many operators see uncertainty especially in the forestry sector especially due to the cascade principle envisaged in the draft of the Renewable Energy Directive. In addition, many farmers rely on delivering their wood to the local biomass heating plant and see themselves within this local value chain. If more, e.g., HPs are to be used in local heating networks, local usage of the wood might not be possible anymore.

On the side of decision-making, policy makers could effectively use the concept of spatial energy planning to enforce specifications regarding the preferred use of local or DH in certain areas.

Furthermore, and valid for most EU countries, decarbonization targets tend to focus on the electricity sector, whereas targets specifically for the heating sector need to be further developed. Additionally, negative framework conditions, such as promotion of fossil-fuel based boilers constitute a big barrier due to distortion of the market [93].

### 6.1.2 Policy barriers in Sweden

The lack of policies promoting recycled energy is seen as a barrier to prosumer integration as well as the limited cooperation between DH companies.

Similarly, proper metrics not in place to keep up with the pace of development especially with respect to reuse of waste heat and low temperature heat is seen as another barrier. One barrier that is specific for data centers as prosumers is that existing metrics either evaluate energy performance based on the perspective of energy consumers or from the perspective of energy producers. This reduces the incentives for improvements from a higher system perspective including both upstream renewable integration and downstream heat reuse.

A report points out that in addition to the economics, view of energy efficiency and reduced energy use in environmental certification systems and building regulations also affects the competitive situation, with respect to the potential prosumer [94]. Traditionally, buildings are recommended to choose a level of efficiency that is cost-effective, which means that the efficiency measures that are profitable based on the supply cost should be implemented while avoiding the others. Today, however, assessments of the level of efficiency are often made based on other, more building-based assessment criteria, for example policy objectives and standards, or based on the many environmental certification schemes. In addition, there are self-imposed goals by the property owners themselves. This has meant that cost efficiency in some cases has come second, and then the prosumer option is not as attractive. This explanation also points to how potential prosumers will avoid becoming customers of DH grids, or avoid buying heat from DH companies, but rather produce their own heat through self-owned HPs. This is also a barrier to becoming a prosumer in the Swedish DH grid.

### 6.1.3 Implications of policy and legal barriers on developing new services

Due to the not so much regulated and not competitive (district) heat market, customer prices are often quite high. This can lead to customer's switching to other technologies, such as decentralized electric HPs for heating, even if DH would be the most efficient solution concerning energy consumption. This effect then can then negatively influence the achievement of strategies for DH, as well as put additional pressure on other sectors, such as the electricity sector. Additionally, DH networks rely on a certain density of heat costumers and can fall into unprofitability if customers decide to disconnect.

Additionally, the slow processes in policy making (see e.g., Renewable Expansion Act and Renewable Heat Act in Austria) hinder the "get into gear" of renewable, sustainable investments in DH to achieve carbon neutrality by 2040 (Austria), 2045 (Sweden), or 2050 (EU). Combined with often changing subsidy schemes, as well as the overall focus on the electricity sector, DH strategies are not promoted and driven forward efficiently enough.

Further legal barriers, such as uncertainties regarding the competitive situation in the procurement of combined energy services, for offering the optimization services proposed in the study, have been identified. These should be overcome for each individual case through the adaptation of agreements and the offer's packaging.

## 6.2 Technical risks and barriers

There exist a broad range of technical risks and barriers that need to be overcome to enhance flexibility provision and the applicability of the new service within DH networks. These include the installation of the network itself or further components (terrain characteristics, fuel availability, urban location (surplus heat), etc.). Additional technical risks include the installation of technology alternatives (e.g. decentralized HPs in buildings), growing network size (and the implications on demand and supply profiles) and changing heating and cooling temperatures that need adjustment of the infrastructure [95] [96].

The technical risks need to be considered in the project development (or project expansion) phase. Certain risks, such as a potential switch of customers to alternative heating and cooling technologies, can be overcome by knowledge transfer to customers and planners/installers, by certain regulatory framework conditions (e.g., spatial energy planning) and by providing financial incentives (e.g., support).

## 6.3 Financial risks and barriers

There are also financial risks and barriers related to the flexibilization of DH networks. These include the uncertainty (or, in the case of electricity, the volatility) of fuel costs and other costs that imply variability. Furthermore, financial parameters such as inflation and taxes (which vary greatly depending on the energy carrier) have a significant impact on profitability of a system [97]. Additionally, support mechanisms influence the economic viability to a large extend, whereas also the bankability of projects is related to certain support regimes (due to lower risk if project receives operational support).

