Thermal Energy Storage in Greater Copenhagen

A study of the role of calculative devices and social perceptions in facilitating the implementation of thermal energy storage in Greater Copenhagen

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Summary:

This report examines the issues of implementing Pit Thermal Energy Storage (PTES) which actors of the Greater Copenhagen district heating (DH) system currently face. The issue is characterized by a catch-22 situation: In order to invest in the technology, actors need to know which benefits they will get. However, before the investment is made and the technology implemented, the actors cannot know exactly which benefits it will entail.

This report takes an interdisciplinary approach to the issue at hand, and combines inquiry into the actors' valuations of the PTES with techno-economic energy system modelling. By analysing which valuations are deployed by the actors, knowledge about which potential benefits actors will prefer is gained. By combining this with a calculative demonstration of the potential benefits through energy system modelling, the PTES' effects are made visible to the actors.

Several valuation framings are identified among the actors. While some suggestions overlap, others diverge, suggesting a situation of uncertainty concerning the properties of the PTES. As the energy system model is able to support some framings while rejecting others, the demonstration can decrease the uncertainty around the benefits from the PTES. These benefits include increased CHP production, lowered natural gas boiler production and decreased heat expenses for transmission companies.

Based on these two analyses, a business model is proposed, describing possible ways of sharing the investment between the actors who stand to gain benefits.

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Preface

This report is the product of authors' master's thesis written on the 4th semester of the Master of Science in Engineering in Sustainable Cities at Aalborg University Copenhagen, under the supervision of professor Peter Karnøe. The report was written in the period from February 1st to June 9th, 2017.

The report focuses on the potentials and the conditions for implementing thermal energy storage in the Greater Copenhagen district heating system. The topic is relevant, as stakeholders in the industry are currently facing issues of uncertainty. The aim of the report is therefore to contribute to the process of implementing thermal energy storage in district heating systems, by producing scientific knowledge of the social, technical and economic conditions which co-shape the potentials of implementing the technology in the existing system. The report thus draws on relevant literature, interviews with relevant stakeholders and a comprehensive energy system analysis using the modelling tool EnergyPRO.

For referencing, the Chicago Manual of Style 16th Edition is used, and thus references given in the text include the author's name and the year of the publication, e.g. (Jensen 2017). The bibliography is available in the end of the report, presenting the authors in alphabetical order according to surname. Figures and tables are numbered sequentially according to chapter. The currency used for economic values is 2016 DKK, whereas values originally in € are converted at a rate of 7.45 DKK/€.

Several people have provided valuable inputs to the making of this report, and for this the authors would like to express their sincerest gratitude. The authors were originally made aware of the topic through the energy systems consultancy company Ea Energy Analysis, in which one of the authors was an intern. Furthermore, throughout the process of making this report, Jesper Werling and Anders Kofoed-Wiuff, partners at Ea, provided valuable inputs to how to access and analyse the topic. Access to EnergyPRO was made possible by EMD International A/S, with valuable help provided by Christian Frandsen. Moreover, numerous interviewees enlightened the authors of the complexity of the topic, and thus the authors would also like to thank:

- Morten Stobbe, Vice President, and Jens Brandt Sørensen, project developer at VEKS
- Uffe Schleiss, technical manager at Høje Taastrup District Heating
- Klaus W. Jensen, Vice President at KARA/NOVEREN
- Peter Folke, economist at Varmelast.dk
- Mia Nordqvist Nielsen and Niels Hendriksen, energy planners at HOFOR

Finally, the authors would like to thank Peter Karnøe for supervision and guidance throughout the project period.

Abbreviations

ARC	Amager Ressource Center
AMV	Amagerværket
AVV	Avedøreværket
CTR	Centralkommunernes Transmissionsselskab I/S
CHP	Combined Heat and Power
DEA	Danish Energy Agency
DH	District Heating
ES	Energy Storage
CPH-DHS	Greater Copenhagen District Heating System
HCV	H. C. Ørstedsværket
HP	Heat Pump for district heating
HOFOR	Hovedsstadsområdets Forsyningsselskab
K/N	Kara/Novoren
KKV	Køge Kraftvarmeværk
LCOE	Levelized Cost Of Energy
O&M	Operations and Maintenance
PTES	Pit Thermal Energy Storage
RES	Renewable Energy Sources
STS	Science and Technology Studies
SBI	Statens Byggeforskningsinstitut
TTES	Tank Thermal Energy Storage
TES	Thermal Energy Storage
VPH	Varmeplan Hovedstaden
VEKS	Vestegnens Kraftvarmeselskab I/S
VF	Vestforbrænding

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1 Introduction

Several stakeholders in the Greater Copenhagen district heating system (CPH-DHS) currently seek to increase the Thermal Energy Storage (TES) capacity of the system. Initial studies conducted by the various actors have shown, that this would contribute to the shift from fossil fuel powered peak boilers to biomass combined heat and power plants (CHP), thus decreasing costs for energy system actors and being in line with established low carbon goals.

However, as it is uncertain how the benefits of a TES are distributed among the stakeholders of the system, they face issues regarding the coordination of the investment. To reduce this uncertainty, the potentials of TES implementation must be demonstrated and made visible to the actors by calculations and narratives. Currently, this is a task which one of the Greater Copenhagen transmission companies, VEKS[1], is trying to perform, and a task which this report is seeking to contribute to.

The effects of a TES are relatively well known in decentral district heating (DH) systems, where one plant typically owns and operates the units and the grid. In such cases, it is rather simple to establish the effect of TES implementation, and there are no actors who must share investments and profits. In the CPH-DHS, however, this is different. In such complex multi-actor DH systems with several types of heat producing technologies, multiple stakeholders may profit in different ways from the implementation of a new TES. In this system, four CHP plants and three waste incineration plants are delivering heat to two transmission companies and several distributions companies. The district heating companies also own their own peak boiler capacities and other heat production technologies to ensure stable and efficient supply. Furthermore, as several plants are online at the same time, it is not possible to establish which exact plants are delivering to and utilizing the storage at a specific time. Therefore, investing in the technology is no longer the issue of one single plant, but concerns multiple stakeholders.

If multiple stakeholders are going to harvest benefits from the TES, surely, they should also contribute to its implementation. However, if stakeholders are going to invest in the technology, they need reassurance that they will indeed harvest benefits from its implementation reflecting their share of the investment. As such, the stakeholders find themselves in a catch-22 situation: To invest in the technology, they need to know what benefits they will get. However, before the investment is made and the technology implemented, they cannot know exactly which benefits it will entail. Currently several stakeholders agree, that a TES will improve the DH system economy. Nevertheless, for them to move forward, a further qualification of the impacts for the specific actors is needed.

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[1] A detailed description of VEKS and other actors in the DH system is presented in Chapter 6

1.1 Technical thermal energy storage potential

Several analyses show the potential of integrating the electricity and heating sectors as the first step towards a flexible and integrated energy system, especially with large potential in energy systems with DH (Lund et al. 2010, 2014; Mathiesen, Lund, and Connolly 2014). DH systems enable the use of waste heat from co-generation at power plants, which improves fuel efficiency considerably.

Challenges emerge from coordinating heat and power production from CHP plants in times of either high electricity demand and low heat demand or vice versa, as the heat and power outputs are co-produced. Even though extraction CHP plants can adjust their power-to-heat ratio, they lose fuel efficiency in full condensation mode (only generating electricity). During high electricity price hours, production can be limited in case of low heat demand, while CHP plants can be forced to run during low electricity price hours due to high heat demand. A TES allows the co-production of heat and power while storing the thermal energy for later usage (Verda and Colella 2011; Lee 2013). TES is a well-known and developed technology used in several district heating networks for optimizing the co-production of heat and power. Two commonly used TES technologies exist in Danish DH systems today, Tank Thermal Energy Storage (TTES) and Pit Thermal Energy Storage (PTES). While some TTES capacity is installed at CHP plants in the CPH-DHS, no PTES capacity is installed. However, actors currently seek to increase PTES capacity, and therefore this report investigates the potentials of this technology. Danish examples are regarded as best-practice examples (DEA 2015; PlanEnergi 2016), but these are primarily situated in decentral DH systems in Jutland.

1.2 The situated knowledge of actors and the perception of technology

While the scientific literature has developed well established knowledge about the potential for using PTES with single plants and in decentral DH systems, less knowledge exists about their impact in complex multi-plant DH systems such as that of Greater Copenhagen. As the technical, organizational and institutional setups differ from decentral to central DH areas, it is not simple to transfer knowledge from one setting to another. As mentioned above, it is difficult to establish which actors receive which benefits from PTES implementation. Furthermore, it is not certain that the actors seek the same benefits. While CHP operators will likely wish to increase their production, or produce during peak electricity price hours, distribution companies may seek to lower peak boiler consumption. It is not a simple issue to determine which benefits actors are after, and which benefits they are likely to receive.

The implementation of the PTES is therefore more than merely a technical issue, it also entails a social dimension. This report takes an epistemological relativist position towards technology, and argues that technologies exist in relation to the wider socio-technical network within which they are constituted (Bijker and Law 1997). Furthermore, as will be shown in later chapters, the stakeholders perceive the PTES in relation to their specific situation and position in the socio-technical network, and as such there is no “true” or “pure” form of technology which can be reached through scientific inquiry. Technology and practice rather exist through the perception of the actors' situated knowledge. Just as the pedestrian and SUV driver will have different perceptions of car traffic, so will the CHP plant operator and the director of a transmission company have different perceptions of a PTES. Therefore, it is necessary to understand the different valuations deployed by the actors of the field.

1.3 Making value visible through calculative demonstrations

If agreement and a mutual understanding of the PTES is to be reached, it must be qualified and valued. As the actors are uncertain about the benefits of the PTES, the potentials must be qualified and demonstrated. For the actors to commit to an investment, they must have some idea about which benefits they are likely to receive. By using calculative demonstrations (Jensen, Cashmore, and Elle 2017; Muniesa et al. 2017), the PTES can be revealed and thereby the actors will be able to visualize their own roles and benefits. Mitchell (2008) argues that when Thomas Edison proposed his electrical systems for investors, they were not enrolled by the precision of his calculations, but by his ability to visualize their roles. Just at Edison's demonstrations allowed him to enrol allies, so can demonstration of the PTES enrol the actors of the CPH-DHS to support the PTES. Energy system models can make the demonstration of technical impacts visible. While such calculative demonstrations will never be true representations of reality, they possibly produce realities that enable the involved actors to engage in the shaping of the PTES.

Just as energy system modelling is an enactment of reality, so is the business model. A business model is perceived as one form of a calculative device, that presents the given investment in a certain framing, to meet the investors particular valuation (Doganova and Eyquem-Renault 2009). Therefore, it is a tool to make the PTES visible to the actors. These devices are not seen as objective representations of reality, but as specific framings, bringing a given object into being. The process of describing objects make them visible, and thereby real. Their purpose and ability is to enrol actors into their narrative of investment, by showcasing the given object as calculations and figures.

The purpose of this report is thereby to demonstrate the potential of implementing a PTES in the CPH-DHS system, while considering the specific framings and understandings of the actors in question. Based on the analysis of actor perceptions and calculative demonstrations, this report will propose a business model, to be used in the work of enrolling actors in the investment of a PTES.

1.4 Research Question

Based upon this presentation and understanding of the subject in question, the following overall research question is posed:

How can model-based knowledge be applied for facilitating the implementation of a PTES in the Greater Copenhagen district heating system?

With the following sub questions explicating the subject matter:

- *Which different perceptions and valuations of the properties of a PTES can be identified among the actors of the system?*
- *How can a technical calculative model demonstrate the benefits of a PTES?*
- *How can the actors' perceptions and valuations of the demonstrated benefits be integrated in a business model enabling the actors to envision their role in the collective investment?*

1.5 Report structure

This report consists of 13 chapters plus bibliography and appendices. The report structure is illustrated in Figure 1.1 to the right.

Chapters 2 develops the scientific foundation for this research project, as it includes methodological considerations for designing the research process with the chosen theories and methods.

Chapter 3 presents the theoretical framework used to analyse the identified subject matter, while chapter 4 presents the methods used for data generation.

Chapter 5 provides a description of the TES technology, including its role and potentials for the energy system. This chapter also compares two relevant technologies, i.e. the TTES and the PTES, and recommends the PTES as the suitable technology to pursue in in the CHP-DHS.

Chapter 6 presents the CPH-DHS as a socio-technical network of organisations, technologies and a specific market architecture.

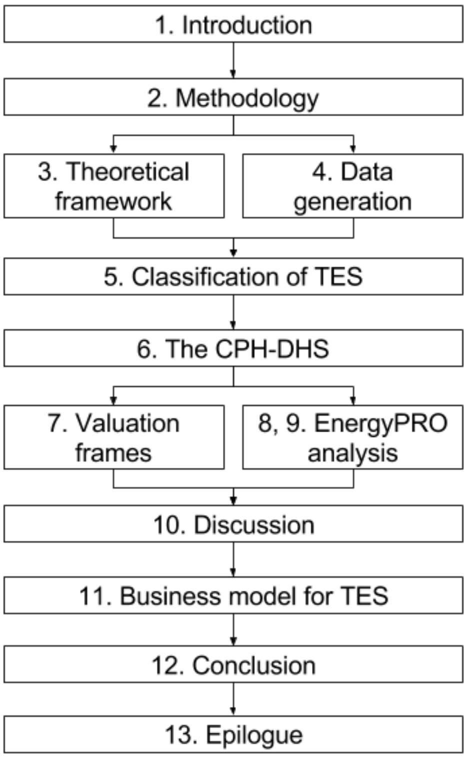

Figure 1.1 Report structure

Chapter 7 is an analysis of how the actors of the CPH-DHS perceive and value a PTES. Thereby, this chapter investigates the first research sub-question.

Chapters 8 and 9 demonstrate and analyse the technical and economic impact from implementing a PTES in the CPH-DHS. The former is an analysis of the technical impacts of implementing a PTES in the system, while the latter is an analysis of the economic impacts from implementing a PTES. Thus, this chapter investigates the second research sub question.

Chapter 10 compares the obtained results from the valuation analysis and the EnergyPRO analysis, and discusses how accurate the valuations are compared to the demonstrated impacts of the PTES, as well as contemplates on the significance of these conditions for the implementation of the PTES.

Chapter 11 integrates the obtained results in a business model for the PTES, proposing four alternatives for dividing the investment among the actors of the system, thereby investigating the third sub-research question.

Chapter 12 is the conclusion, which answers the research question including the three sub questions.

Chapter 13 reflects upon the benefits and limitations of the chosen research design, including choices of theories and methods.

2 Methodology

This chapter describes the research process and the choices made regarding theories and methods for analysing the topic of this research project.

2.1 Research approach

The research question entails two scientific dimensions. First, it entails a sociological dimension, calling for a sociological investigation of how the different stakeholders perceive and value the PTES to understand how a business model can convince relevant stakeholders to invest in the PTES. Second, it entails an engineering dimension, calling for a techno-economic analysis based on an energy system modelling tool. Very often, these two dimensions are not combined, but rather treated as separate fields of research. Nevertheless, being a product of the authors scientific position within the interdisciplinary studies of engineering and social sciences, the combination of both dimensions, the authors argue, provides valuable insights and knowledge of the conditions that shape the realization of the PTES technology in society.

Combining these two dimensions in the research project thus requires establishing a theoretical framework, which takes both dimensions into account. Therefore, as will be further described below, this report draws upon literature within the field of Science and Technology Studies (STS). Furthermore, as the aim is to make calculations and to propose a business model for the PTES, these are also considered in the theoretical framework, which describes how business models, in this report, are viewed as both calculative and narrative devices.

The nature of the research question also requires combining quantitative methods of energy system modelling and qualitative methods of studying how stakeholders value the PTES technology. Therefore, as will be further explained in chapter 4 below, the energy system modelling tool EnergyPRO was chosen for the techno-economic analysis, and the interview method was chosen for the stakeholder valuation analysis.

As such, the authors of this report view themselves technologists, that use an energy system modelling tool (EnergyPRO) to design energy system simulation-based knowledge about the PTES, demonstrating its technological effects in the DH system. However, without assigning positive value to these effects, the actors of CPH-DHS will not want to invest in the PTES technology. Therefore, the authors also seek to understand how stakeholders come to assign value to the effects of the PTES. Inspired by Mitchell (2008)'s study of Edison's use of economic demonstrations, mentioned in the introduction, the authors then seek to propose a business model designed based on both the EnergyPRO model and the actors' valuation of the PTES.

As the field of inquiry is based upon a specific issue of the implementation of a PTES in the CPH-DHS, it can be regarded as a case study (Bryman 2008), examining the valuation and qualification processes of bringing a technical object into being through epistemic production. While being of concrete value to the actors in question, Flyvbjerg (2006) also argue for the scientific value of conducting in-depth case research, as it enables valuable context-dependent knowledge.

2.2 Theories of science

Consider, for a second, the definition of water. An essentialist approach to defining water would say, that water is the composition of hydrogen and oxygen molecules in the chemical formula of H_2O. However, this one-dimensional definition does not include physical qualities of water, such as its ability to keep ships afloat or to extinguish fires, the risk of it being contaminated or its necessity in maintaining all life on earth. How accurate then is the definition of H_2O?

Essentialism seeks to find an inherent value that defines an object's properties through scientific inquiry. This report takes an alternative approach, by arguing that an object under investigation, be it water or be it a PTES, can be defined in many ways. To account for this fact, John Dewey proposed the term *subject matter*, which is "*not a one-dimensional object waiting to be viewed correctly once and for all*", but rather a "*repository of multiple possibilities*" (Boisvert 1998). From this perspective, multiple definitions of objects may exist, and they may all be valid. Following this perspective, the authors discard the essentialist's view which would assume that there is one true way of viewing the PTES. Rather, the authors approach the PTES with an epistemological relativist view, meaning that the differing ways stakeholders view the PTES are all considered valid. Examining a subject matter is thus done with a particular objective, such as the chemist examining the chemical formula of water as H_2O or the biologist examining water's importance for maintaining biological life. This act of examining subject matters from a particular objective is what Dewey describes as *productive inquiry* (Boisvert 1998) . In addition to the objective, objects must be provoked or interfered with to get a response. The particular objective of this research project is to generate knowledge which may support the implementation of a PTES in the CPH-DHS. The theoretical framework and the methods chosen for doing this research are thus acts of productive inquiry, examining the topic with a specific objective.

2.3 Epistemological processes in Science and Technology Studies

From the research question it is shown, that for the new PTES to be successfully implemented, new knowledge of how the PTES technology will function in the DH system needs to be produced.

This raises questions of what knowledge is and how it is to be produced. An essentialist approach to this question might argue, that PTES as a technology has fixed properties that are possible to define through scientific inquiry. From this view, existing PTES implemented in the fields of Jutland should be similar to the one being planned in Høje Taastrup and should thus provide adequate knowledge for stakeholders to implement the technology in the CPH-DHS. This, however, is clearly not the case, as the problem description above illustrates. The PTES technology does not stand alone, but is rather part of a larger socio-technical network comprised of existing technology and its limitations, differing political and economic interests, spatial constraints and much more. Accordingly, Unruh (2000) argues:

> In general, the limits on technological change lie not with science and technology, which tend to evolve much faster than governing institutions, but rather with the organizational, social and institutional changes that allow the diffusion of new technological solutions (Unruh 2000).

As Unruh argues, the diffusion of novel technology is dependent on the wider societal context within which it is implemented. Thus, the case of a PTES from Jutland cannot be directly transferred to the CPH-DHS as the organizational and institutional setups differ. Therefore, in order to account for these dimensions of the PTES when producing new knowledge about it, an STS approach is applied for this report. Opposite the mentioned essentialist approach, Sismondo (2010) argues, that "*STS takes a variety of anti-essentialist positions with respect to science and technology. Neither science nor technology is a natural kind, having simple properties that define it once and for all.*"

Literature in the field of STS has paid special attention to what knowledge is and how it is generated. The general logic of this approach is, that

> The sources of knowledge and artefacts are complex and various: there is no privileged scientific method that can translate nature into knowledge, and no technological method that can translate knowledge into artefacts (Sismondo 2010).

As such, opposed to the idea that knowledge creation is a rational process of producing facts from observations of nature, knowledge is a social-technical *construction*. Being constructed, Sismondo (2010) argues, "*the interpretations of knowledge and artefacts are complex and various: claims, theories, facts, and objects may have very different meanings to different audiences*". As the interpretation of knowledge and artefacts depends on the actors, several understandings of the same technological artefact can be present. Furthermore, the actors' perception of technology is dependent upon the specific socio-technical network within which they are placed. As such, the applied knowledge within a socio-technical network regarding a technology may be defined as *situated knowledge* (Sismondo 2010).

While there is a need for new technical knowledge about the functionality of the PTES for it to be implemented, existing social structures, technological infrastructures, organisations and institutions around it need to be taken into account in this process. Sismondo (2010) argues that the *"builders of technology do heterogenous engineering"* and that "*technologists need to combine raw material, skills, knowledge, and capital, and to do this they must enrol any number of actors, not all of whom may be immediately compatible"*. The engineer building technological artefacts must also construct networks by manufacturing statements and claims, i.e. making representations of the material world. The technologist's work thus consists of his ability to translate and enrol actors to support the network in which he and the technological artefact are situated.

Callon (1995) describes science as a process driven by the production of statements, through the notion of *translation networks*. Statements build upon a vast network of other scientific statements from peer reviewed journals, observations and claims etc. To make credible claims about the world, the researcher needs to draw upon an accepted and established translation network for him to be able to engage with and enrol other actors (Callon 1995). As scientists create the conditions for enacting, i.e. measure and observe their objects, their epistemic conclusions may be inscribed and circulated in networks. As more observations supporting these claims surface, they start to translate into reports and documents and thus expand the translation network. For example, within the science of climate change there is a strong translation network building upon reports, conferences and agreements. The Brundtland Report, the Kyoto Protocol, the COP conferences and the Paris Agreement, all based on scientific measurements of ice caps, tree rings, forecasts of CO_2 emissions etc, inscribed in tables, figures and report, are building and expanding the translation network.

Furthermore, new scientific findings and statements are continuously being produced within this network about the critical state of the earth's climate and the increasing need for countries and individuals to act. This translation network is, however, continuously being challenged by those who argue, that climate change is not caused by humans; a translation network having gained strength through past geopolitical events such as the presidential election in the USA.

Taking these matters into account, knowledge creation from the STS perspective builds upon observations about the world, and acknowledges that objects are framed and mediated by instruments that shape how frames and statements are produced through situated chains and networks, and therefore they are socio-technically produced. STS does not oppose the ability to measure the material world to make claims, but argues, that this will always be the technologist's representation mediated through the utilized epistemic devices and networks.

By having developed a general framework for the understanding of epistemological processes, this report now turns to the theoretical question of how novel technologies are valued and enter into already established systems.

3 Theoretical Framework

This chapter presents the theoretical framework through which the issue presented in chapter 1 is approached and analysed. First, the chapter describes how novel technologies entering markets are valued in a process of framing and calculation. It is argued that the devices which mediate the observations are important in the framing of objects. Second, this chapter presents this report's definition of business models and describes what they do and how they are used.

3.1 Valuation processes of novel technologies

Just as knowledge creation is dependent on the situated network as argued in chapter 2, so is the *valuation* of a certain good. *Valuation studies* (e.g. Beunza and Garud 2007; Muniesa et al. 2017; Doganova and Eyquem-Renault 2009) are concerned with how stakeholders define and value the properties of objects.

Novel goods, products and technologies entering a market need to have their qualities defined, classified and eventually priced. Whereas neoclassical economics traditionally proclaims that in a free market this is a natural and inevitable process settled by the forces of supply and demand, scholars within the field of Economic Sociology argue, that this is a social process happening within a framed market architecture. Accordingly, Fligstein and Calder (2015) define markets as follows:

> Markets are socially constructed arenas where repeated exchanges occur between buyers and sellers under a set of formal and informal rules governing relations among competitors, suppliers, and customers. These arenas operate according to local understandings and rules that guide interaction, facilitate trade, define what products are produced, indeed constitute the products themselves, and provide stability for buyers, sellers, and producers. Marketplaces are also dependent on governments, laws, and cultural understandings supporting market activity (Fligstein and Calder 2015).

From Fligstein and Calder's (2015) perspective, governmental actors, firms and organisations have inputs as to how a product's qualities should be defined and valued. Furthermore, the markets in which the new good is to be embedded consists of established trust and common understandings between these actors. Therefore, the qualities and values of novel goods are produced by social relationships and common understandings evolving over time, which in turn generates stable prices; i.e. through processes of valuation.

In processes of valuation, Çalışkan and Callon (2010) argue, there are two types of entities; i.e. the *things to be valued* and the *agencies of valuation*. The things to be valued are entities where qualities have not yet been defined, whereas the agencies of valuation are entities, which can engage in calculations and judgement of the former's qualities. If in the present case, the thing to be valued is the new PTES, then the agencies of valuation must be the actors, which through calculations and judgement are active in the decision-making process of implementing the PTES, i.e. the heterogeneous actors of the DH market. Within STS, the term heterogeneous actors accounts for human and non-human entities, which have agency in a socio-technical network (E.g. Sismondo

2010). These actors of valuation are participating in a process of disentangling the object from a *wild unknown* to a *passive object*, through epistemic processes (Çalışkan and Callon 2010).

Once a consensus regarding the properties of a new good is reached, it is *rendered passive*. This notion, which was developed by Çalışkan and Callon (2010), is used to illustrate, that once a good is finally defined, it is unable to express novelty or perform unexpectedly, i.e. it is passive. Before objects are pacified, the situation indicates *uncertainty* (Weick 1995) as the actors try to make sense of the situation. In situations of uncertainty, there is a lack of information available for the actors to make informed decisions, and it is possible for actors to project their own understanding into the situation, and as such propose their own problem-solving or object properties. In such situations, actors may have different value orientations, which causes them to rely on personal and/or professional values, when trying to make sense of the situation (Weick 1995). Here, the existence of different epistemic positions among actors becomes clear, as also argued by Sismondo (2010) above.

The following two subsections present two key notions which describe how valuation is performed. First, the notion of a *valuation frame* is presented, to explain how actors compete in imposing their definitions and values to novel goods. Second, the notion of a *calculative device* is presented, to explain how actors apply certain calculations and models to support certain valuation frames and to qualify novel goods.

3.1.1 Valuation frames

The notion of a *valuation frame* refers to what qualities are included and excluded when market actors classify and calculate the worth of a given good or service, including which specific metrics and analogies are used to describe the value of the good. These can be economic qualities such as costs and prices, but also non-economic social qualities, such as environmentally friendly, CO_2 neutral, organic, etc. (Doganova and Karnøe 2012). While framing is to *put the world into brackets,* what is left out of the framing may be defined as *overflows*, which closely relates to the notion of *externalities* in economic terms (Callon 1998).

The notion of valuation frame is related to that of *frame-maker* used by Beunza and Garud (2007) in their description of how different financial analysts value the internet bookstore Amazon.com. One analyst compares the likely revenue of Amazon.com to other internet companies such as Dell or AOL and thus he recommends investors to buy stock. Another analyst compares Amazon.com to other bookstores such as Barnes & Nobles with lower revenue, and thus recommends investors to sell. These different conclusions constitute two different valuation frames, which are created based on specific assumptions and calculations used by the two analysts.

The activity of proposing new value to things also entails a political dimension, as competing market actors may benefit from enrolling new actors to their valuation frame, creating *valuation networks* (Doganova and Karnøe 2012) supporting certain dominant valuation frames. For example, Mortensen and Karnøe (2017) analysed the framing of the British nuclear power plant Hinkley Point C, and how stakeholders developed and changed the valuation frame of nuclear energy from 'unsubsidized and cheap' to 'subsidized but necessary'. The valuation frame included heterogeneous elements such as political coalitions, ageing infrastructure, engineering and energy systems knowledge and the physical-materiality of steel for constructing the reactor. When once-loyal actors failed to support the established framing, contestations and overflows were limited by re-framing the valuations. Valuation frames were shifted after calculative devices showed increasing plant LCOE, which thus failed to support the 'unsubsidized' framing. This, in turn, called for new coalitions, new key metrics and valuation frames, as support had to be found elsewhere in the networks.

As such, calculative devices are a key component constructing, and being constructed by, valuation frames. Before a novel good has been rendered passive in a market, market actors compete in defining the dominant valuation frame, including the key metrics and calculative means through which to value the good. As will be seen in later chapters of this report, the market actors of the CPH-DHS currently propose differing valuation frames, when defining the value the new PTES. Accordingly, the identified valuation frames entail certain metrics, which describe the value of the PTES under the respective valuation frames. The following sub-section elaborates on the role of calculative devices in such situations.

3.1.2 The role of calculative devices – bringing innovations into being

Jensen, Cashmore, and Elle (2017) propose the term *calculative device* "*as any analytical apparatus used to structure knowledge production"*. Using calculative devices, epistemic practices may be made visible, thereby bringing novel ways of perceiving the impact of technology into being. The establishment and use of calculative devices are important in this process, as they participate in the construction and framing of statements and facts about objects as explained by Callon's (1995) notion of translation networks. By constructing claims about the object with calculative devices, building on translation chains, statements and claims about the material world can be made. As situations of uncertainty can produce divergent perceptions of the artefact, new statements can possibly translate actors into the network of the calculative device. The device's ability to translate actors depends on the power of the translation network and its ability to enrol actors. Powerful statements, building on established translation networks, can, as powerful magnets pull objects closer, enrol other actors in the network. But some statements can also be weaker than others, just as one magnet will be pulled towards a more powerful magnet, or statements can further divide the argument between actors, just like magnets of opposite poles are pushed away from each other.

By taking the current market architecture into account, calculative demonstrations have the ability to make innovations and technologies visible and tangible. In doing this, the valuation is framed and boundaries are established between which qualities of the innovations are included and which are excluded (Doganova and Karnøe 2012; Doganova and Eyquem-Renault 2009). Muniesa et al. (2017) present this as an *organized space* in which the valuation can take place. An example of such a process is presented in Mitchell (2008)'s study of the success of Edison's electrical system. Crucial for Edison's success was his ability of building alliances between patents, generators, political connections and capital etc. Economic calculations were largely a part of demonstrating the abilities of his inventions, and were thus "*helping to bring into being the world they calculated*" (Mitchell 2008). As Mitchell points out, it was not the accuracy of the calculations, but rather the enabling of the network being built where actors could envision their own roles, that was the primary objective of the demonstrative calculations. While calculating, the demonstrations also envision new relationships (Doganova and Eyquem-Renault 2009).

Calculative devices are thus important tools in alleviating uncertain situations. For novel goods to become pacified, alliances must be built and actors translated to follow and support a dominant valuation frame. While calculations should not be seen as objective truths, they can support the enrolment of actors into certain valuation networks, as well as lead to the pacification of novel goods. In this regard, establishing a business model for the novel good may serve as a crucial catalyst. The following section presents a novel approach to business models, defining them as calculative and narrative devices able to translate and enrol actors by demonstrating and framing a good.

3.2 A novel approach to business models

Very often, the business model has been viewed as a more or less realistic description or representation of how value is created for a company and how to marketize a new good. Conventionally, a business model has been defined as a combination of three main components (Doganova and Karnøe 2012; Doganova and Eyquem-Renault 2009):

1. *The value proposition*, which identifies a current unmet need, problem or challenge and proposes a solution for solving these for the actors in question.
2. *The value architecture*, which considers the partners and channels through which value is delivered.
3. *The revenue model*, which translates the value into a cost and revenue stream supporting the proposed innovation, making a sustainable business model (Muniesa et al. 2017; Doganova and Karnøe 2012).

However, as argued by Doganova and Eyquem-Renault (2009), this essentialist view is problematic, especially if applied for business models for new ventures as their reality has not yet materialised. The business model for such ventures thus describes or represents something which does not yet exist. To illustrate this point, two examples of how a business model for a PTES could be constructed are presented in Table 3.1 below. Both are possible representations of how the business model for a PTES could be constructed, but as the PTES has not yet materialized, different focus and perspectives lead to differing business models.

Table 3.1 Two examples of the focus for a business model

Business model component	Example 1	Example 2
The value proposition	Inefficient use of energy	CHP plants unable to produce during peak electricity spot prices
The value architecture	Shifting production with a PTES from peak boilers to CHP plants	Load shifting operation of CHP plants to produce during peak pricing hours, as they are not limited by heat demand
The revenue model	Lowering heat expenses for DH transmission and distribution companies by shifting from peak to CHP production.	CHP plants increase revenue, as they can produce during peak pricing hours.

As argued above, the knowledge and perceptions of technologists are situated in their specific network, and this will influence their representation through the business model. This has led scholars to question the ability of the business model to realistically represent the ventures, and instead of asking what a business model is, they ask *what do business models do*? (Doganova and Eyquem-Renault 2009).

From this perspective, a business model can be viewed as a calculative device. As such, a business model allows an entrepreneur to bring his innovation into existence through calculations and narratives. Furthermore, as it circulates, it builds the network of the new venture that it represents (Doganova and Eyquem-Renault 2009). In other words, it creates the coalitions and alliances that form the valuation network. Accordingly, examining the business model of a new venture from this perspective led Doganova and Eyquem-Renault (2009) to conclude:

> Like demonstrations, business models aim at providing evidence for the feasibility of an innovative project and at gaining the interest of third parties by mobilising the repertoires of both proof and persuasion, and the logic and rhetoric elements that they include.

As such, business models are means for storytelling and of calculation, tying stories to numbers (Doganova and Eyquem-Renault 2009). Therefore, the way the numbers and calculations which guide the narrative are generated is a crucial element of a business model.

Calculative demonstrations do as such provide examples of what could be, they are a *calculative articulation* of answers to the three typical components of the business model (Muniesa et al. 2017). In this sense, the purpose of calculative demonstrations in the business model is to provide a sense of certainty to the investor, while not necessarily to be a representation of reality. Instead, the purpose of the calculations is to enrol and convince investors of the plans overall seriousness. And it is only once a "wild unknown" object has been quantified and transformed by the mechanics of valuation that investors and others can compare the object to other possible investments and thus be more certain of their investment (Muniesa et al. 2017). As such, the business model serves to reduce uncertainty for the investors by producing *news* about the object (Weick 1995). Weick argues that *news* alleviate uncertainty as they bring information about possible futures, and provide guidance of which direction for actors to take (Weick 1995). New calculative demonstrations can enrol actors into new or reconfigured networks, while also limiting the influence of others.

3.3 Summary

With an STS approach, this report acknowledges, that there may be many multiple contradicting definitions and perceptions of the PTES technology, and seeks to identify these. Furthermore, when creating new knowledge about how the technology would impact the CPH-DHS, existing social structures, technological infrastructures, organisations and institutions around it need to be taken into account. As such, calculations alone are not enough to generate sufficient knowledge, but the valuation frames promoted by the incumbent market actors need to be accounted for as well. To enrol actors in the investment of a PTES, the identified valuation frames must be represented and supported through the calculative devices, while the calculative devices again shape the valuation frames.

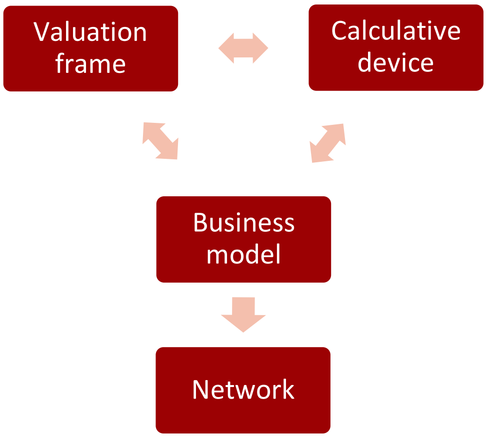

Figure 3.1 Illustration of the relationship between valuation frames, calculative devices and businessmdels in a process of enrolling

Figure 3.1 illustrates the authors' view of the relationship between the valuation frame, the calculative device and the business model. Valuation frames may be supported by using calculative devices, just as certain calculative devices gain validity through the empowerment of the valuation frames. As such, they coproduce each other. Through the establishment and use of a business model, these two may be presented to other actors in the socio-technical network such as potential investors, in a known format which is designed to translate and enrol other actors, thus further empowering the valuation frame and calculative device.

Considering the established theoretical framework, this report seeks generate new knowledge regarding the impacts of a new PTES in the CPH-DHS. In doing this, the report seeks to use a calculative device, which considers the existing valuation frames promoted by the incumbent actors of the DH system as well as the existing market architecture of the DH market. From this knowledge, the report seeks to establish a business model which can be used to enrol the actors to participate in the investment of a PTES in Høje Taastrup.

4 Data generation and methods

This chapter presents the methods applied for generating data for this report. In the following sections, the applied methods are described individually with an explanation of the purpose of using each method as well as how each method is used. The methods are:

- Interviews
- Energy system modelling with the tool EnergyPRO
- Literature studies

4.1 Interviews

In order to investigate how the stakeholders of the Greater Copenhagen DH grid value a PTES, five semi-structured interviews were conducted for this report. While traditionally qualitative research is seen as an inductive method for theory building, it can also be used as a deductive method, as it is used in this case (Bryman 2015). As the research questions consider the valuation frames and perceptions in relation to a not yet constructed PTES, the interview method enables the inquiry into the social understanding of this object.

In the sense that validity measures the ability of the method to produce knowledge about its subject matter (Kvale and Brinkmann 2015), then a semi-structured interview method gives an in-depth knowledge about the subject in questions. Bryman (2015) argues, that validity as a measure is problematic, as it originates from positivist quantitative research, and is thus difficult to transfer to relativistic qualitative research. Instead, he presents the measure of *trustworthiness* (Bryman 2015). Social reality can be made up of several possible accounts, and therefore it is not possible to measure the correctness of a statement. Instead, the researchers can use *respondent validation,* to double check if statements, obtained during the interview, were indeed understood and interpreted as the interviewee meant them to be. To increase the research's *transferability*, Bryman argues that a fulfilling account of the interview's setting and details should be presented, to provide the necessary context used for interpretation. The *dependability*, a term related to reliability, must be ensured by providing a fulfilling account of the research process and findings. The process is elaborated below, by the use of Kvale and Brinkmann's (2015) seven phases of interviews. Related to dependability is *confirmability,* which accounts for establishing no overly personal influence from the researchers during the interview phases. As complete objectivity is impossible in research, the credibility must be ensured by a full account of the methods applied and questions asked. Thus, the steps used during the interview phase are presented below.

Kvale and Brinkmann (2015) identify seven chronological phases of qualitative interview research, which have been followed when planning, conducting and analysing the interviews for this report[2] .

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[2] The textbook is in Danish, which is why all references to the specific text are translated by the authors.

The seven phases are:

1. Thematization, which is to identify the purpose of conducting the interviews.
2. Design, which is to decide how the interview study should be structured.
3. Conducting the interview, where good interview conduct needs to be followed.
4. Transcription, which is to consider how to document the acquired information.
5. Analysis, which is to consider how the acquired information is interpreted.
6. Verification, to establish the trustworthiness of the acquired information.
7. Reporting, which is how to present and communicate the obtained information.

The following sections describe how the seven phases were considered for the interview study of this report.

4.1.1 Thematization

The first step of planning the interview is to identify the purpose of conducting the interviews; i.e. *why* choose the interview method and *what* information is needed from the interview (Kvale and Brinkmann 2015). From the theoretical framework, it has been elaborated in order to establish a business model for the PTES, it is relevant and important that the points of view of the stakeholders, i.e. their valuation frames, are identified and included. Therefore, the interview method becomes relevant to apply in this research project, to gather information regarding how the different actors are likely to approach this new unit, to support the creation of a feasible business model.

4.1.2 Design

Having decided to apply the interview method, the next question is *how* to structure the interview in order to get the optimal outcome. The number of interviews needed and the structure of the interviews should also be considered in the design phase (Kvale and Brinkmann 2015).

Due to the complex nature of the research problem at hand, the semi-structured interview was chosen. The flexible nature of the semi-structured interview makes room for follow-up questions, elaboration on specific topics, or discussion of new relevant topics, which go beyond the predefined questions.

There are many actors in the DH system whose operation will be affected by a new PTES. However, due to time restraints, the authors decided not to interview all relevant actors, but to choose one actor from each of a series of actor types. The identified actor types being: CHP plants, waste incineration plants, transmission companies, distribution companies and the market operator. The interviewees, which represent these organisational actor types, are summed up in Table 4.1 below. The implications of this grouping of actors is discussed in chapter 0.

Table 4.1 Overview of the interviewees, the organization they represent and their relevance regarding this report

Organisation	Name / Position	Relevance
VEKS	Jens Brandt Sørensen / Project developer Morten Stobbe / Vice President	VEKS is currently trying to find a business model for the PTES. As such, they, together with Høje Taastrup DH, are the project developers and as such, they are the ones meeting the challenges addressed by this report. Therefore, as project developer and vice president respectively, J.B. Sørensen and M. Stobbe are relevant interviewees, as they can inform the authors of the problem and collaborate on viable solutions.
Høje Taastrup District Heating	Uffe Schleiss / Technical manager	Høje Taastrup DH is planning to implement the PTES in their distribution area. As such, they have made some considerations as to the technical setup of the PTES and have some specific requirements regarding its use. As the technical manager, U. Schleiss is in a position of speaking on behalf of the company about these matters.
KARA/ NOVEREN	Klaus W. Jensen / Vice President	Being a waste incineration plant, K/N might be influenced by the implementation of a PTES, and therefore they are relevant to include in this study. As vice president, K.W. Jensen is in a position of speaking on behalf of the organization regarding their planned PTES.
Varmelast.dk	Peter Folke / Economist	Being the market operator scheduling the daily heat production, Varmelast.dk has an essential role in the potential future operation of the PTES. P. Folke, economist, is part of the team which optimizes the load scheduling, and as such, he has valuable insights as to how the system works as well as how a new PTES storage fits to the current system.
HOFOR	Mia Nordqvist Nielsen / Energy Planner Niels Hendriksen / Energy Planner	HOFOR is both the owner and operator of a CHP plant as well as a utility company. As energy planners, M. N. Nielsen and N. Hendriksen are in a position of speaking both on the behalf of the CHP plant as well as the heating utility.

4.1.3 Conducting the interview

When conducting a semi-structured interview, using an interview guide to steer the interview ensures that the topics are covered, even though the chronology of the topics discussed may vary from the interview guide, due to the nature of the semi-structured approach (Kvale and Brinkmann 2015). Accordingly, interview guides were created for each interview. A couple of days before the interview was to be held, the interview guides were sent out to the interviewees, so that they would know exactly what to expect of the interview and could prepare for it. The interview guides contained specific questions which were divided into categories, such as technical, economic, organizational etc. Due to the differing types of organizations, individual interview guides were created for each interview and these can be found in appendix B. To produce knowledge through *productive inquiry*, the object in questions must be provoked, to get a response. By bringing results and observation from the EnergyPRO analysis to the interviews it enabled the authors to engage the interviewees in a conversation about the object and get their responses and critique. This method gave insight to new knowledge that possibly would not have surfaced without provocation, but also allow for the actors' own bias and perception to enter the interview setting and data generation.

4.1.4 Transcription

The interviews were recorded and afterwards important parts were transcribed. As the process of transcribing interviews can be rather time consuming, the researchers chose to transcribe only the moments of the interview, which are especially useful for the report (Kvale and Brinkmann 2015). The transcription also filtered out any mumbling, long passages without speaking or other part without use. This introduces an interpretation from the researches, as they chose which parts are relevant and which part are not. Furthermore, the process of translating quotes from Danish to English also entails a degree of interpretation. The transcriptions are not included in this report due to concerns of confidentiality, but are available upon request.

