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Article 14(1) of Directive 2012/27/EU:

A comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling in Demark

REPORT

#### Analysis framework for the comprehensive assessment

This 'comprehensive assessment of the Danish potential for the application of high-efficiency cogeneration and efficient district heating and cooling' fulfils the Danish obligations in accordance with Article 14(1) of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, hereinafter referred to as EED.

The report is predominantly based on technology-specific analyses initiated as a follow-up to the Energy Agreement from March 2012 and that were completed during the course of 2014.

In order to ensure consistency and quality in the planning of future energy systems, a strategic and systematic perspective with the widest possible scope has been used. Concurrent with the preparation of the technology-specific analyses, the Danish Energy Agency has therefore prepared a scenario analysis covering the entire Danish energy system, hereinafter referred to as the 'Scenario Analysis'. The purpose of this analysis is to ensure cohesive thinking across sectors and technologies and to establish common assumptions and scenarios for the future energy system.

Therefore, in order to provide the best assessment for Denmark's potential for cogeneration and efficient district heating and cooling, this report will begin with a review of the conclusions from the Scenario Analysis. This is followed by more detailed descriptions, assessments and analyses of high-efficiency cogeneration and efficient district heating and cooling, potential assessments and political measures all related to Article 14(1) of Directive 2012/27/EU and the prescribed method in Annex VIII.

# Contents

| 1   | Sun   | nmary                                                                 | 5  |
|-----|-------|-----------------------------------------------------------------------|----|
| 2   | Met   | thod                                                                  | 9  |
| 2   | .1    | Compliance with the central principles of the Directive               | 9  |
| 2   | .2    | Analysis design                                                       | 9  |
| 2   | .3    | Chapter references, Annex VIII                                        | 11 |
| 2   | .4    | Method description, technical analyses                                | 13 |
|     | 2.4.1 | 1 Scenario Analysis                                                   | 13 |
|     | 2.4.2 | 2 Models and method for the District Heating Analysis                 | 14 |
|     | 2.4.3 | 3 District Cooling Analysis                                           | 16 |
| 3   | Den   | mark's energy supply at present and in the future                     | 19 |
| 3   | .1    | Biomass as the central issue                                          | 19 |
| 3   | .2    | Scenario analyses                                                     | 20 |
|     | 3.2.1 | 1 The role of district heating and cogeneration in the scenarios      | 21 |
|     | 3.2.2 | 2 District cooling and the Scenario Analysis                          | 22 |
|     | 3.2.3 | <b>3</b> Other relevant points of learning from the Scenario Analysis | 22 |
| 4.  | Dist  | trict heating                                                         | 24 |
| 4   | .1    | Introduction                                                          | 24 |
| 4.2 | Н     | leat demand, projections and mapping                                  | 24 |
|     | 4.2.1 | 1 Description of heat demand and projection                           | 24 |
|     | 4.2.2 | 2 Mapping                                                             | 25 |
| 4   | .3    | Role of district heating                                              |    |
|     | 4.3.1 | 1 Financial assessment                                                |    |
| 4   | .4    | Energy efficiency                                                     |    |
|     | 4.4.1 | 1 Heat generation                                                     |    |
|     | 4.4.2 | 2 Heat distribution and consumption                                   |    |
| 5.  | Dist  | trict cooling                                                         |    |
| 5   | .1    | Introduction                                                          |    |
|     | 5.1.1 | 1 Systemic effects                                                    | 35 |
| 5   | .2    | Cooling demand, projections and mapping                               |    |
|     | 5.2.1 | 1 Description of cooling demand                                       |    |
|     | 5.2.2 | 2 Projection of cooling demand                                        |    |
|     | 5.2.3 | 3 Mapping                                                             |    |
| 5   | .3    | Role of district cooling                                              | 42 |

|   | 5.3. | 1       | Baseline projection                                   | 12         |
|---|------|---------|-------------------------------------------------------|------------|
|   | 5.3. | 2       | Potential assessment4                                 | 12         |
|   | 5.4  | Ene     | rgy efficiency4                                       | 13         |
| 6 | Cog  | gener   | ation4                                                | 14         |
|   | 6.1  | Intr    | oduction4                                             | 14         |
|   | 6.2  | Pro     | jection of the role of cogeneration4                  | ł5         |
|   | 6.2. | 1       | Micro-cogeneration4                                   | <b>1</b> 7 |
|   | 6.2. | 2       | Potential of cogeneration to meet cooling demands4    | 18         |
|   | 6.3  | Pote    | ential assessment4                                    | 19         |
|   | 6.4  | Pro     | gress in accordance with Directive 2004/8/EC4         | 19         |
| 7 | Ove  | erall a | assessment                                            | 51         |
|   | 7.1  | Stra    | stegies, policies and measures5                       | 51         |
|   | 7.1. | 1       | Cogeneration                                          | 52         |
|   | 7.1. | 2       | District heating and district cooling infrastructure5 | 53         |
|   | 7.1. | 3       | Physical planning                                     | 58         |
|   | 7.2  | Prir    | nary energy savings6                                  | 50         |
|   | 7.3  | Sup     | port measures and impact assessment6                  | 50         |
|   | 7.3. | 1       | Cogeneration support6                                 | 51         |
| 8 | Ref  | erenc   | ces6                                                  | 52         |

# 1 Summary

The overall purpose of this comprehensive assessment is (see Article 14(3) of EED) to facilitate the identification of the most resource- and cost-efficient solutions to meet heating and cooling needs in Denmark.

Technical analyses I. District heating II. District cooling III. Scenario analysis (Energy and growth analysis analysis policy initiatives)

|                                              | IV. System description                                                                                                                                                     |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Comprehensive assessment<br>(EED initiative) | V. Separate handling of questions relating<br>to <u>district heating</u> , <u>district cooling</u><br>and <u>cogeneration</u> in accordance with<br>Directive (2012/27/EU) |
|                                              | VI. Assessment of strategies, policies and measures                                                                                                                        |
|                                              | VII. Primary energy VIII. Support<br>saving measures and impact<br>analyses                                                                                                |

The comprehensive assessment has been prepared on the basis of several separate technical analyses. The District Heating Analysis and the District Cooling Analysis both use cost-benefit analyses to describe the potential for both district heating and district cooling<sup>1</sup>, while the Scenario Analysis uses a system-technical back-casting method to describe the overall energy system and potential development scenarios as to how given political targets can be achieved.

The results of the comprehensive assessment for cogeneration, efficient district heating and district cooling and the utilisation of industrial waste heat are summarised in this article.

# High-efficiency cogeneration

In 2012, Denmark was the European country with the second highest percentage of cogeneration measured in terms of <u>gross electricity generation</u> (around 50%). This percentage has gradually reduced over the past decade (the proportion was 62% in 1998) as a Pe result of steadily increasing quantities of wind energy in the electricity system.

GRAPH

Percentage of gross electricity generation attributable to cogeneration in Denmark.

However, if cogeneration's percentage of the

<sup>&</sup>lt;sup>1</sup> The Waste Heat Analysis is also linked to the technical potential assessments to a certain extent (Danish Energy Agency, 2013).

thermal electricity generation is viewed in isolation, this is steadily increasing, and in 2012 reached its highest proportion hitherto. Cogeneration's percentage of district heat generation is in return inverted, and since 2005 has fallen from 83 % to 73 % in 2012 and is expected to fall below 65 % in 2025 (baseline projection 2014).

#### GRAPH

District heating

Electricity

Percentage of district heating and thermal electricity generation attributable to cogeneration.

It is generally considered that cogeneration will continue to play a crucial role in the Danish energy system, but that this percentage will in future be affected by the growing quantities of wind and solar energy in the electricity system. The development will at the same time be dependent on whether there is a focus on primary biomass or a wind-based energy system, which will largely be dependent on political prioritisation.

The analysis concludes that there is no basis to further promote cogeneration and its percentage of cooling, heating and electricity generation over and above existing initiatives. The object clause of the Danish Heat Supply Act (Article 1(2)) for example warrants the promotion of cogeneration as much as possible. As a derivative of this, the Danish Executive Order on Projects (Article 11) makes it a requirement that heat generating facilities exceeding 1 MW be designed for the purposes of cogeneration, provided that this is deemed to be economically viable. Cogeneration is furthermore promoted through the taxation policy and support for efficient electricity generation at decentralised installations.

#### **Efficient district heating**

Developments in the net heat demand are primarily determined by developments in the area being heated and the heat loss from this area. Historically, the growth in net heat demand has been significantly less than the amount of living space, which has increased by more than 30 % since 1980. Therefore, the final energy consumption required for heating per  $m^2$  has fallen by more than 34 % since 1980 and by 16 % since 1990. During the period between 2000 and 2012, there was minor growth in the total net heat demand of around 7 %. More stringent requirements in building legislation coupled with a targeted savings initiative with respect to existing buildings has meant that the net heat demand in the projection fell by around 7 % during the period between 2011 and 2020, despite a continuing rise in the amount of living space.

| Heat demand for Consumers | 2013 | 2020 | 2035 |
|---------------------------|------|------|------|
| Denmark                   | 199  | 189  | 166  |
| Urban areas               | 160  | 152  | 134  |
| District heating coverage | 50 % | 69 % | 62 % |
|                           |      |      |      |

Heat demand for consumers [PJ]

In 2013, it was estimated that the district heating percentage amounted to around 50 % of the total heat demand. It is anticipated that this percentage could be increased considerably, although primarily through the densification of the existing distribution areas and only to a limited extent through the establishment of new supply areas.

According to the analysis, the district heating infrastructure will play a crucial role in the future energy system in relation to ensuring energy efficiency and flexibility in connection with increased quantities of fluctuating electricity generation from e.g. wind power. New initiatives to promote the desired development are not currently considered to be necessary. However, it must be noted that the existing and ongoing analysis work such as the taxation and subsidy analysis and the analysis of the financial situation of district heating installations from 2019 may lead to new initiatives for the sector.

#### Industrial waste heat

The potential to utilise industrial waste heat was most recently investigated in 2013 in a national analysis. The conclusion was that under the given framework conditions there is potential for the further utilisation of 9 PJ/year with a simple repayment time of four years.

Of this potential, it is believed that 5 PJ/year could be used internally in industry for space heating purposes and heating hot water, while 4 PJ/year could be allocated externally for district heating purposes. The majority of the total potential (7 PJ/year) could be utilised via heat pumps, as this potential exists at relatively low temperatures that do not meet the temperature requirements for direct use for heating purposes.

The potential to increase the use of waste heat is included as a sub-element of the ongoing taxation and subsidy analysis with a view to ensuring the right incentives to promote the use of waste heat.

#### **Effective district cooling**

The total electricity consumption for cooling purposes was estimated at 2 300 GWh/year in 2006. This corresponds to 13 % of electricity usage in the sectors using cooling. The total cooling demand is estimated to be 9 000 GWh/year and the power demand is assessed as being around 5 000 MW cooling. As is shown by the projection, the demand for cooling is assessed as increasing.

The District Cooling Analysis concludes that under current conditions, district cooling will come to play a crucial role in the supply of cooling. The assessment is that at the present time only 1 % of the cooling supply comes from district cooling, while the analysis estimates a socioeconomic district cooling potential in excess of 43 % of the cooling demand.

#### Strategies, policies and measures

Annex VIII to EED states that the present comprehensive assessment must cover strategies, policies and measures that can be adopted in the period leading up to 2020 and up to 2030 to realise the potential in point e). Point e) focuses in particular on the increased use of waste heat from power generation installations and industrial installations.

According to Article 14(1), the present comprehensive assessment must be updated every five years and be submitted to the Commission.

#### GRAPH

Cooling demand Electricity consumption

Development in cooling demand and electricity consumption for cooling.

GRAPH

Individual District cooling

Development in cooling generation.

#### Period up until 2020

The Energy Agreement of 22 March 2012 determines the specific energy policy initiatives for the period leading up to 2020.

The Energy Agreement ensures that there is broad political backing for an ambitious green conversion with a focus on saving energy throughout society as a whole and increasing the use of renewable energy in the form of increased numbers of wind turbines, more biogas and more biomass.

The agreement ensures a 12 % reduction in gross energy consumption in 2020 in relation to 2006, just over 35 % renewable energy in 2020 and around 50 % wind power in Danish electricity consumption in 2020.

Therefore, the agreement is an important milestone in the process of converting all of Denmark's energy supplies (electricity, heating, industry and transport) to renewable energy by 2050.

The agreement contains a considerable number of energy policy initiatives for the period 2012-2020, including a number of measures to promote cogeneration, district cooling and the further use of renewable energy for district heating and the better utilisation of waste heat from industry.

Supplementary initiatives will be discussed before the end of 2018 for the period beyond 2020.

The initiatives in the Energy Agreement are expected to lead to large reductions in greenhouse gas emissions. At the time when the Energy Agreement was signed, the corrected greenhouse gas emissions were estimated to be 34.1 % lower in 2020 than the actual 1990 emissions, which formed the basis for the determination of the Danish Kyoto commitment.

# Period up until 2030

The government platform for the government that took office in June 2015 stated that an Energy Commission must be appointed to investigate energy policy targets and tools for the period 2020-2030, including as regards how Denmark could fulfil its international obligations in a cost-effective and market-based manner, particularly in relation to the EU. The Energy Commission is expected to begin its work at the start of 2016. There has been an initial focus on the national energy policy framework and the development of the European market for energy in relation to the EU for the period 2020-2030.