The cannibalization effect of renewables (lower electricity prices with more RES generation) as well as for storages also puts an additional risk factor on flexibilization measures in DH grids that focus on benefitting from price levels or spreads [97] [95].

For DH projects, it is crucial to evaluate available financing instruments such as public and/or private funding and to prepare a risk management plan. This is crucial for the bankability perception and in order to secure the operation of the plant(s) [95].

Currently, there exist no explicit flexibility markets in Austria or Sweden. The introduction of such markets could enhance the application of these concepts. Furthermore, innovative and flexible tariff models could be an incentive for customers to make flexibility available to the system [98].

## 6.4 Organizational risks and barriers

Organizational issues are seen as a significant barrier on DH planning and operation. In countries like Austria, with a big number of DH networks and a decentralized organizational structure, knowledge sharing, and collaboration is difficult [98]. Furthermore, standardization is seen as a barrier for the new service(s), since DH networks are widely inhomogeneous (concerning their heat generation, size, temperature levels, etc.). A standardized service thus needs to be adaptive to a range of networks.

# 7 CONCLUSIONS

The integration of HP/DH solutions can provide a balance between district energy markets and electricity markets through fuel flexibility in heating and create a competitive advantage by leveraging cost-effective economies of scale. In Sweden, the most common way for owners to use both heating options is to prioritize HP and use DH connections when the HP capacity is insufficient to meet the full heating demand in the building. Therefore, DH is used to meet peak demand, which can be a challenge for DH network. In addition, the integrated system of CHP, DH, and HP could contribute to increased flexibility in district energy and electricity markets in Austria. The new services developed in Flexi-Sync address exactly these issues on a technical level and are demonstrated through several demo sites. These sites differ in their design and in their operation in mature or less mature heating markets. The new service developed in the project considers different heat generation and storage technologies and optimizes their dispatch in the cost-optimal way. This new service uses demand response to reduce or shift thermal load peaks, thus contributing to optimal operation of DH systems and more flexible electricity markets.

In the analysis related to business models, we analyze different use cases in Austria and Sweden where supply-side systems (including DH networks, CHP, central HPs and heat only boilers) and demand-side systems (including HPs and heat storage) are integrated to provide flexibility, not only in district energy systems but also in electricity markets. These two cases represent both the smaller DH market and the larger DH market. After use case testing, the new service is developed as an advanced commercial prototype and qualified for market operation.

In Austria, 30% of the total final energy consumption is used for heating (including hot water and air conditioning). The use of high-efficiency CHP plants in urban DH districts has been successful in significantly reducing Austria's $CO_2$ emissions. However, these plants are under significant economic pressure due to rising natural gas and electricity prices. In the Flexi-Sync Austria demo site, flexibility measures such as DSM (using the customer's building as a heat storage), expansion of the central heating facility, utilization of existing central heat storage tanks, and additional electricity market participation were evaluated. In the Austrian case, two business models are proposed. The first new business model is added to the current business model by including new components (i.e., CHP and HP). This inclusion provides additional flexibility to the existing DH network. The second innovative business model is an extension of the first business model, including CHP and HP's DA and/or aFRR balanced power market participation, as their combination proved to be a profitable option. Their respective business model modifications are also analyzed.

Using the Swedish case, we propose two representative business models. These two business models are the connected product business model and the performance contract business model. The main difference between these two business models is the investment arrangement and the operating model of the demand-side HP. The performance contract business model instead of simply paying for a unit of fuel, provides the consumer with an agreed heating plan (heat is a packaged service). This business model will attract greater interest in the future, as heating based on this can attract customers to participate in the energy market and support companies in adopting demand-side response mechanisms, which can help reduce system costs. In addition, it also supports the deployment of energy efficiency measures and low carbon technologies, as increased incentives for heat providers to provide agreed heating levels at the lowest cost. On this basis, modifications are made to different blocks of the BMC. However, problems such as mutual trust issues and risk hedge strategies, high upfront investments, business strategy shifts, and customer engagement need to be tackled to employ new business models. Furthermore, how to design contractual agreements between stakeholders (including price models of heat, pricing the installation and maintenance fees of the digital tool), and digital exclusion (due to concerns on data privacy) from customers' side should not be neglected either.