4.1.5 Analysis

Depending on the type of interview study, there are multiple ways of analyzing the interviews and multiple levels of detail which may be relevant to dig into. Some studies may wish to compare the answers of the interviewees, while others may wish to analyze the specific language used by the interviewees etc. (Kvale and Brinkmann 2015). When analyzing the interviews conducted for this report, the focus was to identify how each interviewee values and frames the PTES. Therefore, even though much valuable information was obtained in each interview, only the statements regarding these specific matters were applied in the actual analysis.

4.1.6 Verification

While in a positivist approach validity would be seen as replicability and the ability of the method to measure what is in question, the epistemological relativist approach is concerned with the perceptions of the actors in question. As such, there is no right or wrong answers. Kvale and Brinkmann (2015) argue, that instead of seeking to verify statements produced from interviews, the transparent methods, presentation of results and critical reflections are enough to ensure the validity and reliability. Following Bryman (2015), respondent validation was ensured by confirming all statements with the interviewees before publication.

4.1.7 Reporting

The reporting has taken ethical considerations into account (Kvale and Brinkmann 2015), by making agreements about the use of statements with the interviewees. The interviewees were also accepting their statements in writing before publication.

The results are presented in chapter 7, where quotes are used to present the interviewees perceptions. In order to contextualize the statements, they are interpreted and related to each other, to present the wider context in which they were stated. As it is not possible to present an objective account of the interviews, this report presents the interviews in relation to interpretations to put the statements into context.

4.1.8 Limitations of the interview method

Some limitations of the data generated by the qualitative inquiry apply. One interview with each type of district heating actor was conducted, being transmission company, system operator, CHP plant, waste incineration, and two distribution companies, HOFOR and Høje Taastrup DH. As HOFOR and Høje Taastrup DH are different in size, ownership of plants, organization etc., it is difficult to compare the two actors. This showcases that it is difficult to generalize across actors within the same type. Therefore, the results should not be seen as general statements for that particular type of actor, but as examples of how different actors can perceive the object in question. Had more interviews been conducted; more valuation frames would have surfaced.

The applied method generates knowledge of the different actors' valuation frames, but does not make inquiry into what shapes these different valuations. Following Callon's (1995) argument of translation chains, the actors' valuation frames build upon past obtained knowledge. Several actors mentioned, that past analytical work shapes their understanding of potentials of the PTES, but due to time and resource constraints, these sources of knowledge have not been possible to examine. Therefore, the inquiry into different valuation frames only consider the identified frames, but does not develop what shapes these framings in detail.

4.2 EnergyPRO modelling

To generate knowledge of the impact of implementing a PTES in the CPH-DHS, a digital energy system modelling tool is applied. As such, the purpose is to 'bring the PTES into being' by using a calculative device, capable of modelling the CPH-DHS, including plants, transmission areas, storages, heat demands, electricity prices etc. This section presents the chosen modelling software, EnergyPRO, including why it was chosen, how it is used and what its limitations are. The EnergyPRO (version 4.4) modelling software was chosen for the energy system analysis, due to its capability of making detailed techno-economic analyses of regional and local energy systems with fossil, bio and renewable energy sources and technologies (EMD 2016). Analysing the Copenhagen energy system alone, the local scale configuration of EnergyPRO is considered suitable, compared to e.g. the EnergyPLAN software, which is more suitable for larger national energy systems, following an aggregation approach in which it combines total capacities rather than modelling individual plants (e.g. Lund 2005). EnergyPRO can model limitations in district heating transmission systems, an important limitation to consider when load-scheduling plants.

The model takes an analytical and least-cost approach to fulfilling demands, by calculating a priority number for every unit for every time step. Units are then scheduled based on this priority, with the units with highest priority scheduled first. For CHP plants, this takes the electricity spot price into account, where a high spot price result in high priority and vice-versa. Certain units are prioritized in the market as HOFOR's geothermal heat pump. These units are thus given the highest priority every hour they are available. The model then dispatches available units to fulfil demands in every time step. This process is illustrated in figure A.4 in appendix A

4.2.1 Setup of the analysis

In the tool, a reference scenario is established, which represents a business-as-usual situation, where no new actions are taken other than already established policies towards the year 2025. This reference year was chosen, as the system is expected to change during the years up to 2025, phasing out the use of coal and oil as fuels as well as moving away from steam-based DH to water-based DH in Central Copenhagen. Having built the reference scenario, this is tested against two alternative scenarios, which include two ways of configuring the PTES in Høje Taastrup. The purpose of these scenarios are to analyse, how the implementation of the PTES will influence the system in terms of fuel use, energy production and economy. In this section, the overall design of the analysis and scenarios is presented, whereas the detailed inputs for the model are presented in appendix A.

4.2.1.1 Building the reference scenario

The EnergyPRO interface is presented in Figure 4.1 below. In general, the different input data are inserted in the folders in the 'input data' box is the top left corner, while the large window is a visualisation of the model and the interconnections between the different inputs. Different outputs are available when running the model, and these are generated by choosing one of the reports in the lower left box. When building a model, the inputs are added following the order of the list presented in the top left corner of the figure.

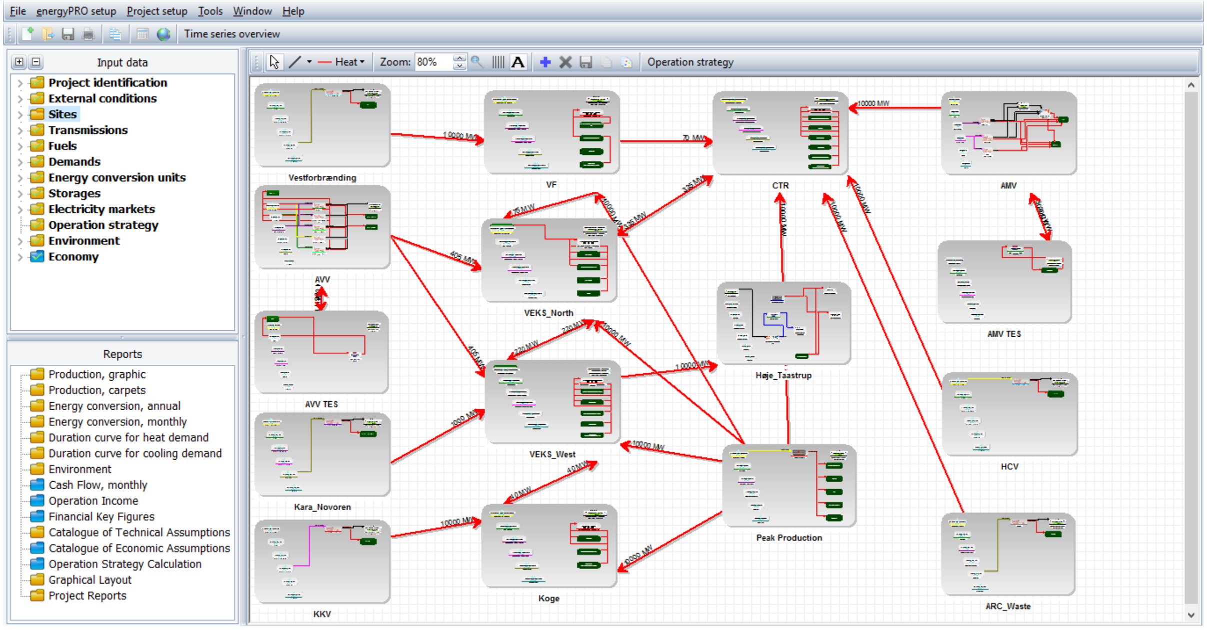

Figure 4.1 Screenshot showing the EnergyPRO interface including an overview of the modelled reference scenario

In the reference scenario, the entire CPH-DHS is modelled, including all transmission areas and their demands, all fuels with costs and heat values, all plants and their production as well as all connections and their capacities. However, due to lengthy computational time and excessive data handling, a certain level of aggregation is applied. For example, some production units have been grouped to get outputs representing each plant instead of each unit of a plant. Appendix C provides an overview of the grouped units. Furthermore, the model only includes the transmission grid level, having aggregated all the demands of the distribution areas. The only distribution area which is modelled individually is that of Høje Taastrup, as this where the PTES is to be installed.

The tool offers certain options regarding the operation strategy of the plants to fit the model to the desired market design. In the current DH market, certain units are prioritized, such as waste incineration plants and HOFOR's geothermal heat pump, meaning that these will always be scheduled first for production. These units thus produce at peak load every hour they are available, regardless of heat production costs. However, in the established model, the waste incineration plants are not prioritized, but follow the same marginal price load scheduling as the CHP plants. The reason for this change in the model is, that people within the industry are currently discussing whether waste incineration should remain prioritized, or whether it should be subject to the same scheduling rules as other plants. Therefore it is relevant to include in the analysis, how a PTES would influence the waste incineration plants in such a case. By prioritizing the waste incineration plants, any potential impact from the PTES would not be analysed, and therefore does this approach give insight into possible changes in waste incineration production.

Emissions from the operation of the system as well as their costs are accounted for in the model. The emissions are modelled per plant based on fuel type. Finally, all the different costs are added to the model, including taxes and emission fees, yet without investment costs.

4.2.1.2 Alternative scenarios

The alternative scenarios are similar to the reference scenario in all matters, except they have an added PTES connected to the distribution area of Høje Taastrup. In alternative 1, the PTES can receive heat from the transmission grid but it cannot transport heat back to the transmission grid, whereas in alternative 2 heat can be transported both ways. These alternatives were chosen, to analyse whether the PTES should only supply heat for the distribution grid in Høje Taastrup, or if it should rather be capable of receiving and supply heat on transmission grid level.

4.2.2 Business economic calculations

As EnergyPRO only takes the system economy into question, it does not consider the bilateral heat sales contracts between producers and transmission companies. As will be presented in section 6.3, the heat production costs and the price at which heat is sold are not the same. Thus, the demonstration of the impacts on the individual plants and transmission companies are done in a separate spreadsheet analysis. It assumes the heat sales price is determined by bilateral contracts, and is calculated by a fixed share of fuel use and O&M for the heat and electricity production.

The import and export heat price between the transmission companies is assumed to be governed by a marginal pricing principle, where the marginal producer in the given exporting area sets the export price. As all plants supply heat through a transmission company, and several producers are online at the same time, it is not possible to determine which plants production is being exported. Therefore, a single price for export must be determined, and a reasonable assumption is that the transmission company will set the export price at the marginal producer's sales price. As information about the method of heat price determination, this is an assumption. The calculations are presented in Appendix A.

4.2.3 Model limitations

While the model predicts perfect worlds, complex systems like the CPH-DHS are prone to mistakes, unforeseen events and abnormalities. In a digital model, technology is pure in the sense that no unforeseen events or influences affect the operation of the system. As such, there are a number of inevitable limitations present when modelling complex energy systems, and a couple of the most evident limitations of the model are presented here.

The model has perfect knowledge about external conditions such as electricity prices, weather conditions and heating demands, and thus the software can plan optimal unit dispatch for the whole year without any unexpected happenings such as extreme weather events or unforeseen outages, which in real circumstances would cause sub-optimal operation. Such events would be handled by back-up generators and other adjustable units, but is not included in this analysis. For example, the TTES at AMV and AVV are used in the optimal dispatch planning of EnergyPRO, but according to HOFOR they are actually mostly used to adjust to variations in demand and production (HOFOR 2017).

Electricity marked bidding strategies and regulation markets are not considered, even though this could have an impact on operation strategies. Units as AVV2 gas turbines or Høje Taastrup DH's heat pump could possibly gain revenue by providing balancing services, although that is beyond the scope of this report. As the electricity prices are external conditions in the EnergyPRO model and defined before analysis, they are not affected by changes in supply and demand. Theoretically, changes in CHP production would affect the electricity price, but this is not considered in the model. Furthermore, a number of limitations apply to the unit modelling. Due to model constraints, it is not possible to model extraction plants with a variable heat and power output. Therefore, all CHP plants are modelled as back-pressure units with a fixed ratio between heat and power production. As the computational time increases significantly, ramp up and down times are also not considered in the model. The units are thus able to turn on and off without using time and resources on the start-up process. This results in a too optimistic unit scheduling, as they are able to make faster adjustments than in reality.

4.3 Literature Study

Literature studies have been used for various parts of this report. The majority of the data used for energy system modelling in this report is collected by official agencies and organizations, while the theoretical framework builds upon peer-reviewed literature. As mentioned above, Callon (1995) describes how scientific observations are being used in the further production of scientific statements, with the notion of translation networks. In order to produce credible statements, this report utilizes these resources and builds upon already established statements. By building on knowledge from accepted sources, it is possible to produce reliable and valid statements, for further circulation in the translation network. The main literature sources are presented below.

4.3.1 Varmeplan Hovedstaden

A vast amount of the background data used in this report is originally produced by the project Varmeplan Hovedstaden[3] (VPH), which is a cooperative development project between transmission companies CTR and VEKS and distribution and production company HOFOR. The development of the CPH-DHS is coordinated through VPH. This project has been ongoing in phases from 2008-2014 and has collected several datasets describing the transmission networks, plants, units and demands of the DH system. A vast amount of the background data used in this report is originally produced by this project.

4.3.2 The Danish Energy Agency's Technology Catalogue

The Danish Energy Agency (DEA) publishes catalogues on data for energy system technologies. Both technical and economic data is compiled, and forecasts about future developments are included. The data is highly aggregated and therefore, local factors change the actual data from project to project. Moreover, technical and economic forecasts are always difficult to assess, which is why the technology catalogue is updated regularly on novel technologies or where mayor technological innovation has happened. For example, offshore wind and heat pump data have been updated recently (DEA 2016b). Although the data on technologies is generic and lacks site-specific characteristics, it is a trusted and widely used source of information, especially when there is a lack of information from elsewhere. As power plants often withhold specific efficiencies, capacities and emissions as classified information, the technology catalogue has provided reasonable approximations for this data.

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[3] English: Heatplan Greater Copenhagen

4.3.3 Peer-reviewed academic literature

The academic literature has provided insights primarily in two fields for this report: for the theoretical understanding of socio-technical systems, and for energy system dynamics and the impacts from PTES implementation. The academic literature enables the report to build upon the past work of scholars, thereby again utilizing the translations networks of scientific facts. As Kuhn argues that science exists in paradigms (Sismondo 2010), scientific facts and arguments should not be understood as the only truths or reality, but as situated knowledge built in specific scientific networks. STS open doors for explaining the socio-technical existence of technology and how changes in such networks can be understood. Other theoretical understandings would perceive the problem area and possible solutions different, and thus come up with different conclusions. This will be elaborated in chapter 13 about limitations and other possible routes.

5 Classification of thermal energy storage technologies

This chapter presents a general description of thermal energy storage (TES) technologies. First, this chapter provides an explanation of how TES in general fits and compliments an energy system with fluctuating energy supply and demand. Second, this chapter provides a description of two types of TES technologies, i.e. the Tank TES and the Pit TES, which are considered the most relevant to apply in the CPH-DHS and recommends the Pit TES be implemented.

5.1 Energy storage technologies

Supply and demand for energy does not necessarily occur simultaneously. Demand varies on a daily, weekly and seasonal basis, while the energy supply also increasingly fluctuates; both due to more and more intermittent renewable energy sources (RES) being added to the energy system, as well as due to volatile electricity prices causing CHP plants to wish to produce at high prices without being limited by having to meet the heating demand. This mismatch between supply and demand for energy has led to increased interest in energy storage (ES) technologies (Lee 2013).

Depending on the setting (i.e. energy system requirements and limitations, geographical conditions etc.), different types of ES technologies become attractive to apply. Among the electrical ES technologies available, the most reliable and well-developed is pumped hydro. However, the specific geographical requirements for this solution limit the number of applicable locations for this technology. Other electrical ES technologies have seen major development in both increased efficiency and reduced costs in the past few years, including battery solutions for private houses and electrical vehicles. Nevertheless, among large scale ES solutions, TES has proven to be the most efficient and economically feasible (Powell et al. 2016).

The basic principle of TES is as follows: The TES is charged at times with abundant or cheap energy, and stored for a certain amount of time. Later, when energy is scarce or expensive, the TES is discharged. This makes TES capable of detaching the energy production from the demand, providing flexibility to the system (Lee 2013; Kousksou et al. 2014).

There are multiple types of TES technologies available today with differing characteristics. As illustrated in Figure 5.1, Lee (2013) classifies the different characteristics of TES into three categories, stating that they may vary in temperature level, time duration of storage and physical storage material.

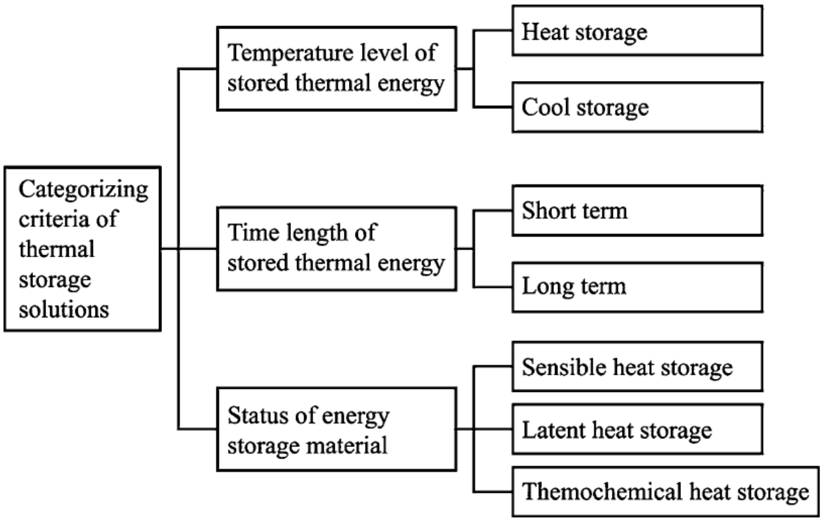

Figure 5.1 Three categories of characteristics in which TES solutions may vary (Lee 2013)

TES may work at different temperature levels, including both heat storage and cool storage, depending on the setting in which it is applied. The time length of the stored thermal energy may also vary. In some settings, TES can be applied to level out fluctuations between supply and demand of energy on daily or weekly basis, e.g. charging during the day, discharging during the night. In other settings, TES can be used for storing heat on a seasonal basis, charging during the summer and discharging during the winter (Lee 2013).

The status of the energy storage material can be classified into three categories: Sensible, latent and thermochemical:

- **Sensible heat** is stored by changing the temperature of the storage medium, which can be either liquids or solid material.
- **Latent heat** storages use materials which change phase, utilizing the energy stored when a material changes from one phase to another, e.g. as ice melting into water.
- **Thermochemical heat** is based on a reversible chemical reaction of certain substances, which uses energy in one direction and yields energy in the reverse direction. (Lee 2013).

Among the different types, Sensible TES is currently the most commonly used storage solution (Kousksou et al. 2014). More specifically, hot water storage is the most applied form of storage, due to the low costs, non-toxicity, simplicity and versatility of water as a storage medium (DEA 2015).

As the agenda of the stakeholders working for implementing the TES in the CPH-DHS is to identify an efficient and feasible TES solution in the urban area of Greater Copenhagen, rather than to develop further some emerging ES technology, sensible TES are chosen as the most relevant to pursue in this project. The following section describes some of the most advanced sensible TES technologies available today.

5.2 Potential TES technologies

Among sensible TES technologies, this report examines two. The Pit Thermal Energy Storage (PTES) and Tank Thermal Energy Storage (TTES) are two options used in Danish DH grids. Other options, such as Borehole and Aquifier thermal energy storage, are also available but will not be analysed in this report.

5.2.1 Tank Thermal Energy Storage (TTES)

A TTES is essentially an insulated tank in which water is stored. The size of the TTES may vary according to the needed storage capacity. The TTES can be constructed in steel, glass-fibre reinforced plastic or concrete, and it is usually insulated with 30-35cm mineral wool (DEA 2015).

TTES is an established technology. In Denmark, the technology is typically used together with CHP plants (see Figure 5.2), allowing the plant to run more efficiently and strategically according to the electricity spot market or heat demand. TTES is also applied for almost all biomass heating plants, smoothing their operation and reducing emissions, and also frequently used together with solar thermal plants (DEA 2015). The main issue with this technology is that it requires large volumes, and therefore the setting in which it is implemented needs to have the required space (DEA 2015). TTES are most commonly placed on ground level, but may also be placed underground, as illustrated in Figure 5.3 below.

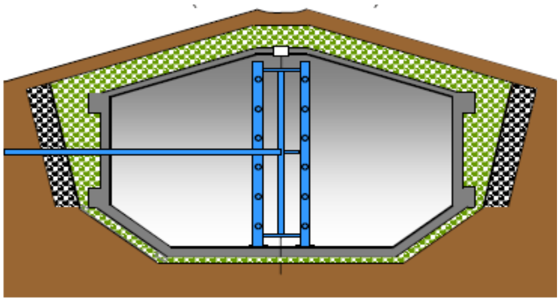

Figure 5.3 Conceptual drawing of underground TTES (DEA 2015)

Figure 5.2 CPH plant with connected TTES in Viborg, Denmark (Mørch 2014)

All TTES have certain degrees of thermal stratification, as warm water rises to the top and chilly water remains at the bottom. Accordingly, a distribution system is installed in the centre of the storage, to eliminate mixing of the temperatures during storage, and studies have shown that this feature increases the efficiency of the storage (Kousksou et al. 2014). The concept is illustrated in the conceptual figure above.

Recent TTES installed in Danish DH systems have been from 1,000 m^3 to above 50,000 m^3, while the TTES at AMV is 24,000 m^3 (Varmeplan Hovedstaden 2014a). In order to be able to charge and discharge following CHP production, TTES typically has a higher charge/discharge capacity than a Pit Thermal Energy Storage (PTES). The TTES at AMV has a charge/discharge capacity of 330 MJ/s.

There is an economy-of-scale present for the technology, meaning that the price per volume differs depending of the size of the tank. A 5000 m^3 tank costs around 1100 DKK/m3, while a larger tang is expected to be slightly cheaper, due to the economy of scale. It is worth noting, that this price does not include the cost of the land on which the TTES is to be placed. The typical heat loss is approximately 5% with a charge/discharge cycle of one week (DEA 2015).

5.2.2 Pit Thermal Energy Storage (PTES)

PTES is a relatively cheap solution for storing large volumes of energy in water (DEA 2015; PlanEnergi et al. 2013). The technology essentially consists of a large pit in the ground with a water-proof membrane preventing the water from leaking into the ground. The pit is filled with water and is covered by an insulating lid. The side walls of the pit are normally not insulated, as the soil provides an insulating effect.

Like the TTES, thermal stratification occurs within the pit, and so, a distribution system is also installed in the centre of the pit, as illustrated in Figure 5.5 below. The side walls of the pit are normally not insulated, as the soil provides an insulating effect During the first four years of operation, the heat loss of the PTES is higher than afterwards. This is due to the fact, that the surrounding ground needs to be heated up to ensure proper insulation, and this takes time. The heat loss however gets as low as 3 % after the first few years for very large storages of 500,000 m^3, while smaller storages have a bit more loss.

Figure 5.4 PTES connected to solar thermal plant in Dronninglund, Denmark (PlanEnergi 2016)

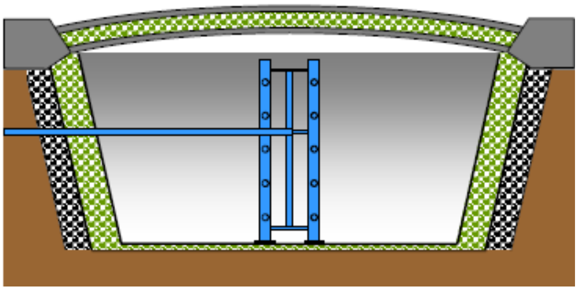

Figure 5.5 Conceptual drawing of PTES (DEA 2015)

The annual heat loss from a PTES is dependent on the temperatures in the storage, the insulation quality and the charge/discharge capacity. PTES are normally used for seasonal storage, particularly together with solar thermal plants. The size of PTES is therefore typically greater than that of TTES and the costs are lower, although the charge/discharge capacity is lower than a TTES. Due to the spatial requirements of PTES, they are most frequently applied in the perimeter of small towns, where land for accommodating the storage unit (and typically the solar collectors) is relatively cheap (PlanEnergi et al. 2013).

Denmark has numerous PTES installed, including one of the world's largest, a 203,000 m^3 unit in Vojens. The unit has a loss of about 7 % over one charge/discharge cycle and a cost of approximately 150 DKK/m^3. Other examples in Denmark are a 60,000 m^3 PTES in Dronninglund (Figure 5.4 above), which had a cost of 253 DKK/m^3 of which the insulating cover constituted the largest individual cost of around 26% (DEA 2015; PlanEnergi 2016). Like the TTES, these prices do not include the cost for purchasing the land, and depending on the geography, these costs may be high, especially in dense urban areas such as the city of Copenhagen.

5.2.3 Summary of TES technologies

The two types of TES technologies mentioned above come with different qualities and down sides. The TTES has higher investment costs than the PTES. The PTES has lower cost, but comes with higher space requirements. The PTES also have a higher storage capacity than the TTES. The different characteristics of the mentioned TES technologies are summed up in Table 5.1 below.

Table 5.1 Summary of characteristics of the TES technologies

	TTES	**PTES**
Storage medium	Water	Water
Heat loss (%)	5	5 - 20
Investment (DKK/m^3)	1100	253
Advantage	High charge/discharge capacity	Low investment costs/ high storage amount
Disadvantage	High investment costs / Requires lots of space	Requires lots of space/ low charge/discharge capacity

Due to these characteristics, a PTES solution for implementation in Høje Taastrup DH is chosen. Costing approximately 20% of what a TTES costs, the PTES is the most cost effective and recommendable storage technology for the specific location of Høje Taastrup.

6 The district heating system of Greater Copenhagen

This chapter presents an overview of the CPH-DHS, including an introduction of the relevant organisational actors, plants and infrastructure, development plans and market setup for DH. The CHP-DHS is a socio-technical network, constituted by the heterogeneous actors of physical transmission and connected heat production plants, organizations, legislation and regulation governing the transactions and delivery of heat. Heat is generated at multiple locations with multiple technologies, spread across municipal borders and managed by multiple companies. Furthermore, the market architecture for DH is designed in a particular way with overall algorithms scheduling the plants and bilateral contracts which determine the price of heat. As such, the CPH-DHS is the market in which the new PTES is to enter. Therefore, this chapter seeks to classify the system and its actors, in order to understand the socio-economic and technological interests of the actors in question.

6.1 The systems, companies and plants

The following two subsections describe the transmission companies and their role in the DH system as well as the heat producing plants and their ownership.

6.1.1 Transmission companies

There are two DH transmission companies in the Greater Copenhagen area: VEKS[4] and CTR[5]. Figure 6.1 to the right shows the logos of the companies, while Figure 6.2 below shows the geographical areas which these companies cover. VEKS, illustrated in blue, covers 12 municipalities in the western part of the system, while CTR, illustrated in red, covers 5 municipalities in the eastern part of the system. There are currently two additional DH systems in the area. The yellow area in Central Copenhagen illustrates a steam-based DH system which is managed by HOFOR. The green area in the north illustrates the West Incineration area, supplied by the waste incineration plant Vestforbrænding (VF) (Varmeplan Hovedstaden 2014b).

Figure 6.1 The logos of transmission companies VEKS and CTR

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[4] Western Municipalities' Heat and Power Company. In Danish: Vestegnens Kraftvarme Selskab

[5] Central Municipalities' Transmission Company. In Danish: Centralkommunernes Transmissionsselskab

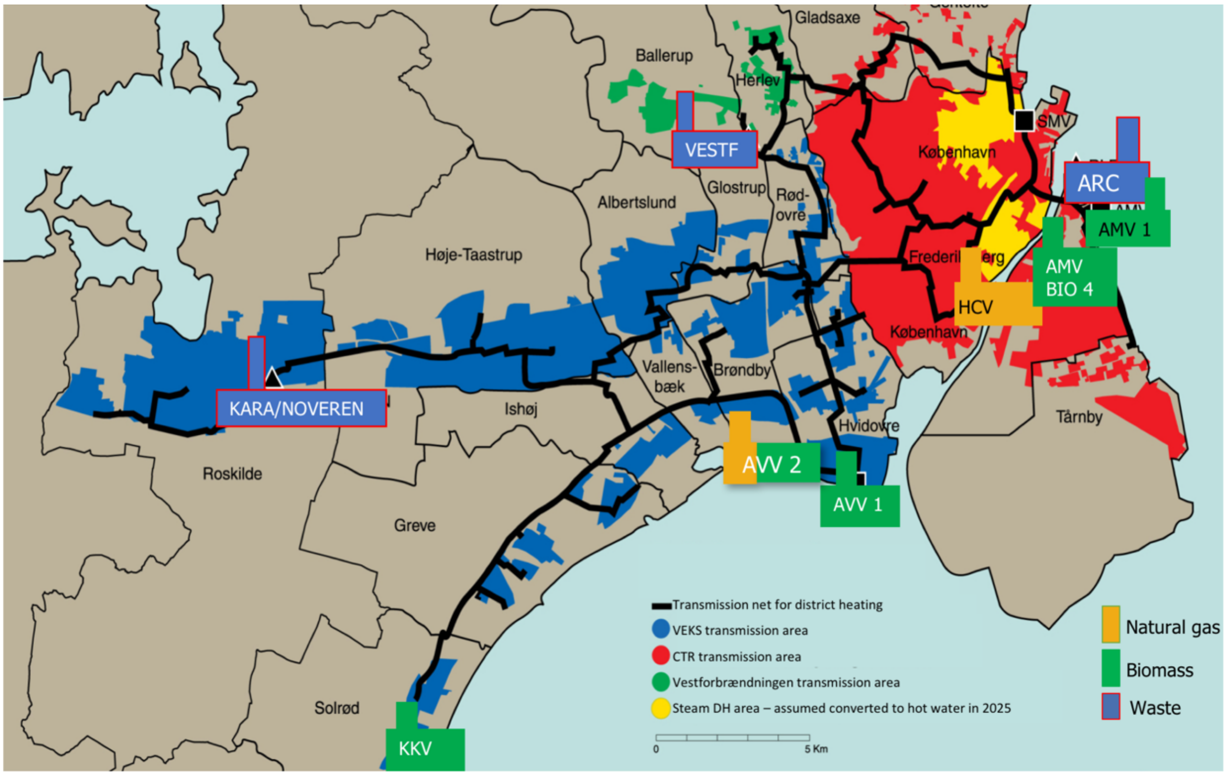

Figure 6.2 The district heating system of Greater Copenhagen,Authers own representation after Varmelast.dk

The transmission systems of VEKS and CTR, as well as the West Incineration Area, are connected, adding to the flexibility of the overall system, as heat can be transported across organizational boundaries to supply heat demands. The transmission between CTR and VEKS is limited by one 335 MJ/s connection (Varmeplan Hovedstaden 2013). The temperature of the West Incineration Area is higher than that of VEKS and CTR, and therefore heat can only be transferred from the West Incineration Area to VEKS and CTR and not back to the West Incineration Area.

The different plants spread across the system deliver heat to the transmission companies, who in turn deliver it to local DH distribution companies or directly to the consumers (Varmeplan Hovedstaden 2014b). The following section provides an overview of the existing plants.

6.1.2 The plants

There are currently four CHP plants and three waste incineration plants in the system, and these are also illustrated in Figure 6.2 above. The waste incineration plants are:

- KARA/NOVEREN (K/N),
- Vestforbrænding (VF),
- Amager Ressource Center (ARC).

The CHP plants are:

- Avedøreværket (AVV), which is owned and operated by DONG Energy
- H.C. Ørstedværket (HCV), which is also owned and operated by DONG Energy
- Amagerværket (AMV), which is owned and operated by HOFOR
- Køge Kraftvarmeværk (KKV), which is owned and operated by VEKS

In the figure, AVV and AMV are represented by two units each, as they are composed of two different heat producing units each. In addition to these, there is also a geothermal plant at AMV, a heat pump (HP) supplying district heating and cooling in Høje Taastrup, and multiple peak load boilers placed across the system supplying peak load heating and providing backup capacity in case of outages in the main plants. DONG Energy also owns the plant of Svanemølleværket, but as this only produce at peak consumption, it is included as part of the peak natural gas boiler capacity.

Towards 2025, which is the reference year of the EnergyPRO model, certain developments are assumed to be done in the system. Firstly, the steam-based DH system in Central Copenhagen is assumed converted to hot water. Second, the AVV and AMV, which currently run on natural gas, coal and biomass, are assumed to be converted fully to biomass in 2025. AVV still has two gas turbines, which are assumed to run on natural gas in 2025. These developments can be expected to occur towards 2025, as DONG has published goals to phase out coal before 2025 (DONG Energy 2017a), and as they are some of the goals established by the project Varmeplan Hovedstaden, which is described below.

6.2 Varmeplan Hovedstaden

The major heating companies of Copenhagen, VEKS, HOFOR and CTR started the project Varmeplan Hovedstaden (VPH) in 2008. The initial purpose of the project was to describe available options for developing the DH system towards 2025 (Varmeplan Hovedstaden 2014b). VEKS, HOFOR and CTR all agree on moving towards a CO_2-neutral DH supply in 2025. Therefore, the plan seeks to phase out fossil fuels, largely substituting them with biomass. For peak production units, the substitution of fuels is not determined, yet it is assumed to be CO_2-neutral. As this transition is still uncertain, this report assumes natural gas is used for peak production, while oil boilers are assumed to be phased out in 2025. VPH argues that large-scale heat pumps (HP) and electrification has potential in the CPH-DHS, if the biomass resources are restricted and terms are made more favorable for HP.

The VPH project also concludes, that there is potential for increasing the TES capacity to increase the flexibility between electricity and thermal production. Further conclusions include positive benefits from lowering the DH temperature to increase the efficiency of plants and allow better conditions for HP and geothermal (Varmeplan Hovedstaden 2014b). The overall DH demand is projected to increase as more dwellings are assumed connected to DH grids, while investments in energy efficiency can limit the overall increase.

As such, the work done by VPH is meant to be a calculative demonstration of the possible future of a CO_2-neutral DH supply. It enables a framing of future development where certain technologies are sanctioned, while others, such as fossil fuels, are not part of the future system. It translates DH actors to support a common direction for the system, and thus serves to limit contestations about the future of the DH supply. The VPH project is a central epistemic device, showcasing possible futures for developing the CPH-DHS towards CO_2-neutrality. As the project has the support of VEKS, CTR and HOFOR, it shapes the further development of the system by translating actors into a common understanding of the direction of development.

As the above sections show, the DH system is highly interconnected with differing types of companies working together while also having individual interests to pursue, as they own and operate individual plants. To maintain this system, a particular market is established, designed to schedule plants in a least cost marginal price order while also allowing the actors to negotiate individual bilateral contracts determining the price of heat. This market architecture is explained below.

6.3 The district heating market architecture

A specific market architecture regulates the heat production and transmission of the CPH-DHS. This report argues, that there are always a set of rules and understandings, laws and regulations, relationships and agreements which constitute a specific market architecture, in which a commodity is traded and priced. DH as a commodity has, in a Danish context, traditionally been produced as a by-product of electricity generation, and has thereby increased overall plant efficiency. It is produced at CHP or waste incineration plants, and supplied through a dedicated infrastructural system of pipes, pumps and exchange stations. This, in turn, has coevolved with the supporting legislation and organizational setup, where heat price regulation is in place to counter monopoly pricing while making sure plants can cover their investments. Today in the CPH-DHS, load-scheduling is done following marginal production prices by one central actor, Varmelast.dk, while prices are set by bilateral contracts. Thus, a specific market architecture exists for the scheduling of plants, and one exists for determining the price. The following sections will elaborate on the scheduling of plants and the price setting mechanisms in the CPH-DHS.

6.3.1 Load scheduling of plants

Load-scheduling is done by Varmelast.dk, by optimizing after least-cost approach to meet the heat demands. Varmelast.dk is a partnership between VEKS, CTR and HOFOR established in 2008 (Varmelast.dk 2017a). The reason for establishing a separate scheduling institution was to economically optimise the heat production across all plants, while still maintaining the needed confidentiality related to the CHP plants' operation on the electricity market. The daily heat plans are generated based on an economic optimisation considering the following criteria:

- Heat and electricity demand forecasts
- Prioritised production capacities
- Production costs, including
    - Fuel prices,
    - O&M costs,
    - Taxation,
    - CO_2 quotas,
    - Revenue from electricity sales

- Transmission bottlenecks (Varmelast.dk 2017c)

Optimising the heat plans is a process of communication between CHP plants (i.e. DONG Energy, HOFOR and VEKS) and Varmelast.dk. Figure 6.3 is an illustration of this process, and the following section describes the process in detail.

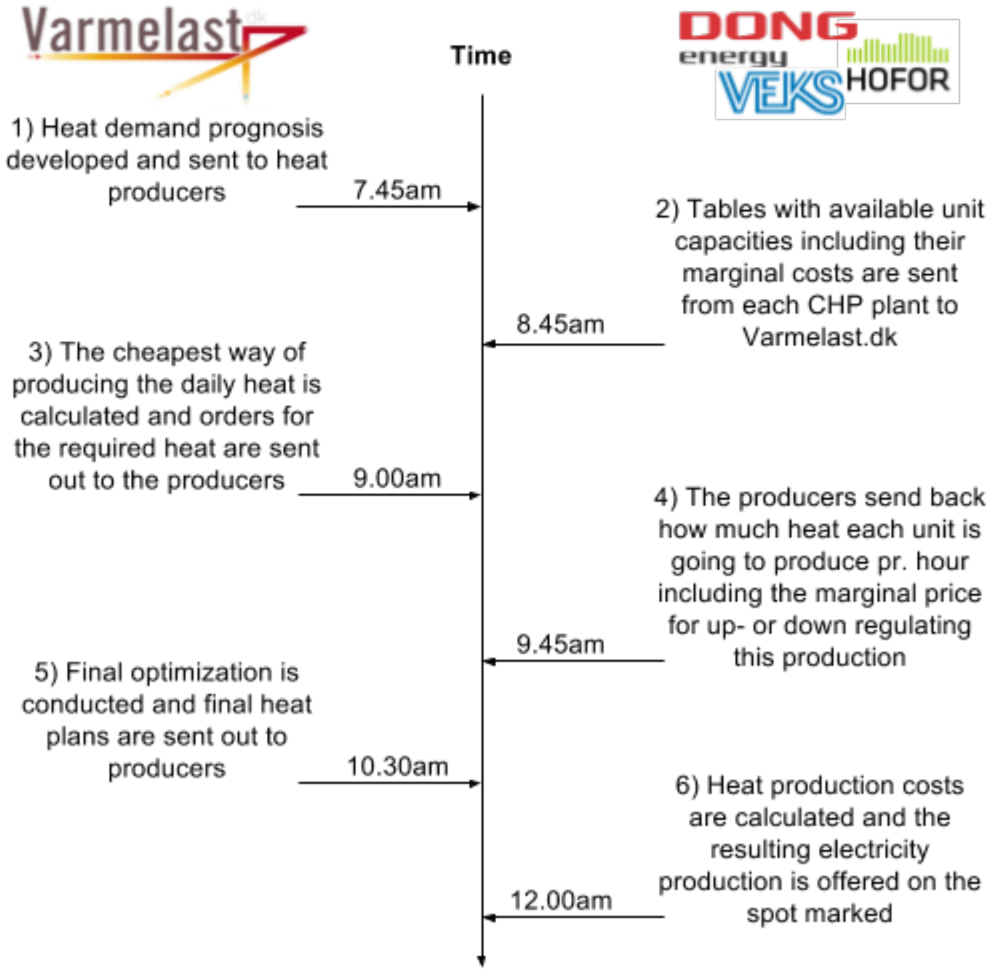

Figure 6.3 The process of creating daily heat plans. Figure reconstructed by the authors based on (Varmelast.dk 2017b)

As Figure 6.3 above illustrates, every day a series of calculations and communications are performed by Varmelast.dk and the CHP companies. The following describes this process:

1) Before 8 AM, the daily demand prognosis must be sent from Varmelast.dk to the heat producers.
2) The heat producers then establish tables with available production units, their capacity and their marginal costs, which are sent back to Varmelast.dk.
3) Having acquired this information from all plants, Varmelast.dk calculates the cheapest way of meeting the demand hour-by-hour and sends out orders to each plant, telling how much heat they are to deliver throughout the day.
4) The CHP plants then calculate the cheapest way of meeting Varmelast.dk's orders, considering electricity production, fuel prices, CO_2 quotas and energy taxes. Based on these

calculations, the heat producers send detailed plans to Varmelast.dk for how much each unit is going to produce hour by hour, as well as marginal prices for up or down regulating this production.

5) Having gathered this information, Varmelast.dk performs a final optimization considering bottlenecks in the system and optimal usage of the TTES at AMV and AVV. Final heat plans are then sent to each producer ordering the exact amount of heat to be produced by each unit, hour-by-hour for the next 24 hours.
6) Due to the producers' parallel operation on the electricity spot market, the final scheduling of the plants must be done before 10.30 AM so that the producers know how much heat they are to produce, and thereby also how much electricity they can offer on the spot market which closes at noon.

Nevertheless, even after the calculations and optimisations, the heat plans are adjusted three times a day to meet unexpected events affecting the supply and demand. For example, the actual heat demand might differ from the projected head demand on which the plans are based, or incidences might occur at the CHP plants causing them not to be able to meet the required production. Therefore, the heat plans are adjusted at 8 AM, 3.30 PM and at 10 PM (Varmelast.dk 2017c).

While this method ensures that the plant with the lowest marginal heat costs is scheduled first, this does not translate into the actual heat sale price. This is explained in the next section.

6.3.2 Determining the heat price

The price at which heat is traded is not determined at Varmelast.dk, but by bilateral agreements between VEKS, CTR and HOFOR on one side, and the CHP and waste incineration plants on the other. Several schemes are used in determining the heat prices. First off, the price of heat is determined by a non-profit principle[6], described in §20 of the *Statutory order of law on heat supply* (LBK nr 1307 2014)[7]. It describes, that only necessary expenses can be included in the price, such as investments, fuel costs, O&M, salaries etc. Biomass fuelled plants can include the taxation advantage[8] compared to fossil fuels in the heat price, according to §20 pt. 15. This states, that biomass fuelled plants may include the difference payed in energy taxation between fossil fuels and biomass, as revenue from their heat sales, thus resulting a financial advantage for biomass based plants.

The price of heat production from waste incineration plants is regulated by the lowest of two calculation methods (BEK nr 1213 2012): *the price cap* or *the necessary cost of heat* as described in LBK 1307 §20 above. The price cap is 306 DKK/MWh in 2017 (Danish Energy Regulatory Authority 2016), thus not allowing waste incineration plants to charge more for their heat production. The waste incineration plants must choose the lowest price of their heat production costs and the price cap. The necessary cost of heat is determined following the same regulation as other CHP plants.

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[6] Danish: Hvile-i-sig-selv princippet

[7] Bekendtgørelse af lov om varmeforsyning (Varmeforsyningsloven)

[8] Danish: Afgiftsfordel

Furthermore, waste incineration plants are subject to the *substitution principle*, regulating that no plant can produce heat, if a cheaper option is available. This principle is what Varmelast.dk follows in their load scheduling, by prioritizing the least cost plants. It is, however, not necessarily subject to the actual heat pricing, as the heat sales price is different from the scheduling costs.