The analysis results and new initiatives following from this work in the new Energy Commission will be included in the next report, which, according to EED, must be made to the Commission in five years' time. Any new initiatives as a result of the ongoing analyses and assessments for the areas of district heating, cogeneration and district cooling may also be included in the next report.

# 2 Method

# 2.1 Compliance with the central principles of the Directive

The overall purpose of the current comprehensive assessment is (see Article 14(3) of EED) to facilitate the identification of the most resource and cost-effective solutions with a view to addressing heating and cooling demand in Denmark.

The Scenario Analysis presented in this report provides a systematic and contextual overview of the Danish energy system and its technical development potential and thereby also contributes to the illumination of the long-term potential for district heating, cogeneration and district cooling under different development potentials for the energy system.

The comprehensive assessment must be based on a national cost-benefit analysis that follows the principles specified in Annex IX, Part 1. The Danish assessment summarises the results from several different analyses.

Specific definitions in EED, e.g. for high-efficiency cogeneration, efficient district heating and plot ratio, will be introduced in the text on an ongoing basis as these are used.

# 2.2 Analysis design

| Technical analysesI. District heating(Energy and growthanalysispolicy initiatives)analysis | II. District cooling III. Scenario analysis analysis                                                                                                                       |
|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                            | IV. System description                                                                                                                                                     |
| Comprehensive assessment<br>(EED initiative)                                               | V. Separate handling of questions relating<br>to <u>district heating</u> , <u>district cooling</u><br>and <u>cogeneration</u> in accordance with<br>Directive (2012/27/EU) |
|                                                                                            | VI. Assessment of strategies, policies and measures                                                                                                                        |
|                                                                                            | VII. Primary energy VIII. Support<br>saving measures and impact<br>analyses                                                                                                |

**I.** – **III.** The District Heating Analysis and Scenario Analysis follow from the Energy Settlement *(Energiforliget)* of 2012, while the District Cooling analysis has been prepared with a view to fulfilling the obligations pursuant to Article 14(1) of EED. The analyses performed are more comprehensive than those requested in the Energy Efficiency Directive to meet national

considerations in Denmark; however, the analyses have been prepared in such a way that they cover the requirements of Annex VIII of EED in terms of form and content.

**IV.** Chapter 3 describes possible developments (back-casting) initially based on the energy system overall. This does not form part of the assignment description in the Directive, but is considered appropriate, as this provides a better reference framework to understand the results and conclusions from the comprehensive assessment for district heating, district cooling and cogeneration.

**V.** On the basis of the analyses (I-III) and the systematic tendencies described in IV, district heating, district cooling and cogeneration are considered in three separate chapters. Each Chapter reviews the information requested in the Directive, such as demand, projections, potentials and geographic mapping, and with continuous reference to the overall energy system.

**VI.** Based on the previous analysis of the system and the technical sub-systems (district heating, district cooling and cogeneration), the relevant strategies, policies and measures are described up until 2020 and further ahead until 2030 within the following regulation areas: *cogeneration, district heating district cooling infrastructure* and *physical planning*.

**VII.** An estimate will be prepared of the primary savings through the implementation of the future measures. This assessment is performed on the basis of a comparison between primary energy consumption at present and consumption under various future scenarios.

**VIII.** An estimate is provided here of the public support measures for heating and cooling, in addition to information regarding the annual budget and the identification of potential support elements.

# 2.3 Chapter references, Annex VIII

The comprehensive assessment of national heating and cooling potentials must contain the following responses pursuant to Annex VIII of Directive 2012/27/EU:

| Sub-as | ssignments                                                  | Chapter reference |
|--------|-------------------------------------------------------------|-------------------|
| a.     | a description of heating and cooling demand;                | 4.2.1 and 5.2.1   |
| b.     | a forecast of how this demand will change in the next       | 4.2.1 and 5.2.2   |
|        | 10 years, taking into account in particular the evolution   |                   |
|        | of demand in buildings and the different sectors of         |                   |
|        | industry;                                                   |                   |
| с.     | a map of the national territory, identifying, while         | 4.2.2 and 5.2.3   |
|        | preserving commercially sensitive information:              |                   |
|        | i. heating and cooling demand points, including:            |                   |
|        | • municipalities and conurbations with a plot ratio         |                   |
|        | of at least 0.3, and;                                       |                   |
|        | • industrial zones with a total annual heating and          |                   |
|        | cooling consumption of more than 20 GWh;                    |                   |
|        | ii. existing and planned district heating and               |                   |
|        | cooling infrastructure;                                     |                   |
|        | iii. potential heating and cooling supply points,           |                   |
|        | including:                                                  |                   |
|        | • electricity generation installations with a total         |                   |
|        | annual electricity generation of more than 20               |                   |
|        | GWh, and;                                                   |                   |
|        | <ul> <li>waste incineration plants;</li> </ul>              |                   |
|        | • existing and planned cogeneration installations           |                   |
|        | using technologies referred to in Part II of                |                   |
|        | Annex I, and district heating installations;                |                   |
|        |                                                             |                   |
| d.     | identification of the heating and cooling demand that       | 4.3, 5.3 and 6.1  |
|        | could be satisfied by high-efficiency cogeneration,         |                   |
|        | including residential micro-cogeneration, and by            |                   |
|        | district heating and cooling;                               |                   |
| e.     | identification of the potential for additional high-        | 6.2               |
|        | efficiency cogeneration, including from the                 |                   |
|        | refurbishment of existing and the construction of new       |                   |
|        | generation and industrial installations or other facilities |                   |
| 6      | generating waste heat;                                      |                   |
| t.     | identification of energy efficiency potentials of district  | 4.4 and 5.4       |
|        | heating and cooling infrastructure;                         | 8.1               |
| g.     | strategies, policies and measures that may be adopted       | 7.1               |
|        | up to 2020 and up to 2030 to realise the potential in       |                   |
|        | point (e) in order to meet the demand in point (d),         |                   |
|        | including, where appropriate, proposals to:                 |                   |
|        | 1. Increase the share of cogeneration in heating            |                   |
|        | and coording generation and in electricity                  |                   |
|        | generation;                                                 |                   |
| 1      | 11. develop efficient district heating and cooling          |                   |

|    | infrastructure to accommodate the                      |     |
|----|--------------------------------------------------------|-----|
|    | development of high-efficiency cogeneration            |     |
|    | and the use of heating and cooling from waste          |     |
|    | heat and renewable energy sources;                     |     |
|    | iii. encourage new thermal electricity generation      |     |
|    | installations and industrial plants producing          |     |
|    | waste heat to be located in sites where a              |     |
|    | maximum amount of the available waste heat             |     |
|    | will be recovered to meet existing or                  |     |
|    | forecasted heat and cooling demand;                    |     |
|    | iv. encourage new residential zones or new             |     |
|    | industrial plants which consume heat in their          |     |
|    | production processes to be located where               |     |
|    | available waste heat, as identified in the             |     |
|    | comprehensive assessment, can contribute to            |     |
|    | meeting their heat and cooling demands. This           |     |
|    | could include proposals that support the               |     |
|    | clustering of a number of individual                   |     |
|    | installations in the same location with a view         |     |
|    | to ensuring an optimal matching between                |     |
|    | demand and supply for heat and cooling;                |     |
|    | v. encourage thermal electricity generating            |     |
|    | installations, industrial plants producing waste       |     |
|    | heat, waste incineration plants and other              |     |
|    | waste-to-energy plants to be connected to the          |     |
|    | local district heating or cooling network;             |     |
|    | vi. encourage residential zones and industrial         |     |
|    | plants which consume heat in their production          |     |
|    | processes to be connected to the local district        |     |
|    | heating or cooling network;                            |     |
|    |                                                        |     |
| h. | the share of high-efficiency cogeneration and the      | 6.3 |
|    | potential established and progress achieved under      |     |
|    | Directive 2004/8/EC;                                   |     |
| i. | an estimate of the primary energy to be saved;         | 7.2 |
| j. | an estimate of public support measures to heating and  | 7.3 |
|    | cooling, if any, with the annual budget and            |     |
|    | identification of the potential aid element. This does |     |
|    | not prejudge a separate notification of the public     |     |
|    | support schemes for a State aid assessment.            |     |
|    |                                                        |     |

In accordance with Annex VIII (point 2) of Directive 2012/27/EU, the comprehensive assessment may be made up of an assembly of regional or local plans and strategies to the extent appropriate. The relevant analyses are often prepared at national level in Denmark, and the availability of national data is comprehensive. Therefore, it is not considered necessary to use local or regional plans and strategies in order to prepare the comprehensive assessment.

#### Visual structure of the report

The individual <u>sub-assignments</u> in the comprehensive assessment are highlighted on an ongoing basis using this <u>blue text box</u>, followed by the associated response.

# 2.4 Method description, technical analyses

As the Scenario Analysis, District Heating Analysis and District Cooling Analysis have been prepared as independent reports, the method basis for each of these is summarised below.

# 2.4.1 Scenario Analysis<sup>2</sup>

The Scenario Analysis arising from the Energy Agreement of 22 March 2012 was prepared to form a common framework of understanding for the individual technical analyses, including comparable assumptions. Therefore, the main objective of this was to highlight the outcome for the development of the future Danish energy supply.

The scenarios fulfil energy policy targets at the time for heat and electricity supplies to be entirely based on renewable energy in 2035, and that the energy system overall (including the processing and transport sectors) must be entirely based on renewable energy by 2050. Therefore, the anticipated roles of district heating and cogeneration are also highlighted, which provides a framework of understanding for the potential assessments later in the report.

The scenarios highlight the technical potential to 'construct' the future Danish energy system under given premises and illustrates what the challenges associated with transferring to a fossil-free system mean, along with the critical parameters. Additionally, the scenarios may illustrate when important choices must be made in order to achieve the political goals.

Consequently, the scenarios must not be interpreted as detailed forecasts as to what the energy system of the future will be like or should be like. The assumptions may change considerably and many factors will be subject to a considerable element of uncertainty.

#### Technical assumptions used

The net energy consumption is calculated using a consumption model that models energy consumption in both 2035 and 2050, divided according to energy quality at three different energy saving levels (moderate, large savings and extra-large savings). Electricity, district heating, process heat, individual heating and transport energy (including all air traffic and domestic shipping) have been included. The oil and gas recovery sector has been excluded from the analyses. The same energy service level has been assumed for all scenarios, i.e. the same outputs from commercial activities, the same living area being heated and the same traffic work, etc. have been included in the scenario year

<sup>&</sup>lt;sup>2</sup> This method description partially consists of an extract from the Scenario Analysis (ENS 2014b: page 5).

selected (reference year) for the scenarios analysed. Therefore, it has also been implicitly assumed that the technologies with varying scope between the scenarios are perfect substitutes, e.g. that an electric vehicle provides the same use value as a vehicle with a combustion engine.

The energy generation in the scenarios have been worked out using an hourly simulation model, with which the requisite capacities and the annual fuel consumption is determined. The total annual costs for the reference years for each of the scenarios is estimated on the basis of the hourly simulation. The settlement of the annual costs includes the annualised investment costs and the annual operation and maintenance expenses, where technology data has been taken from the Energy Agency's most recent technology catalogues, which include the expected development in technology leading up to 2050. The developments in fuel prices are assumed to be in accordance with the three scenarios in the World Energy Outlook 2013 (Current Policies Scenario, New Policies Scenario, 450 Scenario).

# 2.4.2 Models and method for the District Heating Analysis<sup>3</sup>

Various bodies such as industry organisations and research institutes, etc. have performed ongoing 'top-down' analyses<sup>4</sup> in recent years of the potential and consequences of the incorporation of renewable energy into the Danish system as a whole with a view to fulfilling the national political targets.<sup>5</sup> In parallel with this, a number of Danish municipalities, regions and supply companies are working with a 'bottom-up' approach, where assessments and analyses are being performed as to how local goals within the frameworks of the national targets can be fulfilled.

Using the Balmorel Model and Varmeatlas (*heat atlas*) tools, a combined top-down/bottom-up process has been used in this analysis, which is described in the following text.

# Model tools for district heating supplies

#### Balmorel

The model calculations for district heating supplies have been performed using the Balmorel model, which is a market model used for the analysis of coherent electricity and cogeneration markets. The model optimises the operation of electricity and district heating systems under the assumption of well-functioning markets. The model also contains an investment module that can calculate the investment process on the basis of technology data and the requirements of investors for a return on investments. Therefore, the investment module can compile a financially optimised portfolio of investment for market actors or for the social economy. The model can also perform operating calculations at an hourly level taking into consideration, e.g. the increase in reserve requirements in energy systems with a considerable element of wind power.

The Danish electricity system is highly integrated with the energy systems of neighbouring countries. This is reflected by the fact that the total transmission capacity for foreign connections amounts to around 5 000 MW, while the average electricity consumption in Denmark is around 4 000 MW. Therefore, the energy systems of our neighbouring countries, and the development of these, are of considerable importance for determining electricity prices in Denmark. The implication of prices is particularly large because Denmark is located between the large hydropower-based electricity systems

<sup>&</sup>lt;sup>3</sup> This method description is an extract from the District Heating Analysis (ENS 2014a: pages 19-21).

<sup>&</sup>lt;sup>4</sup> In this case, 'top-down' refers to analyses of the continuous energy system at regional and national level that can be used to draw conclusions regarding the overall framework, and also provide guidelines for specific

district heating projects in relation to the development of the continuous energy system. <sup>5</sup> Including in connection with the work of the Danish Commission on Climate Change.

in the Nordic countries, which can act as effective electricity storage facilities for wind power, and the large thermal nuclear power-based (and now also wind power-based) electricity systems in Germany.