It can be concluded that policy and financial support has a great influence on the deployment of new business models. Policy risks, technology risks, financial risks, and organizational risks are presented to safeguard future new business models. Policy and regulatory risks include lack of transparent pricing and billing, weak price controls, lack of consumer protection, or other lack of alternative legal protection options. New system installations, network scale-up, and new requirements for temperature regulation may pose technical barriers. Financial risks involve uncertainty about fuel costs, access to financing, and other costs that may affect investment feasibility. Finally, standardization is seen as a barrier to new services and new markets.

In addition, replication of results within and outside the consortium will be encouraged. The service that is developed in Flexi-Sync will be the most important results of the project. At the end of the project, it will be important to develop its future use and promote its market uptake through the designs of new business models. The business model development and market analysis of the new service in this report will facilitate its replication and scale-up in other European cities or regions with district energy systems.

# LIST OF FIGURES

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# APPENDIX A: PROFITABILITY OF DH NETWORK DEMO SITE IN AUSTRIA

The following two tables show parameters of the profitability optimization developed for the Austrian demo site.

*Table 10. Parameters of the profitability optimization of the DH network of Maria Laach, Austria.*

| Parameter | Value | Unit |
|---|---|---|
| **Status Quo** | | |
| **Heat only boilers (HOB1 and HOB2), each** | | |
| Minimum heat flow | 120 | kW |
| Maximum heat flow | 400 | kW |
| Minimum efficiency | 75 | % |
| Maximum efficiency | 85 | % |
| **Central thermal storage tank** | | |
| Volume | 8 | $m^3$ |
| Storage capacity | 370 | kWh |
| **Heat customers** | | |
| Buildings | 30 | - |
| Total annual heat demand | 1,898 | MWh |
| **Additional flexibility measures** | | |
| **Combined Heat and Power (CHP)** | | |
| Maximum heat flow | 100 | kW |
| Maximum power flow | 50 | kW |
| Efficiency | 83 | % |
| Power to heat ratio | 50 | % |
| **Heat Pump (HP)** | | |
| Maximum heat flow | 100 | kW |
| Maximum power flow | 40 | kW |
| Coefficient of performance | 2.5 | - |
| **Flexible buildings** | | |
| Buildings | 6 | - |
| Total annual heat demand | 811 | MWh |

*Table 11. Cost and income parameters for the profitability analysis for the Austrian demo DH network (year 2018).*

| Cost and income parameters | HOBs | CHP [99] | HP [99] |
|---|---|---|---|
| **Operational costs** | | | |
| **Fuel costs (biomass)** | 2.5 ct/kWh | 2.5 ct/kWh | See electricity purchase |
| **Startup costs** | 2.9 € / startup | - | - |
| **Maintenance** | 6% of inv. costs/a | 15% of inv. costs/a | 3.5% of inv. costs/a |

| | | | |
|---|---|---|---|
| **Electricity grid tariffs feed-in (NL 6)** | - | 28.8 €/a[3], also for pos. balancing energy (other costs neglected) | |
| **Electricity grid levies/taxes for feed-in (NL 6)** | - | - | - |
| **Electricity grid tariffs purchase (NL 6)** | - | - | 1.7 ct/kWh[4], 4.1 €/kW[5], 28.8 €/a[6] (neg. balancing energy: 0.2 €/MWh, 0.2 €/kW, 28.8 €/a) |
| **Electricity grid levies/taxes for purchase (NL 6)** | - | - | 865.5 €/a[7], 1.9 ct/kWh[8], 10.3 €/kW[9] |
| **Investment costs (as annuities)** | Depreciated | 11.066 €/a | 4.116 €/a |
| **Heat sale** | 7.5 ct/kWh | 7.5 ct/kWh | 7.5 ct/kWh |
| **Electricity sale/purchase** | - | 4.58/18.97/25.83/ volatile DA ct/kWh | 4.58/ volatile DA ct/kWh |

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[3] The value constitutes the measurement fee.

[4] The MWh-based network tariffs consist of the grid use tariff and the grid losses tariff.

[5] The kW-based network tariffs consist of the power-component of the grid use tariff.

[6] The value constitutes the measurement fee.

[7] The annual taxes/levies consist of the renewables levy and the CHP levy.