As the heat sale prices are determined in classified bilateral contracts, it has not been possible to access and confirm the specific method used for heat price setting. From interviews with the actors in the field, a general understanding of the principles used is reached. Typically, the heat sales are split between a fixed yearly cost covering investment costs, fixed O&M and other non-production dependent expenses, and a variable cost covering fuel costs, variable O&M and other production dependent expenses. As it is difficult the determine the share of fuel costs and O&M between the electricity and heat production, a fixed ratio is used. For waste incineration plants, the heat sales price cover both fixed and variable costs, as they have historically run as base load units. As a result, the actual heat sale price is not necessarily a representation of the actual costs attributed to heat production, but rather a negotiated method of pricing.

The pricing mechanisms used is thus shaped by the particular market architecture of the DH system. Legislation describes which factors can be included in the heat price, and the actual share of fuel used for heat and electricity must be approximated. Although a general non-profit principle exists, there are possibilities for actors to include some revenue, either through a larger share of fuel costs covered by the heat side or including the option of the biomass taxation benefit.

6.4 Summary

This chapter has presented the CPH-DHS, including the organisations, technologies and market architecture of which it consists. Conclusively, the system is a socio-technical network composed of an interconnected web of different heterogeneous actors. On the one side, the organisations cooperate in developing the DH system through the planning activities of the VPH. On the other side, however, they also have their own technical and economic interests to pursue, as they own and operate different plants and infrastructure. Therefore, their position and operation in the DH market are governed by a specific market architecture, which has coevolved with the technological development of the DH system. A particular property of the DH market set-up is the fact, that the price of heating is not the same as the marginal cost for producing heating, as load scheduling is performed after a marginal cost optimisation, while the price of heating is determined in bilateral contracts between heating companies and producers.

As the different organisational actors of the CHP-DHS are configured differently within the socio-technical network, their perceptions and valuations of a new PTES entering the DH market are shaped by their configuration and thus they differ. Embarking from the descriptions of this chapter, the following chapter analyses how the interviewed actors value a new PTES.

7 The valuation framings of the PTES

Novel technologies need to have their properties defined, valued and eventually priced. This also applies when the PTES is to enter the DH market of Greater Copenhagen. This chapter seeks to analyse, which qualities of a PTES are highlighted, when the incumbent actors of the DH market describe their specific wishes and requirements regarding the technical and economic configuration of the new PTES. It also aims to present the state of uncertainty actors experience when addressing the PTES, as this can result in a divergence of valuations, with a larger emphasis of actors own socio-technical network position and perception of the technology. As such, the goal is to identify these differing valuations, and analyse them as valuation frames. The valuation frames are identified by perceiving the interviewed actors as frame-makers.

To assess why the actors propose differing valuation frames, it is also necessary to consider their socio-technical and economic positions, which shape their way of valuing the qualities of the new PTES. The actors' techno-economic constellation is described above in the preceding chapter. This is further applied in this chapter in relation to how this shapes the actors' valuation of the PTES. Starting with VEKS, this chapter thus describes which valuation frames are proposed by the interviewed actors. This is done by considering their techno-economical configuration as well as applying their statements during the interviews. Furthermore, this chapter concludes with a discussion of how the identified valuation frames overlap or differ in the pursuit of settling the qualities of the PTES, as the actors support different valuation frames.

To recapitulate, the interviewed actors are:

- VEKS
- Høje Taastrup District Heating
- KARA/NOVEREN
- Varmelast.dk
- HOFOR

7.1 VEKS

VEKS is one of the transmission companies in the CPH-DHS and delivers heat to 12 municipalities in the western part of the system. Furthermore, they are part of the VPH collaboration and they are part of Varmelast.dk. As such, they have a significant role in the system, being the link between producers and consumers of heat and being one of the key developers of the system. This role has led them to view themselves as either the project owner or as owning the project together with someone else. J.B. Sørensen explains:

> When something is added to the system, we want it to go through Varmelast.dk, to ensure that no one is sub-optimizing for themselves. And this, we believe, works best if we are the ones adding it to the system, and thereby are the owners of it (VEKS 2017).

This statement presents the valuation frame of "system optimization". VEKS believes the best setup would be for the PTES to be dispatched through the optimisation process at Varmelast.dk, so that the entire system benefits from it, rather than individual actors sub-optimizing for themselves.

Being the project owner, VEKS need to convince the other actors that the project is a worthwhile investment. This requires VEKS to consider the value for other actors in the system, and this seems to characterise the valuation frames VEKS creates. During the interview, M. Stobbe and J.B. Sørensen frame several potentials from implementing the PTES, including benefits for both heating and producing companies:

> We can all agree, that the benefit for the heating companies will typically be, that they can exchange some peak production [Natural gas boiler production, ed.] with some CHP production … And the CHP plants also see a benefit in using the storage, when they can sell their electricity at a good price (VEKS 2017).

This statement frames the PTES as having the ability of lowering natural gas boiler production as well as increasing the electricity sales for CHP plants, creating valuation frames "reduce peak production" and "increase CHP production". However, they also mention that CHP plants are likely to have the greatest potential benefit, and therefore, they should also contribute to the investment of the PTES:

> There is a value in the storage for both heating companies and CHP companies, and it looks like … it is the CHP companies, who receive the largest value from it. This is what we want to try to tell them. And if they think that it is interesting and they buy into the premise, well, then we think that they should contribute to the installation costs, corresponding approximately to the share of value, which they gain from it (VEKS 2017).

In order to enrol actors, VEKS suggests that a set of qualifying calculations should be set up, through which all actors can get their valuations tested and classified. The comment by M. Stobbe of *"It looks like..",* suggest a uncertain situation where several devices of both profession and calculation shape the valuation. J.B. Sørensen states, "*We need to make some calculations, which all stakeholders believe in, and then this is what we act upon*". As such, calculative work is needed, "bringing the PTES into being" to alleviate the uncertainty surrounding the impacts of the PTES.

Currently one factor of uncertainty is related the PTES's ability to deliver back to the transmission grid. VEKS's former analytical work implies that there is a benefit in it being able to return to transmission, but the technical solution of how to practically discharge to the transmission grid is not determined yet. VEKS has one main proposal; discharging into the return transmission and thereby increasing the return temperature as a consequence. This implies a tariff for decreasing the efficiency at the CHP plants, but according to their analyses this would still be a feasible option. A framing of "deliver to transmission via return" is identified.

If all actors can be enrolled to support the investment by a calculative device, then the calculations could form the basis for dividing the investment among the actors. According to J.B. Sørensen, agreeing on the division before the investment is made would be better than trying to identify who really harvests the benefits of the PTES after its implementation and dividing the investment based on this. VEKS rather argues, that the investments should be split according to the actors' benefits. Thus a framing of the investment model of "actors invest per benefits" is identified.

Thus, VEKS, just like Mitchell's (2008) example with Edison, creates a set of valuation frames which together are supposed to translate and enrol the other actors to participate in the investment of the PTES. The valuation frames proposed by VEKS are presented in Figure 7.1. Firstly, they frame the PTES as substituting peak production with CHP production, lowering expenses for heating companies and increasing profits for CHP plants. Furthermore, they frame the PTES as being a system storage, which accordingly should be dispatched through the optimisation process at Varmelast.dk. Uncertainties still exist about the benefits for individual actors and the method for enabling the PTES to deliver back to the transmission grid.

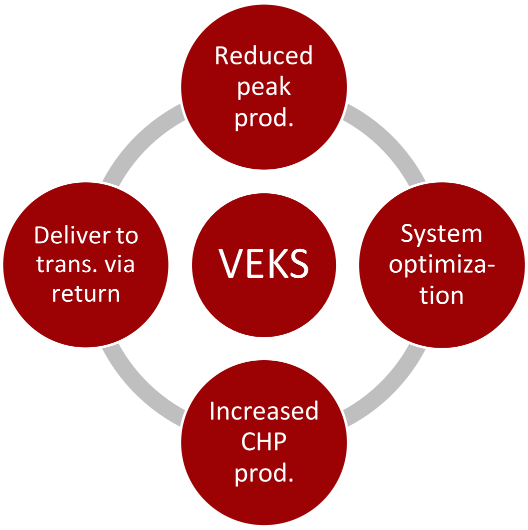


Figure 7.1 Elements in the valuation frame of VEKS

7.2 Høje Taastrup District Heating

Høje Taastrup District Heating is the DH company of the municipality of Høje Taastrup. As such, they buy heat from VEKS, and distribute it to their local costumers. A reason why Høje Taastrup DH proposed building a PTES, is that they have excess heat available from a HP, which currently generates district cooling during the summer season. It also generates heating, but during the summer period, where cooling demand is high and heating demand low, part of the heating is not utilized and thus wasted. The idea is therefore, that the excess heat from the HP could be stored during the summer and used during colder months; hence the valuation framing of "use excess heat" is identified. According to the initial project proposal for their HP, the PTES and utilization of the excess heat is a condition for the economic feasibility of the HP (Rambøll 2015). In addition to the HP, there is also industry in Høje Taastrup DH, which generates some excess heat that can be utilized, and there are currently plans for adding photovoltaics, which will also provide excess heating from electricity production. In addition to this, U. Schleiss also sees a possibility for the HP to play a role in the Balancing Market for electricity, if the HP is connected to the PTES (Høje Taastrup Fjernvarme 2017).

HTDH argues, that being able to deliver back to the transmission network will increase the value, but they are uncertain about the specific method for doing this. While the "deliver via return" is possible as mentioned by VEKS, Høje Taastrup DH also propose an option of "deliver via booster", which via an electric boiler or heat pump can increase the temperature of the water, and supply to the delivery transmission system. This has

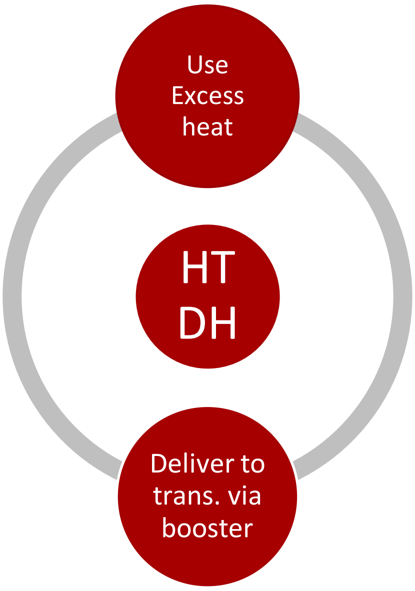


Figure 7.2 Elements in the valuation frame of Høje Taastrup DH DH

higher investment costs, but does not increase the return temperature and thus eliminates the need for a tariff payment for the resulting lower plant efficiency.

HTDH argues that as long as they can utilize the excess heat, the store can be operated by other actors, for example Varmelast.dk. Their main priority is the ability to store heat, and not necessarily who operates the PTES.

7.3 KARA/NOVEREN

Kara/Noveren (K/N) is a waste incineration plant in the town of Roskilde, located in the transmission grid of VEKS. Being a waste incineration plant, their main purpose is to incinerate waste produced by the nine municipalities which own the plant. As waste disposal is a bound task, they are currently prioritised in Varmelast.dk's daily heat plans and they produce district heating and electricity at peak capacity most of the time. According to K/N, had they not been prioritised in the heat plans, however, they would probably still produce heat and power at baseload, as they have the low marginal costs. This is because, whereas conventional CHP plants must pay for the fuel they burn, waste incineration plants are payed for receiving and incinerating waste.

As K/N is prioritised in the market, even with a new PTES, they would not have much incentive to run flexibly following the electricity price, according to K.W. Hansen, but rather produce stable baseload. However, they see another type of potential in the new PTES. According to K.W. Hansen, the heat demand is currently too low during the summer months, which means that the incineration plants do not get to run on full capacity. This wears down their turbines, which should preferably run at full capacity at all times. As such, K.W. Hansen frames the PTES as a new heat consumer, which would increase the demand during the summer, thereby potentially making the summer operation of K/N smoother. Therefore, the valuation framing of "increasing summer demand" is identified.

In addition to the summer-related challenge, K/N also sees a potential for the PTES to make their operations and maintenance more flexible. Currently, they are bound to perform a thorough three-week cleaning of their boilers during the summer months, as this is the period of the lowest heat demand. However, this is also the time during which the other incineration plants perform their cleaning. This creates a logistical problem, as there are only a limited number of maintenance workers available, who can do these types of operations, and this makes the whole affair more costly and complicated. Furthermore, due to an increasing expertise in operating and maintaining waste incineration plants, there is, according to K. W. Jensen, no longer a need for cleaning the boilers every summer. Technically, the three-week cleaning could take place less frequently. This would make the incineration plant run more hours a year, increasing the feasibility of the plants, thus resulting in the "flexible O&M" framing (KARA/NOVEREN 2017).

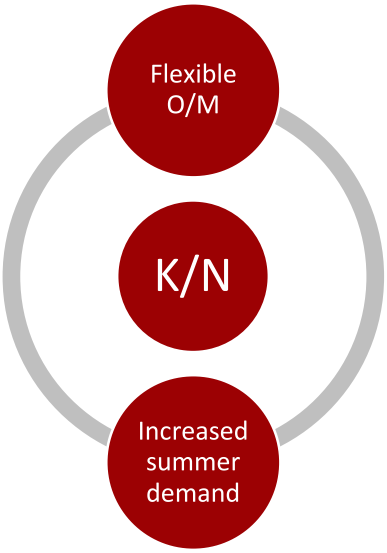


Figure 7.3 Valuation frame of K/N

Asked if he believes the new PTES would make this possible, K.W. Jensen states: "*yes, because there needs to be a demand somewhere, and the PTES is essentially just a large consumer*" (KARA/NOVEREN 2017).

Thus, K/N frames the PTES as having the potential of increasing heat demand during the summer period as well as bringing the possibility of postponing the three-week cleaning period. These two valuation frames are presented in Figure 7.3.

7.4 Varmelast.dk

As previously explained, Varmelast.dk is the coordinator of the daily heat plans, scheduling when and how much heat each plant needs to produce every day. As such, they seek to optimize both heat and power production.

P. Folke, economist at Varmelast.dk, sees potentials for implementing more storage capacity in the CPH-DHS. Especially a new PTES would supplement the existing TTES well, because a PTES typically has low charge and discharge capacities, but high total heat storage capacities, in contrast to the existing TTES, which have high charge and discharge capacities, but low total heat storage capacity. However, P. Folke sees one major limitation in the CPH-DHS when it comes to implementing more TES capacity: the connection between VEKS' transmission system in the west and CTR's transmission system in the east has too low capacity. He explains:

> We have a lot of production [in VEKS' area] and a lot of consumption [in CTR's area], and then we have one connection between CTR and VEKS' systems, which is by Damhussøen. And it is a constant challenge to push the heat in to Copenhagen, where the consumption is (Varmelast.dk 2017b).

Here P. Folke stress, that because most of the heat demand is in Copenhagen and most of the production capacity is located in the western part of Greater Copenhagen, the one connection poses challenges for the system to supply heat efficiently to all customers. Furthermore, this fact causes P. Folke to believe, that a new TES would be more beneficial if it was implemented east of Damhussøen, i.e. in the transmission system of CTR. "*It would be so much better, if you build a storage in here* [i.e. in CTR's area, ed.]" he states (Varmelast.dk 2017b). The challenge, however, is finding an area in this part of Copenhagen, with enough space and which is not too costly. As P. Folke puts it: "*It's not so straight-forward to find an unused gravel pit in Central Copenhagen.*"(Varmelast.dk 2017b).

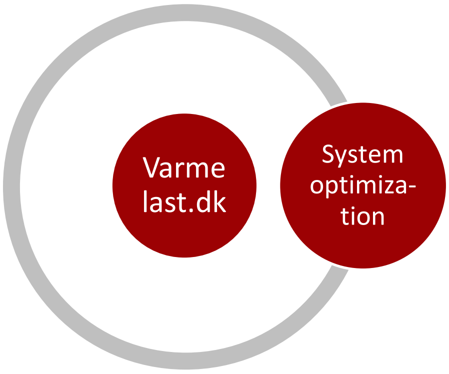


Figure 7.4 Valuation frame of Varmelast.dk

Therefore, Varmelast.dk frames the PTES as being a "system storage", which has the potential of supplementing the existing TTES, if it is operated through their optimization. This valuation frame is presented in Figure 7.4.

7.5 HOFOR

HOFOR is the Copenhagen utility company in charge of supplying DH for Central Copenhagen. Furthermore, they own and operate Amagerværket (AMV). Together with CTR and VEKS, they engaged in VPH and the establishment of Varmelast.dk. Furthermore, HOFOR is responsible for managing the planning activities of the Municipality of Copenhagen in reaching its 2025 carbon neutrality climate plan. As such, they have had interest in increasing TES capacities in their area for some time, and have made some analyses of the issue, including one feasibility study of building a PTES in a drydock in the North Harbour. This location, however, turned out to be too far away from the transmission lines for the project to be feasible (HOFOR 2017).

M. N. Nielsen explains, that they have since looked at the geographical and technical opportunities that are present in Central Copenhagen, and due to the limitations of being in the city, the most realistic option, from their view, is to build more TTES capacity in the vicinity of AMV. Accordingly, they agree with Varmelast.dk in that the spatial requirements for at PTES is a limitation in the eastern part of Greater Copenhagen. As N. Hendriksen states, "*It's not like there is a giant field available, and if there is, it would rather be used for housing, as otherwise the TES would become extremely expensive*" (HOFOR 2017). Nevertheless, they also agree that having both PTES and TTES capacities would be the optimal setup. M. N. Nielsen argues, "*It would be optimal to have both* [types of storages, ed.] *in the capital's district heating area, since they are capable of different things*"(HOFOR 2017).

Through HOFOR's own analyses, they have found out, that the most economically feasible set up of a storage is for it to be a system storage, meaning that it should be connected to the transmission grid and dispatched through Varmelast.dk. HOFOR's analyses contribute to the view that a PTES will enable increased CHP production while decreasing peak production, this being of value to HOFOR and AMV. They, like VEKS, argue, that the most feasible solution is a PTES that can deliver heat back to the transmission system. They although disagree on the solution for transmission discharge through the return delivery, as this will increase the return temperature and be against the goals from VPH of lowering the DH temperatures. For HOFOR, another solution, such as a connected electric booster HP would be a preferable option, and they thus apply the "return to transmission via booster" framing.

However, in their economic analyses they have reached the same problem as VEKS; i.e. they have identified a set of system potentials from implementing more storage capacity, but they have not been able to specify, which actors will harvest the profits. Therefore, they are also faced with the issue of establishing a business model which fairly divides the investment and the use of the storage among the actors, according to their harvested benefits. Nevertheless, they have made some considerations as to how a business model could and should look like. M. N. Nielsen states:

> I, for one, see it as being problematic, if multiple actors competing on the electricity market invest or own the same heat storage together. I don't think it would work. That's why we have concluded, that a new heat storage in Copenhagen can only be owned by a DH company, e.g. HOFOR DH, and then the producers should somehow pay to the storage, whether it be a rental cost or a tariff or something (HOFOR 2017).

Accordingly, they believe that the heating companies should agree on one type of best-practice model, which they can present to the heat producers as *the* model which will be used for all storages in the future. Furthermore, HOFOR has doubts regarding a version of a business model where competing CHP plants invest in the same PTES, like AVV and AMV. HOFOR applies a "no competitors should invest together" as a framing of the investment. Essential for the investment model, they argue, is that every actor pays according to his share of the profits, unlike the case of the existing TTES at AMV and AVV, where VEKS and CTR invested one third each, while AMV invested the remaining third for the AMV TTES and AVV invested the remaining third for the AVV TTES (HOFOR 2017). This model includes some overflows, as some actors are bound to pay for the benefits harvested by others. Therefore, HOFOR promotes the framing of the investment, that "actors pay per benefits".

HOFOR thus values the system benefits, increased CHP production and return via booster of an eventual TES, and therefore promotes these valuation frames, as shown in Figure 7.5. Whether it should be a PTES or TTES depends on the actor planning it, and HOFOR has found increased TTES capacity more applicable in their area, while still agreeing, that a PTES would work well in VEKS' area. However, HOFOR stresses, the business model for both types of storages should be similar and agreed upon before any investment is made. The model should be based on a set of energy system calculations, which show the division of the benefits, and on which all actors concur; i.e. calculations which bring the TES into being. HOFOR also have two framings of the business model: that actors should pay according to benefits, and it is problematic to have competitors invest in the same storage.

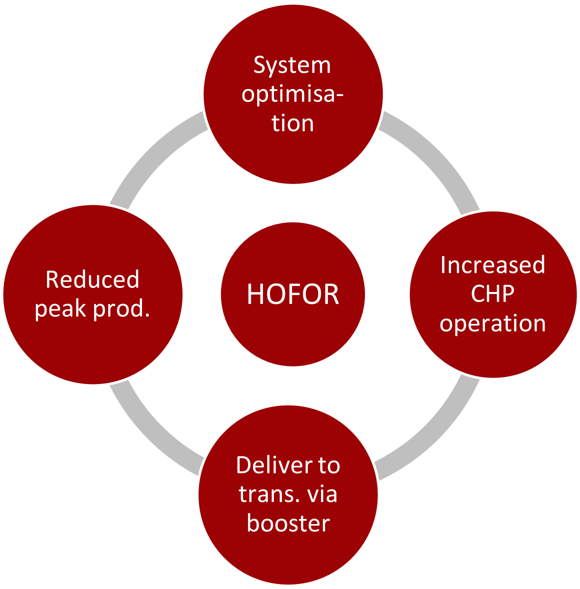


Figure 7.5 Valuation frame of HOFOR

7.6 Discussion of valuation frames

From the above sections, multiple valuation frames have been identified, and these are summed up in Table 7.1 below. Different valuation realities have been identified, being shaped by the actors' socio-technical configurations within the district heating infrastructure.

Table 7.1 Valuation frames of the interviewed actors

Valuation frame	Narrative/Metric	Valuation network
Reduced peak production	District Heating companies save expenses and shift away from fossil fuels.	VEKS, HOFOR
Increased CHP production	CHP companies increase revenue from electricity sales.	VEKS, HOFOR
System economy and optimization	The PTES brings benefits for the system and should therefore be dispatched through the optimization process at Varmelast.dk.	VEKS, HOFOR, Varmelast.dk
Use Excess heat	The PTES utilizes excess heat available in Høje Taastrup.	Høje Taastrup DH
Flexible incineration plant renovation and increased summer demand	The PTES is a new heat consumer, which increases the heat demand during summer and allows for postponing the renovation period.	KARA/NOVEREN
Deliver to transmission – Via return	Increasing the value of the PTES, as the DH system it can deliver to is expanded. Will deliver through the return on transmission network.	VEKS
Deliver to transmission – Via booster	Increasing the value of the PTES, as the DH system it can deliver to is expanded. Argues, that delivery via return decreases the efficiency at plants and is against goals set by VPH. Hence recommending a booster HP.	HOFOR, Høje Taastrup DH

From the identified valuation frames it can be seen, that the current situation is unsettled. The actors find themselves in a techno-economically uncertain space, in which they have certain wishes and anticipations regarding the qualities of the PTES, but since these have not been qualified, they remain uncertain about them. All the actors have expressed uncertainty about the situation, and called for additional knowledge production concerning the PTES.

However, whether the qualification will lead to a settlement of the situation is not certain, as the valuation going into creating the model may produce results which do not comply with those of the actors. If a settlement is to be reached, then some valuation frames must prevail over others and actors must be enrolled into the valuation network. As argued in the theoretical framework in chapter 3, situations of framing do often also result in overflows, where certain valuation framings are not considered or left out. Thus, it is important to be aware of which valuation frames are not supported by prevailing framings.

The different proposed valuation frames imply, that the PTES has not yet been rendered passive and still has several "unknown" properties. As an example, several actors promote the valuation frame of *system optimization*, arguing that the PTES needs to support the overall system performance rather than individual actor's proposals. Simultaneously, actors also promote valuation frames closely tied to their own technological reality, as Høje Taastrup DH and K/N mention the usage of excess heat in Høje Taastrup DH and the flexible O&M at K/N, thus promoting valuation frames supporting individual needs for the actors. As the PTES has not yet been qualified, it remains uncertain whether it is able to meet all these valuation frames.

Likewise, HOFOR is also basing their valuation framings on their own calculative demonstration, analysing a different storage, yet subject to the same challenges of valuation. While HOFOR agrees that a business model needs to be replicable, and the PTES should operate as a system store, they do not deploy the same valuation of the *ability to return on transmission level*. While VEKS is prepared to pay a tariff for using the return transmission, HOFOR argues that this conflicts with overall goals of lowering the DH temperature. The value of both the "return to transmission" and how the two models are proposed to technically function, are in a need of being qualified.

While not directly related to the value of the PTES, framings of the investment have also been identified. HOFOR applies a "no competitors should invest together" framing, and VEKS and HOFOR both argue, that the investment should be made so "actors invests per benefits". The "actors invest per benefits" implies a shift from past models where the investment costs were distributed evenly among investors, not taking individual benefits into account.

The valuation frames deployed by actors are clearly divergent, which suggests that the properties of the PTES are not yet settled. Figure 7.6 above illustrates the different valuation frames identified in this analysis, and their difficulty of meeting. A central narrative and demonstrative object must, like the magnet example in chapter 2 above, try to pull the different valuations closer, for them to agree on the object. As the situation implies uncertainty about the object, the actors have valuation frames grounded in their technological reality and based upon their personal or professional preferences. As the object of PTES is not stabilized or passive, several actors stress the need for additional qualification of benefits. The following two chapters will thus present the model demonstration of the possible impacts of implementing the PTES.

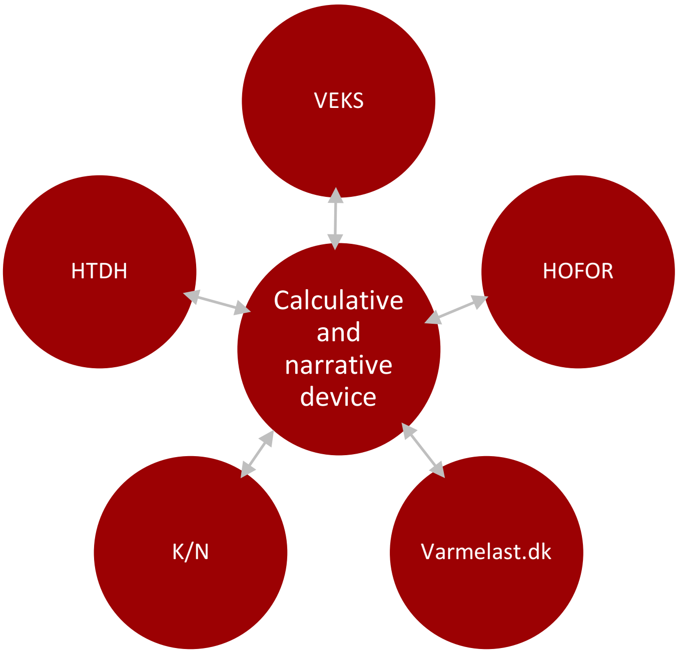


Figure 7.6 The valuation frames of actors in question, and the relation to a calculative device

8 Technical impact of PTES implementation

This chapter presents the technical results of the EnergyPRO analysis. The structure of this analysis is as follows: First, the results of the established business-as-usual reference scenario are presented. Second, the two alternative scenarios are compared to the reference scenario in terms of technical impacts of implementing the PTES. To recapitulate, the alternative scenarios are:

- Alternative 1: Implementation of 100.000 m^3 PTES in the Høje Taastrup DH distribution area, *without* the ability to deliver heat back to transmission level.
- Alternative 2: Implementation of 100.000 m^3 PTES in the Høje Taastrup DH distribution area, *with* the ability to deliver heat back to transmission level.

8.1 Reference scenario

The following subsections present the results of the reference scenario. First the overall heat production of the reference year 2025 is presented, including which plants produce heat when throughout the year. Second, the heat production from the HP currently installed in Høje Taastrup is presented.

8.1.1 CPH-DHS heat production

Figure 8.1 illustrates the share of production units meeting the demand in the reference scenario. CHP plants produce two-thirds of the supply with waste incineration supplying 29%. Peak boilers supply 4%, and the Høje Taastrup HP and geothermal unit at AMV supplies the last 1%.

Figure 8.2 below presents the daily heat production in the reference scenario. Waste incineration plants produce throughout almost the entire year, with CHP plants supplying heat outside of the summer period. Natural gas boilers are producing to meet peak demand during high consumption.

Except for the waste incineration plants and partly AVV2, the production is limited during summer due to low heat demand. The downtime for plant renovation can also be observed in Figure 8.2, for example as AVV2 is out during May, and the waste incineration facilities following each other from end of July to August.

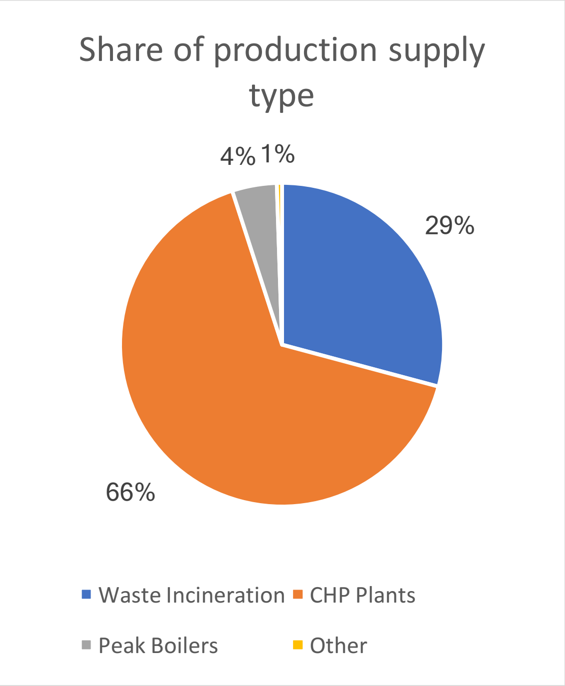


Figure 8.1 Share of production type

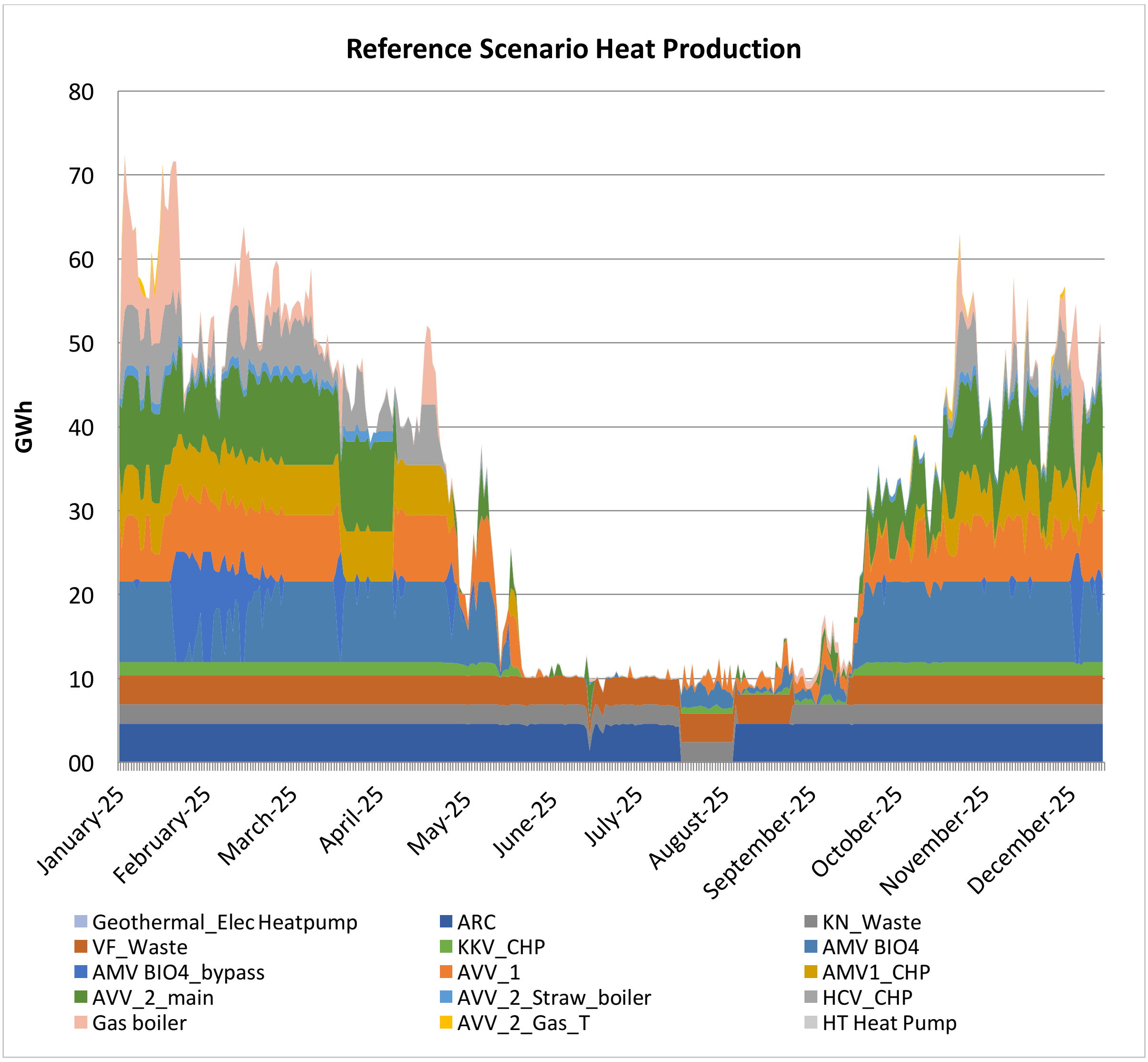


Figure 8.2 The reference scenario heat production profile, daily.

A duration curve for the yearly heat production profile is presented in Figure 8.3 below. Waste incineration supplies baseload through most of the year. ARC and KN have a capacity factor of 94% with 93% for VF. The CHP plants are producing with capacity factors around 50%. Natural gas boiler production is needed for about a third of the year, and 89 days with a daily production above 1000 MWh. The total amount of natural gas production is 484.000 MWh in the reference scenario, with a capacity factor of 4%. The maximum natural gas peak boiler capacity used is 1546 MW.

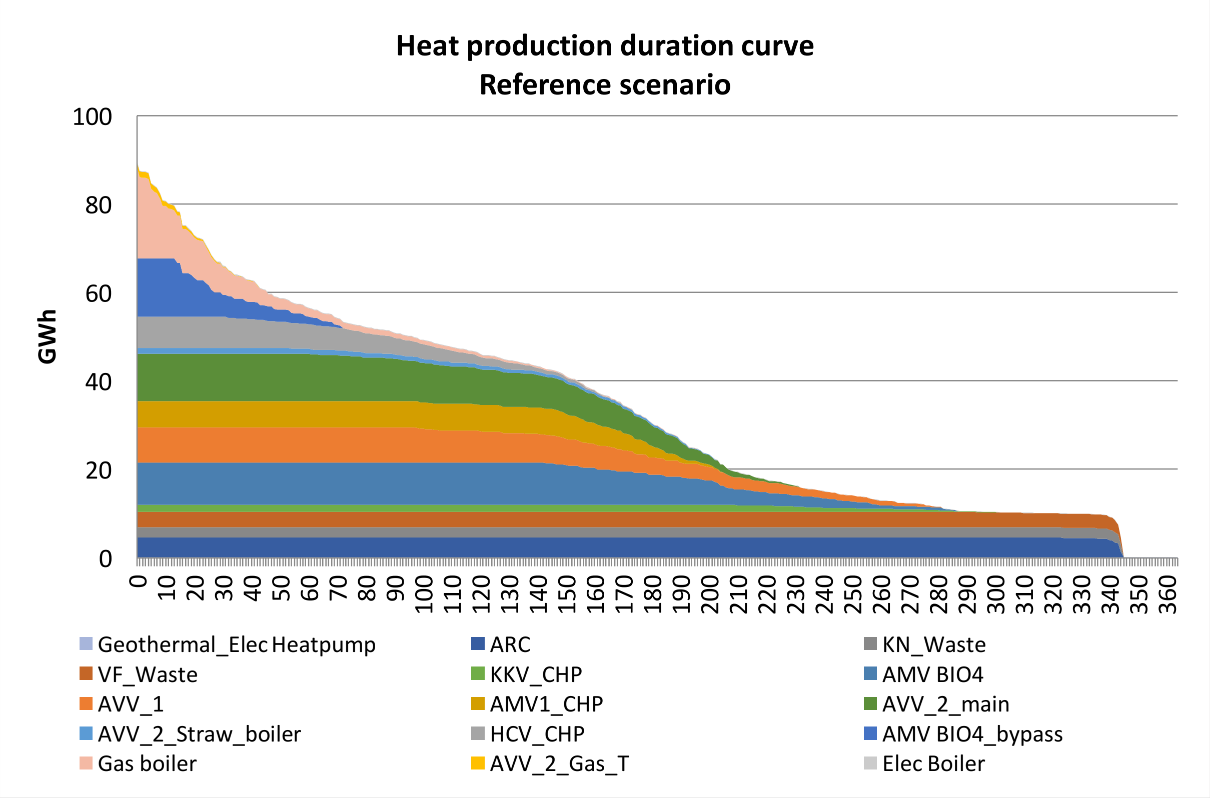


Figure 8.3 Duration curve for heat production, daily

In the reference scenario, 67.6% of the fuel consumed is biomass, with the majority being wood pellets (40.6%), followed by wood chips (23.5%) and straw (3.5%). Waste supplies 28.7% of the fuel consumption, and natural gas supplies 3.7%. The system is therefore widely dependent on biomass and waste supply, and no significant amount of electricity for heating is used in the system.

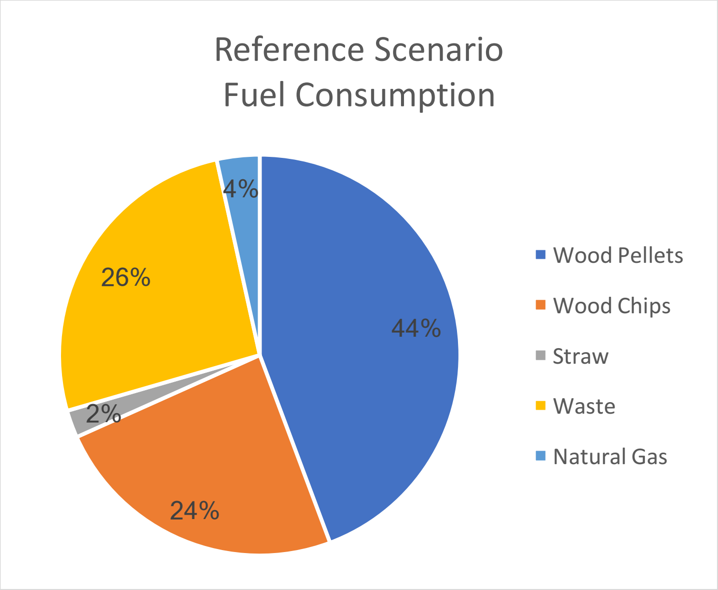


Figure 8.4 Share of fuel consumption in the reference scenario

8.2 Høje Taastrup Distribution system

The only distribution level system included in the analysis is the district heating area of Høje Taastrup, due to the location and technical aspects of the PTES. Figure 8.5 below presents the production profile of the heat pump along with the surplus heat produced during summer. The heat pump production profile is tied to the cooling demand, and capacity increases from 10 MW to 14 MW as efficiency increases during summer. This results in a yearly heat rejection of 4,039 MWh from a total production of 35,224 MWh, or 11.5% of the total heat pump thermal production.

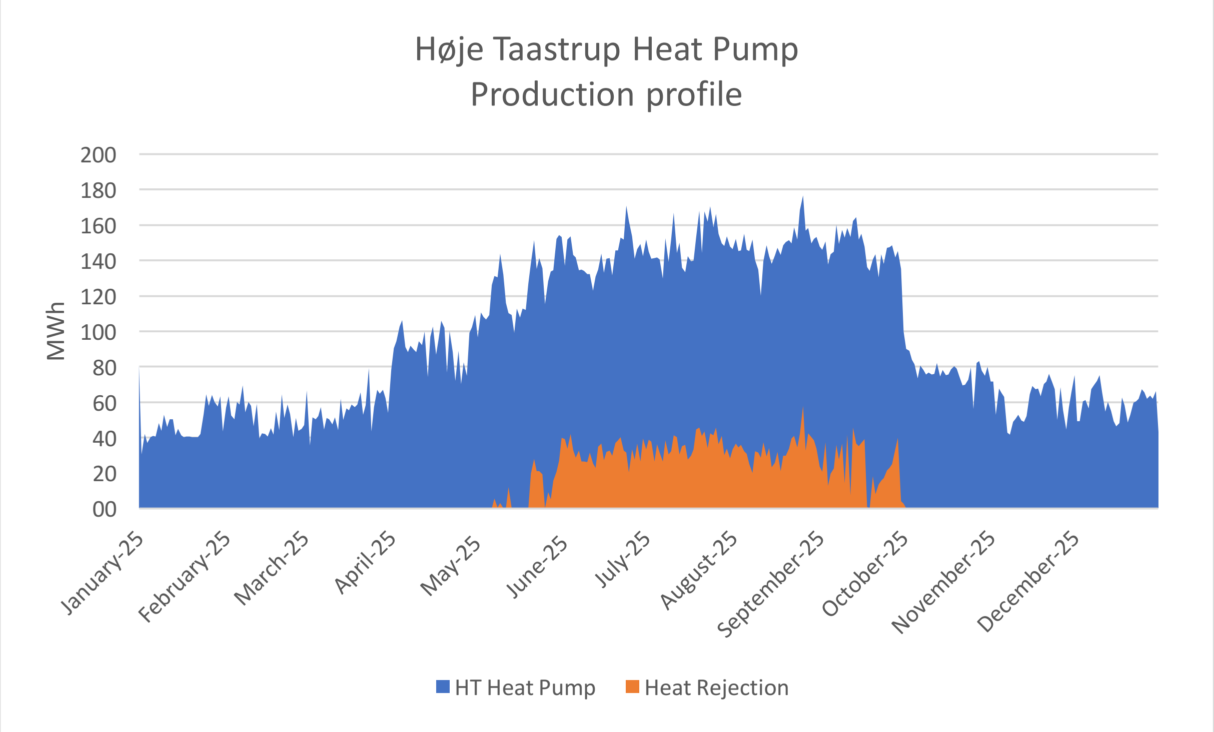


Figure 8.5 Høje Taastrup DH heat pump production profile, with unused heat production

8.3 System impact of PTES implementation

The following sub-sections present the technical impacts of implementing a PTES in the CPH-DHS. First, the impacts on the production units are addressed including how the PTES affects heat and electricity production, as well as fuel consumption of the system. Then follows an in-depth description of how waste incineration plants are affected when unprioritized in the market.

8.3.1 Production unit impact

The change in heat production per unit from the implementation of a PTES, compared to the reference scenario, can be seen on Figure 8.6 below. Positive impact illustrates increased production, while negative impact illustrates decreased heat production. Figure 8.6 shows that there is not necessarily a linear impact on the same unit from alternative 1 and 2, meaning that some units increase production in alternative 1 while decrease in alternative 2, and vice-versa. Other plants have more clear impact of increased or decreased production.