The Balmorel Model covers Finland, Norway, Sweden, Denmark and Germany in this analysis, which allows the potential to analyse the interaction between the electricity systems in the various countries. For technical reasons, the model divides the countries into regions that are separated by the transmission limitations.

There has been a significant development of the model's data structure for district heating in Denmark for the District Heating Analysis, such that the supply of district heating in Denmark is represented in considerable detail.

#### Varmeatlas

A heat atlas (*Varmeatlas*) has been developed for Denmark in connection with the work on the District Heating Analysis. The heat atlas is a database of the supply of heat to selected buildings. The Danish Building and Dwelling Register (*Bygnings- og Boligregister*) (BBR) provides details of the types of heating installations and forms of heating for buildings. Information is also provided regarding the building's size, age and usage. This information, together with key figures for the heat demand per  $m^2$  for buildings, provides an estimate of the heat demand of buildings. BBR also specifies the geographical location of buildings, and therefore all buildings can be mapped using a GIS tool.

District heating and electricity generation prices are calculated in Balmorel and are used to calculate heat supply prices for all urban areas for both district heating supplies and for individual electricity heating supplies. The price for individual supplies can be found by using a spreadsheet tool that provides an overview of the financial conditions associated with the supply of heat for different types of individual heating technologies. Economic district heating potentials may be found by comparing the costs associated with district heating supplies with the costs associated with individual heating supplies under the various optimisation processes.

#### Interaction between models

The result of the potential assessments in the heat atlas for the analysis are used to correct the size of the district heating areas in Balmorel. Therefore, as is illustrated in Figure 2.1, this is an iterative process, as Balmorel provides updated district heating and electricity generation prices, which in turn can be used to update the district heating potential assessment.



Figure 2.1. Tools used in the District Heating Analysis.

The overall model complex has been constructed in such a way that it can be used in connection with future analyses that connect scenario analyses for future energy systems with the relevant heat atlas based on the actual BBR data for all urban areas in Denmark. Gradual technological developments in terms of the efficiency of the technology and costs, etc. can be incorporated into the assumptions element of the model structure on an ongoing basis.

# 2.4.3 District Cooling Analysis<sup>6</sup>

# Assessment of cooling demand

The assessment of the cooling demand had three main objectives:

- To determine the scope of cooling and energy consumption for cooling at a national and regional level;
- To determine the geographical distribution of the cooling demand to thereby facilitate the potential to identify geographical areas where the potential for district cooling is likely;
- To create a basis for a projection of the cooling demand and energy consumption for cooling.

An indirect method for cooling demand has been developed because such an assessment has not previously been performed at national level, and these types of investigations have only been performed to a very limited extent at company level.

The method uses available data for electricity consumption for cooling presented in commercial mapping of energy consumption from 2008, supplemented with information from specific projects. This allowed the creation of an overall inventory divided into 82 different industry sectors and subdivided into comfort, process and IT cooling. Based on BBR and Central Business Register (CVR) data, along with all buildings and associated floor areas and industry codes, key figures have been

<sup>&</sup>lt;sup>6</sup> This method description is an extract from the District Cooling Analysis (ENS 2014c: pages 7-8 and pages 60-63).

calculated for the average electricity consumption per  $m^2$  of floor area for the 82 industry sectors. An estimated COP value was then calculated (the COP value is an expression of energy efficiency) based on knowledge of the anticipated cooling processes and temperature levels for the different industry sectors.

However, this does not simply allow the calculation of an overall national cooling demand, but also the calculation of the maximum cooling effect for each individual building based on an estimate of the period of use and annual cooling consumption.

# Forecasts

The forecast for electricity consumption for cooling is generally calculated based on consumption from 2006 when the mapping used was performed. Forecasts have been prepared for the years 2013, 2020, 2025 and 2030. Both comfort cooling and process cooling can be projected using a factor that is determined in the development in an activity parameter multiplied by the development of an intensity parameter and multiplied by a parameter for the development in the percentage of cooling provided by electricity:

$$P_{el} = P_{2006} * \frac{A2}{A1} * \frac{I2}{I1} * \frac{R2}{R1}$$

Where:

- P is the annual electricity consumption
- A is the activity parameter
- I is the energy intensity (Pel/A)
- R is the percentage of the cooling demand driven electrically
- 2 and 1 refer to both the projection year and the year 2006

The exception for the use of this method is electricity consumption for IT cooling. For this, a projection of the electricity consumption initially based on historical data is used. The gross floor area is used as the activity parameter for comfort cooling. The gross value added is used for process cooling.

# **Potential calculation**

# Technical potential

The existing demand for cooling described previously was used as a dataset for a geographical calculation model for the calculation of the technical potential for district cooling.

Based on knowledge of the specific demand for all cooling consumers in Denmark and the size of the building and industry sector, the cooling capacity demand for each individual cooling consumer can be calculated. Following from this knowledge and standardised model calculations of the project economics for both individual projects and district cooling projects, the potential saving in terms of project economics can be calculated for each given cooling consumer by investing in district cooling installations instead of an individual installation. The financial saving is then converted into a given length of district cooling pipeline. If the length of pipeline between two or more individual consumers can reach each other, these consumers are calculated as being covered by a potential district cooling project.

#### Socio-economic potential

The technical potential is used as a basis in the calculation of the socio-economic potential, from which a deduction is made for the part of the potential not considered as being socio-economically profitable.

In specific terms, this means that 50 % of the indirect cooling is deducted, as the socio-economic benefit is limited. In the case of indirect cooling, the district heating installation exchanges energy with the condenser at a local cooling installation. All projects with an overall capacity of less than 1 MW are deducted, as these are considered as being too small to represent a realistic district cooling project.

# **3** Denmark's energy supply at present and in the future<sup>7</sup>

The present government basis is aiming for Denmark to be independent of fossil fuels by 2050. An element of Denmark's energy policy is based on a broad political agreement from 2012 on energy policy from 2012 to 2020. As part of this agreement, a number of technical energy analyses and potential assessments were initiated, including an electricity analysis, a district heating analysis, a gas analysis, a bioenergy analysis and a waste heat analysis. These analyses highlight different aspects of the transition to being independent of fossil fuels. Wherever possible, work has been performed using common assumptions and common scenarios for the future energy system as a background to the analyses. This has also enabled an overall scenario analysis with input from the various analyses.

# **3.1** Biomass as the central issue

As bioenergy (straw, timber, biogas, organic waste and energy crops and fuels derived from these) are the only 'permitted' fuels in 2050, it is relevant to consider the potential for the generation of these fuels in Demark. The Danish potential for bioenergy, together with the foreign potential gives an indication of how much fuel may be used in a given context in terms of fuel security of supply and sustainability.

| PJ           | Consumption 2011 | Of which imports | Potential |
|--------------|------------------|------------------|-----------|
| Straw        | 20               | 0                | 148       |
| Woodchips    | 17               | 6                | 40        |
| Fuel wood    | 24               | 3                | 0         |
| Wood pellets | 30               | 28               | 0         |
| Wood waste   | 8                | 0                | 0         |
| Biogas       | 4                | 0                | 42        |
| Bio-oil      | 9                | 6                | 0         |
| Waste        | 39               | 0                | 42        |
| Total        | 151              | 43               | 265       |

Table 3.1. Use of biomass in Denmark in 2011, and the potential for 2050.

In 2013, the Danish Energy Agency estimated national bioenergy resources as being around 175 PJ (40 PJ for wood, biogas and waste and 55 PJ for straw). However, potential analyses indicate that there is considerable potential to increase this in order to achieve a total biomass potential of around 265 PJ, including waste (see Table 3.1). Therefore, for Denmark, the national bioenergy potential corresponds to around one third or a quarter of the future gross energy consumption, depending on the size of the assumed energy savings (Article 3.2).

As international reports from IPPC and IEA, etc. simultaneously estimate that the global bioenergy potential could meet between a quarter and a third of the primary energy supply by 2050, this would suggest that the world cannot be fossil fuel free by only replacing fossil fuels with bioenergy should this be desired.

As Denmark is a small country, it is possible for Denmark to become fossil fuel-free by replacing fossil fuels with bioenergy. However, this could lead to a number of climate and environmental challenges, and in the long-term could also lead to uncertainty in fuel supply. Therefore, this would suggest that bioenergy consumption should be restricted to a certain extent and be used strategically where the consumption would add greatest value, unless the aforementioned risk was accepted.

There are a number of other renewable energy sources, of which wind energy has been a particular focus in Denmark. In 2010, the potential for wind power was estimated to be 33 PJ on land, 150 PJ for 'coastal' wind turbines and 1040 PJ for wind turbines in the Danish sector of the North Sea, thus amounting to a total of 1 200 PJ. Potential also exists in other Danish coastal waters, although these

<sup>&</sup>lt;sup>7</sup> Reproduction of results from the Scenario Analysis (ENS 2014b).

have not been included in the estimate from 2010. In 2011, generation was 35 PJ, while the wind scenario described in more detail below would utilise 250 PJ in wind power.

The sun is another renewable source of energy. In this case, the potential for solar cells is estimated to be 104 PJ, of which 61 PJ would utilise existing roof areas. 6 PJ would be used in the wind scenario.

Therefore, there is considerable technical potential for both solar and wind energy in Denmark that is not fully utilised in the wind scenario. These renewable energy sources are both fluctuating in nature and therefore cannot form the sole basis for energy supplies, but could be supplemented with considerable biomass consumption. This interaction is central in the preparation of the scenario analyses.

#### **3.2** Scenario analyses

The energy scenarios cover a number of technically consistent models for future energy supplies in Denmark (including transport) that comply with given political targets. As the entire system is included in the scenarios, the relationship between the energy system's subsectors is also highlighted. Thereby, this seeks to ensure a link between the individual sector analyses in terms of resource use and energy turnover. Overall, the Hydrogen scenario and Bio+ scenario may be considered as technological extremes or extremities that together show the expected sample space for the energy system in 2050.

| The | The four scenarios and the 'reference' scenario |    |                                 |  |  |  |  |
|-----|-------------------------------------------------|----|---------------------------------|--|--|--|--|
| 1.  | Wind scenario                                   | 5. | The fossil scenario (reference) |  |  |  |  |
| 2.  | Biomass scenario                                |    |                                 |  |  |  |  |
| 3.  | Bio+ scenario                                   |    |                                 |  |  |  |  |
| 4.  | Hydrogen scenario                               |    |                                 |  |  |  |  |
|     |                                                 |    |                                 |  |  |  |  |

- The wind scenario has been designed with a view to limiting the use of bioenergy so that this approximately corresponds to what Denmark can supply itself, i.e. around 250 PJ. This does not necessarily mean that the bioenergy is produced in Denmark, but that this corresponds to the quantity that can be produced in Denmark. This scenario would require huge amounts of electrification in transport, industry and district heating and a large expansion in offshore wind turbines. In order to keep bioenergy consumption down, hydrogen is used for the upgrading of biomass and biogas to make this goes further;
- The biomass scenario is designed for an annual bioenergy consumption of around 450 PJ. This would involve a certain degree of net biomass imports in a normal year (around 200 PJ). Hydrogen is not used in this scenario;
- The Bio+ scenario is a fuel-based system resembling that of the present day. However, coal, oil and natural gas are replaced with bioenergy. Biofuel consumption would be around 700 PJ. Hydrogen is not used in this scenario;
- The Hydrogen scenario is designed with a very limited bioenergy consumption (less than 200 PJ) in mind. This would involve extensive use of hydrogen and more wind power than in the wind scenario;
- The fossil scenario describes a theoretical situation in which fossil fuels continue to be used and where all political targets are disregarded. The fossil scenario illustrates an alternative in which the focus is the lowest possible cost.

The tables below summarise fuel consumers, self-sufficiency and gross energy consumption for each of the scenarios in both 2035 and 2050.

| Scenario         | Wind   | Biomass | Bio+   | Hydrogen | Fossil |
|------------------|--------|---------|--------|----------|--------|
| Fuel             | 458 PJ | 526 PJ  | 631 PJ | 443 PJ   | 680 PJ |
| consumption      |        |         |        |          |        |
| Self-sufficiency | 74 %   | 68 %    | 57 %   | 77 %     | (*)    |
| Gross energy     | 594 PJ | 606 PJ  | 634 PJ | 590 PJ   | 653 PJ |
| consumption      |        |         |        |          |        |

Table 3.2. Key figures from the scenario calculations for 2035. (\*) is dependent on Danish fossil fuel generation in 2035.

| Scenario         | Wind   | Biomass | Bio+   | Hydrogen | Fossil |
|------------------|--------|---------|--------|----------|--------|
| Fuel             | 255 PJ | 443 PJ  | 710 PJ | 192 PJ   | 483 PJ |
| consumption      |        |         |        |          |        |
| Self-sufficiency | 104 %  | 79 %    | 58 %   | 116 %    | (*)    |
| Gross energy     | 575 PJ | 590 PJ  | 674 PJ | 562 PJ   | 546 PJ |
| consumption      |        |         |        |          |        |

Table 3.3. Key figures from the scenario calculations for 2050. (\*) is dependent on Danish fossil fuel generation in 2050.