[8] The MWh-based taxes/levies consist of contribution to the renewables support scheme and the electricity levy.

[9] The kW-based taxes/levies consist of the power-component of the contribution to the renewables support scheme.

# APPENDIX B: FUNDING FOR DH IN AUSTRIA

Facilities associated with heat feed-in into DH systems can be funded by the state of Austria, as well as federal or municipal subsidies. This Section sums up national funding possibilities – investment subsidies as well as operational funding.

### *Investment subsidies for companies*

- **Utilization of biogenic residues and raw materials:** Substitution of fossil fuels with biogenic fuels for heat generation; biogas CHP plants (whose generated electricity is not subsidized as green electricity), thermal use of wastes.
  <u>Funding scope</u>: max. 25% of additional investment costs [100]
- **Efficient wood heating facilities, HPs or DH connection < 100 kW$_{th}$ ("out-of-oil subsidy")**: Efficient wood heating facilities (wood pellets, wood chips from solid biomass or lump wood), HPs or DH connections (latter based on at least 80% renewable energy).
  <u>Funding scope:</u> max. 35% of investment costs [101]
- **DH connection ≥ 100 kW$_{th}$:** Plant components for a connection to a highly efficient local/DH system.
  <u>Funding scope:</u> max. 30% of additional investment costs [102]
- **Efficient wood heating ≥ 100 kW$_{th}$**: Wood heating systems (boiler systems based on wood pellets, wood chips from solid biomass or lump wood) for the central heat supply of one or more company-owned buildings; as well as micro-grids for the internal heat supply.
  <u>Funding scope:</u> max. 30% of additional investment costs [103]
- **HPs ≥ 100 kW$_{th}$**: Electric HPs for the predominant generation of heating, hot water, or process heat or the supply of heat networks.
  <u>Funding scope:</u> max. 20% of additional investment costs [104]
- **Large scale solar thermal plants:** Investments in the planning and construction of solar plants with a collector area of 100 m² or more are subsidized, which provide process heat, feed into micro, local and DH networks, heat for commercial/service companies with high solar coverage rates (> 20%), heat in combination with HPs incl. PVT collectors, heat with innovative approaches or heat from solar plants >5000 m²
  <u>Funding scope:</u> max. 40% (+5% for SMEs and additional +5% for storage innovations for SMEs) for solar plants up to 2,000 m² [105]
- **Local heating based on renewables**: Biomass local heating systems (without existing local heating network); new construction and expansion of heat distribution networks based on biomass, geothermal energy or industrial waste heat; optimization of local heating systems; renewal of boiler systems in existing biomass

local heating systems (which have been in operation for at least 15 years); geothermal local heating plants
<u>Funding scope:</u> max. 35% of investment costs [106]

- **Biomass CHP and wood gas generation**: Biomass cogeneration plants for self-supply with electricity, self-supply with heat or feed-in of heat into a local/DH network based on thermal gasification of solid biomass (wood pellets, wood chips from solid biomass or lump wood); thermal gasification plants for self-supply of companies with product gas based on solid biomass
  <u>Funding scope:</u> max. 35% of investment costs [107]
- **Densification of heat distribution networks:** Funding is provided for the construction of up to 25 additional consumer connections on existing pipeline routes of heat distribution networks based on biomass, geothermal energy or industrial waste heat up to a maximum of 50 kW nominal heat output.
  <u>Funding scope:</u> 4,000 € per customer connection and max. 35% of investment costs [108]
- **Innovative local DH networks:** Construction of local heating plants based on renewable energy sources or waste heat to supply heat to third parties as well as the distribution network.
  Innovation criteria: low system temperatures/use of ambient heat, combination and optimization of several renewable heat generators, intelligent networking of generators and consumers (higher-level measurement and control, load management, storage systems), realization of aspects for sector coupling (e.g., provision of plants for the balancing market).
  <u>Funding scope:</u> 35% of additional investment costs [109]

Additionally, the Renewable Expansion Act (Ger. Erneuerbaren-Ausbau-Gesetz EAG) enables investment subsidies for biomass CHP plants with an electric capacity of up to 50 kW and an energy utilization rate of at least 60%. Furthermore, the retrofitting of an existing biogas plant for the production and upgrading of renewable gas with state-of-the-art technology can be supported by an investment subsidy. However, only if no more than 50% of the fuels used consist of grain and corn and a concept for the supply of raw materials as well as for the utilization of the biogas slurry generated is available for at least the first five years of operation.