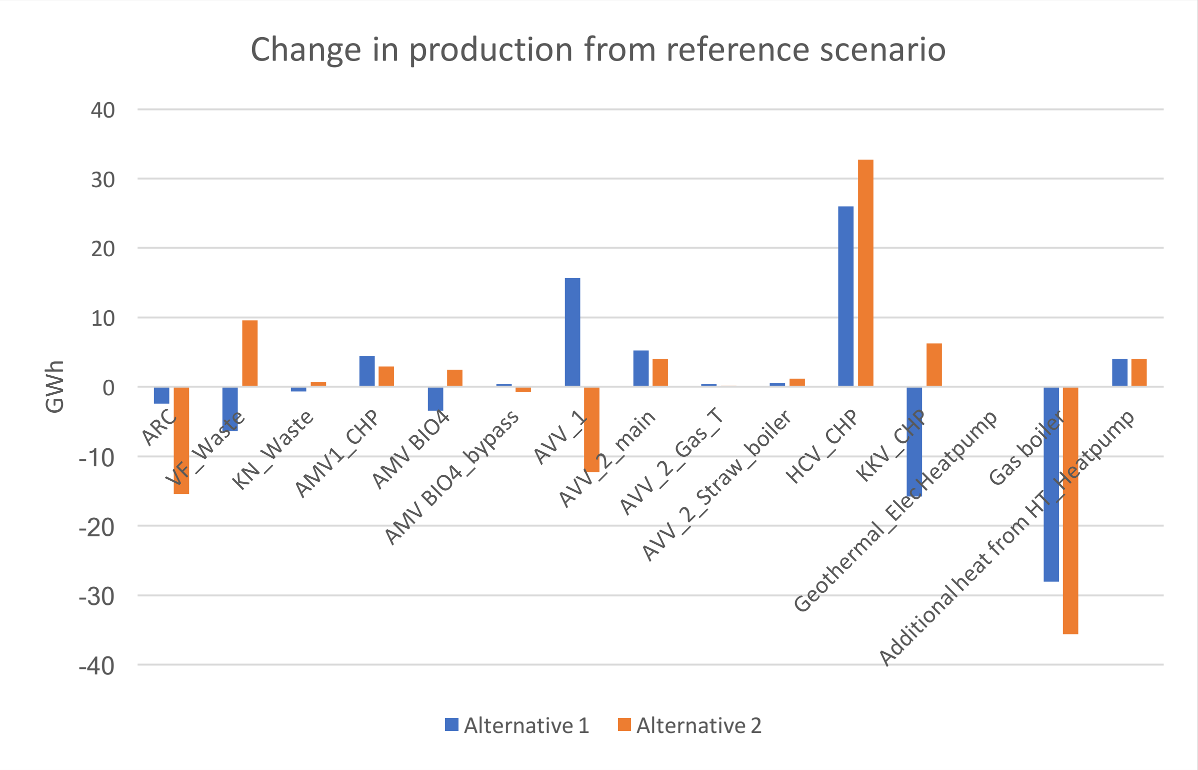


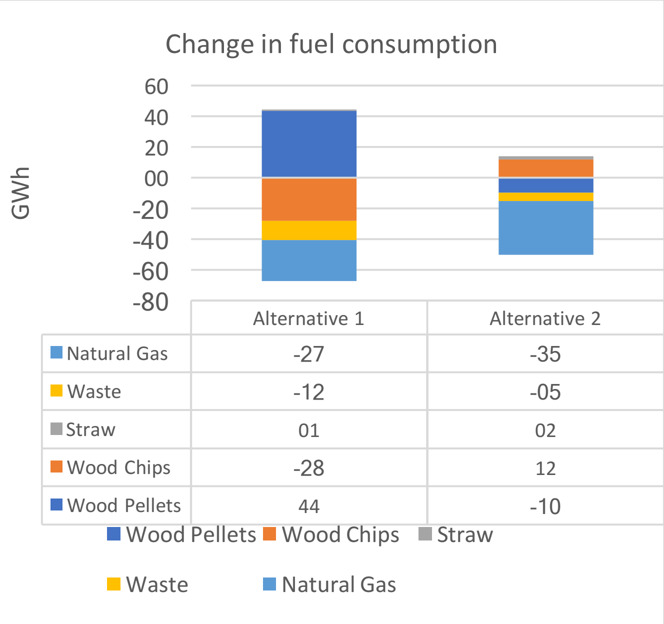
Figure 8.6 The change in heat production per plant in alternative 1 and alternative 2

The calculations show, that ARC is lowering the heat production in alternative 1 and 2, and VF and K/N are lowering the heat production in alternative 1 but increasing the production in alternative 2. AMV 1 is projected to increase the heat production, but with a higher heat production in alternative 1 than alternative 2. AMV BIO4 decrease production in alternative 1 and increase production in alternative 2, while the bypass function has the opposite impact. AVV 1 is increasing the heat production in alternative 1 while lowering the heat production in alternative 2. All units at AVV 2 are expected to increase heat production. The CHP production at HCV is increasing in both scenarios, while KKV is decreasing in alternative 1 and increasing in alternative 2. The Peak heat production is lowered in both scenarios. Furthermore, the excess heat from the HP in Høje

Taastrup is utilized with the PTES, and as such is 4,039 MWh of heat is added from the HP production.

8.3.2 Change in fuel consumption

The change in fuel consumption is presented in Figure 8.7. The natural gas consumption is decreasing in both alternatives as peak generation is limited. Waste incineration is also decreasing, while straw usage is increasing in alternative 1 but decreasing in alternative 2. Wood chip consumption decreases in alternative 1 but increases in alternative 2, while wood pellet consumption increases in alternative 1 and decrease in alternative 2. Alternative 1 saves 27 GWh and Alternative 2 saves 35 GWh of natural gas consumption, while shifting the consumption towards biomass. For Alternative 1 this is a reduction of 4.4% while Alternative 2 reduces the natural gas consumption with 5.8%.



	Alternative 1	Alternative 2
🟦 Natural Gas	-27	-35
🟨 Waste	-12	-05
⬜ Straw	01	02
🟧 Wood Chips	-28	12
🟦 Wood Pellets	44	-10

Figure 8.7 Change in fuel consumption from the reference scenario to alternatives 1 and 2. GWh

8.3.3 Change in electricity production

Figure 8.8 below shows the change in electricity production from the reference scenario to the two alternatives. From implementing a PTES, several MWh will be shifted and additional electricity generation is allowed. The increase in electricity generation is 14.3 GWh for alternative 1 and 8.1 GWh for alternative 2. As the figure only illustrates the change in electricity generation, the peaks illustrated only represent increased or decreased production in a given day. In general t can be seen, that due to the PTES implementation, more electricity is generated during hours with high electricity prices, and less electricity is produced during hours with low electricity prices.

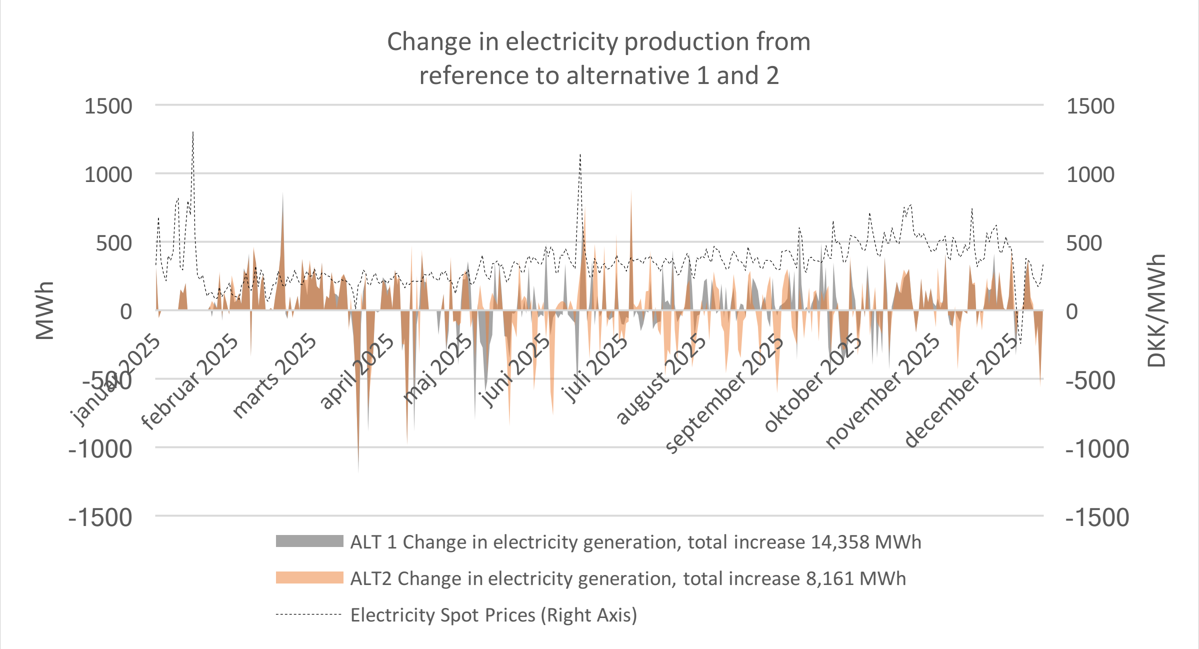
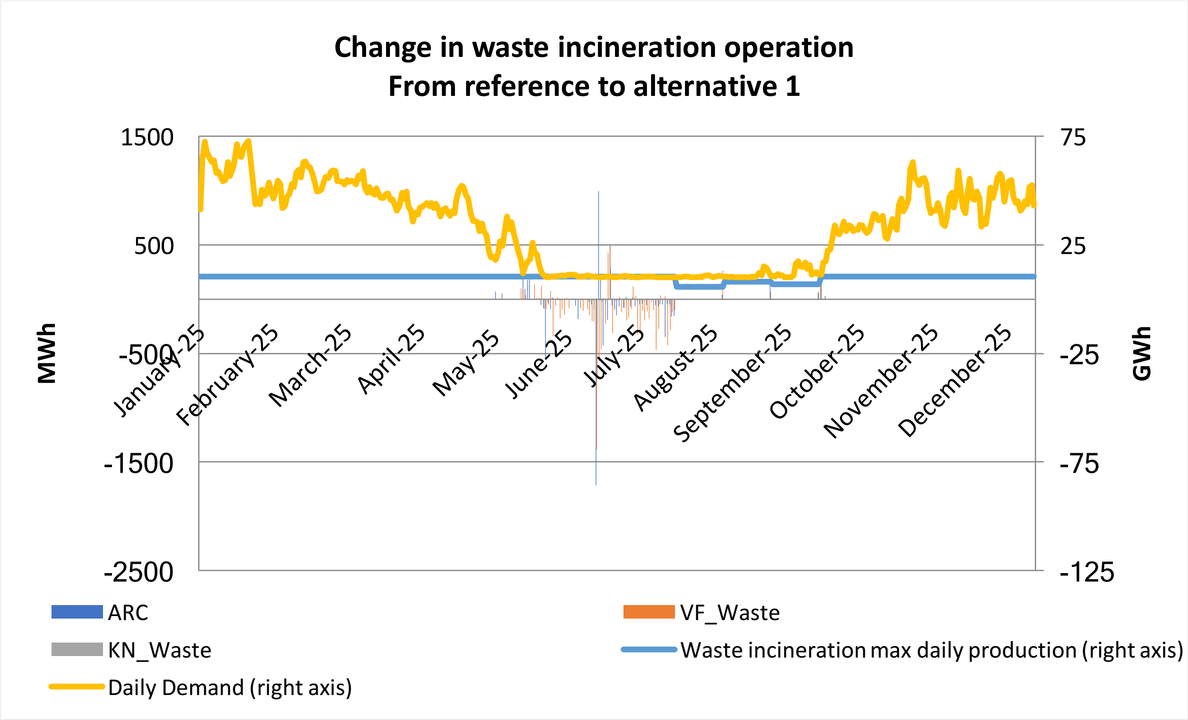


Figure 8.8 Change in electricity generation from reference to alternative 1 and 2, daily

8.3.4 Change in waste incineration operation

The model results show, that un-prioritising the waste incineration plants and adding a new PTES has an impact on waste incineration plant operation, and depending on the chosen alternative, these results can be positive and negative for their production profiles. Especially ARC is facing a lowering of their heat production as Figure 8.6 above shows. The main impact on waste incineration facilities occurs during the summer period of low heat consumption, where the combined waste incineration capacity exceeds the heat demand as shown in Figure 8.9 below.



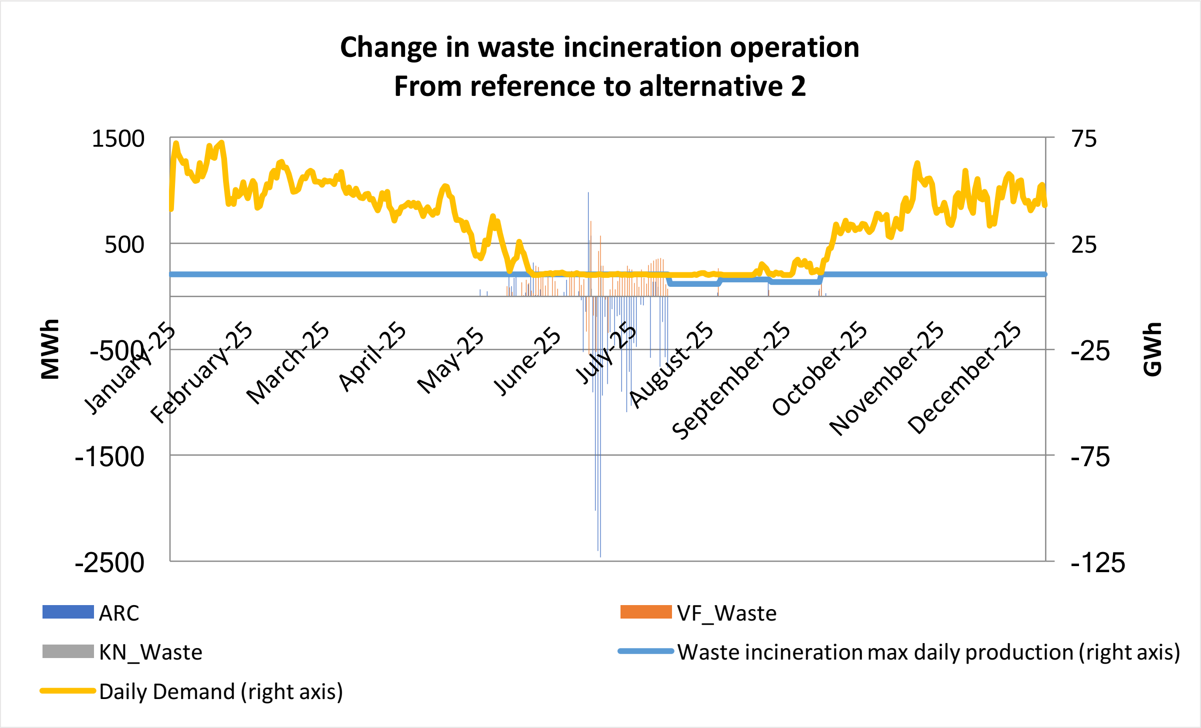


Figure 8.9 Change in waste incineration operation from reference to alternative 1 and 2

Figure 8.9 illustrates the changes in waste incineration heat production from the reference scenario to the two alternative scenarios. The change in production is illustrated per plant, to describe which plant experiences positive or negative impacts from the implementation of the PTES. The total system heat demand is illustrated by the yellow curve, and the combined waste incineration capacity is illustrated by the green line. The change in waste incineration heat production occurs mainly in the period where the total waste incineration capacity is higher than the total demand. During this period, one of the waste incineration plants will likely be the marginal producer, and thus subject to changes in production. From the figure above it can be seen, that the implementation of a PTES in the CPH-DHS impacts the production at waste incineration plants, as changes occur in both alternative scenarios. Alternative 2, however, shows greater changes in production, with ARC producing less. The following section seeks to explain why this happens.

8.3.4.1 How volatile electricity prices and PTES affect waste incineration heat production – a 10-day example from June 2025

A detailed description of the energy system dynamics is needed to explain the shift in waste incineration operation when implementing a PTES in the system. Figure 8.10 below illustrates the period between 19/06/2025 and 29/06/2025, where a high increase in electricity prices occurs. This situation occurs three times during the period in the reference scenario, where CHP plants, illustrated in orange, turn on to produce during high electricity prices. As the heat demand is met by waste incineration plants in the beginning of the period, the CHP plants produce to the existing TTES available at AMV and AVV. The charging of the TTES is illustrated by the blue line in Figure 8.10 which is illustrated as negative as the PTES takes produced energy out of the system for later usage. To allow for continued production on the CHP plants during the next electricity price peak, the TTES is discharged, illustrated in yellow, pushing out production on the waste incineration plants.

In alternative 1, the PTES is used only during the hours where electricity prices are above 1,700 DKK/MWh in this 10-day cycle, illustrated by the dark-blue line which like the TTES falls negative during charge. However, its presence allows for increased use of the TTES especially during the 26/06 and 27/06 and a decreased use between 28/06 and 29/06, compared to the reference scenario. The PTES is not discharged in a significant amount during this period. Compared to the reference scenario, the TTES is charged one additional cycle in alternative 1, between the 26/06 and 27/06.

The PTES is allowed a larger role in alternative 2, as here it can also deliver back to the DH transmission system. The PTES is charged during hours of high electricity prices, and discharged during hours of lower electricity price. In addition to the increased usage of the PTES, the TTES are also used more compared to the reference scenario. As the storages are charged through high electricity price hours, they allow for decreasing the production on waste incineration facilities in the following hours.

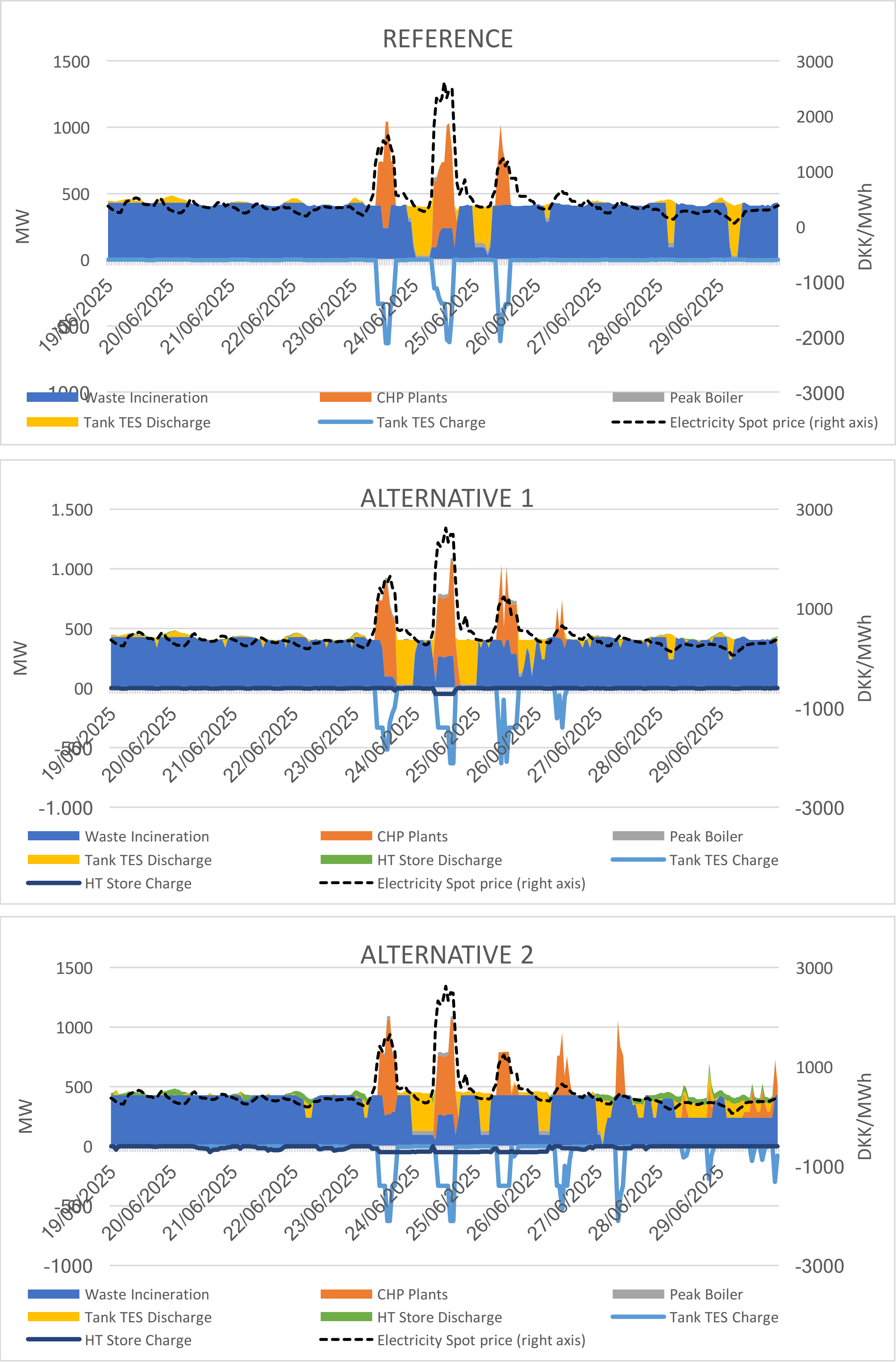


Figure 8.10 Plant operation 19/06/2025 - 29/06/2025

8.3.4.2 Summary waste impact

This section has described the impact from un-prioritising waste incineration plants and implementing the PTES. The model results indicate, that ARC will decrease the heat production in both alternatives, while VF and K/N decrease their production in alternative 1 but increase it in alternative 2. While the PTES does not directly impact the waste incineration heat production, it allows for alternative use of the TTES which replaces waste incineration during periods of low demand, where waste incineration is the marginal producer.

8.4 PTES operation

A central question regarding the PTES, is whether it should have the ability to return heat to the transmission system, or whether it should be limited to delivering to the Høje Taastrup DH area. This is what alternatives 1 and 2 aim at exploring. Figure 8.11 presents a duration curve for the Høje Taastrup heat demands compared to the discharge capacity of the PTES. The PTES with a discharge capacity of 50 MW would be able to discharge full load in 41 days of the year, while it must deliver on partial load for the remaining days of the year. If the PTES can return to the transmission grid, as Alternative 2 describes, this limitation will be removed.

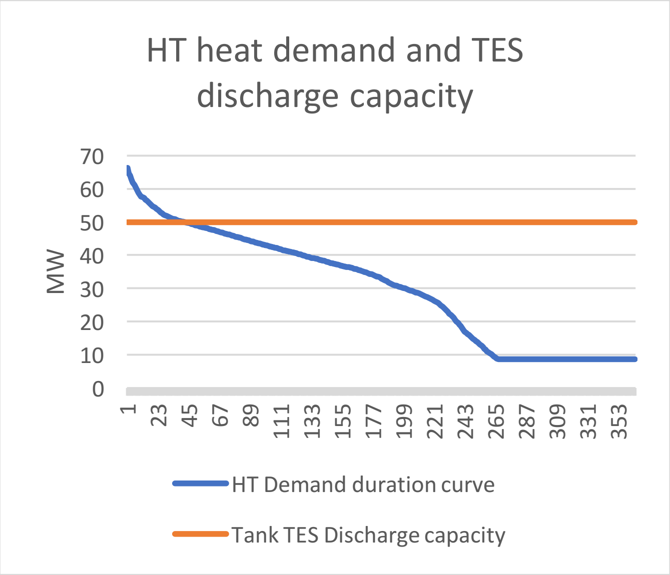


Figure 8.11 Høje Taastrup DH heat demand duration curve and

The hourly amount of stored energy in the proposed PTES is presented in Figure 8.12 below. The PTES operates in cycles, where the store is charged during high electricity prices and discharged when the spot price drops. The PTES is thus mainly used to adjust the production on daily and weekly basis, and not on a monthly or seasonal basis. In alternative 1, however, the usage of the PTES during June to September is limited. In alternative 2, the PTES is used for several cycles during this period. The total amount stored in alternative 1 is 92,849 MWh whereas in alternative 2, 137,274 MWh is stored. Both scenarios eliminate the heat rejection from the Høje Taastrup HP.

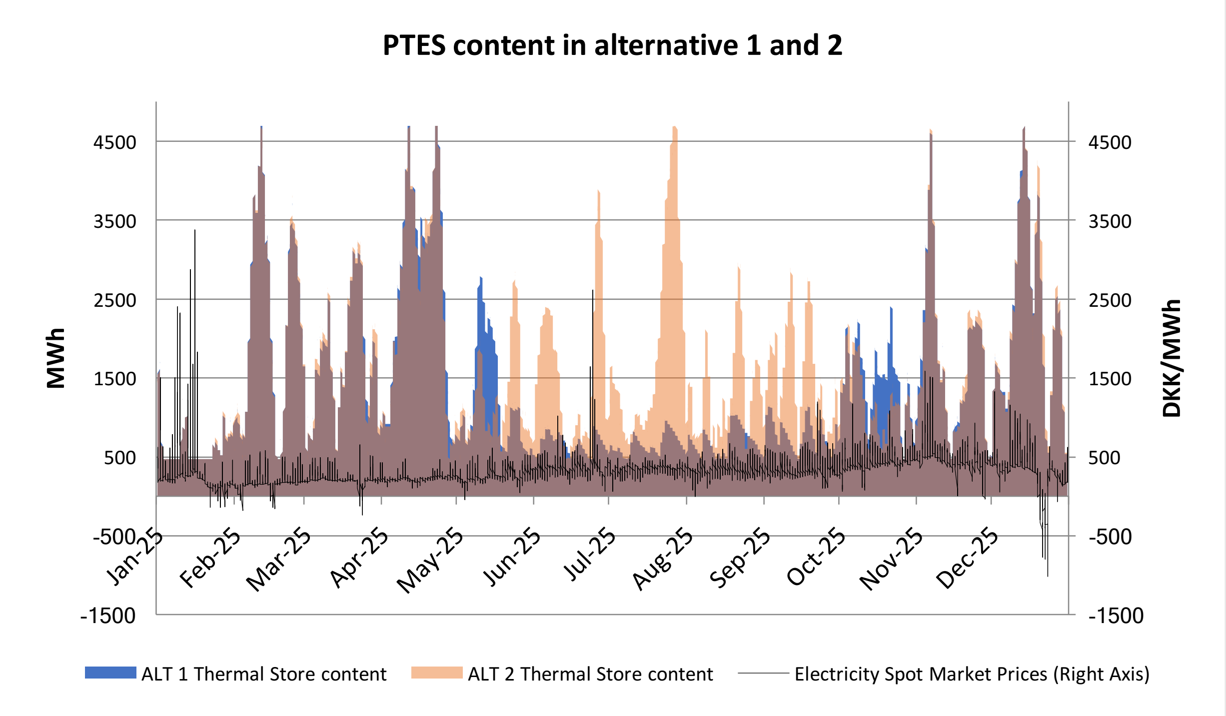


Figure 8.12 Hourly energy stored in the proposed PTES in alternative 1 and 2. The colours in the figure are graduated, which is why there appear to be three colours. The dark-brown colour, however, represents hours that have similar storage content in both alternatives.

It can also be seen, that the PTES is used according to the electricity spot market prices. It is both charged during high electricity price periods to increase electricity sales, and discharged during low electricity price periods to avoid losses. The PTES is fully charged at 4,693 MWh five times in alternative 1 and six times in alternative 2, suggesting that increasing the capacity of this particular storage is not needed.

Figure 8.13 below presents the total of PTES usage in the three scenarios. The total amount of thermal energy stored is 612 GWh in the reference, 689 GWh in alternative 1 and 715 GWh in alternative 2. As the PTES is implemented, the amount of stored energy in the AMV and AVV TTES slightly decreases.

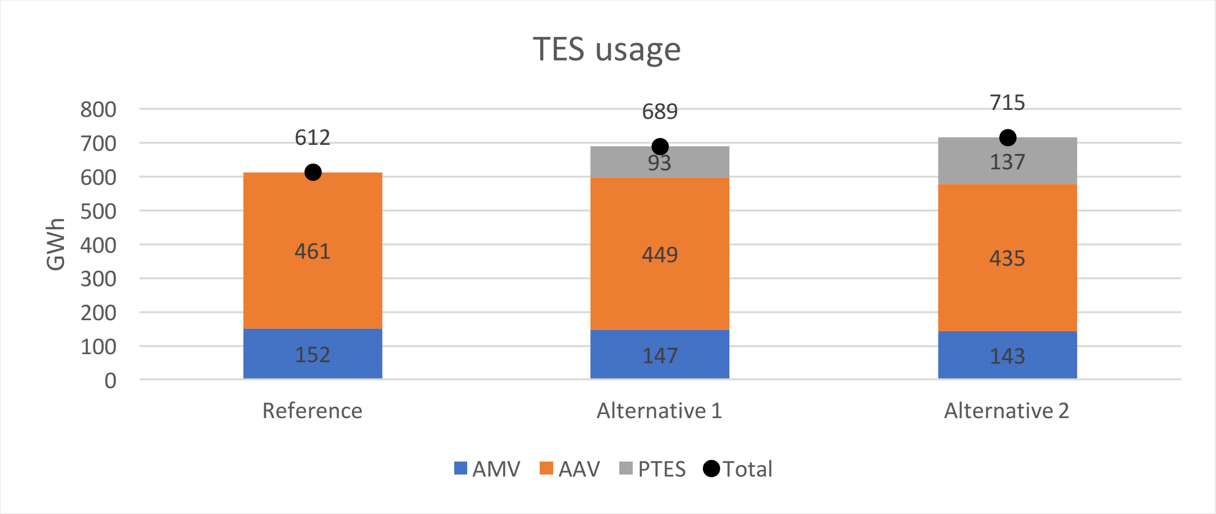


Figure 8.13 TES usage in the reference scenario and alternative 1 and 2

8.5 Transmission company impacts

This section presents the potential benefits for the transmission companies in CPH-DHS, VEKS and CTR, as well as for the company of VF, which supplies heat to the northern part of Greater Copenhagen.

8.5.1 The heat production for VEKS, CTR and VF

Figure 8.14 below shows the units supplying heat for the transmission area of VEKS as well as the impact of implementing a PTES in Høje Taastrup. Overall, VEKS is a major exporter of heat to CTR, which is set to increase from 1,338 GWh in the reference scenario to 1,339 GWh in alternative 1 and 1,358 GWh in alternative 2. As AVV 1, AVV2 and K/N supply most the heat in VEKS, peak boiler production is relatively low, with 5.3 GWh in the reference scenario, 4.1 GWh in alternative 1 and 3.9 GWh in alternative 2.

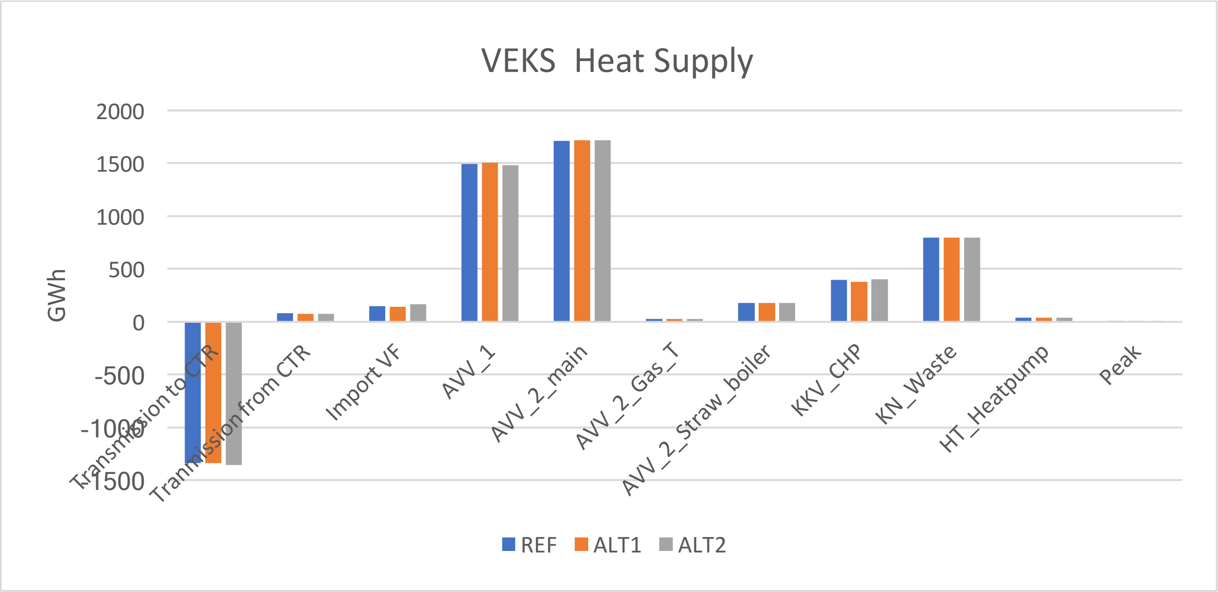


Figure 8.14 The heat supply for VEKS transmission area, GWh

As shown in Figure 8.15 below, CTR is a net importer of heat from VEKS and VF, with the import from VEKS expected to increase, while decreasing from VF in the two alternatives. AMV BIO4 supplies the majority of heat, with ARC and HCV following. Peak heat supply is set to decrease from 439 GWh in the reference scenario, to 413 GWh in alternative 1 and 406 GWh in alternative 2.

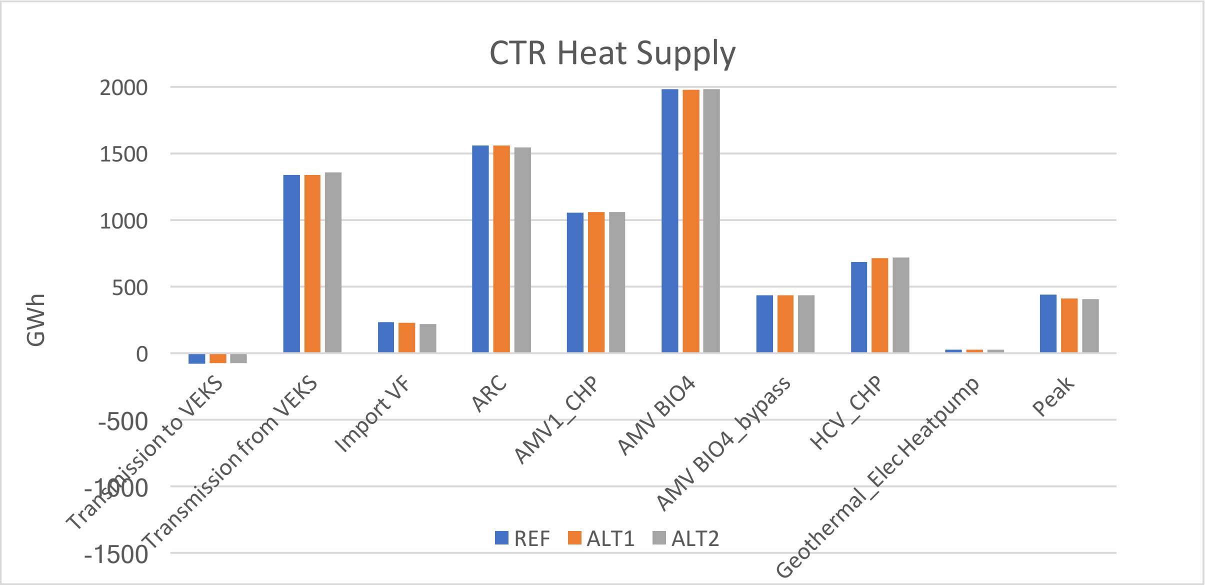


Figure 8.15 The heat supply for CTR transmission area, GWh

Figure 8.16 below shows the heat supply in the transmission area of VF. The waste incineration facility of VF supplies most of the heat with a limited peak supply. VF is an exporter of heat, and cannot import as the DH temperature is higher in the VF area than in CTR and VEKS, as mentioned in chapter 6. The waste incineration production decreases from the reference scenario to alternative 1, but increases in alternative 2, from 1168 GWh to 1162 GWh and 1178 GWh respectively. The peak boiler production decreases in both alternative 1 and 2, from 95.5 GWh in the reference scenario to 94.7 GWh and 94.4 GWh respectively. The transmission of heat to VEKS and CTR thus decreases from 378.2 GWh in the reference scenario to 370.9 GWh in alternative 1, while increasing to 386.7 GWh in alternative 2.

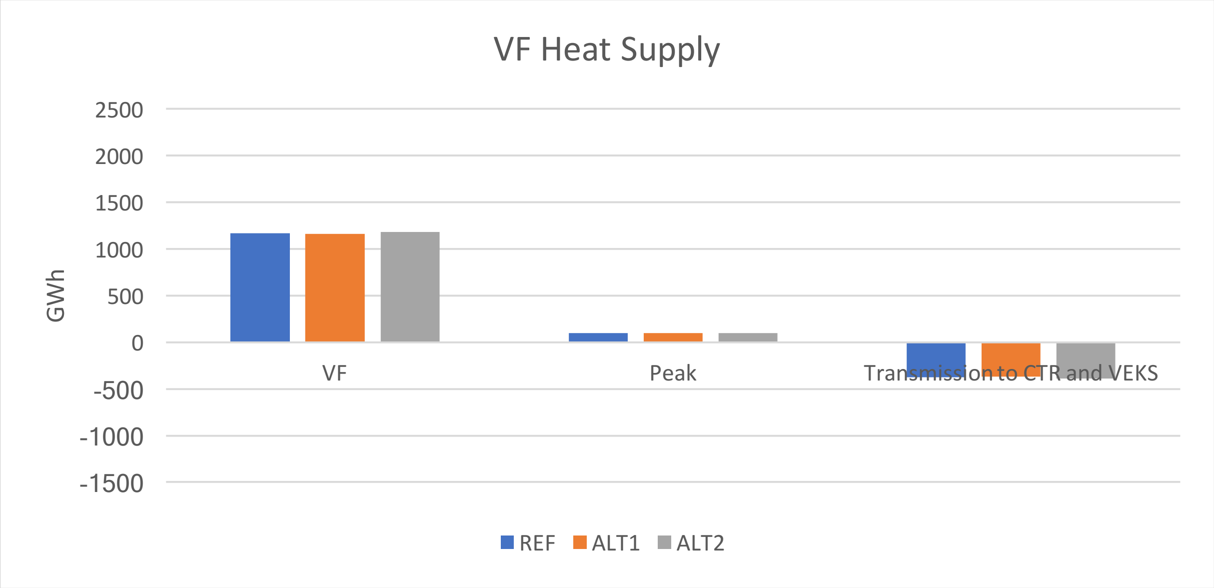


Figure 8.16 The heat supply for VEKS transmission area, GWh

8.6 Summary of technical impacts from PTES implementation

The first part of the analysis presented above shows, that by implementing a PTES in the CPH-DHS, the fuel consumption can be shifted from natural gas to biomass, primarily by lowering the peak boiler consumption. CHP plants can produce increased amounts of electricity and heat due to the PTES and by replacing peak boiler production. According to the model, the PTES is utilized in cycles and not as a seasonal storage. As such it enables CHP and waste incineration plants to produce following fluctuations in electricity prices, by increasing production during high price hours and lowering production during low price hours.

The model results also show, that the changes in production for the individual plants can be both positive and negative. Especially ARC is projected to lower the production, due to electricity spot price spikes during the summer period of low consumption where the waste incineration plants are the marginal producers. Other plants are also subject to decreasing production, depending on the chosen scenario. AAV1 is projected to increase production in alternative 1 while decrease in alternative 2.

The second part of the analysis above present the technical results for the transmission companies. Table 8.1 below illustrates the change in heat supply for VEKS, CTR and the VF area compared to the reference. CTR increases the heat supply from CHP plants, while VEKS increases the supply in alternative 1 but decrease in alternative 2. The waste incineration heat supply in VEKS is almost constant, while CTR has a lowered waste incineration heat supply. VF decrease the heat supply from waste incineration in alternative 1, but increase in alternative 2. Peak boiler consumption is decreasing in all areas for both scenarios, with the majority of the savings in the CTR area.

Table 8.1 Change in heat supply compared to reference scenario, GWh

	CHP Production, GWh	Waste Incineration, GWh	Peak Boiler, GWh	Export, GWh	Import, GWh
		VEKS			
Alternative 1	6.0	-0.7	-1.2	1.2	-7.0
Alternative 2	-0.7	0.7	-1.4	20.7	18.1
		CTR			
Alternative 1	27.5	-2.4	-26.0	-1.9	-1.1
Alternative 2	37.5	-15.5	-33.1	-2.7	8.4
		VF			
Alternative 1	-	-6.4	-0.8	-7.3	-
Alternative 2	-	9.6	-1.1	8.5	-

Having presented the technical impacts, the following chapter presents the economic impacts from implementing a PTES in the CPH-DHS.

9 Economic impact of PTES implementation

This chapter presents the results from the economic analysis of implementing a PTES in the CPH-DHS. Firstly, the overall system economy is presented. As argued above, the system economy is difficult to translate into actor economy, as the specific market architecture needs to be taken into account. Therefore, secondly, economic changes for transmission companies CTR and VEKS are considered. Thirdly, economic changes for production units in the system are considered.

9.1 System economy impact

The overall system economy is presented in Table 9.1 below. The implementation of a PTES results in increased revenue from sales of electricity on the spot market, increased fuel costs, lower O&M and decreased spending on energy taxation. As CHP plants increase production, their revenue from electricity sales increase. As fuel use is shifted from natural gas to biomass, fuel costs increase, as shown in appendix A. Alternative 1 increases more than alternative 2, but both increase compared to the reference scenario. O&M expenses decrease slightly from the reference to alternative 1 and 2. Energy taxation expenses decrease, again as fuel usage is shifted from natural gas toward biomass. The system economy is thus in a deficit, to be covered by district heating sales. As this deficit decrease from the reference to the two alternatives, district heating sales are covering a smaller part of the system economy, thus resulting in a saving for the overall system costs.

Table 9.1 System economy M.DKK

	Electricity Sales	**Fuel Cost**	**O&M**	**Taxation**	**District heating consumer coverage**
REF	1,804.6	2,672.3	144.1	523.4	-1,535.2
ALT1	1,812.6	2,681.4	143.6	521.3	-1,533.6
ALT2	1,811.3	2,675.7	143.4	520.9	-1,528.8

The change from the reference scenario to the two alternatives is presented in Figure 9.1 below. The increase in electricity spot market revenue is 8 M. DKK in alternative 1, and 6.6 M. DKK in alternative 2. Fuel costs increase with 9.1 M. DKK in alternative 1 and 3.4 M. DKK in alternative 2, O&M decrease with 0.5 and 0.7 M. DKK, and the energy taxation expenses decrease with 2.1 M. DKK and 2.5 M. DKK in alternative 1 and 2 respectively. The total system saving is thus 1.6 M. DKK in alternative 1 and 6.4 M. DKK in alternative 2.