#### 3.2.1 The role of district heating and cogeneration in the scenarios

The scenarios involve a minor increase in the uptake of district heating so that the number of households with individual boiler heating is reduced correspondingly. The district heat network provides considerable potential (for a moderate cost) to incorporate flexibility into the energy system. The costs associated with the district heating networks are included in all scenarios, but at the same level, irrespective of the quantity of district heating. This is to say that the district heating savings cannot be assumed to result in savings in maintenance and investments in the district heating network.

| Scenario         | Wind | Biomass | Bio+ | Hydrogen | Fossil |
|------------------|------|---------|------|----------|--------|
| Electricity      | 281  | 165     | 123  | 320      | 147    |
| network          |      |         |      |          |        |
| District heating | 93   | 93      | 93   | 93       | 93     |
| network          |      |         |      |          |        |
| Gas network      | 60   | 60      | 60   | 60       | 60     |

Table 3.4. Dimensioning energy input in the networks in 2050 (PJ).

The role of cogeneration will to a large extent depend on the scenario that unfolds. As illustrated in Table 3.5, cogeneration would end completely in 2050 for the Wind and Hydrogen scenarios, while the Bio+ scenario would largely replace the fossil fuels with primarily imported biomass and thereby a significant electricity capacity would be retained by central cogeneration installations. The use of cogeneration would also continue for the biomass scenario. The difference from that of the Bio+ scenario is that this would assume the comprehensive electrification of the transport system. More indepth information regarding the role of cogeneration can be found in Chapter 6.

| Scenario     | Wind           | Biomass        | Bio+           | Hydrogen       | Fossil         |
|--------------|----------------|----------------|----------------|----------------|----------------|
| Offshore     | 14 000 (4 116) | 5 000 (4 141)  | 2 500 (4 132)  | 17 500 (4 073) | 5 000 (4 135)  |
| turbines     |                |                |                |                |                |
| Onshore      | 3 500 (3 076)  | 3 500 (3 076)  | 3 500 (3 069)  | 3 500 (3 076)  | 3 500 (3 076)  |
| turbines     |                |                |                |                |                |
| Solar cells  | 2 000 (849)    | 2 000 (849)    | 1 000 (849)    | 2 000 (849)    | 800 (849)      |
| Gas turbines | 4 600 (300)    | 1 000 (492)    | 400 (677)      | 4 600 (299)    | 1 400 (200)    |
| Central      | 0 (0)          | 2 040 (4 306)  | 2 400 (4 526)  | 0 (0)          | 0 (0)          |
| cogeneration |                |                |                |                |                |
| biomass      |                |                |                |                |                |
| Central      | 0 (0)          | 0 (0)          | 0 (0)          | 0 (0)          | 1 575 (3 980)  |
| cogeneration |                |                |                |                |                |
| coal         |                |                |                |                |                |
| Fuel cells   | 0 (0)          | 0 (0)          | 0 (0)          | 500 (0)        | 0 (0)          |
| Electricity  | 3 740 (3 467)  | 3 740 (1 147)  | 3 740 (402)    | 3 740 (3 380)  | 3 740 (511)    |
| imports      |                |                |                |                |                |
| Electricity  | -4 140 (3 483) | -4 140 (2 863) | -4 140 (3 112) | -4 140 (3 734) | -4 140 (4 169) |
| exports      |                |                |                |                |                |

Table 3.5. Electricity capacity in 2050 (MW electricity). Annual usage time in parentheses).

#### 3.2.2 District cooling and the Scenario Analysis

District cooling potentials are not included in the Scenario Analysis, as the analysis of this was only performed following the completion of the Scenario Analysis. However, this is not considered of fundamental importance for the usability of either one of the analyses. More in-depth information in this assessment is provided in Chapter 5, although this fundamentally assumes that the district cooling potential does not change the assumptions in the Scenario Analysis, but merely provides potential system flexibility and a financial saving.

# 3.2.3 Other relevant points of learning from the Scenario Analysis

- 1) It is technically possible to construct different energy systems that fulfil the vision of a fossilfree future. The technology already exists, albeit that certain elements must be further developed in terms of price, efficiency or performance ability;
- 2) The annual costs in the fossil fuel scenario in 2050 are around DKK 6 billion lower (around 5 %) than the cheapest fossil-free scenario, and around DKK 29 billion lower (around 20 %) than the most expensive fossil-free scenario (with a CO<sub>2</sub> price of DKK 245 per tonne);
- 3) Bioenergy is a limited resource. As Denmark is a small country, this presents a choice in terms of whether a decision is made to regulate with a view to creating a fuel-based system involving large imports of biomass or an electricity-based system with limited use of bioenergy, e.g. at a level corresponding to what Denmark can supply itself;
- 4) A wind-based through-electrified energy system would have a high level of fuel supply certainty, but would be challenged in terms of the security of electricity supplies, while a bioenergy-based system would be challenged in terms of fuel supply certainty;
- 5) Security of electricity supply in a wind-based system can be ensured through a combination of cheap investment rapid regulating gas motors/turbines with limited operating times, and an increase in the capacity of the transmission cables abroad;
- 6) A fossil-free transport sector would require very large quantities of bioenergy in 2050 and therefore the level of electrification in the transport sector is of crucial importance for the design of the overall energy system;

- 7) There are a number of decisions that will need to be reached soon regarding the route selected, as this is of great importance for the expansion of the requisite infrastructure and technology development. Infrastructure investments have a long lifetime and will therefore will be of influence for many decades into the future;
- 8) The extent to which the anticipated fuel manufacturing facilities are located in Denmark or abroad will be of great importance. If biofuels are to a large extent produced in Denmark, there will potentially be large quantities of waste heat, which may be used for district heating purposes. If the timing is correct, the expansion of the requisite infrastructure will be of great importance for the design of the electricity and district heating system;
- 9) Heat storage is included in the scenarios to a large extent. The heat stores play an important role in the intelligent electricity system for the adaptation of wind power, and the district heating systems are a crucial element in this;

# 4. District heating

# 4.1 Introduction

As part of the Energy Agreement it was agreed that 'an analysis of the role of district heating in the future supply of energy will be prepared and presented before the end of 2013'. The main focus of the analysis was to identify how district heating is to be produced in the future and the extent to which district heating should continue to be expanded or possibly reduced.

The results of the analysis indicate that there is still a certain amount of potential for district heating expansion in Denmark; however, this is primarily in areas with existing district heating supplies. In general, district heating will experience challenges on two fronts:

- Lower heat demands due to growing demands relating to the energy consumption of buildings challenging the economics of district heating, particularly new establishments;
- Less thermal electricity generation as a result of growing quantities of wind power. This will increasingly mean that cogeneration will change from representing the base load to increasingly representing the medium and peak loads. This development will lead to significantly lower numbers of full load hours for cogeneration installations and therefore a poorer operating economy.

Therefore, in terms of socio-economics, it is also possible that certain areas of Denmark will in time find that district heating gives way to efficient individual solutions as a result heat loss and maintenance costs.

# 4.2 Heat demand, projections and mapping

# 4.2.1 Description of heat demand and projection

**Assignment:** (*a*) a description of the heating demand; **Assignment:** (*b*) a forecast of how this demand will change in the next 10 years, taking into account in particular the evolution of demand in buildings and the different sectors of industry.

The District Heating Analysis' heat demand projection provides an estimate of the heat demand in 2013 as being 199 PJ for all sectors. Taking into consideration the demand for buildings and the various industry sectors, the demand for district heating in Denmark is considered to be falling. Overall, under given assumptions there is considered to be a district heating demand of 166 PJ, of which 134 PJ is considered to be in urban areas.

| District heating demand for consumers [PJ] | 2013 | 2020 | 2035 |
|--------------------------------------------|------|------|------|
| Denmark                                    | 199  | 189  | 166  |
| Urban areas                                | 160  | 152  | 134  |

Table 4.1. Heat demand for consumers in Denmark and in urban areas in 2013, 2020 and 2035 (District Heating Analysis 2014, Danish Energy Agency).

# In-depth information regarding heat demand for households<sup>8</sup>

<sup>&</sup>lt;sup>8</sup> This article originates from the Baseline Projection 2014 (*Basisfremskrivning*) (ENS, 2014d).

The development in the net heat demand is primarily determined by the development is the area being heated and the heat loss from this area. Building regulations determine the limits for heat loss from newly constructed areas, and it has historically proved to be the case that these limits have long been decisive for the actual energy consumption for new builds. Heat loss in existing living areas can be reduced through additional insulation, and the building regulations contain requirements for energy improvements that must be adhered to in connection with major renovations and when replacing building components.

Historically, net heat demand has grown at a significantly lower rate compared with living area, which has increased by more than 30 % since 1980. Therefore, the final energy consumption used for heating per  $m^2$  has fallen by more than 34 % since 1980, and by 16 % since 1990. During the period between 2000 and 2012, there has been a small increase in the overall net heat demand of around 7 %, which is a consequence of the development in the area being heated.

However, since 2005 several more stringent changes have been introduced to the building regulations, and further a further tightening of requirements has been determined with effect from 2015 and 2020. The tightening of the building regulations will, together with the savings initiative targeted at the existing housing stock, contribute to the net heat demand in the projection falling by around 7 % from 2011 until 2020 despite continued increase in living area. Figure 4.1 illustrates this development in net heat demand in the period leading up to 2025.

| Household net heat demand (PJ) |  |
|--------------------------------|--|
|                                |  |
| GRAPH                          |  |
|                                |  |
|                                |  |

Figure 4.1. Net heat demand of households, climate corrected (PJ).

# 4.2.2 Mapping

**Assignment:** (*c*) *a map of the national territory, identifying, while preserving commercially sensitive information:* 

- *i. heating demand points, including:*
- municipalities and conurbations with a plot ratio of at least 0.3, and;
- industrial zones with a total annual heating consumption of more than 20 GWh;
- *ii. existing and planned district heating infrastructure;*
- *iii. potential heating supply points, including:*
- electricity generation installations with a total annual electricity generation of more than 20 GWh, and;
- waste incineration plants;
- existing and planned cogeneration installations using technologies referred to in Part II of Annex I, and district heating installations.

#### Mapping method

<u>Heat demand</u> (Figure 4.2) builds on heat atlas data prepared in connection with the District Heat Analysis and follows the method description in Chapter 2. The heat atlas includes all buildings in Denmark and locates the total area heated geographically via the Danish Building and Dwelling Register (BBR). Therefore, this ensures optimal precision in relation to the calculation of the geographical heat demand. The requirement for a plot ratio<sup>9</sup> of at least 0.3 is therefore fulfilled as a consequence of this. Similarly, it is ensured that all industrial zones are included, also including those with a heat consumption of less than 20 GWh.

<u>The district heating network</u> (Figure 4.3) is based on data from the Energy Agency's GIS database 2014. The mapping includes both distribution and transmission lines.

<u>Supply points</u> (Figure 4.4) have been calculated based on the Energy Agency's producer count from 2013, which was the most recently available data basis. All installations have been included with a total of more than 10 TJ (2 778 MWh) in thermal generation at a given address in 2013. Therefore, an installation may consist of several different technical installations.

All commercial installations with some form of electricity generation are designated as '*Industrial cogeneration*', while other commercial installations are designated as '*Industrial waste heat*'. Installations where more than 25 % of the fuel is designated as waste are categorised as '*Waste incineration*'.

<sup>&</sup>lt;sup>9</sup> 'Plot ratio' is defined in Article 2(40) of the Energy Efficiency Directive as: 'the ratio of the building floor area to the land area in a given territory'.

# Heat demand

| IN  |    |    |               |                                                                                                                    |
|-----|----|----|---------------|--------------------------------------------------------------------------------------------------------------------|
|     |    |    |               | Heat demand<br>MWh/km <sup>2</sup><br>0 - 1 000<br>1 000 - 10 000<br>10 000 - 20 000<br>20 000 - 50 000<br>50 000+ |
|     |    |    |               |                                                                                                                    |
| MAP |    |    |               |                                                                                                                    |
|     |    |    |               |                                                                                                                    |
| 0   | 20 | 40 | 80 Kilometres |                                                                                                                    |

Figure 4.2. Heat demand (Heat Atlas, District Heating Analysis) MWh/km<sup>2</sup>.

# **District heating network**



Figure 4.3. Existing district heating infrastructure (Danish Energy Agency, 2014), net.

# Supply points

| Ν   |    |    |               |                                                                                                                                                                                     |                                                                   |
|-----|----|----|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
|     |    |    |               | Technical<br>installations<br>Waste incinerati<br>Central installati<br>Decentral install<br>District<br>installations<br>Industrial cogen<br>Industrial waste<br>Local installatio | energy<br>on<br>ons<br>ations<br>heating<br>eration<br>heat<br>ns |
|     |    |    |               |                                                                                                                                                                                     |                                                                   |
| MAP |    |    |               |                                                                                                                                                                                     |                                                                   |
| 0   | 20 | 40 | 80 Kilometres |                                                                                                                                                                                     |                                                                   |

Figure 4.4. Potential supply points (Energy producer count (Energipraducenttælling) 2013, Danish Energy Agency).

#### 4.3 Role of district heating

**Assignment:** (*d*) *identification of the heat demand that could be satisfied by high-efficiency cogeneration.* 

The potential assessment of district heating is divided into a technical, user/company-economic and a socio-economic assessment.

According to the technical assessment, a further 50 PJ of district heating will be possible in Denmark in 2035. In Figure 4.5, this further potential is divided into '*non-district heating consumers in district heating areas*', '*non-district heating consumers in urban areas with district heating*' and '*heating consumers in urban areas with district heating*' and '*heating consumers in urban areas without district heating*'.