The corresponding ordinances to enable EAG investment subsidy calls are in place since April 2022 [110].

### *Operational subsidies (for companies)*

Electricity from remote controllable biomass-based CHP plants (solid biomass or biogas) with a fuel utilization rate or total energy utilization rate of at least 60% were eligible for the national FiT, administered by the Green Electricity Settlement Agency (Ger. Ökostromabwicklungsstelle AG OeMAG). This feed-in premium, according to Green Electricity Act (Ger. Ökostromgesetz ÖSG 2012), was to be paid for 15 years. The *Green Electricity Feed-In Tariff Ordinance* (*Ger. Ökostrom-Einspeisetarifverordnung ÖSET-VO 2018*) lists the corresponding tariffs for solid and liquid biomass, as well as biogas CHP electricity of plants that are smaller than 100 MW capacity in total, see Table 12 [76] [99].

*Table 12. Feed-in tariffs for biomass/biogas CHP electricity according to ÖSG 2012 [76] [99].*

| Capacity | Solid biomass CHP electricity | Liquid biomass CHP electricity | Biogas CHP electricity |
|---|---|---|---|
| **Until 500 kW for highly efficient plants** | 2018: 21.78 ct/kWh<br>2019: 21.56 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | 2018: 5.45 ct/kWh<br>2019: 5.40 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | 2018: 19.14 ct/kWh<br>2019: 18.97 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) |
| **Until 500 kW** | 2018: 17.33 ct/kWh<br>2019: 17.16 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | | |
| **>500 kW until 1 MW** | 2018: 14.77 ct/kWh<br>2019: 14.62 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | | |
| **>1 MW until 1,5 MW** | 2018: 13.30 ct/kWh<br>2019: 13.17 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | | |
| **>1,5 MW until 2 MW** | 2018: 12.62 ct/kWh<br>2019: 12.49 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | | |
| **>2 MW until 5 MW** | 2018: 11.86 ct/kWh<br>2019: 11.74 ct/kWh | | |

| | | | |
|---|---|---|---|
| | 2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | | |
| **>5 MW until 10 MW** | 2018: 11.22 ct/kWh<br>2019: 11.11 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | | |
| **>10 MW** | 2018: 10.10 ct/kWh<br>2019: 10.00 ct/kWh<br>2020: same as 2019 (§ 18 par. 1 ÖSG)<br>2021: -1% of 2019 (§ 19 par. 2 ÖSG) | | |

The fixed FiT are to be replaced by market premiums by the entry into force of the Renewable Expansion Act (Ger. Erneuerbaren-Ausbau-Gesetz EAG) by 2022. The market premium functions as an additional payment on top of the revenues obtained on the wholesale electricity market to even-out price volatility and to enhance competitiveness of renewables. The examination of the EAG market premiums by the European Commission was determined in January 2022, which led to changes and therefore an amendment of the EAG (adopted on 20/01/2022). Until the market premiums of the EAG enter into force, the operational subsidies under the ÖSG 2012 are still ongoing [75] [76].

The EAG foresees operational subsidies (as a market premium on top of the sold electricity) for both biomass and biogas CHP plants. The following criteria needs to be considered [75]:

- New or repowered biomass CHP plants shall receive a market premium for capacities of up to 5 $MW_{el}$, if their energy utilization rate is at least 60%. The market premium for biomass plants of up to 0,5 $MW_{el}$ shall be defined as an administrative value, whereas the premium for larger plants is to be set in a competitive manner in an auction. Minimum reinvestment level and minimum years of operation for repowered plants may be established as additional eligibility requirements.
- Biogas CHP plants shall receive a market premium for capacities of up to 250 $kW_{el}$ if their energy utilization rate is at least 65% and biomass from biodegradable waste and residues is used (min. 30% farm manure and max. 30% grassland and follow-up crops as fuel). The market premium for biogas plants shall be defined as an administrative value.
- Furthermore, certain succeeding premiums (Ger. Nachfolgeprämien) and exchange premiums (coming from the ÖSG subsidy scheme, Ger. Wechselprämien) are

foreseen (on application, succeeding premiums can be granted for existing biomass plants without size limitation up to the 30th year of operation [75]).

However, the corresponding ordinances for market premiums are not yet in place (the draft is currently under review as of August 2022 [111]).

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