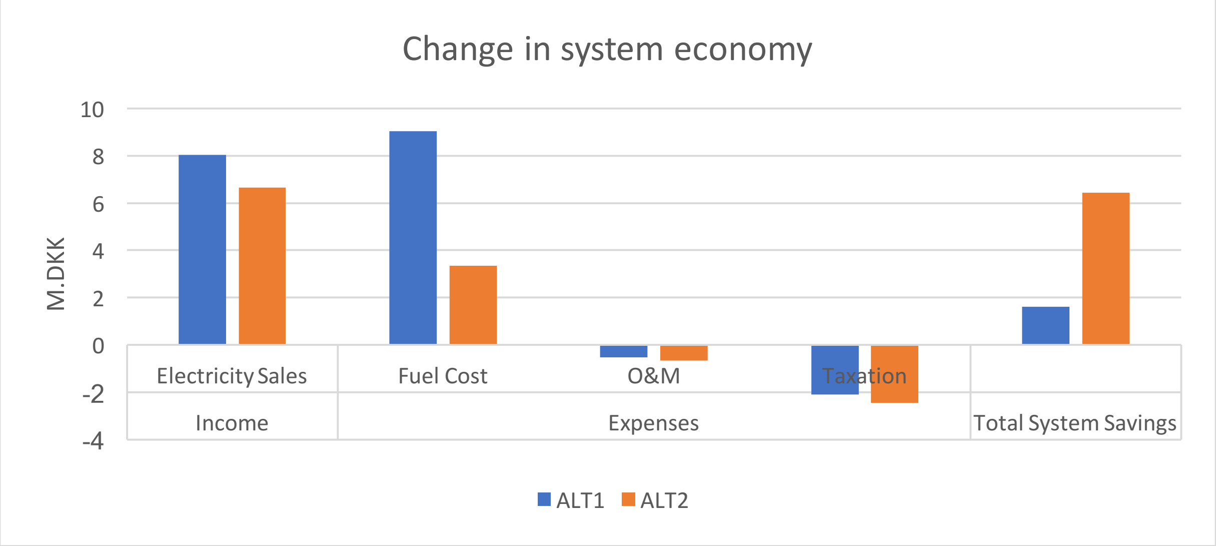


Figure 9.1 Alternative 1 and 2 system economy compared to the reference scenario

The results show, that implementing a PTES in the Høje Taastrup DH distribution area would be beneficial for the system economy. These system benefits, however, do not specify which actor receives the benefits in the form of savings and earning, and this is the great challenge addressed by the interviewed actors. Therefore, the next section analyses which actors could benefit from the PTES. As argued, the benefits depend on the specific market architecture of the DH network, as bilateral contracts, technical difficulties of determining the share of fuel between heat and electricity production, norms and practices govern how the benefits from PTES will be distributed. This market architecture is accounted for in the following.

9.2 Transmission company impact

This section presents the impacts of PTES implementation for VEKS and CTR. As the transmission companies buy heat from plants and transmit it to distribution companies and among themselves, their potential savings come from changes in supply mix or increased export. Export of DH is considered as the only revenue for the transmission companies, as all other heat sales are covered by sales to distribution companies within their area. As such do both VEKS and CTR have a share that must be covered by DH consumers, and their main objective is to lower this share.

In the following analysis, a marginal pricing principle is assumed for the heat exchange, meaning that the marginal heat producer in each area sets the exchange price in that given hour. This principle is described in chapter 4 and appendix A. Furthermore, as it is difficult to determine the exact distribution of fuel between heat and electricity production, it is assumed that a method of a fixed share between heat and power is negotiated in the heat sales contracts, as argued in chapter 4.

9.2.1 VEKS economy impacts

The expenses from heat purchases for VEKS are presented in Table 9.2 below. The analysis shows a DH heat consumer coverage savings of 0.67 M. DKK in Alternative 1 and a saving of 1.79 M. DKK. VEKS decreases spending on peak heat production in both alternatives. Revenue from export to CTR increases in alternative 1, while expenses from import, waste incineration and peak production decrease. Expenses from CHP plants increase.

In alternative 2, the import expenses, waste incineration expenses and export revenue are higher than the reference, while CHP plant and peak heat production expenses are lower, resulting in a saving compared to the reference scenario.

Table 9.2 Impact on VEKS: revenue and expenses, M. DKK

	Revenue from	**Expenses from**					
	Export	Import	Waste Incineration	CHP plants	Peak production	HT HP	District heating consumer coverage
REF	467.1	72.1	244.2	1,306.0	2.3	5.8	1,163.5
Change from reference							
ALT1	0.49	-2.44	-0.21	2.97	-0.52	-	-0.67
ALT2	6.05	5.30	0.21	-0.65	-0.60	-	-1.79

As shown in Figure 8.6 above, the PTES makes it possible to utilize 4,039 MWh more from the Høje Taastrup HP, as this production is not rejected in alternative 1 and 2. As Høje Taastrup DH is located within the transmission area of VEKS, their economic impacts are included in the overall impacts of the economy of VEKS. While Table 9.2 shows no change in the economy from the Høje Taastrup HP, it is because this heat is produced regardless of the scenario. The utilized heat replaces other production in the area of VEKS, thereby assisting in decreasing the DH consumer coverage.

9.2.2 CTR economy impacts

The heat purchase expenses for CTR is presented in Table 9.3 below. Both alternatives result in a lower DH coverage for CTR, with 0.50 M. DKK saved in alternative 1 and 1.36 M. DKK saved in alternative 2. In alternative 1, CTR decrease the revenue from export, decrease the expenses for waste incineration, peak production and import, while increase the expenses from CHP plants. In alternative 2, CTR decrease the revenue from export, increase the expenses from import and CHP plants while lowering the expenses for waste incineration and peak production.

Table 9.3 Impact on CTR: revenue and expenses, M. DKK

	Revenue from	**Expenses from**					
	Export	Import	Waste Incineration	CHP plants	Peak production	Geo-thermal	District heating consumer coverage
REF	-27.6	538.3	477.5	1,342.9	193.6	1.2	2,525.9
				Change from reference			
ALT1	-0.89	-0.21	-0.73	11.03	-11.49	-	0.50
ALT2	-1.08	2.26	-4.73	14.65	-14.62	-	1.36

9.2.3 VF economy impacts

As a distribution company, VF can supply district heating with waste incineration and peak gas boilers. As VF both owns and operates the waste incineration facility and supplies heat directly to customers, they are treated as both a production plant and distribution company in Table 9.4. Thus, VF gains revenue from heat and electricity sales as well as from waste incineration. They have expenses for O&M, energy taxation and the peak boiler production necessary to meet the demand which the waste incineration facility cannot.

Table 9.4 Change in VF economy from reference to alternative 1 and 2, M. DKK

	Revenue From		**Expenses From**				
	Electricity Sales	Heat Sales	Waste Incineration	O&M	Taxation	Peak boiler production	District heating consumer coverage
Ref	109.1	357.5	145.6	12.0	94.1	0.1	506.1
				Change from reference			
ALT 1	-1.59	-1.96	-0.81	-0.07	-0.71	-0.0008	3.58
ALT 2	0.53	2.93	1.21	0.11	1.08	-0.0008	-3.49

As VF decrease production in alternative 1, they decrease revenue from waste incineration, electricity and heat sales. Likewise, O&M and taxation is decreasing. As the waste incineration plant covers a higher share of the heat demand, peak boiler production is also decreased. The result is increased district heating costs of 3.58 M. DKK. In alternative 2, the production increases, and so does the revenue from waste incineration, electricity and heat sales, while O&M and taxation also increase. The same impact on peak boiler production as in alternative 1 is identified, although it is near zero. This results in alternative 2 is a lower cost to be covered by district heating sales of 3.49 M. DKK.

9.3 Production plant impact

Figure 9.2 below presents the changes in revenue on a plant scale for the waste incineration and CHP plants. Figure 9.2 shows, that in general, when revenue from electricity and heat production increases, so do expenses for fuel and taxation where applicable, and vice versa. In alternative 1, the revenue of ARC, KN, AMV and KKV decrease, while AVV and HCV increase their revenue. In alternative 2, it is only ARC that has a negative impact on the income, while the remaining plants increase profits from the implementation of a PTES.

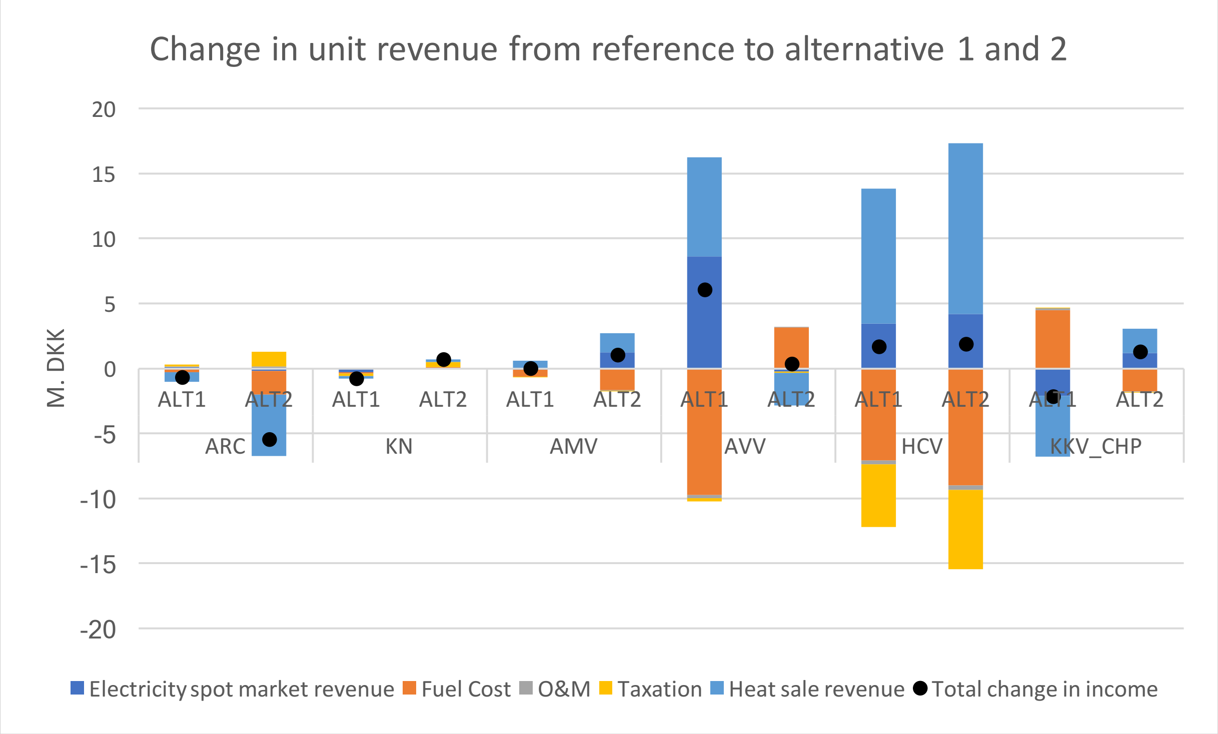


Figure 9.2 Changes in revenue and expenses from reference to alternative 1 and 2 M. DKK

In general, CHP and waste incineration plants can increase profits in two ways: by increasing production and by shifting production to hours with more favourable electricity prices. A ratio describing the relation between electricity and heat production revenue is presented for all plants in the three scenarios in Figure 9.3 below. It is calculated by dividing the electricity spot market revenue with the heat sales revenue for each plant in each scenario, and describes the electricity revenue for each unit of heat sold.

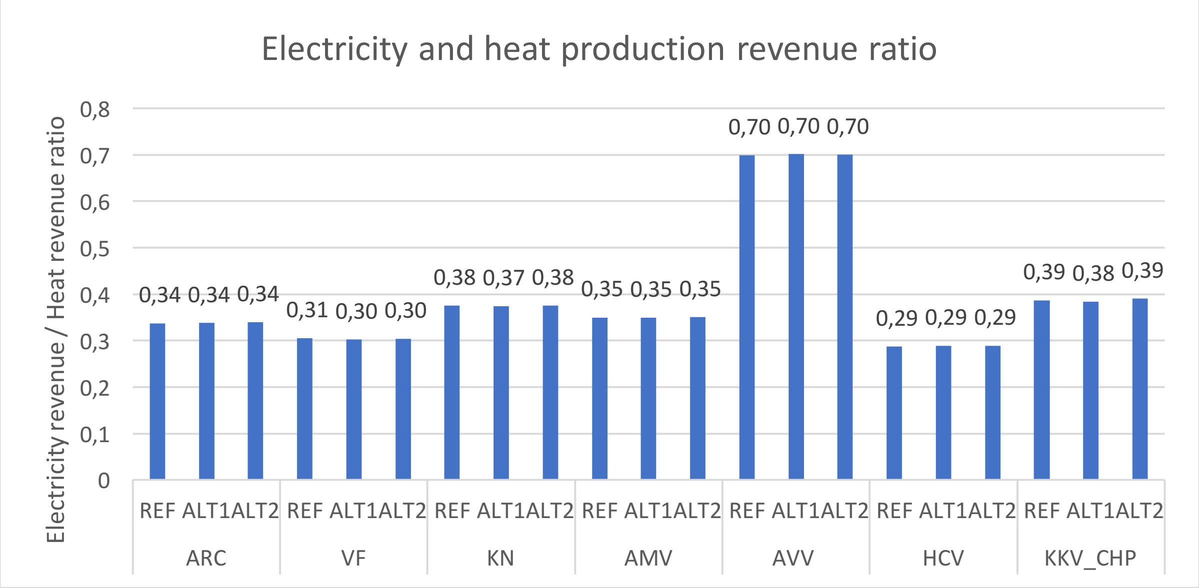


Figure 9.3 Electricity and heat production ratio factor for reference scenario and alternative 1 and 2

As the electricity and heat revenue ratio is close to constant for the individual plants, no significant change from shifting production hours to more favorable electricity prices, is detected. The main difference in revenue for each plant is mainly due to increasing or decreasing production.

9.4 Summary of economic impact of implementing PTES

Table 9.5 below shows the change in income due to the PTES implementation. In alternative 1, ARC, KN, AMV, KKV and VF are projected to have a negative impact, while AVV, HCV, VEKS and CTR are set to gain a positive impact. The total benefit, when taking the specific DH market architecture into account, is 1.51 M. DKK, compared to the system benefit of 1.62 M. DKK. In alternative 2, KN, AMV, AVV, HCV, KKV, VEKS, CTR and VF are set to have a benefit from the PTES implementation, while ARC is set to have a negative impact. The total benefit is 6.28 M. DKK compared to the system savings of 6.44 M.DKK.

Table 9.5 Change in income per actor from reference to alternative 1 and 2, M. DKK

	ARC	KN	AMV	AVV	HCV	KKV	VEKS	CTR	VF	Total
REF	-	-	-	-	-	-	-	-	-	-
ALT1	-0.71	-0.79	-0.05	6.03	1.63	-2.19	0.67	0.50	-3.58	1.51
ALT2	-5.47	0.68	1.00	0.32	1.86	1.24	1.79	1.36	3.49	6.28

As alternative 2 provides the highest increased income combined for the majority of actors, this alternative is recommended, despite the fact that it results in a 5.47 M. DKK loss for ARC as shown in Figure 9.4 below. Furthermore, AVV has the potential of increasing the income with 6.03 M.

DKK in alternative 1, but as their result still is positive in alternative 2, this scenario is recommended.

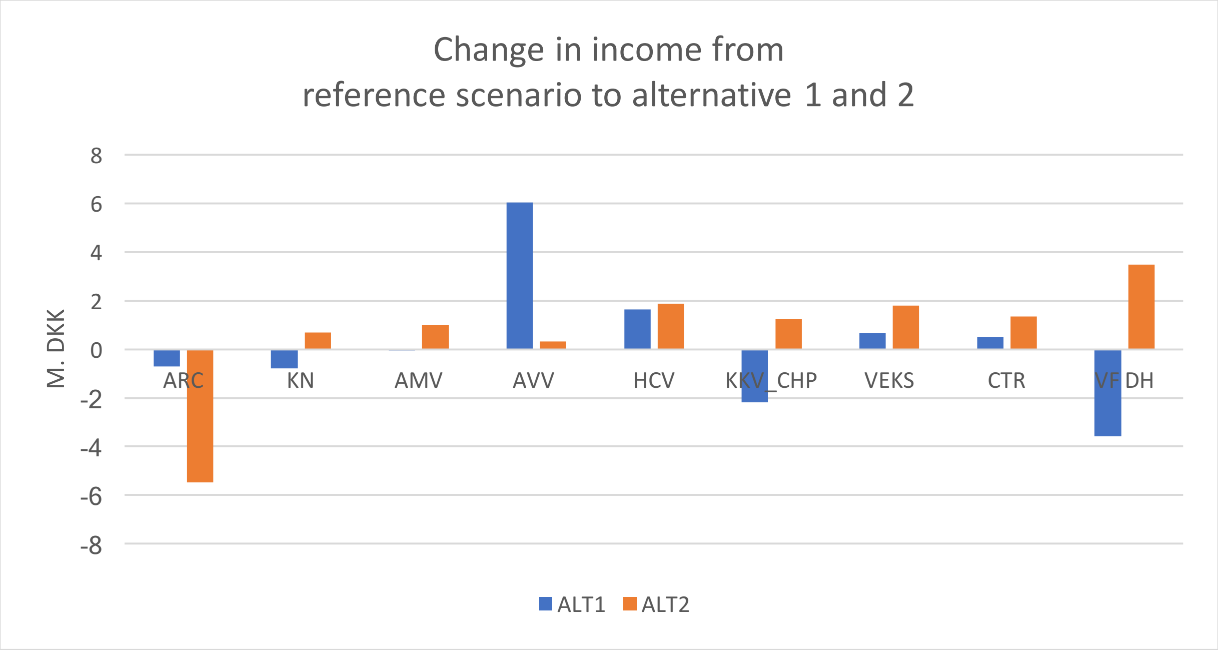


Figure 9.4 Changes in plant income in from reference scenario to the two alternatives.

Having brought the PTES into being by demonstrating its technical and economic impacts on the system and actors of the CPH-DHS, it is relevant to compare and discuss these results against the valuation frames promoted by the interviewed actors. Therefore, this is done in the following chapter.

10 Discussion of results

This chapter compares and discusses the results acquired from the three preceding analyses, i.e. the valuation frame analysis in chapter 7 and the EnergyPRO analyses in chapters 8 and 9. Comparing the results, some of the identified valuation frames are confirmed and qualified in the model, whereas others are not. The following sections discuss and qualify the identified valuation frames individually, comparing them to the modelled results

10.1 "Reducing peak production"

VEKS and HOFOR frame the PTES as reducing peak production. This valuation frame represents the means through which the PTES could generate value for the heating companies, i.e. by saving expenses for natural gas peak boilers while also shifting away from fossil fuels. This has been analysed in the EnergyPRO model. On an actor level, alternative 1 entails peak production savings of approximately 0.52 M. DKK for VEKS and 11.4 M.DKK for CTR while alternative 2 entails peak savings of 0.60 M. DKK for VEKS and 14.6 M. DKK for CTR (see Table 9.2 and Table 9.3). As peak load boilers have the highest marginal price for producing heating, a reduced use of these entails economic savings for the heating companies, as well as reduced use of fossil fuels. As such, the model confirms this valuation frame.

10.2 "Increasing CHP production"

The second valuation frame presented by VEKS and HOFOR is the framing of the PTES as increasing CHP production. This valuation frame represents how the PTES can generate value for the CHP companies, i.e. by increasing their revenue. These matters have been analysed in the EnergyPRO model and electricity sales increase by 8.0 M. DKK in alternative 1 and 6.6 M.DKK in alternative 2 (see Figure 9.1). However, as Figure 9.4 shows, the division of the increased income are not evenly distributed among the plants in the two alternative scenarios. In alternative 1, AVV and HCV are the only plants with increased incomes, whereas all other plants have reduced incomes. In alternative 2, on the other hand, all CHP plants are expected to have increased incomes from the implementation of the PTES. Therefore, this valuation frame is also confirmed by the EnergyPRO model. The analysis shows, that the primary increase in revenue comes from increased production, and not from CHP plants being able to shift production to other, more favourable hours. The PTES is, however, shown to be used flexibly following electricity prices.

10.3 "System economy and optimization"

Multiple actors promote the valuation frame of system economy and optimization, arguing that the PTES should be operated through the optimization process at Varmelast.dk, which schedules plants in a least cost marginal price order. As explained in chapter 4, the EnergyPRO model optimizes the load scheduling across the different plants in a similar manner. Therefore, the model arguably confirms this valuation frame, as it shows positive economy from operating the PTES this way.

10.4 “Using excess heat”

HTDH frame the PTES as being able to store excess heat available from the HP in Høje Taastrup during the summer months. In both alternatives of the EnergyPRO model, the waste heat is utilised. The 4,039 MWh of rejected heat is 4% of the total stored amount in alternative 1 and 3% in alternative 2, thus not enough to justify the investment in a PTES alone. However, if looking at the value of this heat for Høje Taastrup DH specifically, there is a benefit. All in all, the heat which is currently being rejected, but which is utilized in the alternative scenarios, is 4,039 MWh corresponding to 11.5% of the total heat pump thermal production (see Figure 8.5). If calculating the value of not having to buy this heat from VEKS, it corresponds to 1.2 M. DKK. Therefore, the EnergyPRO model confirms Høje Taastrup DH’s valuation frame.

10.5 “Flexible incineration plant renovation” and “Increased summer demand”

K/N frame the PTES as being able to provide flexible incineration plant renovation and to increase the summer heating demand which would result in increased waste incineration during the summer period. Due to model constraints, it has not been possible to analyse the first valuation frame. However, the EnergyPRO model provides some qualification of the second valuation frame. The model confirms, that during the summer period waste incineration plant capacity exceeds the heating demand, causing them to run below full capacity. Likewise does the model show that during the summer period, the PTES will be charged, thus increasing demand. However, as the PTES is used in cycles, it does not charge during the whole summer period, and will thus only be charged when feasible. Figure 8.12 presents the modelled operation of the PTES, and it shows a short-term operation profile, not a seasonal steady consumption during summer.

As shown in Figure 8.7, alternative 1 shows a 12 GWh reduction of total waste incineration, while alternative 2 shows a 5 GWh reduction. This indicates, that adding a PTES to the system in fact causes total waste incineration to decrease, rather than increase as framed by K/N. However, the model also shows, that the individual plants are affected differently in the two alternatives. While all incineration plants are subject to reduced production in alternative 1, ARC is subject to most of the reduced production in alternative 2, while K/N and VF increase production slightly. Therefore, the valuation framing of “increased summer demand” is partially confirmed, as the PTES does allow for increased production during low summer demand, but as it is shown to operate in cycles it will not be charged during the whole low demand period. A major cause for these identified variations is in fact that the modelled waste incineration plants are not prioritized in the load scheduling.

10.6 “Deliver to transmission grid via return or booster”

The final identified valuation frames argue, that the PTES should be able to deliver back to transmission grid. This is analysed in the EnergyPRO model by testing the two alternative scenarios. A central result from the analysis is that alternative 2 is the most feasible for the system economy and for several actors and therefore the recommended alternative. Therefore, the analysis shows that allowing the PTES to both receive and deliver heat to the transmission supply is the most feasible set-up. As such, this result confirms the valuation frame of VEKS, HOFOR and

Høje Taastrup DH, which argue, that the PTES should be able to deliver to the transmission grid. However, whether this should be done via the return flow or via a booster has not been analysed due to model constraints. A limitation in the modelling analysis is that EnergyPRO does not allow to test either solution, and therefore it can neither be confirmed nor rejected. While it is confirmed that the ability to deliver back to transmission is preferable, the uncertainty to which method of return deliver has not been solved.

10.7 Summary

This chapter has compared and discussed the results acquired through the three preceding analyses. The chapter has shown, that some valuation frames are confirmed by the EnergyPRO model, some are disconfirmed, while some remain uncertain. The overall perception of the PTES as beneficial for the system operation has been confirmed. Heating companies are indeed expected to save expenses for natural gas peak load boilers, and CHP plants are also expected to gain revenue from electricity sales. Høje Taastrup DH can utilize their excess heat, saving expenses for buying heat from the transmission grid. If waste incineration plants are not prioritised in the system, VF and K/N are expected to either decrease or increase production slightly from the implementation of a PTES, depending on the chosen scenario, while ARC is expected to decrease production severely in both scenarios. As alternative 2 has proven to be the most feasible alternative, the PTES should be able to deliver heat back to the transmission grid. Some uncertainties remain. The model results have partillay confirmed the valuation framing of K/N, and neither have they considered how the PTES should deliver heat back to the transmission grid.

11 Developing a business model for a PTES

This chapter departs from the results of the previous chapters and presents a proposal for a business model for financing a PTES in the distribution area of Høje Taastrup. As highlighted by the third research sub-question, the aim is to propose a business model, which integrates the actors' valuation frames as well as the modelled benefits of the PTES, enabling the actors to envision their role in the collective investment of the PTES.

Developing a business model is done in the following order: First, based on discussions of the results acquired in previous analyses chapters, the setup of a business model is developed, including a definition of the three components of a business model, i.e. the value proposition, the value architecture and the revenue model. Here it is argued, that while the acquired results lead to a total of four potential revenue models, the value proposition and the value architecture are the same for all four potential revenue models. Second, the economic conditions constituting the investment is presented, explicating the total costs of the investment as well as the annual payments needed to cover the investment. Third, the four revenue models are elaborated, explicating how much each actor is to pay according to the principles of the mentioned revenue models. Advantages and disadvantages of the four identified revenue models are discussed as well.

11.1 Setup of the business model

Several results acquired in the previous analysis chapters are relevant to consider when establishing a business model for the PTES, and these are discussed in this section. The valuation frame analysis, chapter 7, identified several valuation frames among the interviewed actors, whereas the energy system analysis, chapter 8 and 9, confirmed some valuation frames and disconfirmed other. The confirmed valuation frames form the basis for the value proposition and the value architecture of the business model proposed in this report.

The value proposition identifies challenges, which the PTES is capable of solving. As the PTES can solve multiple issues, these together form the value proposition. For the district heating companies, the value proposition is the PTES' ability to solve the issue of inefficient and expensive energy production based on peak load DH boilers. For the CHP plants, the value proposition is the PTES' ability to solve the issue related to limited production due to heat demand. Lastly, for the waste incineration plants, the value proposition is the PTES' ability to increase heating demand during the summer period. These value propositions are summed up in Table 11.1 below.

The value architecture is closely related to the value proposition, but explicates the means through which value is created for the actors. Therefore, the value architecture for the heating companies is that the PTES shifts production from expensive peak load DH boilers to CHP plants, thereby increasing fuel efficiency and decreasing heating expenses. This valuation frame was promoted by VEKS and CTR and it was also confirmed by the EnergyPRO model, and thus, this can be used for translating and enrolling the heating companies. The value architecture for the CHP plants is that the PTES decouples the electricity production from the heating demand, granting CHP plants the ability to produce more heat and power. This valuation frame was promoted by VEKS and HOFOR, which represents the CHP plant AMV. Thus, this can be used for translating and enrolling CHP plant actors. The value architecture for the waste incineration plants is that the PTES is essentially a heat consumer, which increases the heating demand during the summer period, allowing certain incineration plants to produce more heat and power. These value architectures are also summed up in Table 11.1 below.

The identified value proposition and architecture may be considered as the narrative of the business model, and depending on which actors are to be enrolled, different narratives should be applied; i.e. when seeking to enrol CHP plants, the narrative (and calculative background) of the CHP plants ability to produce more heat and power should be applied. If seeking to enrol waste incineration plants, the narrative and calculative background of the increased heating demand should be applied.

Having identified the value proposition and the value architecture, the remaining element to identify is the revenue model. From the acquired results it is clear, that multiple revenue models can be proposed. Firstly, as the results from the EnergyPRO analysis provide knowledge of the division of benefits among all the actors in the system, one option for dividing the investment of the PTES among the actors is for each actor to invest a share corresponding to his share of the calculated benefits. This is presented in Table 11.1 below as the "Shared investment model". A prerequisite for this model is that all actors agree on the calculated results.

Considering the statements made by VEKS and HOFOR, this type of setup fits well to the valuation frame of "actors invest per benefit", through which they argue, that the division of the investment should reflect the actors' individual benefits. However, considering another statement by HOFOR, this type of setup might prove difficult to implement. HOFOR promoted the valuation frame of "no competitors should invest together", arguing that it would be problematic, if competing plants co-invest in a PTES. Therefore, considering this statement, a second type of revenue model is proposed in Table 11.1, in which the heating companies invest in the PTES, while the producers pay for using the PTES through reduced heat sale tariffs. This model, however, consists of two options, which each have their pros and cons. Either the producers should pay a common tariff per MWh heat produced, or they should pay individual tariffs, corresponding to the benefits they harvest. The former is beneficial in the sense that it would be highly replicable; a quality which VEKS and HOFOR promote. Furthermore, it would be easy to manage, as it would not require individual contracts to be negotiated. On the other hand, however, this model would not divide the costs fairly, corresponding to the actors' harvested benefits. Therefore, a second model can be proposed, arguing that the producers should pay individual tariffs corresponding to their share of the benefits. As the calculated results show a highly unequal division of benefits among the different plants, this model would be more fair, especially considering ARC which is expected to be affected negatively from the PTES' implementation. This model however also requires, that all actors agree on the calculated results.

A final revenue model which can be discussed, is a model based on differences in marginal costs of heating. This model proposes, that the heating companies establishing a new market actor which runs the PTES, buying heat at hours with low heat prices (such as hours with high electricity prices), and selling heat at hours with high heating prices (such as during peak heat demand and low electricity prices). The price difference would thus cover the investment expenses for the PTES. Due to the current market architecture of the DH system, however, this model is not realistic, since the price of heating is not settled by the marginal cost of producing it, as explained in previous chapters. However, the authors argue, that this model would be highly transparent and market based, although it requires the market architecture to change radically. This option was presented to the actors during the interviews. Even though the actors expressed interest in the idea, the topic was not developed further throughout this report, as radically changing the market architecture is outside the scope of this report. Nevertheless, it poses a relevant discussion, and thus it is granted space here.

Table 11.1 The three components of a business model for the PTES

	Shared investment model	**Heating companies invest, producers pay through reduced heat sale prices**		**Marginal price model**
		Common tariff model	Individual tariff model	
The value proposition	• Inefficient and expensive energy production • CHP production limited by heat demand • Not enough heat demand during summer			
The value architecture	• PTES shifts production from peak boilers to CHP, thereby increasing efficiency of energy production • PTES decouples electricity production from heating demand, allowing CHP plants to increase production • PTES increases the heating demand during the summer period, thus allowing certain waste incineration plants to produce more heat			
The revenue model	Actors agree on the calculated results, and thus they make a shared investment based on individual calculated benefits	No competing actors should co-invest, and thus the heating companies invest and the producers pay a common tariff, no matter who gets which benefits	All actors agree on the calculated results. No competing actors should co-invest, and thus the heating companies invest and the producers pay individual tariffs corresponding to their harvested benefits	With a marginal-price based system, the PTES would be charged during high electricity prices and discharged during low prices. Initial investment made by heating companies, payback through price-difference.

Having identified the three components of the business model for the new PTES, the following section classifies the investment to be made, including total costs for the PTES as well as annual payments to be covered. Afterwards, this is then applied when elaborating on the proposed revenue models.

11.2 Classification of PTES investment

Based on statements from the actors in question, the investment costs of the PTES are estimated at 70 M. DKK, as mentioned in appendix A. As alternative 2 is chosen, an additional investment is needed, to cover the possibility for the PTES to deliver DH back to the transmission grid. It is estimated, that 2 M. DKK are needed for being able to do this. This is a rough assumption as the method of return delivery has not been qualified, but the investment would either finance a 25 MW electric boiler for boosting the delivery (DEA 2015), or finance a charge of 14.6 DKK/MWh as compensation for delivery via return transmission.

With an interest rate of 4% and a technical lifetime of 20 years, the annual payment would be 5.3 M. DKK as presented in Table 11.2 below. As the DH companies are possibly able to finance a low rate loan, can get municipality guarantees, or are able to provide the financing themselves, a rate of 4% is deemed reasonable.

Table 11.2 PTES investment costs

Investment, M. DKK	**72**
Rate	4%
Lifetime, years	20
Annual payment, M. DKK	5.3

11.3 Potential revenue model alternatives

The following sections elaborate on the four possible revenue models for acquiring the annual 5.3 M. DKK needed to fund the investment, dividing the costs among the actors according to the principles of the proposed revenue models.

11.3.1 Shared investment

The actors who stand to benefit from the PTES implementation are presented with their calculated benefits and share of the total benefits in Table 11.3 below. As ARC are projected at a loss, they are not assumed included in the investment, and thus the total benefit increase from 6.28 M. DKK to 11.75 M. DKK, not counting the loss of ARC. Table 11.3 also illustrates the owners of the plants, as ownership plays a role in the investment. As AMV and KKV are owned by DH companies, they could play a different role in the investment, compared to AVV and HCV owned by DONG Energy. This will be elaborated below.

Table 11.3 Increase in income per actor and share of total increase in income

	KN	AMV (HOFOR)	AVV (DONG Energy)	HCV (DONG Energy)	KKV (VEKS)	VEKS	CTR	VF	Total
M. DKK	0.68	1.00	0.32	1.86	1.24	1.79	1.36	3.49	11.75
Share of benefit	6%	9%	3%	16%	11%	15%	12%	30%	100%

The investment costs shared among all actors are presented in Table 11.4 below, assuming all actors share the investment costs of 5.3 M. DKK based on their calculated share of benefits. The table also presents the surplus which the actors are expected to receive after the investment is made. While the actors who are expected to receive the largest benefit from the PTES also carry the largest parts of the investment, they still stand to receive the largest surplus after investment, and vice versa.

Table 11.4 Investment per actor and surplus after investment

M. DKK	KN	AMV (HOFOR)	AVV (DONG Energy)	HCV (DONG Energy)	KKV (VEKS)	VEKS	CTR	VF	Total
Yearly investment cost	0.31	0.45	0.15	0.84	0.56	0.81	0.61	1.57	5.30
Surplus after investment	0.37	0.55	0.18	1.02	0.68	0.98	0.75	1.92	6.45

11.3.2 Investment based on a reduction in heat sales prices

Following the "no competitor should invest together" investment framing, a model based on a reduction in heat sales prices is presented below. VEKS and HOFOR have expressed that they are willing to make the initial investment, and CTR is expected to be willing as well. VF, KN and DONG Energy (AVV and HCV) should thus pay the investment through a tariff, lowering the heat sales price to VEKS and CTR. They would thus pay their share of the investment through the heat sales price. This raises the question of whether the tariff should be one common tariff for the four plants, or a specific tariff for each plant reflecting their benefit and heat production. These two options are discussed in the following subsections.

11.3.2.1 One common tariff model

By choosing one common tariff for reducing the heat sale price, a simple solution would be selected. This option would not have to be negotiated in bilateral contracts, and all actors would have knowledge of the specific tariff. This option reflects the current scheme for investing in the TTES at AVV and AMV, where the involved parties agreed to a third of the investment costs each. This solution assumes that VEKS (with KKV), HOFOR (with AMV) and CTR carry out the investment and collect the remaining investment costs through a tariff lowering the heat price from VF, KN and DONG. The investment is presented below in Table 11.5.

Table 11.5 DH supply companies' yearly investment costs in PTES

	KKV (VEKS)	VEKS	CTR	AMV (HOFOR)	Total
M. DKK	0.56	0.81	0.61	0.45	2.43

This results in the district heating transmission and distribution companies to cover 2.43 M.DKK of the investment, thereby leaving 2.87 M. DKK for the heat producers. By dividing this investment by the combined heat production of AVV, HCV, VF and K/N of 6.10 TWh, this results in 0.47 DKK/MWh as presented in Table 11.6 One common heat sale price reduction based upon heat production below. For the plants to cover their share of 2.87 M.DKK of the investment, they would thus have to lower their heat sales price with 0.47 DKK/MWh.

Table 11.6 One common heat sale price reduction based upon heat production

	AVV	HCV	VF	K/N	Total
M. DKK	0.15	0.84	1.57	0.31	2.87
TWh heat production	3.40	0.72	1.18	0.80	6.10
Lower heat sale price DKK/MWh					0.47

This method of allocating the investment would penalize the units with high heat production and prioritize the units with lower heat production, as it would not consider the individual benefits from the PTES. The resulting investment costs per plant is presented Table 11.7 Projected investment costs based upon on common reduction in heat sale price below. Although VF stands to gain the highest benefit from the PTES, based on their production they invest 0.55 M. DKK. While AVV increase their income with 0.32 M. DKK, they stand to invest 1.6 M. DKK. When comparing the economy for DONG Energy by combining AVV and HCV, the increased income is 2.18 M. DKK, compared to the investment cost of 1.94 M. DKK, resulting in a net increase in income of 0.24 M. DKK.

Table 11.7 Projected investment costs based upon on common reduction in heat sale price

	AVV	HCV	VF	KN	Total
DKK/MWh	0.47	0.47	0.47	0.47	-
TWh heat production	3.40	0.72	1.18	0.80	6.10
Resulting costs for investment PTES, M. DKK	1.60	0.34	0.55	0.38	2.87

A revenue model with a single tariff for lowering the heat sales price is a simple way of dividing costs, but lacks a mechanism for reflecting the specific plants actual benefits from the PTES. Although simple to manage, the model lacks the ability to translate actors, as it offers, for some actors, a share of investment costs which does not reflect the actual benefit. Therefore, an alternative option is discussed below.

11.3.2.2 Individual tariff model

A second possible tariff model for lowering heat sales prices are individual negotiated tariffs, based on the actors benefits and heat production. Instead of reaching a common tariff, one for each plant would be negotiated. By dividing the investment cost for each plant by the amount of heating supplied, a plant-specific tariff for lowering their heat sales price is reached, as illustrated by Table 11.8 Individual heat sale price reductions based upon heat production below.

Table 11.8 Individual heat sale price reductions based upon heat production

	AVV	HCV	VF	KN	Total
M. DKK benefit	0.15	0.84	1.57	0.31	2.87
TWH produced	3.40	0.72	1.18	0.80	6.10
DKK/MWh	0.04	1.17	1.34	0.38	-

This model would result in a share of the investment corresponding to the plants specific income benefits. However, this model is more complicated than the former, as it relies on individual negotiations with the specific plants, and would re-open contracts already agreed upon. While this model reaches a share of investment costs closer to the calculated benefits, it also relies on a more complicated translation of actors, and requires that all actors agree on the calculated results.

11.3.3 Marginal pricing business model

A model using marginal pricing for heat sales is another plausible way to facilitate the transmission of heat from producers to transmission and distribution companies. By implementing hourly heat pricing, it would, in theory, be possible for the owner and operator of the PTES to charge it during low price hours, and discharge it during high price hours.

When asked about the possibility of a marginal pricing model for facilitating the heat sales from a PTES, several actors agree, that currently several organisational and structural restraints apply before a marginal pricing market for district heating sales can be implemented. A marginal pricing model would require several relations in the market architecture to be redesigned. A major part of the market architecture of the CPH-DHS is the load-scheduling through Varmelast.dk and the actual price setting through bilateral contracts. While the load-scheduling follows a marginal-pricing principle, this structure would have to be carried through to the price setting mechanism, and would remove the existing price-setting contracts.

Several impacts would be the result of a marginal pricing scheme. First, as the electricity sector already has experienced a similar transition to marginal based pricing, the plants in question for the report have experienced such a change. Since the revenue from electricity sales has been based on marginal pricing, plants have faced lowered revenue as a product of declining electricity prices, among others. Although governed by the non-profit principle of the DH sector, heat sales cover part of the plants investment costs. If both revenue streams of CHP and waste incineration plants are subject to marginal pricing, this could possibly further increase the uncertainty of income. It raises the question of whether plants would be able to cover their fixed costs while being subject to a marginal pricing heat market. Second, as previously argued in this report, it is difficult to determine the exact share of fuel and O&M expenses for heat and power generation. In a marginal pricing bidding scheme, these costs would have to be allocated to the heat and power production, instead of the scheme used today of a simple ratio share. Third, as the physical conditions of heat and electricity transmission are different, possibly different time-resolutions could be used. While hourly rates are used in the electricity market, several actors mention that longer time-slots might be useful for heating. The question arises, of whether different time-resolutions for heat and power would constitute problems, as the electricity and heating price could participate in co-producing each other.

11.4 Implications of the proposed revenue models

Four ways of constructing a business model have been proposed above. As business models are calculative devices constructed to enrol actors into their narratives, the next step for these models is to circulate among the actors interested in investing in the PTES. As Doganova and Eyquem-Renault (2009) argue, the business model is not a representation of reality, but a specific framing. Furthermore, in their study of what business models do, Doganova and Eyquem-Renault emphasise that as the model circulates to enrol actors, the model itself also adjusts with the framings and perceptions it meets. The proposed models should thus not be seen as final answers to how to split the investment, but rather as an input to discussion and framing of the investment. Just as Edison enrolled his investors by a convincing narrative, and not by precise calculations, so must these proposed business models enrol actors based on their ability to convince.

If the arguments presented in this report are strong enough to convince investors, then they could move ahead with investing. As the results from the calculative model of this report support other reports and studies made by the actors, they add to the translation chain and thus the validity of the results. In case investors find the numbers and calculations convincing, the proposed models are directly applicable. In the case of overflows, where new valuation frames or contestations of results surface, the actors must re-visit the calculations and the framing of investment. Just as HOFOR and VEKS contest the previous investment model for TES as it produced overflows, so can the proposed model also result in overflows. HOFOR and VEKS argue, that actors should invest according to their share of benefits, but these benefits will be estimates based upon calculative demonstrations. The business model is therefore dependent on the credibility of the numbers. The more credible the numbers, and the more actors they can enrol, the more detailed the share of investments can be made. In the case that the results are contested, then actors must move back to a more general or common investment model.

By taking the different valuations by the actors into account, these overflows can possibly be alleviated, but as framings *put the world in brackets*, it will likely be difficult to establish a stable valuation framing without any contestations and overflows. As the results of this report are calculative demonstrations, they could prove different after the PTES is in operation, and thereby could new valuations surface which are not encompassed in the business model. As possible investment models now have been presented, the process of enrolling actors and converging valuations frames can move forward.

12 Conclusion

This report has examined how the district heating companies of the Greater Copenhagen areas value a PTES, and how the potential benefits of this technology can be demonstrated through energy system modelling. While the heating actors wish to implement a PTES, they find themselves in a Catch-22 situation: to decide and invest in the technology, they need confirmation about the benefits. But before the investment is made and the technology implemented, they cannot know exactly which benefits it will entail. The purpose of this report is therefore to make an epistemic contribution to the issues currently preventing heating companies in investing in a PTES. By mapping the valuations deployed by actors, and demonstrating the potential benefits of the PTES, the decision-making process can hopefully be brought forward. Therefore, inquiry into the valuations through which the actors frame the PTES has been carried out, and by generating model-based knowledge of how the benefits from the storage will be divided, the catch-22 situation may be eluded and the realisation of the investment brought closer.

This concluding chapter seeks to sum up the results obtained throughout the report and to answer the research questions posed in the introduction. Therefore, the following three sections answer the sub-questions individually so that the overall research question may be answered.

12.1 Valuation frames

Based on a Science and Technology Studies approach, this report argues that knowledge and technology may hold different meanings to different audiences. Therefore, while technical model-based knowledge is seen as useful for generating knowledge of the thermal energy storage, the perceptions and valuations promoted by the relevant actors of the DH system need to be taken into account as well.

Through interviews with relevant actors of the DH system, multiple differing perceptions and valuations of the PTES have been identified, some of which are promoted by multiple actors, others which are promoted by individual actors only. In total, seven different valuation frames are identified. These framings stretch from viewing the storage as a piece of equipment, which can optimize the entire system in terms of technical and economic operation, to viewing the storage as a mean for solving individual issues. As the identified valuation frames are diverse, the situation is characterized by uncertainty, and thus the actors relate their valuations to their own technical and professional reality. Conclusively, the situation is unsettled.

As long as the actors apply differing valuation frames, no valuation frame will become dominant, and thus, no settlement can be reached. Furthermore, as long as the valuation frames have not been qualified, the actors cannot know how the benefits from the PTES will be divided, and thus the investment will not be made. Therefore, to qualify the differing valuation frames and bringing the actors' perceptions closer together, while also determining how the benefits of the PTES can be divided, a technical demonstration of the PTES' impacts on the DH system is carried out.