Illegible graph

Figure 4.5. Technical potential in 2035 for district heating supplies (District Heating Analysis 2014, background report, Danish Energy Agency).

Figure 4.5 illustrates that the existing district heating consumption in urban areas constitutes around 80 PJ. The technical potential consists of consumers in district heating areas not supplied by district heating, consumers outside district heating areas in urban areas with district heating and consumers in areas where district heating is not currently established. The first group is characterised by the fact that there are relatively low costs associated with conversion compared with areas where a distribution network, etc. must first be established. Group two requires the expansion of district heating and the establishment of a new distribution network, while group three requires both the establishment of a distribution network and the establishment of a transmission line or alternatively a new generation installation.

# 4.3.1 Financial assessment

When considering the financial assessments, there is a significant, but decreasing economic potential for district heating. In 2020, it is calculated that the company/user-economic potential will be around 150 PJ for district heating, which is almost 60 PJ more than the existing amount. From a socioeconomic perspective, there is a potential to expand the district heating supply to around 130 PJ in 2020, while this would be reduced to around 100 PJ in the period leading up to 2035.

- Central areas
- Smaller areas with waste heat
- Aggregated areas, gas

- Medium-sized areas
- Aggregated areas, biomass

#### Key

| Eksisterende fjernvarmeforbrugere       | Existing district heat consumers          |
|-----------------------------------------|-------------------------------------------|
| Sanfundsøkonomiske fjernvarmepotentiale | Socio-economic district heating potential |
| Selskabs/brugerøkonomiske potentiale    | Company/user-economic potential           |

#### 2020

2035

Figure 4.6. District heating potential (GJ) based on social and user/company-economic assumptions in 2020 and 2035 compared with the existing district heating demand in both years (District Heating Analysis 2014, Danish Energy Agency).

If the potential for expansion identified for district heating is compared with the existing situation, a technical potential of 79.8 % is achieved for the total heat demand in Denmark. However, the socioeconomic potential is somewhat less.

| Heat demand for consumers [PJ] | 2013 | 2020 | 2035 |
|--------------------------------|------|------|------|
| Denmark                        | 199  | 189  | 166  |
| Urban areas                    | 160  | 152  | 134  |
| District heating coverage      | 50 % | 69 % | 62 % |

Table 4.2. Assumptions regarding the development of district heating consumption throughout Denmark as a whole and in urban areas. Results for district heating coverage in 2020 and 2035 for the wind socio-economy (District Heating Analysis 2014, Danish Energy Agency).

The potential has been estimated as being 69 % of the total heat demand in 2020. The potential has been assessed as falling to 62 % in 2035. This is primarily due to a reduction in the heat demand, which will increase the relative costs associated with laying pipelines. Table 4.2 provides an overview of the anticipated development in a situation where the full socio-economic potential is utilised.

# 4.4 Energy efficiency

**Assignment:** (f) identification of energy efficiency potentials of district heating infrastructure.

In order to identify the potential for energy efficiency in the district heating infrastructure, the infrastructure has been divided into *generation* and *distribution (and consumption)*.

# 4.4.1 Heat generation

Energy efficiency in heat generation may take place through the generation optimisation of a given generation situation, the conversion of pure heat to cogeneration or the utilisation of waste heat sources.

Figure 4.7 illustrates how the loss associated with electricity and heat generation has reduced over the years.

Losses associated with electricity and heat generation

#### GRAPH

Figure 4.7. Loss associated with electricity and heat generation in accordance with the Danish Energy Agency's statistics (Source: Danish District Heating Association).

This development is due to a number of factors, but the expansion of cogeneration in Denmark has particularly influenced the efficiency of electricity and heat generation overall.

| GRAPH                                                          | GRAPH                                                                   |
|----------------------------------------------------------------|-------------------------------------------------------------------------|
| Key                                                            | Key                                                                     |
| Fjernvarme – district heating                                  | Tab kondensværker – losses for condensing installations                 |
| El – electricity                                               | Tab centrale værker – losses for centralised installations              |
|                                                                | Tab decentrale værker – losses for distributed installations            |
|                                                                | Tab fjernvarmeværker – Losses for district heating installations        |
|                                                                | Tab private kraftvarmeværker (affald) – losses for private cogeneration |
|                                                                | installations (waste)                                                   |
|                                                                |                                                                         |
| Figure 4.8. Cogeneration percentage of thermal electricity and | Figure 4.9. Losses associated with electricity and heat generation,     |
| district heat generation (Energy Statistics, 2012).            | from District Heat Analysis (Source: Danish District Heating            |
| · · · · · · · · · · · · · · · · · · ·                          | Association)                                                            |
|                                                                | Association.                                                            |

As can be seen from Figures 4.8 and 4.9, it is the falling energy losses highlighted in Figure 4.7, particularly the expansion of cogeneration, which is leading to significantly lower losses than for separate electricity and heat generation. One challenge associated with the increased quantities of wind power is that there will be less 'need' for electricity generation from thermal installations, the benefit in the electricity market will be reduced, and cogeneration may become more expensive in

relative terms. The large quantities of electricity from wind turbines is important for the number of operating hours for cogeneration installations and makes increased demands regarding the flexibility of the installations.

Therefore, there will be a need for instruments that can increase the flexibility of the system for future energy systems with large quantities of wind power. Instruments/technologies that create a demand for electricity when electricity generation is abundant in the system and vice versa ensure efficient electricity generation when there is a need for more electricity generation in the system. For example, this may take place through the use of heat accumulators at centralised and distributed cogeneration installations and the use of turbine bypasses so that the cogeneration installations do not produce electricity at times when there are high quantities of wind, or by the use of electric boilers and heat pumps for the generation of heat based on electricity when too much wind power is being generated. It is important that the gradual development of the energy system of the future takes place with the ongoing optimisation of the efficiency of the overall generation system. Ensuring this flexibility must not be to the detriment of efficiency.

#### Utilisation of waste heat

Another way of optimising overall energy efficiency is to utilise waste heat (normally described as surplus heat in Denmark). The potential for this has been investigated several times and has been the focus of energy efficiency initiatives in Denmark.

The potential to utilise industrial waste heat was most recently investigated in 2013 in a national analysis. The assessment was that under given framework conditions there is potential for the further utilisation of 9 PJ/year with a simple (company-economic) repayment time of four years.

Of this potential, it is assessed that 5 PJ/year could be used internally in industry for space heating purposes and heating hot water, while 4 PJ/year could be externally allocated for district heating purposes. The majority of the total potential (7 PJ/year) could be utilised via heat pumps, as the vast majority of industry waste heat currently exists at relatively low temperatures.

# 4.4.2 Heat distribution and consumption

The average age of the pipe network's main pipelines is currently over 20 years (2014: 23.7 years), and therefore, as a result of corrosion and technological improvements, there would be energy gains if this were to be refurbished. According to the Danish District Heating Association, the current district heating network has a lifetime of around 50 years, and therefore there is limited incentive to undertake a major pipeline replacement at present (Danish District Heating Association, 2014). However, the heat loss for the network indicated a large amount of diffusion and suggests that large energy gains may be obtained in certain locations. According to Danish District Heating Association annual statistics, the average heat loss was 24 % or 197 MWh/km (Danish District Heating Association, 2014). The net loss could be further limited through better temperature and output regulation, which is why the energy behaviour of users is nevertheless crucial.

As it is very costly to invest in the energy efficiency of the existing pipe network, the potential for energy savings will most often only be gained in line with the ordinary replacement of the network. In order to assist with this replacement and ensure that the largest energy potentials are obtained, an industry agreement has already been entered into concerning future energy saving initiatives. The agreement, popularly known as the Energy companies' energy savings initiative, assumes that there is an annual (2012-2020) savings requirement made for network and distribution companies in the areas of electricity, natural gas, district heating and oil. In specific terms, a saving of 12.2 PJ must be saved annually during the years 2015-2020. The savings will primarily be made at the point of end consumption, i.e. with consumers, but may also be obtained in the distribution network. Therefore, this motivates companies to become involved in promoting energy efficiency in a broader sense, and the savings potential for district heat distribution will also become of greater interest. The agreement primarily promotes the implementation of the most cost effective solutions, whereby investments in the district heating network to reduce the net loss has not been the first priority for the majority of undertakings. However, as the cheapest solutions are gradually implemented, undertakings will subsequently be forced to investigate the potential to reduce distribution losses.

# 5. District cooling

The results of this Chapter are to a certain extent based on the 'Analysis of the Danish cooling potential' prepared for the Energy Agency by Rambøll in 2014.

# 5.1 Introduction

District cooling is defined as installations where several buildings share infrastructure for cooling production. Technologically, there are three different production technologies overall; free cooling, absorption cooling and compression cooling. All three technologies have been included in the background analyses; however, as absorption cooling requires high temperature industrial waste heat or an alternative high temperature heat source, absorption cooling has not been included in the final comparison that will be reproduced later in the report. This is because the quantity of unutilised high temperature waste heat is currently considered to be minimal. However, this does not mean that absorption cooling may not be relevant in certain locations. As district cooling was not part of the system-technical evaluation in the Scenario Analysis, some considerations are given here concerning the integration of district cooling into the energy system, in addition to the more specific potential in relation to exploiting synergy opportunities associated with district heating.

# 5.1.1 Systemic effects

It is assessed that there is a capacity potential of around 5 000 MW, which means that there are also systemic incentives to integrate this in the intelligent electricity network/energy system of the future. There are a number of benefits associated with centralising cooling production in a district cooling system in relation to interaction with the energy system in general.

Firstly, a centralised cooling production system makes it more profitable to invest in large storage capacities, which in turn allows more flexible patterns of generation. In the short-term, generation may for example take place during periods with low electricity prices (at night), which it is expected will only become more attractive gradually as the price signal is amplified. In the longer term, it may be possible to develop a so-called capacity market, in which there is interest in the generation capacity, which would be made available to a central board (partially) in return for financial compensation for disconnection during periods of low wind generation and (maximal) connection during periods of high wind generation.

It is assessed that there is no noteworthy energy efficiency potential in large-scale operation for the individual technologies. However, district cooling nevertheless involves significant energy efficiency potentials, as a centralised large-scale operation would allow better utilisation of more effective technologies such as free cooling and absorption cooling. The utilisation of free cooling is often not possible in individual solutions due to a lack of useable sources, while there are better opportunities for locating generation for district cooling, e.g. the ocean or by investing in cost-intensive groundwater solutions. In terms of energy, absorption cooling is difficult to compare with other solutions as this is powered by heat instead of electricity. However, in cases where an unutilised high temperature waste heat source exists, the utilisation of this will contribute to an overall improvement in resource utilisation in the energy system.

# Synergy between district heating and district cooling

There are also efficiency potentials in relation to compression cooling. A compression cooling installation consists of both a cold and hot circuit. It is possible to achieve the cogeneration of cooling and heat by using both of these. Therefore, the compressor cooling installation will also act as a heat

|                                | District cooling using waste<br>heat (cogeneration) | Individual cooling +<br>individual groundwater<br>pump |
|--------------------------------|-----------------------------------------------------|--------------------------------------------------------|
| Cooling production, MWh        | 1                                                   | 1                                                      |
| Heat generation, MWh           | 1.4                                                 | 1.4                                                    |
| COP cooling                    | 2.5                                                 | 7                                                      |
| COP heating                    | 3.5                                                 | 3.5                                                    |
| <b>Electricity</b> consumption | 0.4                                                 | 0.14                                                   |
| cooling, MWh                   |                                                     |                                                        |
| <b>Electricity</b> consumption | 0                                                   | 0.40                                                   |
| heating, MWh                   |                                                     |                                                        |
| Total electricity              | 0.4                                                 | 0.54                                                   |
| consumption, MWh               |                                                     |                                                        |
| Electricity saving, MWh        | 0.14                                                | 0                                                      |
| Electricity saving percentage  |                                                     | 26 %                                                   |
| for district cooling           |                                                     |                                                        |

pump. However, this means that the condensation temperature in the cooling circuit will increase and the COP factor for cooling will therefore be reduced.

Table 5.1. Energy consumption and savings per MWh cooling produced.

Heat generation is achieved in return, which can advantageously be used for district heating or locally. Introductory calculations indicate a savings potential of around 26 % compared with the similar separate generation of cooling and heating.

Besides this potential to reduce electricity consumption, there are also other possible financial benefits associated with coordinating the generation of district cooling and district heating. An obvious saving lies in the potential to reduce the total investment as a result of generation taking place in one installation instead of two. This also allows savings to be made in relation to operation and maintenance.

However, significant economic benefits may also be obtained through district cooling, even in cases where cogeneration does not take place. These include:

- Large-scale benefits of pooling capacities at a single installation;
- Concurrent effect due to different demand profiles associated with cooling users leads to a reduced capacity demand and a more even demand profile;
- More professional operation and maintenance of installation, which may reduce associated costs;
- Large thermal storage capacity allows more economic operation.

At the same time, the collective district cooling solution provides users with additional space, as the areas that they would otherwise use for cooling installations are available for other purposes. Additionally, the operation of the cooling installation can be transferred to the supply undertaking, which gives the undertaking the opportunity to focus on its core business competencies and not on cooling supplies.

As may be expected, the obvious cost is associated with the need to establish a distribution network; however, in contrast to the district heating network, there are no sizeable net losses in a district cooling system because of the temperature of the earth.