12.2 Technical calculative model

The technical demonstration of the PTES is carried out using the energy system modelling tool EnergyPRO. In order to *bring the PTES into being*, the model analysis is designed with a reference scenario set up for the year of 2025 without the PTES. In addition, two alternative scenarios including the PTES in the distribution system of Høje Taastrup are set up. As the actors are currently uncertain of whether the PTES should be able to deliver heat back to the transmission system or not, these two configurations are tested through the two alternative scenarios. Furthermore, the specific market architecture of the CPH-DHS implies, that while heat sales are governed by bilateral contracts, the load scheduling of plants is governed by their marginal production cost. Considering these differences, the modelled results are divided into technical and economic impacts.

The technical results demonstrate the PTES as being a system storage, operating based on marginal pricing. It can shift heat production from natural gas peak boilers to CHP production. CHP plants can increase production as more storage capacity allows heat to be stored for later usage. Waste incineration production is affected as well. The storage causes two waste incineration plants, K/N and VF, to produce more, while the third, ARC, produces less. These results are found with the assumption that waste incineration plants operate according to the same load scheduling criteria as other plants.

The economic results demonstrate, that the PTES has an impact on the income of the individual actors. Transmission companies can decrease their heat expenses as heat production is shifted from natural gas peak boilers to CHP plants. As CHP plants can produce more heat and power, they increase revenue from the electricity spot market and heat sales. In alternative 2, all transmission companies and all plants, except for ARC, increase their income because of the PTES, resulting in a total annual value of 6.28 M.DKK. Therefore, it is concluded that alternative 2, where the PTES is able to deliver back to the transmission grid, is the most feasible alternative, and thus this configuration is recommended.

The demonstration supports certain valuation frames, reject others, and disregards some due to model limitations. As such, the model-based epistemic device has qualified the PTES in several aspects, thereby brought it into being. By demonstrating the potential benefits and addressing certain valuation frames, actors in doubt of the produced effects can now turn to the demonstration to envision the impact and their specific role. However, some valuations have not been qualified in the model and are thus still uncertain and up for contestation. This implies, that valuation is an ongoing process which cannot be completed by a single epistemic device, finally determining the objects properties.

12.3 Business model

Based on the preceding results, this report establishes and proposes a business model, which through narratives and calculations may translate and enrol actors to participate in the investment of the PTES.

As the preceding results indicate a situation of uncertainty, it is not possible to establish one final business model. Therefore, four potential revenue models are proposed, which, depending on their ability to enrol actors, may become dominant, as the business model circulates in the network.

Having identified the existing valuation frames, it is possible to know which valuation frames need to be shifted, and to target the narrative of the business model accordingly. If the valuation frames had not been identified, the aim of the business model might not have been accurate. While CHP plants will likely invest if they can increase their production, district heating companies will likely invest given lower heat costs. Furthermore, by supporting the targeted narratives with the calculations presented through the calculative model, the business model can now circulate in the socio-technical network of the CPH-DHS.

12.4 Applying the generated knowledge

In this report, the role of model-based knowledge has been examined, in the process for the PTES to move from a *wild unknown* towards a *passive object*. By bringing the PTES into being, it has been brought closer to being pacified, as some valuation frames have been confirmed while others have been rejected. The potential of this demonstration, brought forward as a technical energy system simulation and presented in the format of the business model, is the ability to enrol actors by translating their valuations into a common framing supporting the investment.

As such, this report has shown, that through model based knowledge, combined with an insight into the actors' perceptions and valuation of a PTES and the use of a business model, the catch-22 situation may be eluded, although not escaped completely. The actors were in a situation where they could not invest, because the impacts were unknown, and the impacts were unknown as the investment was not yet made. Due to the demonstrated effects, the PTES has been brought into being, allowing the actors to come closer to making the investment.

13 Epilogue

This chapter provides some reflections about the quality and limitations of the research carried out in this report, and presents some thoughts and recommendations for future research.

While the interdisciplinary approach taken in this report allows for the analysis of how the social and technical aspects of DH planning affect each other, it also limits the detail which a more focused approach could provide. Several technical uncertainties remain unanswered, and these could possibly have been solved with increased focus in one of the areas. For example, the questions regarding method of return to transmission level could have been developed further, just a more detailed energy system modeling would have been possible. The modeling of the CPH-DHS is in itself a complicated task, and several assumptions were necessary to take about the operation and technical details of the system. Furthermore, due to space and time constraints, sensitivity analyses were not granted much space in this report; a limitation which could have been averted with a solely technical approach.

Likewise, the valuation part of this report could also have been developed further. As valuation is shaped through heterogeneous networks, the valuations build upon past research, reports and professional perceptions. An analysis, of which factors affect the valuations identified in this report, could provide knowledge about how actors take decisions and frame perceptions of technology in the DH sector. Furthermore, the number of actors included in the analysis could also have been expanded, as actors could have different valuations, given the same kind of technical reality. K/N might not be representable for ARC and VF, nor can HOFOR with AMV speak on behalf of AVV owned by DONG Energy. It is reasonable to expect that more valuations could be uncovered by including a larger dataset.

As valuation and enrollment happens through a process, the process as a whole has been impossible to examine, given the time for the research for this report. Examining the process from the idea was pitched to the investment decision is taken, could provide knowledge about which factors shape investment decisions and how valuation frames are formed and shaped through such a process. As of now, a proposal for how to divide the investment costs has been provided, but it is not possible to examine the effect of the proposal. But as business models circulate, so too will they be valuated and adjusted to the perceptions of the DH actors.

Future research into the process of valuation could examine the next phase of the valuation process, where actors are presented to the business model and have their perceptions converged or diverged. Conversely, future research of the use of calculative modelling tools could examine and compare different models, such as the Energy PRO model and the Balmorel model, currently used by HOFOR and VEKS (via Ea Energy Analysis), and see whether they provide comparable results, and whether this could bring actors closer to an agreement.

The theoretical standpoint of this report has shaped the approach and results. By choosing the STS approach, a broad analysis covering both social and technical aspects was conducted, as otherwise valuable knowledge could be left out. It provides a good starting point for mapping possible barriers for implementation of novel technologies such as the PTES, whereas it lacks the ability to go in depth with identified specific barriers. The strength of this report thus lies in the novel interdisciplinary approach by combining technical model expertise with social inquiry, and can thereby, hopefully, provide new knowledge to an established field of science and technology.

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Appendix A Model Setup

No calculative model is more accurate than the inputs and assumptions going into designing the it. Therefore, to be able to bring the PTES into being, the design of the model needs to represent reality as much as accurately as possible. This chapter describes the data used for building the EnergyPRO model as well as the assumptions applied in this process.

A.1 Heat Demand

The heat demand forecast used in the model is developed by (Varmeplan Hovedstaden 2014c), and takes several questions regarding the future heat demand into account. Central to the heat demand forecast is the level of energy savings and expansion of district heating, as these factors will respectively decrease and increase the district heating demand. The demands are forecasted based on assumptions about additional areas connected to the established district heating systems, new building developments, as well as increasing efforts of energy savings. Most large buildings and half of the residential single-family housing are assumed connected to a DH network in 2025. The main VPH heat demand scenario has been used for the analysis, as this is based upon expectations from the individual distribution companies. The heat demand projection is presented in Figure A.1 below. It is assumed that a large share of the buildings with a potential for connecting to district heating will do so before 2025. This explains the increase in heat demand from 2015 to 2025, and that the majority of the increase is in the area of VEKS and VF as these areas currently have a smaller share of DH than the densely populated area of CTR. The decrease in heat demand after 2025 is caused by energy savings. A total reduction of 22% in 2035 is assumed (Varmeplan Hovedstaden 2014c).

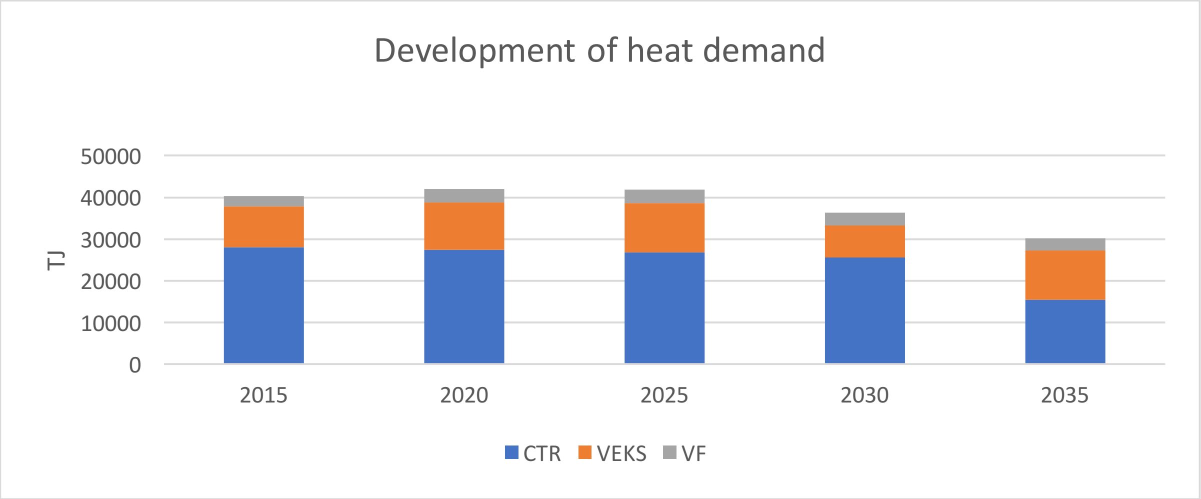

Figure A.1 Heat demand projections from VPH (Varmeplan Hovedstaden 2014c)

To analyze the impact of the PTES in the distribution area of Høje Taastrup, this area is modelled independently and is the only distribution-level area included in the model. The energyPRO model is divided into five transmission areas and one distribution area. Høje Taastrup DH is assumed to be part of the VEKS W area.

Yearly heat demands from the VPH 3 reference scenario forecast for 2025 are used for all analysed areas. The assumed district heating consumption is presented in Table A.1 below.

Table A.1 Yearly consumption for district heating areas

District heating area	Yearly Consumption, MWh	Share of total consumption
Høje Taastrup	254,920	2%
VEKS N	1,306,388	11%
VEKS W (without HT area)	1,485,912	13%
VEKS Køge	225,000	2%
VF	885,833	7%
CTR	7,676,944	65%

The daily heat demand is modelled using EnergyPRO. The heat demand is broadly split into two; i.e. one temperature dependant and one non-temperature dependent share. SBI analysed the share of hot water usage in residential housing to be around 28-34% of total heating usage (Bøhm, Bergsøe, and Schrøder 2009), while DONG assumes 36% is non-temperature dependent (DONG Energy 2017b). As the heat demand also covers industrial heat consumption and transmission losses, a non-temperature dependent share of heating of 40% is assumed.

The heat profile is calculated using a simple degree-day method[9], with 17˚C as the reference grade. For every hour, the consumption is calculated using equation (A.1):

$$\boldsymbol{Hourly\ heat\ consumption} = \left(\frac{\boldsymbol{T_{dep}} \times \boldsymbol{C}}{\boldsymbol{D_{year}}}\right) \times \boldsymbol{D_{hour}} + \left(\frac{\boldsymbol{T_{nondep}} \times \boldsymbol{C}}{\mathbf{8760}}\right) \qquad \textbf{(A.1)}$$

where C is the yearly consumption, T_{dep} is the temperature dependent share, T_{nondep} is the non-temperature dependent share, D_{year} is the yearly amount of degree-days, and D_{hour} is the hourly degree-days. The resulting heat demand profile is presented in Figure A.2 below. The demand goes from a minimum of 414 MW in July to a peak consumption of 3280 MW in January.

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[9] Degree-days refer to the difference between the indoor refence (17 ˚C) and the outside temperature. Every degree difference is one degree-day.

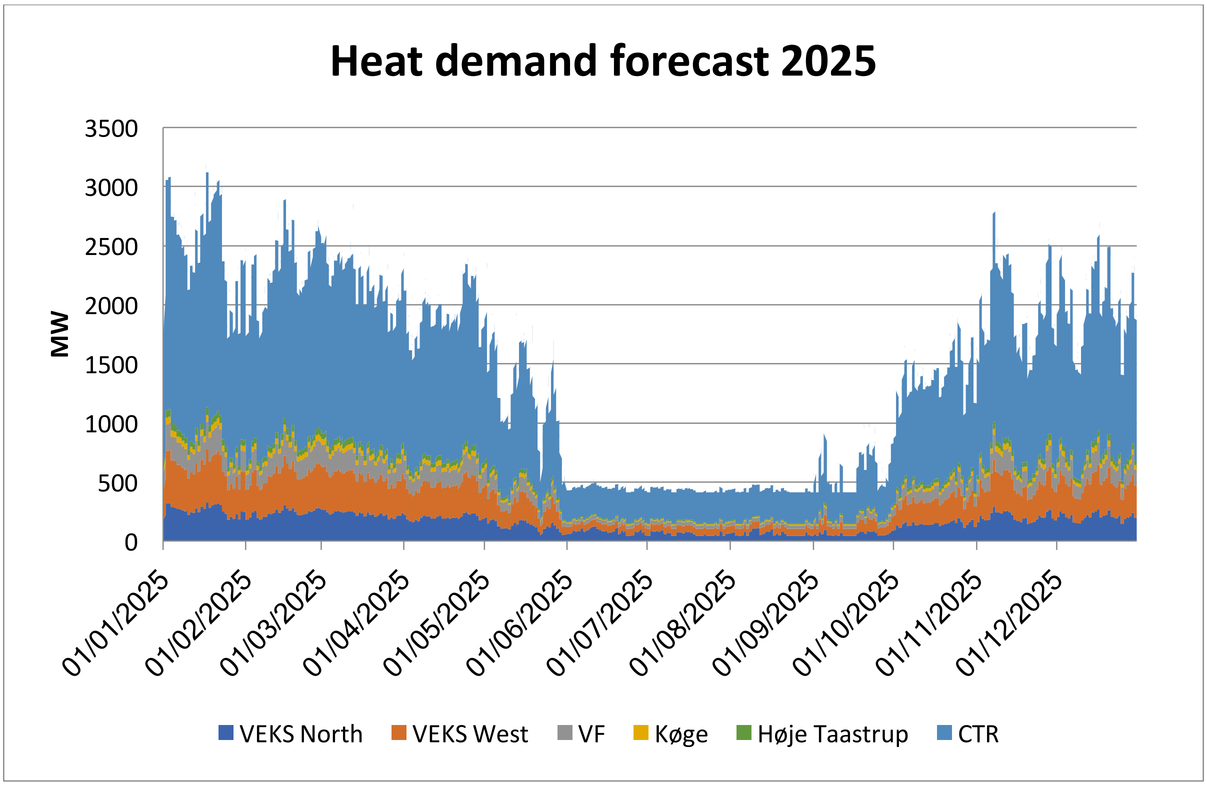

Figure A.2 Heat demand for the areas analyzed

A.2 Electricity price forecast

The DEA's average electricity price forecast for 2025 is used in the model. The average electricity price in 2025, A_{2025}, is assumed to be 344.6 DKK/MWh (DEA 2016a). To simulate the hourly price variations, the 2016 price pattern (Nord Pool Spot 2016) is used. For every hour h, an electricity price P is given, and adjusted with a factor F_{ave} of the relative difference between the 2016 and 2025 averages. As the electricity prices are assumed to have increased fluctuations in 2025 compared to 2016, the prices are adjusted with a fluctuation factor of 1.4, F_{flu}, resulting in an average of 40% increase in electricity price fluctuations. The hourly electricity prices of 2025 are given by equation (A.2).

$$\boldsymbol{Hourly\ electricity\ price\ 2025} = (\boldsymbol{P_h} \times \boldsymbol{F_{Ave}} - \boldsymbol{A_{2025}}) \times \boldsymbol{F_{flu}} + \boldsymbol{A_{2025}} \qquad \textbf{(A.2)}$$

Table A.2 below describes the price range of 2016 electricity prices and the 2025 price forecast. As shown, the expected 2025 average is higher than the 2016 average. As higher fluctuations are expected, the minimum and maximum electricity prices are expected to be more extreme in 2025.

Table A.2 Summary of 2016 and 2025 forecasted electricity price range

	Min	0.25 quantile	Average	0.75 quantile	Max
2025 DKK/MWh	-1018	218	345	427	3378
2016 DKK/MWh	-399	162	219	257	1596

Figure A.3 shows the forecasted 2025 electricity prices compared to the reference 2016 electricity prices in a selected 10-day period of February. Here it can be observed, that fluctuations increase and peaks are accentuated.

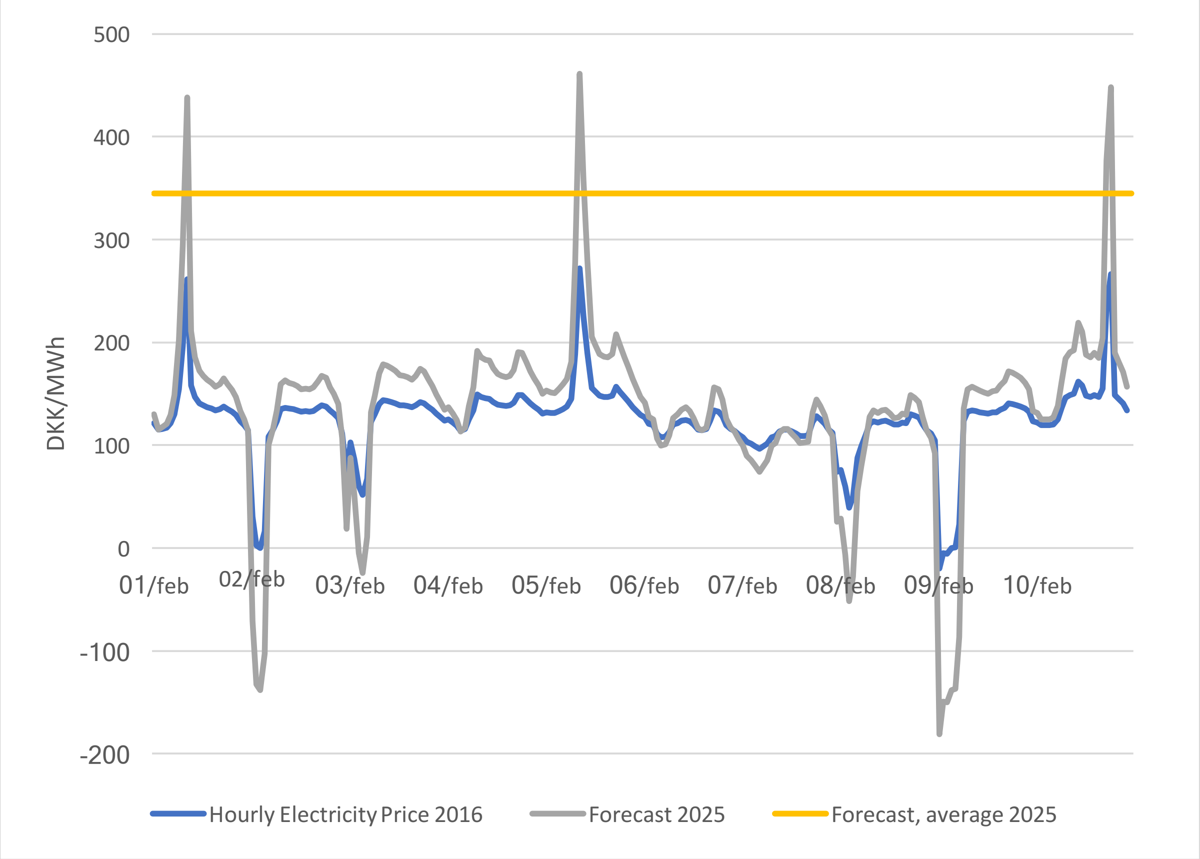

Figure A.3 Example of electricity price fluctuations in a selected 10-day period of February

A.3 Production units

The district heating system is assumed to follow a business-as-usual development, where planned changes and new units are assumed part of the system in 2025. VPH3 is used as the main reference for unit characteristics (Varmeplan Hovedstaden 2014a), while other sources are used when necessary. To lower the computational complexity of the model, most plants are modelled as single units although some plants consist of several independent units. The unit characteristics is presented in Table A.3 below. Only already planned technological changes are used in the model, and as such is the amount of heat pumps and geothermal limited.

Table A.3 Unit characteristics

Plant	Unit	Electric Capacity MW	Heat Capacity MJ/s	Energy Consumption MW	Fuel
AMV	AMV1	68	250	342	Wood Pellets
	AMV BIO4	150	400	591	Wood Chips
	AMV BIO4 Bypass	0	550	591	Wood Chips
AVV	AVV1	215	330	612	Wood Pellets
	AVV1 Condensing	250	0	595	Wood Pellets
	AVV2 Main	280	445	815	Wood Pellets
	AVV2 Gas turbines	128	92	247	Natural Gas
	AVV2 Straw boiler	45	50	101	Straw
HCV		99	299	462	Natural Gas
KKV		22	65	94	Wood Chips
Total CHP capacity		**1.042**	**1.784**	**3.859**	
ARC		57	190	231	Waste
K/N		32	96	131	Waste
VF		39	143	186	Waste
Total Waste incineration capacity		**128**	**429**	**548**	

AMV is modelled as two units. The existing AMV 1 is assumed rebuilt to use wood pellets and the planned AMV 4 unit is assumed in operation in 2025 using wood chips. AMV4 has the option of bypassing the turbine, allowing for a higher heat output but with no electricity production. AVV is assumed to run only on biomass due to DONG Energy's policy of facing out coal before 2023 (DONG Energy 2017a). AVV1 can run in condensing mode, producing only electricity and no DH. AAV 2 consist of the main unit, a wood pellet fired boiler powering a steam turbine[10]. The steam turbine can be boosted from the straw boiler or with excess heat from the gas turbines, while these units cannot operate without the main boiler online. Due to the constraints in the modelling software, the AVV gas turbines and straw boiler are modelled to have both heat and power outputs.

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[10] AVV2 is a multi-fuel plant capable of using coal or biomass. Due to political goals, AVV2 is assumed to only run on wood pellets

At the plant, however, the straw boiler and the excess heat from gas turbines merely boost the main steam turbine, and as such it is not these unit themselves producing heat and power.

The specific unit characteristics are presented in appendix C.

While waste incineration plants are currently prioritized in the load scheduling at Varmelast.dk, this is uncertain in the future. To analyse the potential impact of a PTES on the waste incineration plants, they are assumed to follow the same load dispatch as the remaining plants. This ensures that the potential impact on waste incineration is analysed. If, however, the waste incineration plants remain prioritized in the load dispatch, they will presumably experience no impact from the PTES implementation.

A.4 Fuel Prices

Fuel prices are assumed to follow the DEA's price projections, based on IEA scenarios (DEA 2016a), and are presented in Table A.4 below. Waste price levels are based on an analysis by Ea Energy Analysis (2016), projecting incineration plants to receive 260-300 DKK per ton of received waste in 2025. As local waste amounts are assumed to decrease, due to more recycling and efficiency, waste will become a scarcer resource towards 2025. To maintain production levels at the waste incineration plants waste must be imported from abroad to supplement local resource levels.

Table A.4 Fuel prices

	Natural Gas	**Coal**	**Fuel oil**	**Gasoil**	**Straw**	**Wood Chips**	**Wood Pellets**	**Waste**
2025 DKK/GJ	50.1	22.8	86.1	116.4	46.8	54.7	70.0	-26.7

A.5 Energy taxation, subsidies and quotas

Relevant taxation and subsidies are applied to analyse the district heating system from a business-economic viewpoint. Therefore, plants pay taxation from fuel consumption and will be reimbursed for the share of electricity production, as only fuel used for heat production is taxed. Plants must choose between the E and V formula for calculating the amount of fuel subject to taxation:

- E formula: $1\text{-}EP/0.65$
- V formula: $HP/1.25$, although minimum $EP/0.35$

EP is electricity production and HP is heat production. All plants are assumed to use the V formula for calculation of the fuel consumption, as this is preferable for plants with high heat output.

Table A.5 Overview of how fuels are taxed (PWC 2016; SKAT 2016)

Fuel	Energy Tax	CO2 Tax	Total
Natural Gas	2,175 DKK/1000Nm3	387 DKK/1000Nm3	2,562 DKK/1000Nm3
Waste	205 DKK/Ton	174 DKK/Ton	256 DKK/Ton

A.6 Scheduling of plants

EnergyPRO schedules plants on an hourly basis by calculating a priority number, given their heat production cost using the inputs mentioned above. The marginal heat production cost of selected plants is presented in Figure A.4 below.

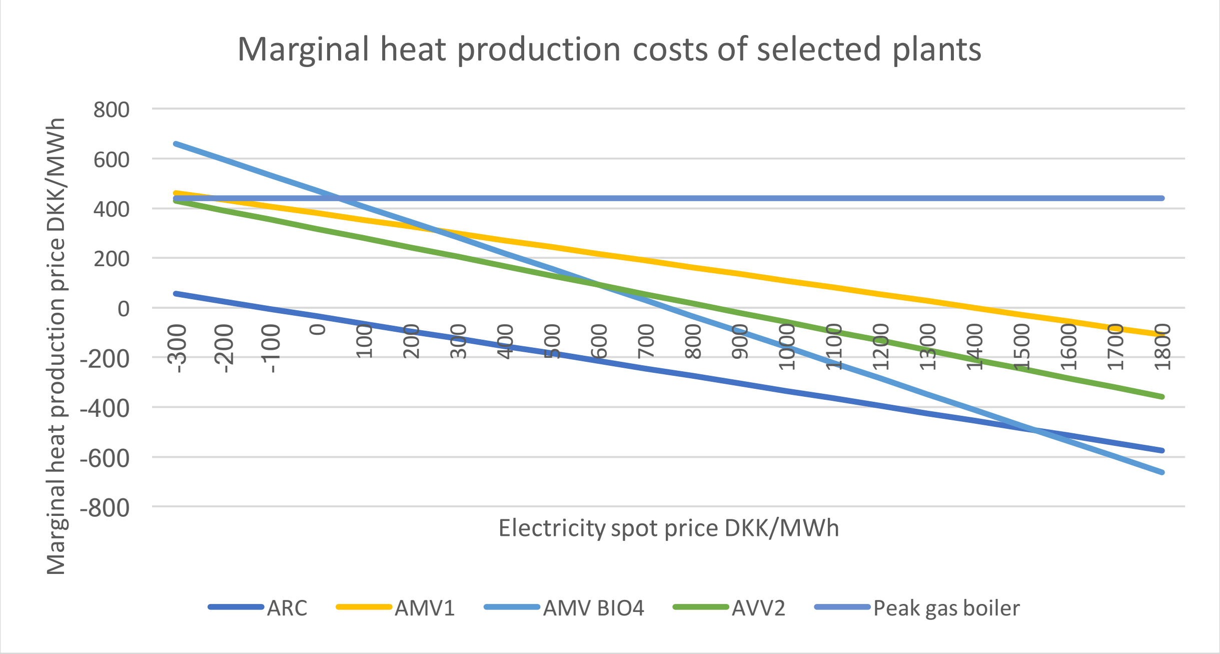

Figure A.4 Marginal heat production costs, selected plants. DKK/MWh

The model schedules the plants with the lowest heat production cost (highest priority) first, thereafter the following and so on, until all demands are met.

A.7 Calculation of the heat sale price

The heat production costs and the heat sales price are not assumed to be the same. As it is difficult to determine the share of fuel and O&M between heat and electricity production, some assumptions about how to share costs are used. The same principle as used in the calculation of the amount of fuel subject to taxation is used here. The total fuel costs, O&M and energy taxation is assumed divided with a fixed ratio describing the share between heat and electricity production. For AVV and HCV owned by DONG Energy, a larger share of the production costs is assumed to be covered by the heat side, as DONG Energy is a commercial company compared to the district heating companies owning AMV and KKV[11]. The ratio assumed to divide the production costs is thus 1.1 for AVV and HCV and 1.2 for AMV and KKV. The heat price calculation is presented in equation **(A.3)** below.

$$\boldsymbol{Heat\ Price} = \frac{\boldsymbol{FC + OM + ET}}{\boldsymbol{R}} + \boldsymbol{TA} \qquad \textbf{(A.3)}$$

Where *FC* is the fuel costs, *OM* is O&M, *ET* is the energy taxation, *R* is the ratio between heat and electricity, and *TA* is the tax advantage biomass can include in the heat sales price. *TA* is zero for non-biomass plants such as HCV using natural gas.

TA is based on an average energy taxation of 272.1 DKK/MWh for coal consumption (PWC 2016). As the level included in the heat sale price is dependent on a negotiation between producer and transmission company, it is assumed that 40% of the taxation advantage is included in the heat sales price, thereby adding 108.8 DKK/MWh to the heat sale price from biomass plants.

Waste incineration plants are assumed to set their heat sale price according to the price cap of 306 DKK/MWh (Danish Energy Regulatory Authority 2016). Figure A.5 below illustrates the calculated heat sales prices.

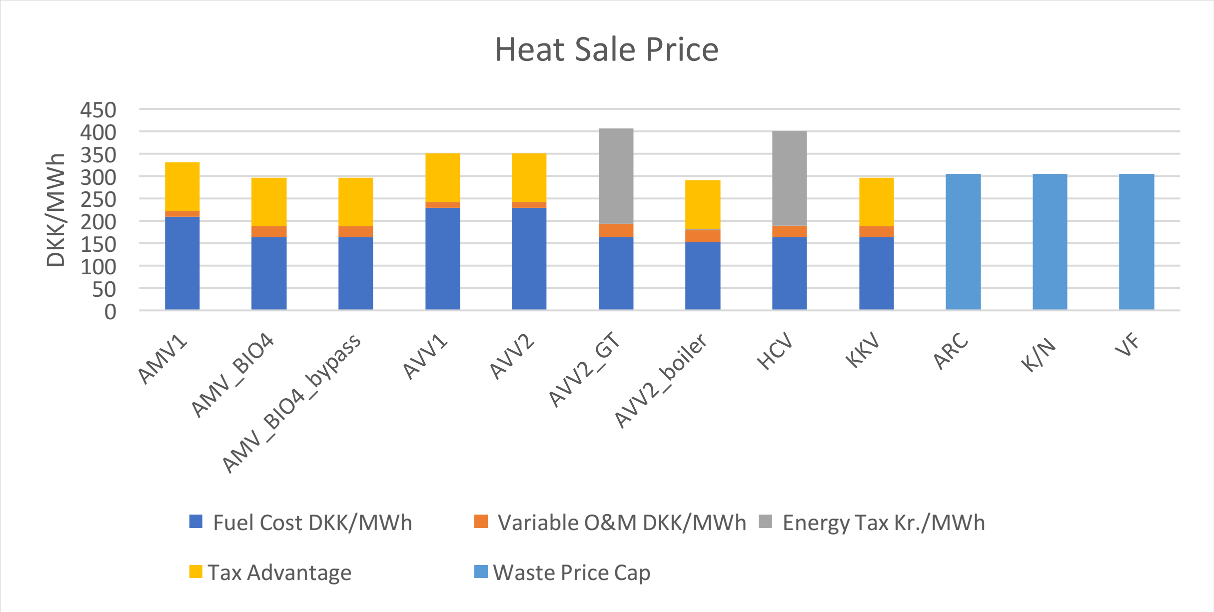

Figure A.5 The assumed heat sale prices for the plants in the Greater Copenhagen District Heating System. DKK/MWh

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[11] This assumption was made with the help of Ea Energy Analysis

A.8 Pit thermal energy storage

Based on interviews with actors in the field, and the review of existing technology presented above in chapter 5, the PTES is assumed to be 100.000 m^3, with a top temperature of 90˚C and a bottom temperature of 50˚C. The charge/discharge capacity is assumed 50 MW.

According to interviews, the investment is assumed to be 70 M. DKK. The investment costs are high compared to the DEA (2015) as a 100.000 m^3 has a projected investment cost of 27 M. DKK, excluding expenses for the plot. This is, however, assumed to be a mayor investment in the Greater Copenhagen area, and a main barrier according to several interviewees. Furthermore, several interviewees state that the distance from the plot to the transmission grid may lead to excessive costs for piping.

Appendix B Interview guides

B.1 Spørgsmål til Jens Brandt Sørensen og Morten Stobbe - VEKS

Generelt

Fortæl lidt om problemstillingen

- Hvorfor bygge et varmelager?
    - Systemoptimering?
    - Miljø?
    - Erhvervsøkonomi eller samfundsøkonomi?
- Hvorfor ikke?
    - Økonomiske barrierer?
    - Andre barrierer?
    - Varmelagre findes flere andre steder – er der specifikke barrierer i dette eksempel?

Hvem vil gerne have et varmelager?

- Høje Taastrup og Roskilde har været på tale?

Økonomi

Hvordan bliver varme handlet? Hvilke markedsmodeller?

Hvad er værdien i lageret?

- Hvad er værdien for VEKS?
- For DONG, lokale fjernvarmeselskaber m.fl.

Hvilke forhold tager i i betragtning?

- Fleksibilitet, CO2
- Forhold der er svære at værdisætte?
- Hvordan værdisætter I det?

Teknisk

Hvilke enheder forestiller i jer skal levere til varmelageret?

- Høje Taastrups varmepumpe?
- Hvilke Kraftværker?

Hvilket slags lager?

- Sæson/korttidslager
- Begge dele? Er det muligt?
- Størrelse

Hvad skal der ske med spidslastkedlerne frem mod 2025, hvor fjernvarmeproduktionen skal være CO2 neutral?

Aktører

Hvilke aktører samarbejder i med (omkring varmelageret)?

Hvilke skal i samarbejde med ift. levering af varme?

Forestillinger om markedsmodel

Hvordan skal varmelageret fungere på et marked?

- Variable timepriser for varme
- Ny aktør der ejer lageret?
- Fast tarif – varmelager som infrastruktur?

B.2 Spørgsmål til Klaus W. Jensen, KARA/NOVEREN

Generelt

Kan du fortælle omkring Kara/Novoren som affaldsværk?

- Hvor meget affald håndterer i?
- Hvordan justerer i driften? Hvilke forhold er bestemmende for jeres produktion (affaldsmængder, varmebehov, elpriser andet?)

Kara/Novoren er prioriteret hos Varmelast.dk – hvad betyder det for jeres drift?

Kan du fortælle lidt om jeres tanker omkring et varmelager og den proces i har været igennem:

- Hvornår begyndte I at se på det?
- Hvorfor begyndte I at se på det?
    - Samarbejdet med VEKS og andre aktører – hvordan har processen været efter VEKS og andre blev involveret?

Varmelager

Hvilke fordele ser I i et lager fra jeres synspunkt?

- Ift det lager Kara/Novoren har foreslået?
- Ift til det lager Høje Taastrup Fjernvarme har foreslået?

Hvordan fungerer et lager i sammenhæng med driftsprioritering fra varmelast.dk?

Hvilke forskelle er der, for jer, i et ”privat” lager og et system lager?

- Driftsmæssigt, værdimæssigt, andre?

Hvordan værdisætter I et varmelager?

- Hvis Kara/Novoren selv ejer lageret?
- Hvis det er et system lager?
- Økonomisk værdi – eller driftsmæssig, miljømæssig eller andre faktorer?

Forretningsmodel

Har I nogle idéer/ønsker til hvordan en forretningsmodel for lageret kan se ud?

- Hvilken forrentningsmodel tænkte i omkring Kara/Novoren lageret?
- Har i nogle tanker om hvordan en forretningsmodel for et systemlager kan fungere?

Fremskrivninger og fremtidssyn

Hvordan forestiller I jer, at markedet for affaldsforbrænding udvikler sig?

- Varmeforbrug, elpriser m.m.
- Hvordan udvikler affaldsmængderne sig?

Hvordan ser I på liberalisering af varmemarkedet?

- Forbliver affaldsværker prioriterede i lastfordelingen?
- Bliver brændselsvalget frit så Kara/Novoren også kan fyre med andre brændsler?

B.3 Spørgsmål til Peter Folke, Varmelast.dk

Generelt

Kan du fortælle lidt om Varmelast.dk og jeres rolle i fjernvarmesystemet?

Kan du uddybe lidt om prioriteringen af affaldsværker? Hvordan foregår dette?

- Vil affaldsværker forblive prioriteret i fremtiden, hvis der sker en liberalisering af varmemarkedet?

Kender I til de igangværende planer om at etablere varmelager i Høje Taastrup?

Varmelager

Hvordan bliver nuværende varmelagre lastfordelt?

- Er det Varmelast.dk der lastfordeler til lagerne, eller er det værkerne der må styre det strategisk ift elpris f.eks.?

Hvordan ville et nyt lager blive lastfordelt? Ville der være nogen forskel?

Er det muligt at forhindre nogen producent i at bruge lageret?

Hvilke fordele ser I i et nyt lager fra jeres synspunkt?

Hvordan værdisætter I et varmelager?

- Hvis det er et system lager?
- Hvis det var et ”lokalt” sæsonlager?
- Har det en økonomisk værdi? Eller driftsmæssig, miljømæssig eller andre faktorer?

Forretningsmodel

Har I nogle idéer/ønsker til hvordan en forretningsmodel for lageret kan se ud?

B.4 Spørgsmål til Uffe Schleiss, Høje Taastrup Forsyning

Generelt

Fortæl lidt om problemstillingen

- Hvorfor bygge et varmelager?
    - Hvor kommer ideen fra? Varmepumpen?
    - Hvilken rolle har HTF i etableringen af et varmelager?
    - Systemoptimering?
    - Miljøhensyn?
    - Positiv økonomi – samfunds eller forretningsmæssigt?
- Hvorfor ikke / hvad er problemet?
    - Økonomiske eller tekniske barrierer?
    - Andre barrierer?
    - Varmelagre findes flere andre steder – er der specifikke barrierer i dette eksempel?

Placering og aktører?

- Samarbejde med VEKS? Hvem står for planlægningen?
- Hvordan er samarbejdet koordineret, og hvem er ansvarlig?

Hvilket slags lager?

- Sæson eller uge-til-uge
- Hvad er HTF's grund til at få et varmelager?

Økonomi

Hvordan bliver varme handlet? Hvilke markedsmodeller?

- Kontrakter?
- Kunne man forestille sig andre modeller? Timepriser f.eks.

Hvad er værdien i lageret?

- Hvad er værdien for HTF?
- For DONG, VEKS m.fl.

Hvilke forhold tager i i betragtning?

- Fleksibilitet, CO2 udledning
- Forhold der er svære at værdisætte?
- Hvordan værdisætter I det?
- Peak produktion, øget produktion på KV?

Teknisk

Hvilke enheder forestiller i jer skal levere til varmelageret?

- Kun Høje Taastrups varmepumpe?
- Andre enheder?
- Måske ikke et enkelt anlæg, men baseret på markedsmekanismer?

Hvilket slags lager?

- Sæson/korttidslager
- Begge dele? Er det muligt?

- Størrelse

Hvad skal der ske med spidslastkedlerne frem mod 2035, hvor fjernvarmeproduktionen skal være CO2 neutral? – Hvad er HTF og de enkelte selskabers rolle i dette?

Aktører

Hvilke aktører samarbejder i med (omkring varmelageret)?

Hvilke skal i samarbejde med ift. levering af varme?

Forestillinger om markedsmodel

Hvordan skal varmelageret fungere på et marked?

- Variable timepriser for varme
- Ny aktør der ejer lageret?
- Fast tarif – varmelager som infrastruktur?

B.5 Spørgsmål til Mia Nordqvist Nielsen og Niels Hendriksen, HOFOR

Generelt

Kan I fortælle om jeres tanker omkring et varmelager og den proces i har været igennem?

Herunder:

- Hvilke fordele ser HOFOR i at investere i et varmelager?
- Hvordan opgør i nytteværdien i et lager?
- Samarbejder I med CTR, VEKS og andre aktører om lagerprojektet?
- Hvilken lagerteknologi har i set på?
  - Er det et systemlager eller et lager, som kun er koblet til AMV's drift?
  - Hvad er afgørende for valg af teknologi og set-up?
  - Hvilke fordele/ulemper ser I i de forskellige lager typer? Hvorfor VAK fremfor damlager? (andre forhold end pladsproblemer?)

Varmelager

Hvad vil Amagerværket få ud at et lager?

- Er der forskel på et damlager og en VAK fra AMV's synspunkt?

Hvad vil HOFOR overordnet få ud af et lager? Er der nogen forskel fra AMV's synspunkt?

Hvordan værdisætter I et varmelager?

- Hvis HOFOR/AMV ejer lageret?
- Hvis det er et system lager?
- Hvordan beregner I nytteværdien, og hvilke faktorer indgår?
  - Økonomisk værdi – eller driftsmæssig, miljømæssig eller andre faktorer?

Er det vigtigt, at HOFOR selv ejer lageret, eller kan det blive opereret af en anden aktør?

Varmesalg

Kan I fortælle om varmesalget imellem værker, transmissions og distributionsfirmaer?

- Hvordan foregår varmesalg mellem AMV, HOFOR, CTR og VEKS?

Som vi har forstået varmesalget bliver det styret af individuelle fortrolige kontrakter imellem aktørerne. Kan i uddybe hvordan de generelt fungerer? (uden nødvendigvis at gå i detaljer)

Forretningsmodel

Har I nogle idéer/ønsker til hvordan en forretningsmodel for lageret kan se ud?

- Hvis det er HOFOR der ejer lageret?
- Hvis det er et system lager?

Appendix C Plant Characteristics

Plant	Unit	El Cap Max MW	Heat Cap Max MJ/s	Primary Energy Max MW	El Cap Min MW	Heat Cap Min MJ/s	Primary Energy Min MW	Total Eff. %	Fuel	Owner	Notes
AMV	AMV1	68.0	250.0	341.9	13.6	50.0	68.4	93.0%	Wood Pellets	HOFOR	Backpressure
	AMV BIO4	150.0	400.0	591.4	30.0	80.0	103.8	106.0%	Wood Chips		Can run as Bypass (only heat) adding 150 MJ/s heat capacity.
	AMV BIO4 Bypass		550.0	591.4		80.0	103.8		Wood Chips		
AVV	AVV1	215.0	330.0	612.4	38.7	59.4	110.2	89.0%	Wood Pellets	DONG	
	AVV1 Condensing	250.0	-	595.2	45.0	-	107.1	42.0%	Wood Pellets		Condensing
	AVV2 Main	280.3	445.1	815.1	50.5	80.1	146.7	89.0%	Wood Pellets		
	AVV2 Gas turbine	128.3	91.9	247.3	23.1	16.5	44.5	89.0%	Natural Gas		Can only run together with AVV2 Main - no min running time or dowtime
	AVV2 Straw boiler	45.0	50.0	100.7	18.0	20.0	42.7	94.3%	Straw		Can only run together with AVV2 Main
HCV	HCV 7	75.0	205.0	325.0	30.0	82.0	130.0	86.2%	Natural Gas		
	HCV 8	24.0	94.0	136.9	9.6	37.6	54.8	86.2%	Natural Gas		
	HCV total	99.0	299.0	461.9	39.6	119.6	184.8	86.2%	Natural Gas		
KKV	KKV7	8.0	32.0	43.0	1.6	6.4	8.6	93.0%	Wood Chips	VEKS	
	KKV8	14.0	33.0	50.5	2.8	6.6	10.1	93.0%	Wood Chips		
	KKV total	22.0	65.0	93.5	4.4	13.0	18.7	93.0%	Wood Chips		
ARC	ARC	57.0	190.0	230.8	42.8	142.5	173.1	107.0%	Waste	Municipalities	
K/N	K/N5	14.3	42.9	58.3	10.7	32.2	43.8	98.0%	Waste		
	K/N6	17.9	53.6	72.9	13.4	40.2	54.7	98.0%	Waste		
	K/N total	32.2	96.5	131.3	24.1	72.4	98.4	98.0%	Waste		
VF	VF5	17.0	70.0	88.8	12.8	52.5	66.6	98.0%	Waste		
	VF6	22.0	73.0	96.9	16.5	54.8	72.7	98.0%	Waste		
	VF Total	39.0	143.0	185.7	29.3	107.3	139.3	98.0%	Waste		
Peak Boilers			2,000.0	2,000.0		0.0	0.0	100%	Natural Gas		Includes also SMV and Peak HCV

Appendix D EnergyPRO Output

Reference.epp

Energy conversion, monthly

Calculated period: 01/2025 - 12/2025

	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heat demand [MWh]													
	12,087,420.5	1,829,870.0	1,503,633.8	1,564,808.7	1,281,113.2	749,940.9	313,768.9	315,482.4	316,530.9	375,579.6	989,598.4	1,390,156.0	1,456,937.6
VEKS_North	**1,306,388.9**	192,652.7	158,390.2	164,896.4	135,155.5	79,566.5	47,935.3	40,787.7	41,836.1	40,331.4	104,662.5	146,574.0	153,600.6
VEKS_West	**1,740,833.3**	264,364.5	217,219.0	226,046.4	185,039.9	108,246.6	42,924.7	44,355.5	44,355.5	54,133.2	142,892.3	200,803.5	210,452.3
VF	**885,833.3**	134,523.5	110,533.2	115,025.1	94,158.7	55,081.9	21,842.5	22,570.5	22,570.5	27,546.0	72,711.6	102,180.0	107,089.9
Koge	**222,500.0**	33,789.1	27,763.3	28,891.5	23,650.4	13,835.3	5,486.3	5,669.2	5,669.2	6,918.9	18,263.4	25,665.2	26,898.4
CTR	**7,676,944.4**	1,165,827.8	957,919.5	996,847.9	816,012.2	477,359.4	189,294.5	195,604.3	195,604.3	238,723.2	630,144.1	885,528.4	928,078.7
Høje_Taastrup	**254,920.6**	38,712.5	31,808.7	33,101.3	27,096.5	15,851.2	6,285.7	6,495.2	6,495.2	7,927.0	20,924.6	29,404.9	30,817.8
Cooling demand [MWh]													
	33,026.0	1,729.6	1,692.7	2,009.1	2,276.6	3,197.5	3,589.3	3,874.2	3,847.4	3,693.4	2,830.3	2,123.3	2,162.5
Høje_Taastrup	**33,026.0**	1,729.6	1,692.7	2,009.1	2,276.6	3,197.5	3,589.3	3,874.2	3,847.4	3,693.4	2,830.3	2,123.3	2,162.5
Electricity produced by energy units [MWh]													
	4,817,624.6	687,135.0	555,365.1	644,928.3	490,454.6	282,626.2	108,917.4	95,687.4	110,362.6	140,009.7	466,139.4	629,948.6	606,050.4
Electricity consumed by energy units [MWh]													
	21,608.2	1,559.5	1,442.0	1,631.2	1,663.8	1,937.1	1,999.1	2,109.4	2,102.5	2,028.9	1,841.8	1,622.5	1,670.5
Exported electricity, Nordpool Spot Price 2025 [MWh]													
	4,796,053.8	685,575.5	553,923.1	643,297.1	488,790.8	280,689.1	106,955.7	93,578.0	108,260.0	137,980.8	464,297.5	628,326.2	604,379.9
Peak [MW]	**1,169.300**	1,169.300	1,006.000	1,006.000	1,006.000	938.000	759.789	450.650	714.557	830.903	1,162.953	1,169.300	1,169.300
Imported electricity, Nordpool Spot Price 2025 [MWh]													
	37.4	0.0	0.0	0.0	0.0	0.0	37.4	0.0	0.0	0.0	0.0	0.0	0.0
Peak [MW]	**4.500**	0.000	0.000	0.000	0.000	0.000	4.500	0.000	0.000	0.000	0.000	0.000	0.000
Energy unit: ARC													
Fuel consum. [ton]	**647,569.2**	58,669.7	52,992.0	58,669.7	56,777.1	58,203.4	53,342.4	49,840.7	28,373.5	56,596.2	58,657.6	56,777.1	58,669.7
Fuel consum. [MWh]	**1,888,743.6**	171,120.0	154,560.0	171,120.0	165,600.0	169,759.9	155,582.0	145,368.7	82,756.2	165,072.1	171,084.7	165,600.0	171,120.0
Heat prod. [MWh]	**1,560,332.6**	141,360.0	127,680.0	141,360.0	136,800.0	140,248.2	128,541.3	120,119.1	68,364.2	136,368.5	141,331.2	136,800.0	141,360.0
Elec. prod. [MWh]	**468,086.5**	42,408.0	38,304.0	42,408.0	41,040.0	42,072.1	38,559.0	36,029.4	20,509.2	40,909.6	42,399.3	41,040.0	42,408.0
Turn ons	**6**	0	0	0	0	0	5	0	1	0	0	0	0
Operating hours	**8,245**	744	672	744	720	744	685	648	360	720	744	720	744
Full load operating hours	**8,212**	744	672	744	720	738	676	632	360	718	744	720	744

Energy conversion, monthly

Energy unit: VF_Waste

Fuel consum. [ton]	**520,172.7**	47,369.4	42,785.3	47,369.4	45,841.4	47,053.9	41,945.0	44,816.5	47,250.4	15,161.2	47,369.4	45,841.4	47,369.4
Fuel consum. [MWh]	**1,517,170.6**	138,160.8	124,790.4	138,160.8	133,704.0	137,240.7	122,339.5	130,714.9	137,813.6	44,220.3	138,160.8	133,704.0	138,160.8
Heat prod. [MWh]	**1,168,462.6**	106,392.0	96,096.0	106,392.0	102,960.0	105,692.8	94,267.7	100,734.1	106,128.2	34,055.8	106,392.0	102,960.0	106,392.0
Elec. prod. [MWh]	**318,482.3**	29,016.0	26,208.0	29,016.0	28,080.0	28,813.6	25,635.5	27,378.0	28,939.6	9,283.5	29,016.0	28,080.0	29,016.0
Turn ons	**7**	0	0	0	0	0	6	0	0	1	0	0	0
Operating hours	**8,250**	744	672	744	720	744	690	744	744	240	744	720	744
Full load operating hours	**8,166**	744	672	744	720	739	657	702	742	238	744	720	744

Energy unit: KN_Waste

Fuel consum. [ton]	**372,303.3**	33,492.8	30,251.5	33,492.8	32,412.3	33,492.8	31,973.7	33,492.8	18,367.0	25,929.9	33,492.8	32,412.3	33,492.8
Fuel consum. [MWh]	**1,085,884.5**	97,687.2	88,233.6	97,687.2	94,536.0	97,687.2	93,256.5	97,687.2	53,570.4	75,628.8	97,687.2	94,536.0	97,687.2
Heat prod. [MWh]	**798,079.6**	71,796.0	64,848.0	71,796.0	69,480.0	71,796.0	68,539.6	71,796.0	39,372.0	55,584.0	71,796.0	69,480.0	71,796.0
Elec. prod. [MWh]	**266,302.2**	23,956.8	21,638.4	23,956.8	23,184.0	23,956.8	22,870.2	23,956.8	13,137.6	18,547.2	23,956.8	23,184.0	23,956.8
Turn ons	**3**	0	0	0	0	0	2	0	0	1	0	0	0
Operating hours	**8,271**	744	672	744	720	744	711	744	408	576	744	720	744
Full load operating hours	**8,270**	744	672	744	720	744	710	744	408	576	744	720	744

Energy unit: AMV1_CHP

Fuel consum. [ton]	**324,231.1**	57,054.8	51,437.6	56,888.5	55,262.3	8,151.5	0.0	0.0	0.0	38.1	5,621.6	42,719.6	47,057.1
Fuel consum. [MWh]	**1,576,123.5**	277,350.0	250,044.0	276,541.2	268,636.2	39,625.2	0.0	0.0	0.0	185.2	27,327.4	207,664.5	228,749.8
Heat prod. [MWh]	**1,056,412.5**	185,796.9	167,500.0	185,250.0	179,955.7	26,641.6	0.0	0.0	0.0	133.3	18,520.3	139,323.5	153,291.2
Elec. prod. [MWh]	**287,344.2**	50,536.8	45,560.0	50,388.0	48,947.9	7,246.5	0.0	0.0	0.0	36.3	5,037.5	37,896.0	41,695.2
Turn ons	**80**	0	1	1	0	11	0	0	0	1	28	23	15
Operating hours	**4,320**	744	670	741	720	122	0	0	0	2	108	591	622
Full load operating hours	**4,226**	743	670	741	720	107	0	0	0	1	74	557	613

Energy unit: AMV BIO4

Fuel consum. [ton]	**1,101,853.7**	116,694.0	80,616.9	150,321.5	154,775.5	90,508.5	892.1	5,177.2	23,187.4	26,541.9	153,065.3	156,878.4	143,195.1
Fuel consum. [MWh]	**3,076,008.4**	325,770.8	225,055.4	419,647.5	432,081.5	252,669.5	2,490.3	14,452.9	64,731.5	74,096.2	427,307.4	437,952.1	399,753.1
Heat prod. [MWh]	**1,980,737.3**	209,600.0	144,800.0	270,000.0	278,000.0	162,787.3	1,631.5	9,462.5	42,388.7	48,042.4	275,042.3	281,782.6	257,200.0
Elec. prod. [MWh]	**742,776.5**	78,600.0	54,300.0	101,250.0	104,250.0	61,045.2	611.8	3,548.4	15,895.8	18,015.9	103,140.9	105,668.5	96,450.0
Turn ons	**200**	10	22	7	5	27	3	10	42	50	12	4	8
Operating hours	**5,116**	524	362	675	695	429	7	40	180	157	699	705	643
Full load operating hours	**4,952**	524	362	675	695	407	4	24	106	120	688	704	643

Energy conversion, monthly

Energy unit: AVV_2_main													
Fuel consum. [ton]	**645,597.9**	113,535.4	93,468.0	113,163.8	50,198.0	10,689.3	4,544.1	0.0	1,162.2	6,639.5	58,704.6	99,433.3	94,059.9
Fuel consum. [MWh]	**3,138,323.4**	551,908.2	454,358.4	550,101.6	244,017.9	51,962.0	22,089.3	0.0	5,649.6	32,275.3	285,369.5	483,356.1	457,235.4
Heat prod. [MWh]	**1,713,266.5**	301,349.4	248,048.9	300,303.9	133,247.1	28,323.9	12,050.4	0.0	3,074.8	17,593.4	155,752.7	263,896.9	249,625.1
Elec. prod. [MWh]	**1,078,939.3**	189,774.6	156,210.0	189,118.3	83,911.9	17,838.6	7,589.1	0.0	1,936.7	11,080.5	98,087.4	166,189.7	157,202.4
Turn ons	**173**	11	17	6	3	20	6	0	4	20	46	20	20
Operating hours	**4,084**	692	588	719	301	89	33	0	12	55	389	617	589
Full load operating hours	**3,849**	677	557	675	299	64	27	0	7	40	350	593	561

Energy unit: AMV BIO4_bypass													
Fuel consum. [ton]	**176,340.7**	48,993.7	69,036.5	15,366.2	5,567.5	10,430.3	0.0	0.0	0.0	0.0	1,558.9	2,895.1	22,492.5
Fuel consum. [MWh]	**492,284.3**	136,774.0	192,727.0	42,897.3	15,542.5	29,117.8	0.0	0.0	0.0	0.0	4,351.9	8,082.1	62,791.7
Heat prod. [MWh]	**435,509.7**	121,000.0	170,500.0	37,950.0	13,750.0	25,759.7	0.0	0.0	0.0	0.0	3,850.0	7,150.0	55,550.0
Turn ons	**66**	11	21	7	5	10	0	0	0	0	1	3	8
Operating hours	**794**	220	310	69	25	49	0	0	0	0	7	13	101
Full load operating hours	**792**	220	310	69	25	47	0	0	0	0	7	13	101

Energy unit: AVV_1													
Fuel consum. [ton]	**539,191.2**	73,795.1	76,340.4	65,361.7	51,526.0	47,667.3	641.8	2,106.6	12,680.2	16,812.5	53,120.4	69,422.6	69,716.7
Fuel consum. [MWh]	**2,621,068.4**	358,726.1	371,099.1	317,730.4	250,473.6	231,716.2	3,119.6	10,240.3	61,639.9	81,727.3	258,224.2	337,471.0	338,900.8
Heat prod. [MWh]	**1,491,809.8**	204,173.2	211,215.4	180,840.0	142,560.0	131,883.4	1,775.5	5,828.4	35,082.7	46,515.9	146,970.8	192,075.5	192,889.1
Elec. prod. [MWh]	**971,936.7**	133,021.9	137,610.0	117,820.0	92,880.0	85,924.0	1,156.8	3,797.3	22,856.9	30,305.8	95,753.7	125,140.1	125,670.2
Turn ons	**267**	17	6	2	1	42	3	5	39	45	53	27	27
Operating hours	**4,608**	619	641	548	432	425	7	18	123	148	466	587	594
Full load operating hours	**4,521**	619	640	548	432	400	5	18	106	141	445	582	585

Energy unit: AVV1_Condensing													
Fuel consum. [ton]	**63,435.2**	12,736.0	0.0	0.0	0.0	0.0	5,878.2	0.0	857.2	3,184.0	17,267.1	13,593.2	9,919.4
Fuel consum. [MWh]	**308,365.4**	61,911.2	0.0	0.0	0.0	0.0	28,574.4	0.0	4,167.1	15,477.8	83,937.3	66,078.3	48,219.3
Heat prod. [MWh]	**51.8**	10.4	0.0	0.0	0.0	0.0	4.8	0.0	0.7	2.6	14.1	11.1	8.1
Elec. prod. [MWh]	**129,500.0**	26,000.0	0.0	0.0	0.0	0.0	12,000.0	0.0	1,750.0	6,500.0	35,250.0	27,750.0	20,250.0
Turn ons	**97**	11	0	0	0	0	8	0	2	9	29	20	18
Operating hours	**518**	104	0	0	0	0	48	0	7	26	141	111	81
Full load operating hours	**518**	104	0	0	0	0	48	0	7	26	141	111	81

Energy conversion, monthly

Energy unit: HCV_CHP

Fuel consum. [1000Nm3]	**96,256.1**	23,248.8	15,884.2	19,560.2	16,758.9	932.7	0.0	0.0	0.0	0.0	49.8	10,344.6	9,477.0
Fuel consum. [MWh]	**1,056,945.8**	255,284.6	174,416.9	214,781.7	184,022.3	10,241.3	0.0	0.0	0.0	0.0	547.1	113,589.4	104,062.5
Heat prod. [MWh]	**685,430.7**	165,354.5	113,156.5	139,357.2	119,193.9	6,686.9	0.0	0.0	0.0	0.0	358.5	73,715.4	67,607.8
Elec. prod. [MWh]	**225,284.4**	54,612.7	37,129.0	45,708.4	39,369.8	2,137.0	0.0	0.0	0.0	0.0	112.8	24,158.2	22,056.4
Turn ons	**146**	12	26	28	28	14	0	0	0	0	1	13	24
Operating hours	**2,803**	595	482	599	428	46	0	0	0	0	3	323	327
Full load operating hours	**2,276**	552	375	462	398	22	0	0	0	0	1	244	223

Energy unit: AVV_2_Gas_T

Fuel consum. [1000Nm3]	**6,354.4**	2,343.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	740.2	1,801.8	1,469.3
Fuel consum. [MWh]	**69,774.8**	25,729.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8,127.4	19,784.3	16,133.4
Heat prod. [MWh]	**25,918.6**	9,557.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,018.9	7,349.2	5,992.9
Elec. prod. [MWh]	**36,184.9**	13,343.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,214.9	10,260.0	8,366.7
Turn ons	**54**	11	0	0	0	0	0	0	0	0	11	17	15
Operating hours	**287**	104	0	0	0	0	0	0	0	0	36	80	67
Full load operating hours	**282**	104	0	0	0	0	0	0	0	0	33	80	65

Energy unit: AVV_2_Straw_boiler

Fuel consum. [ton]	**88,256.3**	16,388.2	13,123.9	16,053.7	7,211.5	825.4	275.0	0.0	0.0	363.8	7,570.3	13,758.9	12,685.5
Fuel consum. [MWh]	**355,476.6**	66,007.9	52,860.2	64,660.7	29,046.2	3,324.4	1,107.7	0.0	0.0	1,465.4	30,491.6	55,417.9	51,094.5
Heat prod. [MWh]	**176,502.5**	32,774.5	26,246.3	32,105.6	14,422.1	1,650.6	550.0	0.0	0.0	727.6	15,139.8	27,516.3	25,369.6
Elec. prod. [MWh]	**158,852.3**	29,497.0	23,621.7	28,895.0	12,979.9	1,485.6	495.0	0.0	0.0	654.8	13,625.8	24,764.7	22,832.7
Turn ons	**189**	13	29	26	7	8	2	0	0	6	45	23	30
Operating hours	**3,545**	657	531	644	289	34	11	0	0	15	304	552	508
Full load operating hours	**3,530**	655	525	642	288	33	11	0	0	15	303	550	507

Energy unit: KKV_CHP

Fuel consum. [ton]	**204,085.8**	24,918.4	22,507.0	24,918.0	24,071.3	18,472.0	0.0	1,501.0	8,191.0	7,168.4	23,677.1	24,080.9	24,580.6
Fuel consum. [MWh]	**569,739.5**	69,564.0	62,832.0	69,562.6	67,199.1	51,567.6	0.0	4,190.4	22,866.5	20,011.8	66,098.6	67,225.9	68,620.9
Heat prod. [MWh]	**396,196.0**	48,360.0	43,680.0	48,359.0	46,716.5	35,875.8	0.0	2,921.6	15,939.9	13,944.4	45,959.3	46,735.1	47,704.4
Elec. prod. [MWh]	**133,935.3**	16,368.0	14,784.0	16,367.7	15,810.9	12,106.8	0.0	977.5	5,336.8	4,676.0	15,544.2	15,817.4	16,146.1
Turn ons	**113**	0	0	0	0	13	0	6	44	42	5	0	3
Operating hours	**6,353**	744	672	744	720	609	0	63	338	284	725	720	734
Full load operating hours	**6,088**	744	672	744	719	550	0	44	243	213	707	719	734

Energy conversion, monthly

Energy unit: Geothermal_Elec Heatpump													
Heat prod. [MWh]	**27,594.0**	2,343.6	2,116.8	2,343.6	2,268.0	2,343.6	2,268.0	2,343.6	2,343.6	2,268.0	2,343.6	2,268.0	2,343.6
Elec. consum. [MWh]	**13,140.0**	1,116.0	1,008.0	1,116.0	1,080.0	1,116.0	1,080.0	1,116.0	1,116.0	1,080.0	1,116.0	1,080.0	1,116.0
Turn ons	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Operating hours	**8,760**	744	672	744	720	744	720	744	744	720	744	720	744
Full load operating hours	**8,760**	744	672	744	720	744	720	744	744	720	744	720	744
Energy unit: Gas boiler													
Fuel consum. [1000Nm3]	**49,167.0**	21,047.4	7,737.5	4,376.9	3,607.3	341.7	80.1	0.0	0.2	1,676.9	48.9	3,349.8	6,900.2
Fuel consum. [MWh]	**539,881.0**	231,112.0	84,961.8	48,061.2	39,610.3	3,751.7	879.8	0.0	2.3	18,413.3	537.2	36,783.0	75,768.3
Heat prod. [MWh]	**539,881.0**	231,112.0	84,961.8	48,061.2	39,610.3	3,751.7	879.8	0.0	2.3	18,413.3	537.2	36,783.0	75,768.3
Turn ons	**152**	5	10	23	22	20	6	0	1	1	11	21	32
Operating hours	**3,345**	643	582	573	220	37	29	0	1	480	17	340	423
Full load operating hours	**270**	116	42	24	20	2	0	0	0	9	0	18	38
Energy unit: HT_HeatPump_cold													
Elec. consum. [MWh]	**8,468.2**	443.5	434.0	515.2	583.8	821.1	919.1	993.4	986.5	948.9	725.8	542.5	554.5
Cooling prod. [MWh]	**33,026.0**	1,729.6	1,692.7	2,009.1	2,276.6	3,202.3	3,584.6	3,874.2	3,847.4	3,700.6	2,830.8	2,115.6	2,162.5
Turn ons	**887**	70	70	83	65	69	70	79	77	75	82	73	74
Operating hours	**4,948**	362	305	317	346	442	486	496	512	461	415	388	418
Full load operating hours	**2,823**	148	145	172	195	274	306	331	329	316	242	181	185
Energy unit: HT_HeatPump													
Heat prod. [MWh]	**35,223.9**	1,478.3	1,446.7	1,717.5	2,726.3	3,831.8	4,288.9	4,630.4	4,609.5	4,414.0	2,424.0	1,808.2	1,848.3
Turn ons	**888**	70	70	82	65	70	70	79	77	76	82	73	74
Operating hours	**4,948**	362	305	317	347	442	485	496	513	460	415	388	418
Full load operating hours	**2,753**	148	145	172	195	274	306	331	329	315	173	181	185
Heat rejection: Høje_Taastrup													
Heat Rejection [MWh]	**4,039**	0	0	0	0	208	964	1,112	1,039	714	3	0	0
Elec. consump [MWh]	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Transmission between Kara_Novoren and VEKS_West													
From Kara_Novoren [MWh]	**798,080**	71,796	64,848	71,796	69,480	71,796	68,540	71,796	39,372	55,584	71,796	69,480	71,796
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Energy conversion, monthly

Transmission between AVV and VEKS_North													
From AVV [MWh]	**1,427,723**	251,903	228,735	239,798	93,023	51,021	2,085	18	546	7,722	116,136	222,511	214,226
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AVV and VEKS_West													
From AVV [MWh]	**1,979,826**	293,616	257,862	272,774	196,901	113,080	12,270	5,176	37,257	55,953	204,923	268,555	261,459
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_North and VEKS_West													
From VEKS_North [MWh]	**38,072**	497	1,494	4,238	10,604	1,824	0	0	5,518	2,752	729	688	9,729
From VEKS_West [MWh]	**1,030,377**	79,009	94,690	110,874	90,641	88,267	29,438	26,892	45,137	62,954	143,749	131,393	127,333
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between KKV and Koge													
From KKV [MWh]	**396,196**	48,360	43,680	48,359	46,717	35,876	0	2,922	15,940	13,944	45,959	46,735	47,704
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Koge and VEKS_West													
From Koge [MWh]	**194,588**	14,698	16,211	19,496	23,066	23,205	0	2,442	13,367	10,932	27,955	21,070	22,146
From VEKS_West [MWh]	**19,101**	0	0	0	0	1,164	5,486	5,189	3,096	3,907	259	0	0
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between CTR and VEKS_North													
From CTR [MWh]	**78,454**	3,139	7,195	4,771	28,580	5,117	296	249	3,264	5,227	815	1,182	18,618
From VEKS_North [MWh]	**1,337,591**	141,202	171,730	187,470	72,947	85,102	10,443	14,631	39,031	44,014	162,634	208,297	200,091
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Vestforbrænding and VF													
From Vestforbrænding [MWh]	**1,168,463**	106,392	96,096	106,392	102,960	105,693	94,268	100,734	106,128	34,056	106,392	102,960	106,392
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and VEKS_North													
From VF [MWh]	**145,498**	302	994	1,161	6,462	22,087	26,560	28,260	37,437	11,194	7,325	473	3,244
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and CTR													
From VF [MWh]	**232,698**	1,130	776	1,299	4,846	28,625	46,776	49,904	46,120	13,617	26,355	7,733	5,518
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Energy conversion, monthly

Transmission between AMV and CTR													
From AMV [MWh]	**3,500,254**	518,499	485,159	495,183	473,702	218,164	3,830	11,200	45,351	49,838	299,743	430,808	468,777
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between HCV and CTR													
From HCV [MWh]	**685,431**	165,354	113,157	139,357	119,194	6,687	0	0	0	0	359	73,715	67,608
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between ARC_Waste and CTR													
From ARC_Waste [MWh]	**1,560,333**	141,360	127,680	141,360	136,800	140,248	128,541	120,119	68,364	136,369	141,331	136,800	141,360
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Peak Production and VEKS_North													
From Peak Production [MWh]	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between CTR and Peak Production													
From Peak Production [MWh]	**439,092**	201,421	66,613	36,950	37,104	3,650	0	0	2	113	537	29,357	63,344
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and Peak Production													
From Peak Production [MWh]	**95,517**	29,564	16,198	11,082	2,506	102	880	0	0	18,300	0	7,426	9,460
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_West and Peak Production													
From Peak Production [MWh]	**3,481**	0	1,856	0	0	0	0	0	0	0	0	0	1,625
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Peak Production and Koge													
From Peak Production [MWh]	**1,791**	128	295	29	0	0	0	0	0	0	0	0	1,340
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_West and Høje_Taastrup													
From VEKS_West [MWh]	**223,736**	37,234	30,362	31,384	24,370	12,227	2,961	2,977	2,925	4,227	18,503	27,597	28,969
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AMV and AMV TES													
From AMV [MWh]	**151,666**	2,934	4,527	5,824	11,752	21,510	2,866	6,561	22,171	25,050	24,077	13,712	10,682

Energy conversion, monthly

From AMV TES [MWh]	**151,666**	2,692	4,769	5,463	11,480	22,142	2,797	5,954	22,790	24,444	24,064	13,996	11,074
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AVV and AVV TES													
From AVV [MWh]	**460,639**	23,492	30,163	37,334	45,547	62,272	11,815	5,811	34,181	50,644	71,606	45,270	42,505
From AVV TES [MWh]	**460,639**	21,146	31,249	36,657	45,241	64,515	11,789	5,176	33,826	49,480	71,769	45,487	44,304
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel consumption: Natural Gas													
Fuel consum. [1000Nm3]	**151,777.5**	46,639.4	23,621.6	23,937.1	20,366.2	1,274.3	80.1	0.0	0.2	1,676.9	838.9	15,496.2	17,846.5
Fuel consum. [MWh]	**1,666,601.5**	512,126.2	259,378.8	262,842.9	223,632.6	13,993.0	879.8	0.0	2.3	18,413.3	9,211.8	170,156.8	195,964.3
Peak [MW]	**1,863.845**	1,863.845	1,550.287	1,062.649	1,064.095	599.141	30.337	0.000	2.342	104.449	680.397	1,281.207	1,545.978
Fuel consumption: Straw													
Fuel consum. [ton]	**88,256.3**	16,388.2	13,123.9	16,053.7	7,211.5	825.4	275.0	0.0	0.0	363.8	7,570.3	13,758.9	12,685.5
Fuel consum. [MWh]	**355,476.6**	66,007.9	52,860.2	64,660.7	29,046.2	3,324.4	1,107.7	0.0	0.0	1,465.4	30,491.6	55,417.9	51,094.5
Peak [MW]	**100.700**	100.700	100.700	100.700	100.700	100.700	100.700	0.000	0.000	100.700	100.700	100.700	100.700
Fuel consumption: Wood Pellets													
Fuel consum. [ton]	**1,572,455.4**	257,121.3	221,246.0	235,413.9	156,986.3	66,508.1	11,064.0	2,106.6	14,699.6	26,674.1	134,713.7	225,168.7	220,753.1
Fuel consum. [MWh]	**7,643,880.6**	1,249,895.4	1,075,501.6	1,144,373.2	763,127.6	323,303.4	53,783.4	10,240.3	71,456.6	129,665.6	654,858.4	1,094,569.9	1,073,105.3
Peak [MW]	**1,783.600**	1,783.600	1,768.100	1,768.100	1,768.100	1,768.100	1,410.400	579.800	1,347.967	1,410.400	1,783.600	1,783.600	1,783.600
Fuel consumption: Wood Chips													
Fuel consum. [ton]	**1,482,280.2**	190,606.1	172,160.4	190,605.6	184,414.2	119,410.7	892.1	6,678.2	31,378.4	33,710.3	178,301.3	183,854.4	190,268.3
Fuel consum. [MWh]	**4,138,032.3**	532,108.8	480,614.4	532,107.4	514,823.1	333,355.0	2,490.3	18,643.4	87,598.0	94,108.1	497,757.9	513,260.2	531,165.7
Peak [MW]	**715.200**	715.200	715.200	715.200	715.200	715.200	472.110	690.020	690.020	705.130	715.200	715.200	715.200
Fuel consumption: Waste													
Fuel consum. [ton]	**1,540,045.2**	139,531.9	126,028.8	139,531.9	135,030.9	138,750.1	127,261.0	128,150.0	93,990.9	97,687.3	139,519.8	135,030.9	139,531.9
Fuel consum. [MWh]	**4,491,798.7**	406,968.0	367,584.0	406,968.0	393,840.0	404,687.7	371,178.0	373,770.8	274,140.2	284,921.3	406,932.7	393,840.0	406,968.0
Peak [MW]	**547.000**	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000
Fuel consumption: Fueloil													
Fuel consum. [Ton]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel consum. [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peak [MW]	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Energy conversion, monthly

Calculated period: 01/2025 - 12/2025

	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heat demand [MWh]													
	12,087,420.5	1,829,870.0	1,503,633.8	1,564,808.7	1,281,113.2	749,940.9	313,768.9	315,482.4	316,530.9	375,579.6	989,598.4	1,390,156.0	1,456,937.6
VEKS_North	**1,306,388.9**	192,652.7	158,390.2	164,896.4	135,155.5	79,566.5	47,935.3	40,787.7	41,836.1	40,331.4	104,662.5	146,574.0	153,600.6
VEKS_West	**1,740,833.3**	264,364.5	217,219.0	226,046.4	185,039.9	108,246.6	42,924.7	44,355.5	44,355.5	54,133.2	142,892.3	200,803.5	210,452.3
VF	**885,833.3**	134,523.5	110,533.2	115,025.1	94,158.7	55,081.9	21,842.5	22,570.5	22,570.5	27,546.0	72,711.6	102,180.0	107,089.9
Koge	**222,500.0**	33,789.1	27,763.3	28,891.5	23,650.4	13,835.3	5,486.3	5,669.2	5,669.2	6,918.9	18,263.4	25,665.2	26,898.4
CTR	**7,676,944.4**	1,165,827.8	957,919.5	996,847.9	816,012.2	477,359.4	189,294.5	195,604.3	195,604.3	238,723.2	630,144.1	885,528.4	928,078.7
Høje_Taastrup	**254,920.6**	38,712.5	31,808.7	33,101.3	27,096.5	15,851.2	6,285.7	6,495.2	6,495.2	7,927.0	20,924.6	29,404.9	30,817.8
Cooling demand [MWh]													
	33,026.0	1,729.6	1,692.7	2,009.1	2,276.6	3,197.5	3,589.3	3,874.2	3,847.4	3,693.4	2,830.3	2,123.3	2,162.5
Høje_Taastrup	**33,026.0**	1,729.6	1,692.7	2,009.1	2,276.6	3,197.5	3,589.3	3,874.2	3,847.4	3,693.4	2,830.3	2,123.3	2,162.5
Electricity produced by energy units [MWh]													
	4,831,982.2	688,284.6	559,537.3	645,396.9	490,329.8	280,571.1	110,234.4	96,560.5	112,437.2	142,709.9	465,782.4	632,021.4	608,116.7
Electricity consumed by energy units [MWh]													
	21,608.2	1,559.5	1,442.0	1,631.2	1,663.8	1,937.1	1,999.1	2,109.4	2,102.5	2,028.9	1,841.8	1,622.5	1,670.5
Exported electricity, Nordpool Spot Price 2025 [MWh]													
	4,810,403.3	686,725.1	558,095.3	643,765.7	488,666.1	278,634.0	108,264.6	94,451.1	110,334.7	140,681.1	463,940.5	630,398.9	606,446.2
Peak [MW]	**1,169.300**	1,169.300	1,006.000	1,006.000	957.184	866.648	768.855	453.019	742.026	830.903	1,094.552	1,169.300	1,169.300
Imported electricity, Nordpool Spot Price 2025 [MWh]													
	29.4	0.0	0.0	0.0	0.0	0.0	29.4	0.0	0.0	0.0	0.0	0.0	0.0
Peak [MW]	**4.500**	0.000	0.000	0.000	0.000	0.000	4.500	0.000	0.000	0.000	0.000	0.000	0.000
Energy unit: ARC													
Fuel consum. [ton]	**646,569.2**	58,669.7	52,992.0	58,669.7	56,777.1	58,474.1	52,562.9	49,141.2	28,388.6	56,777.1	58,669.7	56,777.1	58,669.7
Fuel consum. [MWh]	**1,885,826.8**	171,120.0	154,560.0	171,120.0	165,600.0	170,549.5	153,308.6	143,328.6	82,800.0	165,600.0	171,120.0	165,600.0	171,120.0
Heat prod. [MWh]	**1,557,940.4**	141,360.0	127,680.0	141,360.0	136,800.0	140,893.7	126,679.1	118,447.6	68,400.0	136,800.0	141,360.0	136,800.0	141,360.0
Elec. prod. [MWh]	**467,365.4**	42,408.0	38,304.0	42,408.0	41,040.0	42,267.1	37,997.2	35,525.1	20,520.0	41,040.0	42,408.0	41,040.0	42,408.0
Turn ons	**11**	0	0	0	0	0	9	1	1	0	0	0	0
Operating hours	**8,241**	744	672	744	720	744	683	646	360	720	744	720	744
Full load operating hours	**8,199**	744	672	744	720	742	667	623	360	720	744	720	744

Energy conversion, monthly

Energy unit: VF_Waste

Fuel consum. [ton]	**517,286.8**	47,369.4	42,785.3	47,369.4	45,841.4	47,235.9	40,210.0	43,245.4	47,369.4	15,280.5	47,369.4	45,841.4	47,369.4
Fuel consum. [MWh]	**1,508,753.3**	138,160.8	124,790.4	138,160.8	133,704.0	137,771.3	117,279.3	126,132.4	138,160.8	44,568.0	138,160.8	133,704.0	138,160.8
Heat prod. [MWh]	**1,162,053.4**	106,392.0	96,096.0	106,392.0	102,960.0	106,096.0	90,409.4	97,252.0	106,392.0	34,320.0	106,392.0	102,960.0	106,392.0
Elec. prod. [MWh]	**316,643.6**	29,016.0	26,208.0	29,016.0	28,080.0	28,930.3	24,535.3	26,369.9	29,016.0	9,360.0	29,016.0	28,080.0	29,016.0
Turn ons	**5**	0	0	0	0	0	4	0	0	1	0	0	0
Operating hours	**8,243**	744	672	744	720	744	683	744	744	240	744	720	744
Full load operating hours	**8,119**	744	672	744	720	742	629	676	744	240	744	720	744

Energy unit: KN_Waste

Fuel consum. [ton]	**371,987.9**	33,492.8	30,251.5	33,492.8	32,412.3	33,492.8	31,658.3	33,492.8	18,367.0	25,929.9	33,492.8	32,412.3	33,492.8
Fuel consum. [MWh]	**1,084,964.8**	97,687.2	88,233.6	97,687.2	94,536.0	97,687.2	92,336.8	97,687.2	53,570.4	75,628.8	97,687.2	94,536.0	97,687.2
Heat prod. [MWh]	**797,403.7**	71,796.0	64,848.0	71,796.0	69,480.0	71,796.0	67,863.7	71,796.0	39,372.0	55,584.0	71,796.0	69,480.0	71,796.0
Elec. prod. [MWh]	**266,076.6**	23,956.8	21,638.4	23,956.8	23,184.0	23,956.8	22,644.6	23,956.8	13,137.6	18,547.2	23,956.8	23,184.0	23,956.8
Turn ons	**3**	0	0	0	0	0	2	0	0	1	0	0	0
Operating hours	**8,264**	744	672	744	720	744	704	744	408	576	744	720	744
Full load operating hours	**8,263**	744	672	744	720	744	703	744	408	576	744	720	744

Energy unit: AMV1_CHP

Fuel consum. [ton]	**325,580.8**	57,064.9	51,480.7	56,888.5	55,276.3	8,494.6	0.0	0.0	0.0	0.0	6,031.0	43,156.7	47,188.1
Fuel consum. [MWh]	**1,582,684.2**	277,399.0	250,253.2	276,541.2	268,704.0	41,293.1	0.0	0.0	0.0	0.0	29,317.1	209,789.8	229,386.8
Heat prod. [MWh]	**1,060,847.0**	185,828.9	167,649.0	185,250.0	180,000.0	27,780.7	0.0	0.0	0.0	0.0	19,857.3	140,773.7	153,707.4
Elec. prod. [MWh]	**288,550.4**	50,545.5	45,600.5	50,388.0	48,960.0	7,556.4	0.0	0.0	0.0	0.0	5,401.2	38,290.5	41,808.4
Turn ons	**79**	0	0	1	0	11	0	0	0	0	30	22	15
Operating hours	**4,344**	744	672	741	720	130	0	0	0	0	114	601	622
Full load operating hours	**4,243**	743	671	741	720	111	0	0	0	0	79	563	615

Energy unit: AMV BIO4

Fuel consum. [ton]	**1,099,670.2**	116,694.0	80,616.9	150,321.5	154,775.5	91,041.5	1,054.8	6,371.7	21,990.4	23,567.6	153,057.7	156,983.6	143,195.1
Fuel consum. [MWh]	**3,069,912.8**	325,770.8	225,055.4	419,647.5	432,081.5	254,157.5	2,944.6	17,787.5	61,389.9	65,792.9	427,286.0	438,246.0	399,753.1
Heat prod. [MWh]	**1,977,330.8**	209,600.0	144,800.0	270,000.0	278,000.0	163,857.9	1,926.4	11,672.7	40,222.8	43,006.2	275,077.7	281,967.1	257,200.0
Elec. prod. [MWh]	**741,499.1**	78,600.0	54,300.0	101,250.0	104,250.0	61,446.7	722.4	4,377.3	15,083.6	16,127.3	103,154.1	105,737.6	96,450.0
Turn ons	**210**	10	22	7	5	30	3	13	46	52	10	4	8
Operating hours	**5,159**	524	362	675	695	443	8	52	173	175	704	705	643
Full load operating hours	**4,943**	524	362	675	695	410	5	29	101	108	688	705	643

Energy conversion, monthly

Energy unit: AVV_2_main

Fuel consum. [ton]	**647,581.6**	113,698.3	93,843.1	113,328.3	50,282.7	9,964.0	5,139.4	0.0	1,852.5	8,026.7	58,004.5	99,566.4	93,875.6
Fuel consum. [MWh]	**3,147,966.1**	552,699.9	456,181.9	550,901.6	244,429.8	48,436.2	24,983.2	0.0	9,005.3	39,018.6	281,966.5	484,003.4	456,339.7
Heat prod. [MWh]	**1,718,535.8**	301,785.7	249,049.2	300,746.8	133,473.0	26,401.9	13,623.7	0.0	4,895.4	21,238.0	153,914.2	264,264.1	249,143.8
Elec. prod. [MWh]	**1,082,257.5**	190,049.3	156,839.7	189,397.0	84,054.2	16,628.2	8,580.1	0.0	3,083.6	13,376.9	96,928.9	166,420.5	156,899.0
Turn ons	**186**	11	17	7	3	19	7	0	6	28	46	21	21
Operating hours	**4,094**	691	588	717	301	83	40	0	22	82	375	611	584
Full load operating hours	**3,861**	678	560	676	300	59	31	0	11	48	346	594	560

Energy unit: AMV BIO4_bypass

Fuel consum. [ton]	**176,534.3**	48,993.7	69,036.5	15,366.2	5,567.5	10,408.3	0.0	0.0	0.0	0.0	1,774.6	2,895.1	22,492.5
Fuel consum. [MWh]	**492,825.0**	136,774.0	192,727.0	42,897.3	15,542.5	29,056.4	0.0	0.0	0.0	0.0	4,954.1	8,082.1	62,791.7
Heat prod. [MWh]	**435,988.1**	121,000.0	170,500.0	37,950.0	13,750.0	25,705.4	0.0	0.0	0.0	0.0	4,382.7	7,150.0	55,550.0
Turn ons	**67**	11	21	7	5	10	0	0	0	0	2	3	8
Operating hours	**798**	220	310	69	25	51	0	0	0	0	9	13	101
Full load operating hours	**793**	220	310	69	25	47	0	0	0	0	8	13	101

Energy unit: AVV_1

Fuel consum. [ton]	**544,843.8**	73,824.0	76,340.4	65,361.7	51,526.0	46,757.0	1,751.2	3,143.8	15,014.5	19,016.9	53,394.5	69,056.5	69,657.4
Fuel consum. [MWh]	**2,648,546.4**	358,866.9	371,099.1	317,730.4	250,473.6	227,291.1	8,512.8	15,282.2	72,987.1	92,443.2	259,556.5	335,691.2	338,612.3
Heat prod. [MWh]	**1,507,448.5**	204,253.3	211,215.4	180,840.0	142,560.0	129,364.5	4,845.0	8,698.0	41,541.1	52,614.9	147,728.9	191,062.4	192,724.9
Elec. prod. [MWh]	**982,125.6**	133,074.1	137,610.0	117,820.0	92,880.0	84,282.9	3,156.6	5,666.8	27,064.7	34,279.4	96,247.6	124,480.1	125,563.2
Turn ons	**277**	17	6	2	1	41	7	9	41	49	50	27	27
Operating hours	**4,683**	619	641	548	432	427	19	29	141	170	478	585	594
Full load operating hours	**4,568**	619	640	548	432	392	15	26	126	159	448	579	584

Energy unit: AVV1_Condensing

Fuel consum. [ton]	**63,435.2**	12,736.0	0.0	0.0	0.0	0.0	5,878.2	0.0	857.2	3,184.0	17,267.1	13,593.2	9,919.4
Fuel consum. [MWh]	**308,365.4**	61,911.2	0.0	0.0	0.0	0.0	28,574.4	0.0	4,167.1	15,477.8	83,937.3	66,078.3	48,219.3
Heat prod. [MWh]	**51.8**	10.4	0.0	0.0	0.0	0.0	4.8	0.0	0.7	2.6	14.1	11.1	8.1
Elec. prod. [MWh]	**129,500.0**	26,000.0	0.0	0.0	0.0	0.0	12,000.0	0.0	1,750.0	6,500.0	35,250.0	27,750.0	20,250.0
Turn ons	**97**	11	0	0	0	0	8	0	2	9	29	20	18
Operating hours	**518**	104	0	0	0	0	48	0	7	26	141	111	81
Full load operating hours	**518**	104	0	0	0	0	48	0	7	26	141	111	81

Energy conversion, monthly

Energy unit: HCV_CHP													
Fuel consum. [1000Nm3]	**99,844.6**	23,612.6	17,363.7	19,623.8	16,544.0	1,092.7	0.0	0.0	0.0	0.0	30.8	11,082.9	10,494.1
Fuel consum. [MWh]	**1,096,349.1**	259,279.6	190,662.6	215,480.2	181,662.7	11,998.5	0.0	0.0	0.0	0.0	337.7	121,696.6	115,231.3
Heat prod. [MWh]	**711,436.3**	167,982.4	123,701.3	139,846.7	117,734.3	7,846.6	0.0	0.0	0.0	0.0	226.5	79,065.8	75,032.6
Elec. prod. [MWh]	**233,226.7**	55,426.7	40,582.2	45,820.4	38,795.7	2,491.3	0.0	0.0	0.0	0.0	64.4	25,792.5	24,253.5
Turn ons	**141**	13	18	21	29	13	0	0	0	0	2	17	28
Operating hours	**3,095**	621	529	616	451	59	0	0	0	0	4	383	432
Full load operating hours	**2,356**	560	410	463	392	25	0	0	0	0	1	261	245