# 5.2 Cooling demand, projections and mapping

#### 5.2.1 Description of cooling demand

**Assignment:** (*a*) *a description of cooling demand.* 

The total electricity consumption for cooling purposes was estimated at around 2 300 GWh/year in 2006, which corresponds to 13 % of electricity usage in the sectors using cooling. On the basis of an estimated COP value, this is calculated as corresponding to an overall cooling demand of 9 000 GWh/year, corresponding to an output demand of 5 000 MW<sub>cooling</sub> (see Chapter 2 for further details of method).

#### GRAPH

IT Process Comfort

Figure 5.1. Estimated distribution of electricity consumption divided according to use (MWh/year).

Figure 5.1 shows the distribution of cooling demand for IT, process and air-conditioning cooling, while Figure 5.2 illustrates electricity consumption used for cooling in the various main industry sectors, divided according to the same uses.

GRAPH

Comfort Process IT

Key: Landbrug, gartneri – Agriculture, horticulture Industri – Industry Detailhandel – Retail Øvrig handel & service – Other retail and services Offentlig – Public sector

Figure 5.2. Distribution of electricity consumption for cooling for main industry sectors and applications (MWh/year).

#### 5.2.2 Projection of cooling demand

The baseline forecast for the overall output demand and the percentage covered by district cooling is not expected to change significantly in the period up to 2030.

#### GRAPH

Individual District cooling

Figure 5.3. Baseline projection for the distribution between individual and collective cooling supplies (MW).

However, a significant shift between the sectors in relation to the consumption of electricity for cooling purposes is anticipated. In specific terms, it is anticipated that there will be growth in agriculture and the service sector, while industrial cooling consumption is expected to decline markedly, which is estimated on the basis of the value added during the period 2006-2012, which has a linear projection. However, it must be noted that the value added in industry was particularly affected by the financial crisis of 2008, which has made the projection for this sector particularly uncertain. The development in electricity consumption in the sectors from 2006 until 2030 is illustrated in Figure 5.3. However, it must be noted that the value added in industry was particularly affected by the financial crisis of 2008, which has made the projection for this sector particularly uncertain.

GRAPH

Public sector Other retail and service Retail Industry Agriculture

Figure 5.4. Development in electricity consumption for cooling in the sectors from 2006 until 2030, MWh. (District Cooling Analysis 2014, Danish Energy Agency).

The projection of the development in electricity consumption assumes that the efficiency of cooling production will be improved by 20 % over the next 15 years.

Cooling demand Electricity consumption

Figure 5.5. Projection of cooling demand.

Figure 5.5 illustrates the development in cooling demand from 2016 up until 2026. Under the assumptions for cooling demand described above, it is assessed that the overall cooling demand will increase from around 9.4 TWh in 2016 to around 11 TWh in 2026.

#### 5.2.3 Mapping

**Assignment:** (*c*) *a map of the national territory, identifying, while preserving commercially sensitive information:* 

- *iv. cooling demand points, including:*
- municipalities and conurbations with a plot ratio of at least 0.3, and;
- industrial zones with a total annual cooling consumption of more than 20 GWh;
- v. existing and planned district cooling infrastructure;
- vi. potential cooling supply points, including:
- electricity generation installations with a total annual electricity generation of more than 20 GWh, and;
- waste incineration plants;
- existing and planned cogeneration installations using technologies referred to in Part II of Annex I, and district heating installations.

#### Mapping method

<u>The cooling demand</u> (Figure 5.6) has been prepared in connection with the District Cooling Analysis and follows the method description in Chapter 2.

<u>Supply points</u> (Figure 5.7) have been calculated based on the Energy Agency's producer count from 2013. All installations have been included with a total of more than 10 TJ (2 778 MWh) in thermal generation at a given address in 2013. Therefore, an installation may consist of several different technical installations.

All commercial installations with some form of electricity generation are designated as '*Industrial cogeneration*', while other commercial installations are designated as '*Industrial waste heat*'. Installations where more than 25 % of the fuel is designated as waste are categorised as '*Waste incineration*'.

<u>Existing district cooling infrastructure</u> (Figure 5.7) has been assessed via a national questionnaire survey among existing supply companies. Out of 394 companies, 254 responded. Of these, six had existing district cooling supplies and three were planning the establishment of these. Since this report, the planning of a further district cooling installation in Høje Taastrup has commenced.

# **Cooling demand**



Figure 5.6. Cooling demand, MWh/km2 (District Cooling Analysis 2014, Danish Energy Agency).

# Supply points



Figure 5.7. Supply points and existing infrastructure (Energy producer count 2013 and District Cooling Analysis 2014, Danish Energy Agency).

#### 5.3 Role of district cooling

**Assignment:** (*d*) *identification of the cooling demand that could be satisfied by high-efficiency cogeneration.* 

#### 5.3.1 Baseline projection

The overall cooling demand is expected to remain relatively stable with a final cooling demand of 5 200 MW in 2030.

GRAPH

Individual District cooling

Figure 5.8. Baseline projection of cooling demand and supply form (District Cooling Analysis 2014, Danish Energy Agency).

The baseline projection in reality only includes already established or planned district cooling installations. This is initially done on the assumption that further expansions in capacity cannot be anticipated as a result of various barriers.

#### 5.3.2 Potential assessment

A geographical analysis tool is used to locate potential district cooling projects on the basis of the calculated price difference between individual cooling and district cooling, in addition to the anticipated cooling consumption for all of the country's undertakings (see Chapter 2 for more details on the method).

This initially leads to a technical potential, which can be seen in Table 5.2. The technical potential assessment does not set a lower limit for the size of a potential district cooling project.

| Cooling potential [MW] | District cooling potential [MW] | District cooling percentage |
|------------------------|---------------------------------|-----------------------------|
| 5 142                  | 2 866                           | 56 %                        |
|                        |                                 |                             |

Table 5.2. Technical potential for district cooling (District Cooling Analysis 2014, Danish Energy Agency).

A considerable level of identity was found in the District Cooling Analysis between what is profitable for a company and socio-economically in relation to the establishment of district cooling. The difference between the analysis of the technical and the socio-economic potential analysis therefore primarily constituted the fact that a lower limit of 1 MW has been defined in the calculation of the socio-economic potential. Additionally, a deduction of 50 % is made for the indirect cooling potential, as it is not possible to obtain the same large-scale benefits associated with investments in district cooling in relation to an individual cooling solution.

| Cooling potential [MW] | District cooling potential [MW] | District cooling percentage |
|------------------------|---------------------------------|-----------------------------|
| 5 142                  | 2 211                           | 43 %                        |

Table 5.3. Socio-economic potential for district cooling (District Cooling Analysis 2014, Danish Energy Agency).

MAP

Figure 5.9. Social potential, group sizes larger than 1 MW (District Cooling analysis 2014, Danish Energy Agency).

#### 5.4 Energy efficiency

Assignment: (f) identification of energy efficiency potentials of district cooling infrastructure.

No noteworthy energy efficiency potential has been assessed in connection with the establishment of district cooling instead of individual cooling solutions. However, significant generation efficiency for the overall system may be anticipated as old installations are gradually replaced with new ones. This will nevertheless be the case regardless of whether these are located collectively or as part of an individual system.

The current district cooling capacity is also considered to be limited (40 MW), and the installations sufficiently new that there is considered to be no noteworthy potential in this area. At the same time, energy losses in the distribution of cooling are not particularly relevant to district cooling, as the temperature of the network is close to that of the surroundings (the ground).

However, as described in Article 5.1, there is significant efficiency potential in integrating cooling and heat generation. Calculations performed by the District Cooling Analysis highlight an example of where an electricity saving of 26 % can be made for the generation of the same quantity of cooling and heating at a joint compression installation instead of separate generation using both a compression facility and a heat pump. It must be noted that this example is not necessarily representative, and therefore the savings potential identified cannot be scaled up to indicate the overall savings potential in Denmark. This potential synergy is far from being fully utilised in Denmark at present, and it is believed that Denmark has considerable potential to achieve significant energy and financial savings in connection with this because of the extensive district heating network.

# 6 Cogeneration production

As no separate cogeneration analysis was performed in connection with the Energy Agreement in 2012, this part of the report builds on the results from the District Heating Analysis and the Scenario Analysis, in which cogeneration forms an integrated part of the analyses, supplemented with previous potential assessments in connection with EU reports in accordance with Directive 2004/8/EC.

#### 6.1 Introduction

**Assignment:** (*d*) *identification of the heating and cooling demand that could be satisfied by highefficiency cogeneration\*, including residential micro-cogeneration.* 

# \*High-efficiency cogeneration

Cogeneration produced by cogeneration installations must lead to primary energy savings of at least 10% in relation to the reference value for the separate generation of electricity and heating. Production from small cogeneration units (with an installed capacity of less than 1 Mwe) and from micro-cogeneration units (maximum capacity of less than 50 kWe) may however be considered as high-efficiency cogeneration, provided that there is a primary energy saving also measured in relation to the reference value for the separate generation of electricity and heating.

Cogeneration plays an absolutely crucial role in Danish energy supplies, and Denmark is one of the countries with the highest cogeneration coverage in the EU, which is illustrated in Figure 6.1.

Illegible graph

Figure 6.1. Percentage of cogeneration in gross electricity generation in 2012 (EUROSTAT).

District heating supplies, which supply around 60 % of Danish households with energy for heating purposes, represents the most important basis for cogeneration, and the majority of district heating is currently produced at cogeneration installations in cogeneration with electricity. An element of industrial cogeneration is also included in this.

The large cogeneration coverage is the result of a targeted policy to promote this form of generation; a policy that has created the basis for ensuring that cogeneration will also make a significant future contribution to Danish energy supplies.

However, there are a number of factors which mean the contribution from cogeneration is expected to gradually decline over the coming years.

# 1) Falling heat demand

Many of the benefits associated with cogeneration can only be realised if there is a well-developed district heating network, and as has been shown by the District Heating Analysis (see Table 6.1), it is anticipated that overall heat demands will fall in future. However, it is expected that the percentage of district heating will rise slightly, although the economically viable expansion potential is limited because Denmark already has one of the EU's most extensive district heating networks.

| Heat demand for Consumer [PJ] | 2013 | 2020 | 2035 |
|-------------------------------|------|------|------|
| Denmark                       | 199  | 189  | 166  |
| Urban areas                   | 160  | 152  | 134  |
| District heating coverage     | 50 % | 69 % | 62 % |

Table 6.1. Assumptions regarding the development of district heating consumption throughout Denmark as a whole and in urban areas. Results for district heating coverage in 2020 and 2035 for the wind socio-economy (District Heating Analysis 2014, Danish Energy Agency).

# 2) *Electricity prices*

The determination of electricity prices as a marginal cost in the Nordic electricity market (Nord Pool) gives priority to fossil-free energy sources such as solar and wind power. This is challenging for cogeneration installations because they no longer act as a base load supplier, but serve as a medium or peak load supplier, which results in reduced operating hours and therefore less favourable finances.

# *3) New waste heat*

Cogeneration may also face pressure in the longer term from the anticipated arrival of new larger waste heat sources from district cooling installations and biorefineries. Waste heat from biorefineries is considered as having the potential to play a central role in the Scenario Analysis for the future energy system, such that the majority of the base load of district heat generation can be covered by waste heat in central district heating areas.

# 6.2 **Projection of the role of cogeneration**

The abovementioned tendencies are also reflected in Figure 6.2 and 6.3, where the projection of both heat generation and electricity generation clearly illustrate the reduced role of cogeneration. However, cogeneration will continue to play an important role in terms of capacity, and therefore there will continue to be a demand for new investments and development in this area.

Illegible graph

Illegible graph

Figure 6.2. Development in electricity generation for biomass (left) and for the wind scenario (right). (Scenario Analysis 2014, Danish Energy Agency).

#### With taxes and subsidies

Illegible graph

Illegible graph

Figure 6.3. District heating generation in Denmark divided according to generation form. Heat generation for industrial processes has not been included. (Scenario Analysis 2014, Danish Energy Agency).

This conclusion was also reached in Denmark's Energy and Climate Projection 2014 (*Danmarks Energi- og Klimafremskrivning 2014*), which has the purpose of providing an assessment of how energy consumption, energy generation and greenhouse gas emissions will develop in the period leading up to 2025 if no new political measures are introduced.

The cogeneration percentages for both electricity and district heat generation are also assessed as falling in this analysis of development in the period leading up to 2025.

The cogeneration percentage for district heating generation in the period leading up to 2025 is falling in the projection (see Table 6.2).

| (%)           | 1980 | 1990 | 2000 | 2005 | 2010 | 2011 | 2012 | 2015    | 2020    | 2025    |
|---------------|------|------|------|------|------|------|------|---------|---------|---------|
| Cogeneration  | 39   | 59   | 83   | 83   | 78   | 77   | 73   | Approx. | Approx. | Approx. |
| percentage of |      |      |      |      |      |      |      | 68      | 66      | 63      |
| district      |      |      |      |      |      |      |      |         |         |         |
| heating       |      |      |      |      |      |      |      |         |         |         |
| generation    |      |      |      |      |      |      |      |         |         |         |

Table 6.2. Cogeneration percentage of overall district heating generation.

The decline in cogeneration is primarily due to increasing natural gas prices, which, like everything else, makes cogeneration using natural gas less attractive. The large percentage of power generated by wind turbines is also contributing to cogeneration displacement, as periods of high wind generation supress electricity prices, making it more attractive to generate heat using a boiler or electric boiler compared to using a cogeneration installation.

The same tendency is becoming apparent for the cogeneration percentage of electricity generation, as is illustrated in Figure 6.4.

#### Denmark's electricity generation according to type (TWh)

#### GRAPH

Wind Solar Cogeneration Hydropower Condensing

Figure 6.4. Danish electricity generation divided according to type, shown here with the average estimate for the quota price (TWh).

The historical data in Figure 6.5 also illustrates that the cogeneration percentage for district heating generation is currently already declining. However, the cogeneration percentage for thermal electricity generation is continuing to increase (Figure 6.5). This is an expression of the current energy policy, which continues to favour the promotion of cogeneration over condensing generation.

#### GRAPH

District heating Electricity Figure 6.5. Cogeneration percentage for thermal electricity and district heating generation (Energy Statistics 2012).

However, the cogeneration percentage of gross electricity generation is falling overall, which is predominantly due to the increased quantity of wind power (Figure 6.6).

GRAPH

Figure 6.6. Technical potential for district cooling (District Cooling Analysis 2014, Danish Energy Agency).

#### 6.2.1 Micro-cogeneration

Micro-cogeneration is defined in EED as an installation with a maximum capacity below 50 kWe. There is an emerging market for this type of small installation, which are expected to become more widely used in line with technology becoming cheaper and more efficient.

The Energy Agency has performed an analysis of the potential for micro-cogeneration, which was carried out by the Danish Gas Technology Centre (DGC). The estimate indicates that there were only

around 45 cogeneration installations below 50 kW in operation in 2005. These installations were primarily established in institutions, and there were relatively few installations at household level.

DGC has analysed the potential for micro-cogeneration units up to 15 kWe in buildings outside areas supplied by district heating. Assuming an annual operating time of 4 000 hours and an electricity/heat output ratio of 1:2, a theoretical potential has been identified of 1 100 MWe in areas supplied by natural gas (divided across 380 000 units), and a further 1 100 MWe (divided across approximately 280 000 units) in open countryside, i.e. where there is neither access to district heating nor natural gas.

The total of approximately 600 000 houses will typically have a demand for around 1.5 kW of electrical output. Units of this size are now available on the market in commercial versions and are based on both traditional motor technology and Stirling motor technology.

The largest barrier to the expansion of micro-cogeneration is financial in nature, as both the acquisition and operating economy does not make it attractive for householders to acquire this type of installation. In terms of socio-economics, there is also currently no benefit associated with the installations.

However, fuel cell technology may become more interesting in the long-term, not least as a result of the higher electricity generation from the same heat generation, in addition to improved potential to modulate generation between full and low loads without this affecting electrical efficiency. Besides the abovementioned potential for small buildings, micro-cogeneration (less than 50 kW) and mini-cogeneration (greater than 50 kW and less than 1 MW) may be included in the supply system in different ways, including as local peak and reserve capacity for district heating systems.

# 6.2.2 Potential of cogeneration to meet cooling demands

Absorption cooling uses one or several heat sources to produce cooling. In order to produce effective cooling using absorption, a high temperature heat source is required, which may for example come from a boiler, a waste incineration installation a cogeneration installation or a district heating steam system.

With reference to the District Cooling Analysis, it is considered that under normal conditions, it is not financially viable to use cogeneration in Denmark for the purpose of producing cooling through an absorption heat pump (District Cooling Analysis, page 45).

Therefore, absorption cooling is in practice to be used in installations where there is high temperature industrial waste heat that cannot be allocated to district heating. There may also be instances where very high electricity prices mean that the cogeneration installations must operate at full capacity, which may result in cheap high temperature heat. Absorption pumps may also be used in connection with cogeneration or boiler installations where these can be operated by hot flue gases.

The analysis also highlights that there are only a few hours per year where the electricity prices are actually sufficiently high as to make it profitable to produce cooling by absorption rather than compression. Therefore, potential is only in reality considered to exist for absorption cooling through the use of high temperature waste heat (which may normally be better allocated for district heating) or through the use of hot flue gases. Therefore, the overall potential is considered to be very limited and thus has not been further quantified.

There has also been a focus on the electrification of the energy system in Denmark and to increase the flexibility of this. Therefore, from a system perspective it is considered more appropriate to focus on the promotion of electricity driven cooling, e.g. compression and free cooling.

# 6.3 Potential assessment

**Assignment:** (*e*) *identification of the potential for additional high-efficiency cogeneration, including from the refurbishment of existing and the construction of new generation and industrial installations or other facilities generating waste heat.* 

Although the district heating coverage is very high in Denmark (see Chapter 6), there is still a certain amount of unutilised technical potential.

The technical potential beyond that of the existing district heating was estimated in the first progress report (pursuant to Article 6(3) of 2004/8/EC) submitted to the Commission in February 2007. The potentials were divided into three categories:

- 1. 800 MW(electricity) as decentralised cogeneration. The potential assessment is based on the potential to increase the Cm value (electrical output/thermal output) through the establishment of new cogeneration installations covering the same heating market as the current decentralised cogeneration installations;
- 2. 1 200 MW industrial cogeneration;
- 3. 2 200 MW in the form of micro-cogeneration with an electrical output of less than 50 kW. It must be anticipated that this potential will reduce, as a large percentage of the heating market associated with the potential is expected to be converted to heat pumps and district heating, etc.

It was assessed that the socio-economically profitable cogeneration potential was limited in the subsequent potential assessment the Energy Agency submitted to the Commission in 2010 (see projection of the role of cogeneration in Article 6.2), and this is still considered to be the case.

# 6.4 **Progress in accordance with Directive 2004/8/EC**

**Assignment:** (*h*) the share of high-efficiency cogeneration and the potential established and progress achieved under Directive 2004/8/EC.

The table below shows the development of both heating and electricity generation from cogeneration during the period between 2010 and 2013, and the percentage of the overall electricity and heating generation. The progress achieved under Directive 2004/8/EC is also illustrated.

| Overview |             |          |       | Cogeneration electricity <sup>1</sup> , | generation capacity, fuel<br>input | Main activity producer<br>generation , capacity, fuel | input | Own producer generation,<br>capacity, fuel input | Total percentage of<br>electricity generation,<br>cogeneration | Cogeneration of heat | Main activity producers | Own producers | Total percentage of heat<br>generation, cogeneration | Total for installation<br>(cogeneration and other) <sup>2</sup> | PES <sup>1</sup> |
|----------|-------------|----------|-------|-----------------------------------------|------------------------------------|-------------------------------------------------------|-------|--------------------------------------------------|----------------------------------------------------------------|----------------------|-------------------------|---------------|------------------------------------------------------|-----------------------------------------------------------------|------------------|
|          | electricity | Capacity | [GW]  | 6.1                                     |                                    | 5.6                                                   |       | 0.5                                              | 65 %                                                           |                      |                         |               |                                                      | 13.5                                                            |                  |
|          |             | output   | [TWh] | 25.1                                    |                                    | 23.1                                                  |       | 2.0                                              |                                                                |                      |                         |               |                                                      | 38.9                                                            | 89               |
|          | Heat        | Capacity | [GW]  |                                         |                                    |                                                       |       |                                                  |                                                                | 8.6                  | 7.4                     | 1.2           | 77 %                                                 | 23.4                                                            | PJ               |
| 201      |             | output   | [TWh] |                                         |                                    |                                                       |       |                                                  |                                                                | 32.0                 | 25.3                    | 6.6           |                                                      | 41.8                                                            |                  |
|          | electricity | Capacity | [GW]  | 5.8                                     |                                    | 5.3                                                   |       | 0.5                                              | 62 %                                                           |                      |                         |               |                                                      | 13.6                                                            | 80               |
|          |             | output   | [TWh] | 21.9                                    |                                    | 19.9                                                  |       | 2.0                                              |                                                                |                      |                         |               |                                                      | 35.2                                                            | PJ               |
| -        | Heat        | Capacity | [GW]  |                                         |                                    |                                                       |       |                                                  |                                                                | 8.2                  | 6.9                     | 1.2           | 76 %                                                 | 23.3                                                            |                  |
| 201      |             | output   | [TWh] |                                         |                                    |                                                       |       |                                                  |                                                                | 28.0                 | 21.4                    | 6.6           |                                                      | 36.8                                                            |                  |
|          | electricity | Capacity | [GW]  | 5.7                                     |                                    | 5.2                                                   |       | 0.5                                              | 62 %                                                           |                      |                         |               |                                                      | 14.2                                                            | 77               |
|          |             | output   | [TWh] | 18.9                                    |                                    | 17.0                                                  |       | 1.9                                              |                                                                |                      |                         |               |                                                      | 30.7                                                            | PJ               |
| 2        | Heat        | Capacity | [GW]  |                                         |                                    |                                                       |       |                                                  |                                                                | 7.9                  | 6.7                     | 1.3           | 71%                                                  | 25.6                                                            |                  |
| 201      |             | output   | [TWh] |                                         |                                    |                                                       |       |                                                  |                                                                | 26.8                 | 20.3                    | 6.5           |                                                      | 37.9                                                            |                  |
|          | electricity | Capacity | [GW]  | 5.6                                     |                                    | 5.1                                                   |       | 0.4                                              | 62 %                                                           |                      |                         |               |                                                      | 13.5                                                            | 77               |
|          |             | output   | [TWh] | 21.4                                    |                                    | 19.8                                                  |       | 1.6                                              |                                                                |                      |                         |               |                                                      | 34.7                                                            | PJ               |
| m        | Heat        | Capacity | [GW]  |                                         |                                    |                                                       |       |                                                  |                                                                | 8.0                  | 7.0                     | 1.1           | 70 %                                                 | 23.4                                                            | 1                |
| 201      |             | output   | [TWh] |                                         |                                    |                                                       |       |                                                  |                                                                | 26.4                 | 20.9                    | 5.5           |                                                      | 37.5                                                            |                  |

<sup>1</sup>Only in relation to high-efficiency cogeneration pursuant to Article 3 and Annex III of Directive 2004/8/EC. <sup>2</sup> All forms of electricity and heat producing units. <sup>3</sup> Compared with separate generation of electricity and heating.

# 7 Overall assessment

#### 7.1 Strategies, policies and measures

**Assignment:** (g) strategies, policies and measures that may be adopted up to 2020 and up to 2030 to realise the potential in point (e) (\*cogeneration) in order to meet the demand in point (d) (\*district heating and cooling), including, where appropriate, proposals to:

Annex VIII of EED states that the present 'comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling' must cover strategies, policies and measures that can be adopted in the period leading up to 2020 and up to 2030 to realise the potential in point e. Point e focuses in particular on the increased use of waste heat from power generation installations and industrial installations.

Furthermore, according to Article 14(1), the present comprehensive assessment must be updated every five years and be submitted to the Commission.

#### Period up until 2020

The Energy Agreement of 22 March 2012 determines the specific energy policy initiatives for the period between 2012 and 2020.

The Energy Agreement ensures that there is broad political backing for an ambitious green conversion with a focus on saving energy throughout society as a whole and increasing the use of renewable energy in the form of increased numbers of wind turbines, more biogas and more biomass.

The agreement ensures a 12 % reduction in gross energy consumption in 2020 in relation to 2006, just over 35 % renewable energy in 2020 and around 50 % wind power in Danish electricity consumption in 2020.

The agreement contains a considerable number of energy policy initiatives for the period 2012-2020, including a number of measures to promote cogeneration, district heating supplies and the increased use of biomass and other renewable energy sources for district heating generation. Changes have been made to the Heat Supply Act in connection with this with a view to promoting the conversion to biomass at the central cogeneration installations. The change in legislation has given electricity and heat producers and heat customers the opportunity to enter into voluntary agreements in which the tax benefits in shifting from fossil fuels to biomass for heat generation in future can be freely shared between the two parties and not fall to heat customers in their entirety as a result of the Heat Supply Act's price adjustments. Furthermore, a pool has been established to promote new renewable energy technology in district heating (geothermal and large heat pumps, etc.).

Therefore, the corrected greenhouse gas emissions were estimated to be 34.1 % lower in 2020 as a result of the Energy Agreement than the actual 1990 emissions, which formed the basis for the determination of the Danish Kyoto commitment.

#### Period up until 2030

The government platform for the government that took office in June 2015 stated that an Energy Commission must be appointed to investigate energy policy targets and tools for the period 2020-2030, including as regards how Denmark could fulfil its international obligations in a cost-effective

and market-based manner, particularly in relation to the EU. The Energy Commission is expected to begin its work at the start of 2016. There has been an initial focus on the national energy policy framework and the development of the European market for energy in relation to the EU for the period 2020-2030.

The parties behind the Energy Agreement from 2012 will discuss the need for supplementary initiatives for the period following 2020 before the end of 2018. The result of these discussions will be included in the next report.

#### 7.1.1 Cogeneration

• (...) increase the share of cogeneration in heating and cooling generation and in electricity generation.

With reference to Chapter 6, no basis has been identified for the pursuit of a potential increase in the percentage of cogeneration used for cooling, heating and electricity generation beyond that of the existing initiatives.

#### Existing strategies, policies and measures

As specified in the response in Chapter 6, there has been a substantial expansion of cogeneration in Denmark in recent decades. The object clause of the Heat Supply Act contains a statement specifying that cogeneration is to be promoted as much as possible. The Danish Executive Order on Projects derives a specific requirement from this that heat producing installations larger than 1 MW be arranged as cogeneration installations. However, it is a perquisite that this form of generation is the most socio-economically profitable. A heat producing installations may be approved if this is more socio-economically profitable. However, only cogeneration installations may be approved in central cogeneration areas.