Energy unit: AVV_2_Gas_T													
Fuel consum. [1000Nm3]	**6,461.1**	2,343.2	0.0	0.0	0.0	0.0	10.2	0.0	0.0	8.3	763.9	1,843.6	1,491.9
Fuel consum. [MWh]	**70,946.0**	25,729.6	0.0	0.0	0.0	0.0	112.1	0.0	0.0	90.9	8,388.2	20,243.6	16,381.5
Heat prod. [MWh]	**26,353.4**	9,557.6	0.0	0.0	0.0	0.0	41.6	0.0	0.0	33.7	3,115.8	7,519.7	6,085.0
Elec. prod. [MWh]	**36,792.4**	13,343.2	0.0	0.0	0.0	0.0	58.2	0.0	0.0	47.2	4,350.2	10,498.3	8,495.4
Turn ons	**61**	11	0	0	0	0	1	0	0	1	11	18	19
Operating hours	**298**	104	0	0	0	0	1	0	0	1	38	84	70
Full load operating hours	**287**	104	0	0	0	0	0	0	0	0	34	82	66

Energy unit: AVV_2_Straw_boiler													
Fuel consum. [ton]	**88,512.8**	16,388.2	13,151.0	16,097.0	7,375.4	639.1	300.0	0.0	0.0	508.6	7,496.0	13,851.1	12,706.4
Fuel consum. [MWh]	**356,509.9**	66,007.9	52,969.2	64,835.1	29,706.5	2,574.3	1,208.4	0.0	0.0	2,048.6	30,192.2	55,789.0	51,178.7
Heat prod. [MWh]	**177,015.5**	32,774.5	26,300.4	32,192.2	14,750.0	1,278.1	600.0	0.0	0.0	1,017.1	14,991.1	27,700.6	25,411.4
Elec. prod. [MWh]	**159,313.9**	29,497.0	23,670.3	28,973.0	13,275.0	1,150.3	540.0	0.0	0.0	915.4	13,492.0	24,930.5	22,870.3
Turn ons	**185**	13	29	26	5	8	2	0	0	7	43	23	29
Operating hours	**3,564**	657	533	646	295	29	12	0	0	23	302	557	510
Full load operating hours	**3,540**	655	526	644	295	26	12	0	0	20	300	554	508

Energy unit: KKV_CHP													
Fuel consum. [ton]	**195,954.3**	24,918.4	22,507.0	24,918.0	24,071.3	18,097.4	0.0	1,019.8	4,269.3	3,860.1	23,631.5	24,080.9	24,580.6
Fuel consum. [MWh]	**547,039.2**	69,564.0	62,832.0	69,562.6	67,199.1	50,522.0	0.0	2,846.8	11,918.5	10,776.1	65,971.2	67,225.9	68,620.9
Heat prod. [MWh]	**380,378.3**	48,360.0	43,680.0	48,359.0	46,716.5	35,148.6	0.0	1,984.4	8,308.1	7,510.3	45,871.8	46,735.1	47,704.4
Elec. prod. [MWh]	**128,631.0**	16,368.0	14,784.0	16,367.7	15,810.9	11,861.1	0.0	664.5	2,781.7	2,516.5	15,513.1	15,817.4	16,146.1
Turn ons	**86**	0	0	0	0	12	0	5	26	35	5	0	3
Operating hours	**6,031**	744	672	744	720	597	0	42	176	156	726	720	734
Full load operating hours	**5,847**	744	672	744	719	539	0	30	126	114	705	719	734

Energy conversion, monthly

Energy unit: Geothermal_Elec Heatpump													
Heat prod. [MWh]	**27,594.0**	2,343.6	2,116.8	2,343.6	2,268.0	2,343.6	2,268.0	2,343.6	2,343.6	2,268.0	2,343.6	2,268.0	2,343.6
Elec. consum. [MWh]	**13,140.0**	1,116.0	1,008.0	1,116.0	1,080.0	1,116.0	1,080.0	1,116.0	1,116.0	1,080.0	1,116.0	1,080.0	1,116.0
Turn ons	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Operating hours	**8,760**	744	672	744	720	744	720	744	744	720	744	720	744
Full load operating hours	**8,760**	744	672	744	720	744	720	744	744	720	744	720	744

Energy unit: Gas boiler													
Fuel consum. [1000Nm3]	**46,610.7**	20,775.1	6,744.3	4,071.7	3,755.2	502.3	102.2	2.5	0.0	1,677.1	40.2	2,706.8	6,233.3
Fuel consum. [MWh]	**511,811.1**	228,121.6	74,056.2	44,709.4	41,234.4	5,515.6	1,122.5	27.3	0.0	18,415.6	441.0	29,722.3	68,445.3
Heat prod. [MWh]	**511,811.1**	228,121.6	74,056.2	44,709.4	41,234.4	5,515.6	1,122.5	27.3	0.0	18,415.6	441.0	29,722.3	68,445.3
Turn ons	**181**	5	8	25	33	42	4	2	2	2	14	17	27
Operating hours	**3,407**	644	580	577	249	66	37	2	2	482	18	336	414
Full load operating hours	**256**	114	37	22	21	3	1	0	0	9	0	15	34

Energy unit: HT_HeatPump_cold													
Elec. consum. [MWh]	**8,468.2**	443.5	434.0	515.2	583.8	821.1	919.1	993.4	986.5	948.9	725.8	542.5	554.5
Cooling prod. [MWh]	**33,026.0**	1,729.6	1,692.7	2,009.1	2,276.6	3,202.3	3,584.6	3,874.2	3,847.4	3,700.6	2,830.8	2,115.6	2,162.5
Turn ons	**887**	70	70	83	65	69	70	79	77	75	82	73	74
Operating hours	**4,948**	362	305	317	346	442	486	496	512	461	415	388	418
Full load operating hours	**2,823**	148	145	172	195	274	306	331	329	316	242	181	185

Energy unit: HT_HeatPump													
Heat prod. [MWh]	**35,223.9**	1,478.3	1,446.7	1,717.5	2,726.3	3,831.8	4,288.9	4,630.4	4,609.5	4,414.0	2,424.0	1,808.2	1,848.3
Turn ons	**888**	70	70	82	65	70	70	79	77	76	82	73	74
Operating hours	**4,948**	362	305	317	347	442	485	496	513	460	415	388	418
Full load operating hours	**2,753**	148	145	172	195	274	306	331	329	315	173	181	185

Transmission between Kara_Novoren and VEKS_West													
From Kara_Novoren [MWh]	**797,404**	71,796	64,848	71,796	69,480	71,796	67,864	71,796	39,372	55,584	71,796	69,480	71,796
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Transmission between AVV and VEKS_North													
From AVV [MWh]	**1,397,522**	250,943	228,606	231,015	75,270	49,852	1,922	6	672	8,279	114,143	222,794	214,019

Energy conversion, monthly

Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AVV and VEKS_West													
From AVV [MWh]	**2,031,883**	295,092	259,202	283,335	214,096	108,958	17,297	7,996	45,580	65,732	205,582	267,967	261,047
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_North and VEKS_West													
From VEKS_North [MWh]	**36,983**	646	1,576	2,618	9,350	3,425	0	0	5,766	2,437	1,298	842	9,026
From VEKS_West [MWh]	**1,067,709**	80,205	95,011	120,547	106,707	85,485	34,751	29,883	47,164	66,489	144,634	131,380	125,452
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between KKV and Koge													
From KKV [MWh]	**380,378**	48,360	43,680	48,359	46,717	35,149	0	1,984	8,308	7,510	45,872	46,735	47,704
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Koge and VEKS_West													
From Koge [MWh]	**181,736**	14,698	16,224	19,494	23,066	22,724	0	1,664	6,967	5,850	27,960	21,070	22,019
From VEKS_West [MWh]	**22,184**	0	0	0	0	1,410	5,486	5,349	4,328	5,258	352	0	0
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between CTR and VEKS_North													
From CTR [MWh]	**76,530**	2,832	6,536	4,621	25,618	7,392	369	411	3,740	4,830	1,019	978	18,184
From VEKS_North [MWh]	**1,338,847**	141,246	171,574	189,772	68,652	82,399	13,085	15,272	39,721	47,580	160,712	209,852	198,982
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Vestforbrænding and VF													
From Vestforbrænding [MWh]	**1,162,053**	106,392	96,096	106,392	102,960	106,096	90,409	97,252	106,392	34,320	106,392	102,960	106,392
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and VEKS_North													
From VF [MWh]	**140,459**	564	1,388	1,103	5,562	22,661	23,978	25,760	35,747	10,750	6,877	2,116	3,954
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and CTR													
From VF [MWh]	**230,442**	868	350	1,278	5,745	28,454	45,712	48,922	48,075	14,325	26,804	6,089	3,820
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AMV and CTR													
From AMV [MWh]	**3,501,760**	518,773	485,066	495,544	473,961	219,744	4,188	13,347	43,148	44,734	301,620	432,402	469,233

Energy conversion, monthly

Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between HCV and CTR													
From HCV [MWh]	**711,436**	167,982	123,701	139,847	117,734	7,847	0	0	0	0	226	79,066	75,033
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between ARC_Waste and CTR													
From ARC_Waste [MWh]	**1,557,940**	141,360	127,680	141,360	136,800	140,894	126,679	118,448	68,400	136,800	141,360	136,800	141,360
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Peak Production and VEKS_North													
From Peak Production [MWh]	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between CTR and Peak Production													
From Peak Production [MWh]	**413,048**	198,430	56,084	33,668	38,737	5,414	0	27	0	115	441	22,297	57,835
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and Peak Production													
From Peak Production [MWh]	**94,672**	29,564	16,175	11,015	2,498	102	1,122	0	0	18,300	0	7,426	8,471
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_West and Peak Production													
From Peak Production [MWh]	**2,417**	0	1,490	0	0	0	0	0	0	0	0	0	927
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Peak Production and Koge													
From Peak Production [MWh]	**1,673**	128	307	26	0	0	0	0	0	0	0	0	1,213
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_West and Høje_Taastrup													
From VEKS_West [MWh]	**219,697**	37,662	31,109	30,649	24,244	11,761	1,999	1,869	1,837	3,722	18,758	27,176	28,910
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AMV and AMV TES													
From AMV [MWh]	**146,911**	2,250	4,990	2,911	10,293	20,870	2,641	8,431	23,335	24,160	23,159	13,365	10,507
From AMV TES [MWh]	**146,911**	2,250	4,990	2,911	10,237	20,926	2,635	7,761	23,917	23,619	23,117	13,609	10,939
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Energy conversion, monthly

Transmission between AVV and AVV TES													
From AVV [MWh]	**448,789**	22,514	28,931	30,977	36,229	63,227	14,837	8,014	35,533	51,541	69,914	44,893	42,179
From AVV TES [MWh]	**448,789**	20,167	30,173	31,548	34,812	64,993	14,941	7,318	35,348	50,646	69,875	45,097	43,871
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Høje_Taastrup and HT_store													
From Høje_Taastrup [MWh]	**92,849**	5,071	12,100	12,199	12,022	8,345	2,394	2,385	2,549	3,769	10,823	9,509	11,684
From HT_store [MWh]	**92,849**	4,643	11,353	12,933	12,148	8,604	2,392	2,380	2,598	3,559	10,566	9,930	11,743
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel consumption: Natural Gas													
Fuel consum. [1000Nm3]	**152,916.3**	46,730.9	24,108.0	23,695.5	20,299.3	1,595.0	112.4	2.5	0.0	1,685.4	834.8	15,633.3	18,219.3
Fuel consum. [MWh]	**1,679,106.3**	513,130.8	264,718.9	260,189.6	222,897.1	17,514.1	1,234.6	27.3	0.0	18,506.5	9,166.9	171,662.6	200,058.1
Peak [MW]	**1,863.845**	1,863.845	1,500.287	1,012.649	1,027.474	895.377	142.477	27.318	0.000	127.628	368.920	1,231.207	1,499.292
Fuel consumption: Straw													
Fuel consum. [ton]	**88,512.8**	16,388.2	13,151.0	16,097.0	7,375.4	639.1	300.0	0.0	0.0	508.6	7,496.0	13,851.1	12,706.4
Fuel consum. [MWh]	**356,509.9**	66,007.9	52,969.2	64,835.1	29,706.5	2,574.3	1,208.4	0.0	0.0	2,048.6	30,192.2	55,789.0	51,178.7
Peak [MW]	**100.700**	100.700	100.700	100.700	100.700	100.700	100.700	0.000	0.000	100.700	100.700	100.700	100.700
Fuel consumption: Wood Pellets													
Fuel consum. [ton]	**1,581,441.3**	257,323.3	221,664.2	235,578.5	157,084.9	65,215.6	12,768.8	3,143.8	17,724.2	30,227.6	134,697.1	225,372.9	220,640.5
Fuel consum. [MWh]	**7,687,562.1**	1,250,877.0	1,077,534.3	1,145,173.2	763,607.4	317,020.4	62,070.4	15,282.2	86,159.5	146,939.7	654,777.4	1,095,562.7	1,072,558.1
Peak [MW]	**1,783.600**	1,783.600	1,768.100	1,768.100	1,768.100	1,768.100	1,410.400	579.800	1,410.400	1,410.400	1,783.600	1,783.600	1,783.600
Fuel consumption: Wood Chips													
Fuel consum. [ton]	**1,472,158.9**	190,606.1	172,160.4	190,605.6	184,414.2	119,547.2	1,054.8	7,391.4	26,259.7	27,427.7	178,463.7	183,959.7	190,268.3
Fuel consum. [MWh]	**4,109,777.0**	532,108.8	480,614.4	532,107.4	514,823.1	333,735.9	2,944.6	20,634.4	73,308.4	76,569.0	498,211.2	513,554.0	531,165.7
Peak [MW]	**715.200**	715.200	715.200	715.200	715.200	715.200	462.388	690.020	690.020	705.790	715.200	715.200	715.200
Fuel consumption: Waste													
Fuel consum. [ton]	**1,535,843.9**	139,531.9	126,028.8	139,531.9	135,030.9	139,202.7	124,431.3	125,879.4	94,125.0	97,987.5	139,531.9	135,030.9	139,531.9
Fuel consum. [MWh]	**4,479,544.9**	406,968.0	367,584.0	406,968.0	393,840.0	406,008.0	362,924.7	367,148.2	274,531.2	285,796.8	406,968.0	393,840.0	406,968.0
Peak [MW]	**547.000**	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000
Fuel consumption: Fueloil													
Fuel consum. [Ton]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel consum. [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peak [MW]	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Energy conversion, monthly

Calculated period: 01/2025 - 12/2025

	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heat demand [MWh]													
	12,087,420.5	1,829,870.0	1,503,633.8	1,564,808.7	1,281,113.2	749,940.9	313,768.9	315,482.4	316,530.9	375,579.6	989,598.4	1,390,156.0	1,456,937.6
VEKS_North	**1,306,388.9**	192,652.7	158,390.2	164,896.4	135,155.5	79,566.5	47,935.3	40,787.7	41,836.1	40,331.4	104,662.5	146,574.0	153,600.6
VEKS_West	**1,740,833.3**	264,364.5	217,219.0	226,046.4	185,039.9	108,246.6	42,924.7	44,355.5	44,355.5	54,133.2	142,892.3	200,803.5	210,452.3
VF	**885,833.3**	134,523.5	110,533.2	115,025.1	94,158.7	55,081.9	21,842.5	22,570.5	22,570.5	27,546.0	72,711.6	102,180.0	107,089.9
Koge	**222,500.0**	33,789.1	27,763.3	28,891.5	23,650.4	13,835.3	5,486.3	5,669.2	5,669.2	6,918.9	18,263.4	25,665.2	26,898.4
CTR	**7,676,944.4**	1,165,827.8	957,919.5	996,847.9	816,012.2	477,359.4	189,294.5	195,604.3	195,604.3	238,723.2	630,144.1	885,528.4	928,078.7
Høje_Taastrup	**254,920.6**	38,712.5	31,808.7	33,101.3	27,096.5	15,851.2	6,285.7	6,495.2	6,495.2	7,927.0	20,924.6	29,404.9	30,817.8
Cooling demand [MWh]													
	33,026.0	1,729.6	1,692.7	2,009.1	2,276.6	3,197.5	3,589.3	3,874.2	3,847.4	3,693.4	2,830.3	2,123.3	2,162.5
Høje_Taastrup	**33,026.0**	1,729.6	1,692.7	2,009.1	2,276.6	3,197.5	3,589.3	3,874.2	3,847.4	3,693.4	2,830.3	2,123.3	2,162.5
Electricity produced by energy units [MWh]													
	4,825,785.3	688,421.5	559,595.1	645,905.3	491,027.4	282,008.3	108,766.4	95,731.6	108,902.4	139,783.9	465,541.0	631,847.4	608,255.2
Electricity consumed by energy units [MWh]													
	21,608.2	1,559.5	1,442.0	1,631.2	1,663.8	1,937.1	1,999.1	2,109.4	2,102.5	2,028.9	1,841.8	1,622.5	1,670.5
Exported electricity, Nordpool Spot Price 2025 [MWh]													
	4,804,180.8	686,862.0	558,153.1	644,274.1	489,363.6	280,071.2	106,771.1	93,622.2	106,799.9	137,755.0	463,699.2	630,224.9	606,584.7
Peak [MW]	**1,169.300**	1,169.300	1,006.000	1,006.000	954.427	937.072	768.855	455.328	742.026	830.903	1,094.552	1,169.300	1,169.300
Imported electricity, Nordpool Spot Price 2025 [MWh]													
	3.8	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0
Peak [MW]	**3.750**	0.000	0.000	0.000	0.000	0.000	3.750	0.000	0.000	0.000	0.000	0.000	0.000
Energy unit: ARC													
Fuel consum. [ton]	**641,173.1**	58,669.7	52,992.0	58,669.7	56,777.1	58,669.7	50,348.1	45,764.4	28,388.6	56,777.1	58,669.7	56,777.1	58,669.7
Fuel consum. [MWh]	**1,870,088.2**	171,120.0	154,560.0	171,120.0	165,600.0	171,120.0	146,848.5	133,479.6	82,800.0	165,600.0	171,120.0	165,600.0	171,120.0
Heat prod. [MWh]	**1,544,879.8**	141,360.0	127,680.0	141,360.0	136,800.0	141,360.0	121,320.7	110,279.1	68,400.0	136,800.0	141,360.0	136,800.0	141,360.0
Elec. prod. [MWh]	**463,459.1**	42,408.0	38,304.0	42,408.0	41,040.0	42,408.0	36,394.0	33,081.1	20,520.0	41,040.0	42,408.0	41,040.0	42,408.0
Turn ons	**30**	0	0	0	0	0	12	17	1	0	0	0	0
Operating hours	**8,143**	744	672	744	720	744	644	587	360	720	744	720	744
Full load operating hours	**8,131**	744	672	744	720	744	638	580	360	720	744	720	744

Energy conversion, monthly

Energy unit: VF_Waste													
Fuel consum. [ton]	**524,502.1**	47,369.4	42,785.3	47,369.4	45,841.4	47,369.4	43,456.2	47,080.9	47,369.4	15,280.5	47,369.4	45,841.4	47,369.4
Fuel consum. [MWh]	**1,529,797.9**	138,160.8	124,790.4	138,160.8	133,704.0	138,160.8	126,747.3	137,319.4	138,160.8	44,568.0	138,160.8	133,704.0	138,160.8
Heat prod. [MWh]	**1,178,040.7**	106,392.0	96,096.0	106,392.0	102,960.0	106,392.0	97,607.6	105,745.1	106,392.0	34,320.0	106,392.0	102,960.0	106,392.0
Elec. prod. [MWh]	**321,276.7**	29,016.0	26,208.0	29,016.0	28,080.0	29,016.0	26,614.4	28,838.3	29,016.0	9,360.0	29,016.0	28,080.0	29,016.0
Turn ons	**8**	0	0	0	0	0	5	2	0	1	0	0	0
Operating hours	**8,241**	744	672	744	720	744	685	740	744	240	744	720	744
Full load operating hours	**8,238**	744	672	744	720	744	682	739	744	240	744	720	744

Energy unit: KN_Waste													
Fuel consum. [ton]	**372,630.2**	33,492.8	30,251.5	33,492.8	32,412.3	33,492.8	32,300.6	33,492.8	18,367.0	25,929.9	33,492.8	32,412.3	33,492.8
Fuel consum. [MWh]	**1,086,838.1**	97,687.2	88,233.6	97,687.2	94,536.0	97,687.2	94,210.1	97,687.2	53,570.4	75,628.8	97,687.2	94,536.0	97,687.2
Heat prod. [MWh]	**798,780.5**	71,796.0	64,848.0	71,796.0	69,480.0	71,796.0	69,240.5	71,796.0	39,372.0	55,584.0	71,796.0	69,480.0	71,796.0
Elec. prod. [MWh]	**266,536.1**	23,956.8	21,638.4	23,956.8	23,184.0	23,956.8	23,104.1	23,956.8	13,137.6	18,547.2	23,956.8	23,184.0	23,956.8
Turn ons	**2**	0	0	0	0	0	1	0	0	1	0	0	0
Operating hours	**8,278**	744	672	744	720	744	718	744	408	576	744	720	744
Full load operating hours	**8,278**	744	672	744	720	744	718	744	408	576	744	720	744

Energy unit: AMV1_CHP													
Fuel consum. [ton]	**325,142.4**	57,064.9	51,480.7	56,888.5	55,276.3	8,402.0	0.0	0.0	0.0	0.0	5,924.6	42,878.5	47,227.0
Fuel consum. [MWh]	**1,580,553.5**	277,399.0	250,253.2	276,541.2	268,704.0	40,842.9	0.0	0.0	0.0	0.0	28,800.3	208,437.0	229,575.9
Heat prod. [MWh]	**1,059,374.8**	185,828.9	167,649.0	185,250.0	180,000.0	27,449.6	0.0	0.0	0.0	0.0	19,501.1	139,846.8	153,849.4
Elec. prod. [MWh]	**288,150.0**	50,545.5	45,600.5	50,388.0	48,960.0	7,466.3	0.0	0.0	0.0	0.0	5,304.3	38,038.3	41,847.0
Turn ons	**76**	0	0	1	0	10	0	0	0	0	29	22	14
Operating hours	**4,331**	744	672	741	720	124	0	0	0	0	111	594	625
Full load operating hours	**4,237**	743	671	741	720	110	0	0	0	0	78	559	615

Energy unit: AMV BIO4													
Fuel consum. [ton]	**1,103,197.0**	116,694.0	80,616.9	150,321.5	154,775.5	92,010.0	2,332.1	5,387.5	23,025.6	24,837.1	153,103.1	156,898.7	143,195.1
Fuel consum. [MWh]	**3,079,758.5**	325,770.8	225,055.4	419,647.5	432,081.5	256,861.2	6,510.5	15,040.1	64,279.7	69,336.9	427,412.9	438,008.9	399,753.1
Heat prod. [MWh]	**1,983,218.1**	209,600.0	144,800.0	270,000.0	278,000.0	165,535.5	4,320.8	9,879.9	41,949.0	45,006.2	275,108.5	281,818.2	257,200.0
Elec. prod. [MWh]	**743,706.8**	78,600.0	54,300.0	101,250.0	104,250.0	62,075.8	1,620.3	3,705.0	15,730.9	16,877.3	103,165.7	105,681.8	96,450.0
Turn ons	**207**	10	22	7	5	27	11	14	41	46	12	4	8
Operating hours	**5,129**	524	362	675	695	441	24	45	164	152	699	705	643
Full load operating hours	**4,958**	524	362	675	695	414	11	25	105	113	688	705	643

Energy conversion, monthly

Energy unit: AVV_2_main

Fuel consum. [ton]	**647,096.4**	113,696.3	93,819.9	113,363.7	50,246.3	10,528.5	3,915.0	0.0	1,268.6	7,382.6	59,271.4	99,689.2	93,914.9
Fuel consum. [MWh]	**3,145,607.7**	552,690.1	456,069.1	551,073.7	244,252.9	51,180.3	19,031.3	0.0	6,166.7	35,887.6	288,124.9	484,600.3	456,530.8
Heat prod. [MWh]	**1,717,304.6**	301,780.3	248,989.3	300,841.2	133,376.0	27,903.2	10,383.0	0.0	3,358.5	19,556.8	157,280.3	264,589.5	249,246.6
Elec. prod. [MWh]	**1,081,480.2**	190,045.9	156,802.0	189,456.4	83,993.1	17,573.5	6,539.0	0.0	2,115.3	12,317.2	99,048.6	166,625.4	156,963.8
Turn ons	**181**	11	18	7	3	22	6	0	4	23	45	21	21
Operating hours	**4,063**	691	587	717	301	85	28	0	12	64	381	612	585
Full load operating hours	**3,858**	678	559	676	300	63	23	0	8	44	353	594	560

Energy unit: AMV BIO4_bypass

Fuel consum. [ton]	**176,037.2**	48,993.7	69,036.5	15,366.2	5,567.5	9,983.2	0.0	0.0	0.0	0.0	1,702.5	2,895.1	22,492.5
Fuel consum. [MWh]	**491,437.1**	136,774.0	192,727.0	42,897.3	15,542.5	27,869.7	0.0	0.0	0.0	0.0	4,752.8	8,082.1	62,791.7
Heat prod. [MWh]	**434,760.2**	121,000.0	170,500.0	37,950.0	13,750.0	24,655.5	0.0	0.0	0.0	0.0	4,204.7	7,150.0	55,550.0
Turn ons	**67**	11	21	7	5	10	0	0	0	0	2	3	8
Operating hours	**797**	220	310	69	25	50	0	0	0	0	9	13	101
Full load operating hours	**790**	220	310	69	25	45	0	0	0	0	8	13	101

Energy unit: AVV_1

Fuel consum. [ton]	**534,742.1**	73,802.5	76,340.4	65,361.7	51,526.0	46,111.6	996.2	2,960.0	11,479.7	16,008.1	51,852.1	68,913.1	69,390.7
Fuel consum. [MWh]	**2,599,440.8**	358,762.3	371,099.1	317,730.4	250,473.6	224,153.4	4,842.8	14,388.7	55,804.1	77,817.2	252,059.0	334,994.2	337,316.1
Heat prod. [MWh]	**1,479,500.0**	204,193.8	211,215.4	180,840.0	142,560.0	127,578.6	2,756.3	8,189.4	31,761.3	44,290.3	143,461.9	190,665.8	191,987.2
Elec. prod. [MWh]	**963,916.6**	133,035.3	137,610.0	117,820.0	92,880.0	83,119.4	1,795.8	5,335.5	20,693.0	28,855.8	93,467.6	124,221.6	125,082.6
Turn ons	**261**	17	6	2	1	38	4	9	31	45	54	27	27
Operating hours	**4,581**	619	641	548	432	425	9	28	105	144	454	584	592
Full load operating hours	**4,483**	619	640	548	432	387	8	25	96	134	435	578	582

Energy unit: AVV1_Condensing

Fuel consum. [ton]	**63,435.2**	12,736.0	0.0	0.0	0.0	0.0	5,878.2	0.0	857.2	3,184.0	17,267.1	13,593.2	9,919.4
Fuel consum. [MWh]	**308,365.4**	61,911.2	0.0	0.0	0.0	0.0	28,574.4	0.0	4,167.1	15,477.8	83,937.3	66,078.3	48,219.3
Heat prod. [MWh]	**51.8**	10.4	0.0	0.0	0.0	0.0	4.8	0.0	0.7	2.6	14.1	11.1	8.1
Elec. prod. [MWh]	**129,500.0**	26,000.0	0.0	0.0	0.0	0.0	12,000.0	0.0	1,750.0	6,500.0	35,250.0	27,750.0	20,250.0
Turn ons	**97**	11	0	0	0	0	8	0	2	9	29	20	18
Operating hours	**518**	104	0	0	0	0	48	0	7	26	141	111	81
Full load operating hours	**518**	104	0	0	0	0	48	0	7	26	141	111	81

Energy conversion, monthly

Energy unit: HCV_CHP

Fuel consum. [1000Nm3]	**100,795.0**	23,687.9	17,415.9	19,799.0	16,876.2	1,082.3	0.0	0.0	0.0	0.0	18.6	11,184.1	10,731.0
Fuel consum. [MWh]	**1,106,785.5**	260,106.0	191,236.5	217,403.7	185,309.8	11,884.3	0.0	0.0	0.0	0.0	204.6	122,808.0	117,832.4
Heat prod. [MWh]	**718,205.0**	168,515.5	124,074.7	141,089.0	120,083.3	7,766.0	0.0	0.0	0.0	0.0	136.2	79,810.8	76,729.4
Elec. prod. [MWh]	**235,450.4**	55,605.8	40,703.4	46,235.5	39,589.3	2,473.5	0.0	0.0	0.0	0.0	40.1	26,005.0	24,797.9
Turn ons	**145**	13	19	22	29	15	0	0	0	0	1	19	27
Operating hours	**3,123**	622	531	619	454	56	0	0	0	0	2	396	443
Full load operating hours	**2,378**	562	411	467	400	25	0	0	0	0	0	263	250

Energy unit: AVV_2_Gas_T

Fuel consum. [1000Nm3]	**6,389.7**	2,343.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	721.3	1,835.5	1,489.6
Fuel consum. [MWh]	**70,162.3**	25,729.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7,920.7	20,154.9	16,357.1
Heat prod. [MWh]	**26,062.4**	9,557.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,942.1	7,486.8	6,076.0
Elec. prod. [MWh]	**36,385.9**	13,343.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,107.7	10,452.3	8,482.8
Turn ons	**59**	11	0	0	0	0	0	0	0	0	11	18	19
Operating hours	**292**	104	0	0	0	0	0	0	0	0	36	83	69
Full load operating hours	**284**	104	0	0	0	0	0	0	0	0	32	81	66

Energy unit: AVV_2_Straw_boiler

Fuel consum. [ton]	**88,854.7**	16,388.2	13,136.7	16,115.8	7,356.0	625.0	281.9	0.0	0.0	542.8	7,847.8	13,862.8	12,697.5
Fuel consum. [MWh]	**357,886.9**	66,007.9	52,911.9	64,910.9	29,628.3	2,517.5	1,135.6	0.0	0.0	2,186.4	31,609.4	55,836.3	51,142.7
Heat prod. [MWh]	**177,699.2**	32,774.5	26,271.9	32,229.8	14,711.2	1,250.0	563.8	0.0	0.0	1,085.6	15,694.8	27,724.0	25,393.6
Elec. prod. [MWh]	**159,929.3**	29,497.0	23,644.7	29,006.8	13,240.1	1,125.0	507.4	0.0	0.0	977.0	14,125.3	24,951.6	22,854.2
Turn ons	**186**	13	29	26	5	6	2	0	0	8	45	23	29
Operating hours	**3,574**	657	532	647	295	25	12	0	0	24	315	557	510
Full load operating hours	**3,554**	655	525	645	294	25	11	0	0	22	314	554	508

Energy unit: KKV_CHP

Fuel consum. [ton]	**207,273.5**	24,918.4	22,507.0	24,918.0	24,071.3	19,539.7	293.7	1,251.7	9,121.0	8,149.3	23,841.8	24,080.9	24,580.6
Fuel consum. [MWh]	**578,638.4**	69,564.0	62,832.0	69,562.6	67,199.1	54,548.3	819.8	3,494.4	25,462.8	22,750.1	66,558.4	67,225.9	68,620.9
Heat prod. [MWh]	**402,417.2**	48,360.0	43,680.0	48,359.0	46,716.5	37,961.9	571.4	2,436.5	17,752.8	15,859.1	46,280.4	46,735.1	47,704.4
Elec. prod. [MWh]	**135,994.3**	16,368.0	14,784.0	16,367.7	15,810.9	12,794.0	191.4	814.9	5,939.6	5,309.3	15,650.9	15,817.4	16,146.1
Turn ons	**108**	0	0	0	0	7	1	6	40	49	2	0	3
Operating hours	**6,523**	744	672	744	720	671	12	53	383	337	733	720	734
Full load operating hours	**6,182**	744	672	744	719	582	9	37	270	241	711	719	734

Energy conversion, monthly

Energy unit: Geothermal_Elec Heatpump

Heat prod. [MWh]	**27,594.0**	2,343.6	2,116.8	2,343.6	2,268.0	2,343.6	2,268.0	2,343.6	2,343.6	2,268.0	2,343.6	2,268.0	2,343.6
Elec. consum. [MWh]	**13,140.0**	1,116.0	1,008.0	1,116.0	1,080.0	1,116.0	1,080.0	1,116.0	1,116.0	1,080.0	1,116.0	1,080.0	1,116.0
Turn ons	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Operating hours	**8,760**	744	672	744	720	744	720	744	744	720	744	720	744
Full load operating hours	**8,760**	744	672	744	720	744	720	744	744	720	744	720	744

Energy unit: Gas boiler

Fuel consum. [1000Nm3]	**45,923.5**	20,734.9	6,715.7	3,949.0	3,561.1	242.7	96.7	11.1	3.4	1,680.0	47.5	2,755.3	6,126.1
Fuel consum. [MWh]	**504,265.5**	227,680.5	73,742.5	43,362.5	39,102.5	2,664.6	1,061.8	121.3	37.1	18,447.6	522.1	30,254.5	67,268.4
Heat prod. [MWh]	**504,265.5**	227,680.5	73,742.5	43,362.5	39,102.5	2,664.6	1,061.8	121.3	37.1	18,447.6	522.1	30,254.5	67,268.4
Turn ons	**170**	5	9	24	29	30	5	2	2	4	13	20	27
Operating hours	**3,374**	643	580	577	233	47	35	4	2	483	17	340	413
Full load operating hours	**252**	114	37	22	20	1	1	0	0	9	0	15	34

Energy unit: HT_HeatPump_cold

Elec. consum. [MWh]	**8,468.2**	443.5	434.0	515.2	583.8	821.1	919.1	993.4	986.5	948.9	725.8	542.5	554.5
Cooling prod. [MWh]	**33,026.0**	1,729.6	1,692.7	2,009.1	2,276.6	3,202.3	3,584.6	3,874.2	3,847.4	3,700.6	2,830.8	2,115.6	2,162.5
Turn ons	**887**	70	70	83	65	69	70	79	77	75	82	73	74
Operating hours	**4,948**	362	305	317	346	442	486	496	512	461	415	388	418
Full load operating hours	**2,823**	148	145	172	195	274	306	331	329	316	242	181	185

Energy unit: HT_HeatPump

Heat prod. [MWh]	**35,223.9**	1,478.3	1,446.7	1,717.5	2,726.3	3,831.8	4,288.9	4,630.4	4,609.5	4,414.0	2,424.0	1,808.2	1,848.3
Turn ons	**888**	70	70	82	65	70	70	79	77	76	82	73	74
Operating hours	**4,948**	362	305	317	347	442	485	496	513	460	415	388	418
Full load operating hours	**2,753**	148	145	172	195	274	306	331	329	315	173	181	185

Transmission between Kara_Novoren and VEKS_West

From Kara_Novoren [MWh]	**798,781**	71,796	64,848	71,796	69,480	71,796	69,241	71,796	39,372	55,584	71,796	69,480	71,796
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Transmission between AVV and VEKS_North

From AVV [MWh]	**1,415,208**	251,162	228,781	232,727	80,929	52,519	3,222	282	604	9,630	117,691	223,558	214,103

Energy conversion, monthly

Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AVV and VEKS_West													
From AVV [MWh]	**1,985,410**	294,808	258,938	281,749	208,350	105,316	10,630	8,124	34,345	53,805	201,892	267,150	260,301
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_North and VEKS_West													
From VEKS_North [MWh]	**40,389**	708	1,576	2,725	10,522	3,826	763	644	5,301	3,198	1,581	820	8,726
From VEKS_West [MWh]	**1,047,872**	79,957	94,743	119,028	102,010	85,091	30,494	31,171	44,910	63,881	141,837	130,517	124,232
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between KKV and Koge													
From KKV [MWh]	**402,417**	48,360	43,680	48,359	46,717	37,962	571	2,437	17,753	15,859	46,280	46,735	47,704
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Koge and VEKS_West													
From Koge [MWh]	**199,562**	14,698	16,224	19,490	23,066	24,839	480	2,033	14,837	12,667	28,262	21,070	21,896
From VEKS_West [MWh]	**18,113**	0	0	0	0	713	5,395	5,265	2,753	3,727	245	0	14
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between CTR and VEKS_North													
From CTR [MWh]	**75,745**	2,697	6,363	4,485	26,303	6,331	393	202	3,056	5,745	1,248	892	18,030
From VEKS_North [MWh]	**1,358,396**	141,013	171,283	189,912	69,998	85,439	17,822	26,147	39,021	46,999	162,882	209,973	197,906
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Vestforbrænding and VF													
From Vestforbrænding [MWh]	**1,178,041**	106,392	96,096	106,392	102,960	106,392	97,608	105,745	106,392	34,320	106,392	102,960	106,392
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and VEKS_North													
From VF [MWh]	**166,349**	558	1,363	1,293	6,433	24,890	32,411	35,923	37,588	11,272	8,350	2,400	3,868
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and CTR													
From VF [MWh]	**220,319**	874	375	1,066	4,874	26,521	44,416	47,373	46,234	13,802	25,331	5,806	3,647
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AMV and CTR													
From AMV [MWh]	**3,504,947**	518,773	485,066	495,544	473,961	220,041	6,129	12,008	44,968	46,720	301,161	431,202	469,375

Energy conversion, monthly

Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between HCV and CTR													
From HCV [MWh]	**718,205**	168,516	124,075	141,089	120,083	7,766	0	0	0	0	136	79,811	76,729
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between ARC_Waste and CTR													
From ARC_Waste [MWh]	**1,544,880**	141,360	127,680	141,360	136,800	141,360	121,321	110,279	68,400	136,800	141,360	136,800	141,360
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Peak Production and VEKS_North													
From Peak Production [MWh]	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between CTR and Peak Production													
From Peak Production [MWh]	**405,943**	197,989	55,804	32,361	36,598	2,563	0	0	37	147	522	22,829	57,091
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VF and Peak Production													
From Peak Production [MWh]	**94,418**	29,564	16,149	10,978	2,504	102	1,062	121	0	18,300	0	7,426	8,212
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_West and Peak Production													
From Peak Production [MWh]	**2,372**	0	1,483	0	0	0	0	0	0	0	0	0	890
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Peak Production and Koge													
From Peak Production [MWh]	**1,533**	128	307	23	0	0	0	0	0	0	0	0	1,075
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between VEKS_West and Høje_Taastrup													
From VEKS_West [MWh]	**284,537**	38,029	31,635	32,192	27,823	20,565	10,413	11,388	13,146	14,962	24,671	28,712	31,001
From Høje_Taastrup [MWh]	**64,840**	340	528	1,506	3,455	8,838	8,114	9,583	11,310	11,449	6,114	1,512	2,092
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AMV and AMV TES													
From AMV [MWh]	**143,025**	2,248	5,049	3,498	10,166	20,822	4,772	8,176	19,763	21,563	22,862	13,477	10,630
From AMV TES [MWh]	**143,025**	2,248	5,049	3,498	10,109	20,878	4,312	7,960	20,438	21,009	22,865	13,596	11,062

Energy conversion, monthly

Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between AVV and AVV TES													
From AVV [MWh]	**434,774**	22,806	28,844	31,162	38,287	60,070	10,747	8,111	29,976	48,202	69,946	44,720	41,904
From AVV TES [MWh]	**434,774**	20,459	30,086	31,728	36,918	61,173	10,890	8,328	29,804	46,702	70,137	44,951	43,597
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transmission between Høje_Taastrup and HT_store													
From Høje_Taastrup [MWh]	**137,274**	5,325	12,250	13,073	13,884	14,552	9,090	9,829	11,108	12,399	12,665	10,352	12,749
From HT_store [MWh]	**137,274**	4,870	11,505	13,771	13,886	14,844	8,787	9,889	11,158	12,399	12,607	10,749	12,808
Loss [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel consumption: Natural Gas													
Fuel consum. [1000Nm3]	**153,108.2**	46,766.0	24,131.7	23,748.0	20,437.2	1,325.0	96.7	11.1	3.4	1,680.0	787.5	15,774.9	18,346.8
Fuel consum. [MWh]	**1,681,213.2**	513,516.1	264,979.0	260,766.2	224,412.3	14,548.9	1,061.8	121.3	37.1	18,447.6	8,647.4	173,217.5	201,457.9
Peak [MW]	**1,863.845**	1,863.845	1,500.287	1,012.649	1,014.095	675.245	30.337	30.337	34.250	100.964	368.920	1,231.207	1,495.978
Fuel consumption: Straw													
Fuel consum. [ton]	**88,854.7**	16,388.2	13,136.7	16,115.8	7,356.0	625.0	281.9	0.0	0.0	542.8	7,847.8	13,862.8	12,697.5
Fuel consum. [MWh]	**357,886.9**	66,007.9	52,911.9	64,910.9	29,628.3	2,517.5	1,135.6	0.0	0.0	2,186.4	31,609.4	55,836.3	51,142.7
Peak [MW]	**100.700**	100.700	100.700	100.700	100.700	100.700	100.700	0.000	0.000	100.700	100.700	100.700	100.700
Fuel consumption: Wood Pellets													
Fuel consum. [ton]	**1,570,416.2**	257,299.7	221,641.0	235,613.9	157,048.6	65,042.1	10,789.4	2,960.0	13,605.5	26,574.7	134,315.3	225,074.0	220,452.1
Fuel consum. [MWh]	**7,633,967.5**	1,250,762.6	1,077,421.5	1,145,345.3	763,430.5	316,176.6	52,448.6	14,388.7	66,137.9	129,182.6	652,921.5	1,094,109.8	1,071,642.1
Peak [MW]	**1,783.600**	1,783.600	1,768.100	1,768.100	1,768.100	1,768.100	1,410.400	579.800	1,410.400	1,410.400	1,783.600	1,783.600	1,783.600
Fuel consumption: Wood Chips													
Fuel consum. [ton]	**1,486,507.7**	190,606.1	172,160.4	190,605.6	184,414.2	121,532.8	2,625.8	6,639.2	32,146.6	32,986.4	178,647.4	183,874.7	190,268.3
Fuel consum. [MWh]	**4,149,834.0**	532,108.8	480,614.4	532,107.4	514,823.1	339,279.2	7,330.3	18,534.5	89,742.5	92,087.1	498,724.1	513,316.9	531,165.7
Peak [MW]	**715.200**	715.200	715.200	715.200	715.200	715.200	457.369	690.020	690.020	705.686	715.200	715.200	715.200
Fuel consumption: Waste													
Fuel consum. [ton]	**1,538,305.4**	139,531.9	126,028.8	139,531.9	135,030.9	139,531.9	126,104.9	126,338.1	94,125.0	97,987.5	139,531.9	135,030.9	139,531.9
Fuel consum. [MWh]	**4,486,724.2**	406,968.0	367,584.0	406,968.0	393,840.0	406,968.0	367,805.9	368,486.2	274,531.2	285,796.8	406,968.0	393,840.0	406,968.0
Peak [MW]	**547.000**	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000	547.000
Fuel consumption: Fueloil													
Fuel consum. [Ton]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel consum. [MWh]	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peak [MW]	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000