District heating produced by cogeneration must also be promoted through the use of the so-called V-formula (or alternatively E-formula) used to divide the fuel into one part used for electricity generation (tax exempt) and one part used for heat generation, which is subject to energy tax. This formula is a technical exercise in tax accounting that indirectly promotes district heating produced by cogeneration by giving this an efficiency advantage and therefore a reduction in fuel taxes.

Furthermore, cogeneration is supported through various support mechanisms for efficient electricity generation. See in-depth details, including:

#### Three-step tariff

The three-step tariff was introduced in around 1990 to support more efficient electricity generation through cogeneration at decentralised installations. The support is paid according to whether the electricity generation takes place at low, high or peak load periods (hence the three steps). The scheme was changed in 2004 such that only installations under 10 MW could be awarded support. This was further lowered to 5 MW from 2007 and the support mechanism is lapsing in its entirety from 2015.

#### Basic Amount 1

This support scheme was introduced in 2004 as a consequence of the marketisation of the decentralised cogeneration installations. The purpose of the scheme was to protect heating customers against price increases as a consequence of the increased competition in the electricity market. The

support is generation-independent and in the first instance only covered installations over 10 MW, although this limit was reduced to 5 MW in 2007. This support scheme will lapse at the end of 2018.

# Basic Amount 2

This support scheme initially served as generation-dependent support, but was converted in July 2013 such that it was also generation-independent. This support is not time-limited, although there is a renotification obligation no later than 10 years following the State aid approval, and the scheme has been announced for the period 1 January 2010 to 31 December 2019. The reorganisation of Basic Amount 2 was declared as State aid and approved on 5 June 2013. Therefore, Basic Amount 2 may continue to run unchanged until 31 December 2019. It is believed that it will not be possible to continue Basic Amount 2 in its current form after 2019 (see new EU State aid rules).

# 7.1.2 District heating and district cooling infrastructure

• (...) develop efficient\* district heating and cooling infrastructure to accommodate the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable energy sources.

\*Future district heating and district cooling in Denmark will in all cases be efficient with respect to Article 2(41) of the Energy Efficiency Directive. This is due to the fact that the expansion of district heating to new areas must only take place using biomass or some other form of renewable energy, cogeneration or an alternative environmentally-friendly supply source (Article 7 of the Executive Order on Projects).

\*The supply of district heating and district cooling using electrically powered technology will also by definition be efficient with reference to Article 2(41) of the Energy Efficiency Directive, as electricity supplies in 2013 consisted of 43 % renewable energy. With reference to the Baseline Projection from 2014, the percentage in 2020 is assessed as being 71 % renewable energy (frozen policy).

With reference to Chapter 6, no basis has been identified for the pursuit of a potential increase in the percentage of cogeneration used for cooling, heating and electricity generation. Therefore, new cogeneration is not expected to be a central factor in the development of the district heating and district cooling infrastructure of the future. However, this does not mean that there is no potential for the continued development of efficient district heating and district cooling.

# Efficient district heating infrastructure

The district heating infrastructure (see Chapter 4) will continue to play a prominent role in the Danish energy system in the coming decades. However, it is considered that there is limited potential to expand the technology outside existing distribution areas (ENS, 2014a: page 8).

It is anticipated that future heat generation will come from a very diverse range of sources. It is anticipated that waste heat, heat pumps and biomass will constitute a growing percentage of district heating supplies. However, it has been assessed that this development is already adequately supported through existing strategies, policies and measures. Therefore, there is no immediate prospect of major new initiatives in the area. Nevertheless, ongoing assessments of developments in the sector will be performed and legislative adaptations will be made on the basis of this.

For example, a comprehensive analysis of the overall tax and subsidy system has taken place since 2014 with a view to preparing recommendations as to how the tax and subsidy system can support the environmental and energy targets to a greater extent, in parallel with achieving the fiscal targets for the Treasury.

#### Strategies

There is no explicit district heating strategy in Denmark. The frameworks for the development of district heating are determined in the Heat Supply Act and the Executive Order on Projects. The best socio-economic heating supply method will be promoted based on this regulation. This policy has been in force during recent decades and has resulted in considerable expansion of district heating.

In January 2009, the former Minister of Climate and Energy Connie Hedegaard wrote to all municipal councils urging them to accelerate conversion projects from individual natural gas supplies to district heating. This conversion is limited by the fact that it is not always in the best interests of socioeconomics to convert to district heating. It is anticipated that many of the existing urban areas supplied by natural gas will be converted to being supplied by district heating (see District Heating Analysis).

# Policies

Heat supply, and thus also district heating, is regulated by the Heat Supply Act. The first Heat Supply Act was adopted in 1979 and has been adjusted on an ongoing basis. In 1990, the approach to the planning of heating and the regulation of this was changed significantly. A considerable amount of planning work has taken place since the Act's entry into force, but as the work in connection with this is considered to be more or less complete, a decision was reached to scale down the national planning of heating and instead introduce a project-oriented system. With the overall frameworks and boundaries determined, the assignment was now to assess new projects in relation to the heating plans established and the assumptions determined by the Ministry. This regulatory approach continues to apply, and further details are established in the Executive Order on Projects.

The main principles of the current regulation are as follows:

- Municipalities are responsible for the approval of projects for collective heating supplies;
- Municipalities must approve the most socio-economically profitable project;
- Heating generation must initially be produced in cogeneration with electricity; and
- Collective heating supply installations are subject to a condition concerning the recognition of any necessary costs (the so-called 'self-supporting' principle).
- Project approvals

When a collective heating supply installation or district heating network is established or undergoes significant changes, e.g. changes to fuel type, technical apparatus or an expansion in generation, a project proposal must always be prepared in the first instance. This must be approved by the authorities (initially the municipal authority) before the project may be implemented. This process represents a cornerstone in Danish planning for heating supplies and has done so since the beginning of the 1990s.

• Socio-economic analyses

The legislation prescribes that a socio-economic analysis of the proposed project, in addition to possible alternatives to this must be prepared before a project may be approved. The legislation also prescribes that only the best project in socio-economic terms may be approved, and thus socio-economics is laid down as a governing element for the development.

In order to ensure uniformity and quality in the preparation of the socio-economic analyses, the Energy Agency prepares indicative guidelines for the preparation of the analyses. Central to this are the socio-economic calculation assumptions, technology catalogues and fuel price projections.

• Technology and fuel choices

As part of the Danish State energy planning, rules have been determined in decentralised supply areas regarding energy producers' choice and use of fuels and technologies. There is initially freedom in the choice of fuel for the establishment of a cogeneration installation, although as a general rule this is conditioned by the fulfilment of the requirement for the cogeneration of electricity and heating (cogeneration). The use of tax-free fuels (biomass) purely for the generation of heat is prohibited. This ban applies to the district heating network, which is already supplied by natural gas powered or central cogeneration installations. In practice, this concerns 85-90 % of the total capacity in the district heating networks.

The central cogeneration installations have previously had freedom in the choice of fuel for peak and reserve load installations (i.e. boilers designed purely for the generation of heating) when the market price of electricity is low, or when the heat demand exceeds the cogeneration capacity. As a result of changes made to the Heat Supply Act from 2004, it is now not permitted to replace taxable fuels with tax-free fuels in peak and reserve load boilers.

There are no requirements concerning specific fuels in areas supplied by a central cogeneration installation. In contrast, installations may only initially be approved that produce both electricity and heating (cogeneration installations). Peak and reserve load installations are in this case exempt from the cogeneration requirement. The Energy Agency may also grant dispensation from the cogeneration requirement under special circumstances. An example of such a special circumstance may be the use of industrial waste heat.

• Price determination

As district heating supplies constitute a natural monopoly, a legislative requirement has been introduced specifying that the heating price must be determined in accordance with the so-called 'not-for-profit' principle (heating prices determined according to cost). This protects district heating customers against unnecessarily high heating prices. The principle prescribes that the revenue from the sale of heating must correspond to the necessary costs associated with heat generation. Consequently, the district heating installations have no opportunity to charge any proper profit.

The district heating companies report their heating prices to the supervisory authority (Energy Agency) annually in order to ensure the correct determination of prices.

# Measures

• Taxes

In order to promote conversion to renewable energy sources for heat generation, there is a tax exemption in Denmark for renewable energy sources (wind, solar, biogas and biomass) in connection with the generation of heating.

• Support mechanisms

See cogeneration-related support mechanisms in Article 7.1.

• Analysis of the tax and subsidy system (including the utilisation of waste heat)

The analysis was determined in the Energy Agreement of 2012. In terms of content, the analysis will contain a number of sub-analyses, e.g. focusing on: The development in the tax and subsidy basis, costs associated with public service obligations (PSO), the scope of unregulated externalities associated with energy consumption, the effects of the tax and subsidy system on the integration of green energy and the utilisation of waste heat.

The terms of reference for the work with the waste heat element are worded as follows: 'an analysis of how taxes and subsidies better support the potential for the utilisation of waste heat such that the correct incentives are also ensured in this area for improved energy efficiency'.

The work in connection with this takes place on the basis of the report 'Analysis of the potential for the improved utilisation of waste heat from industry' (Analyse af mulighederne for bedre udnyttelse af overskudsvarme fra industrien) and as follow-up to the previous government's growth plans from February 2013 and July 2014.

• Analysis of the framework conditions for district heating from 2019

The signatory parties to the Energy Agreement decided the following on 26 November 2014: 'When the taxes and subsidies analysis is completed in the spring of 2015, discussions will commence regarding the financial situation of district heating installations from 2019, i.e. when the Basic Amount is phased out. Consideration will be given as to whether the competitive circumstances between heating pumps and biomass is appropriate independently of the taxes and subsidies analysis, including the involvement of tariffs.'

• Financial regulation of the district heating sector

As part of the *Growth Agreement* (*Vækstaftalen*) from June 2014, it has been agreed that the district heating sector should be made more efficient, and this sector must realise a gain of DKK 0.5 billion by 2020. A proposal has been submitted as part of this for the modernisation of the regulation of the district heating sector. Political negotiations concerning the implementation of any new regulation are expected to have been completed by early 2016.

• Construction of heat pumps involving large electrically-driven heat pumps

#### Demonstration fund

The Danish Appropriations Act for 2015 includes a fund for DKK 27.5 million for the establishment and expansion of knowledge in the use of large electrically-driven heat pumps for district heating supplies.

The fund will document through a demonstration programme the operational and company-economic benefits of district heating installations and will kick-start the development of a large-scale development of large heat pumps subsequently.

The demonstration programme additionally has the purpose of:

- Reducing the uncertainty of introducing heat pumps into district heating;
- Obtaining and documenting experiences with large heat pumps such that large quantities of wind power can be incorporated into the district heating sector;
- Ensuring a more flexible and intelligent energy system that is geared towards ensuring that half of Danish electricity consumption in 2020 is covered by wind power.

# Mobile unit

DKK 4.0 million has been allocated to a mobile unit in 2015. The mobile unit has the purpose of assisting district heating installations with the specific implementation of heat pump solutions. The mobile unit will advise the installations regarding specific opportunities for establishing large heat pumps, including:

- Project development, advice and assessment of specific conversion opportunities for district heating installations during the planning and decision-making phase;
- Assessment of available resources in the vicinity, technological solutions, support and financing opportunities, environmental assessments and processing by the authorities;
- Knowledge accumulation, including the preparation of written information material and general dissemination of knowledge to the target group.
- Strategic energy planning

The energy system of the future needs to be much more flexible and more energy efficient if the developments described previously in the period leading up to 2050 are to be realised. This assignment requires comprehensive planning, and therefore work is also being done on developing the planning system at both municipal and inter-municipal levels.

In order to support local energy planning, the Energy Agreement of 2012 allocated a fund of DKK 19 million for strategic energy planning in the municipalities (SEP fund). An emphasis has been placed on the fact that the fund overall is to be used to promote inter-municipal cooperation, e.g. in connection with coordinating the use of local, limited resources or the coordination of district heat development across municipal borders.

The energy policy sub-agreement from June 2013 between the previous government and the Red-Green Alliance concerning the green super fund, among other things, allocated DKK 6 million to support the establishment of partnerships with municipalities taking the lead within the field of climate. The fund supports pilot projects in municipalities wishing to be pioneers in preparing for and demonstrating the conversion of energy supplies such that these are entirely fossil fuel free.

The planning projects under both funds were initiated on 1 January 2014 and were concluded on 30 June 2015. The initiatives under the project were coordinated with a requirement for six-monthly progress reports and participation in six-monthly knowledge sharing seminars. Two seminars were held in 2014 with around 70 participants at each seminar. Experiences were exchanged and common

problems were discussed at the seminars. The effect of the two funds will be evaluated at the end of 2015.

The fund resources were allocated to six regional/inter-municipal projects covering all regions in Denmark, in addition to eight other projects covering the geographical area of one or several municipalities.

Besides municipalities, over 80 other bodies participated as partners in the projects. In total, there was a planning initiative worth an amount of around DKK 50 million in 2014 and 2015.

The preparation of strategic energy plans has been voluntary for municipalities.

#### Efficient district cooling infrastructure

District cooling (see Chapter 5) has a large amount of unutilised potential, and it is considered that there is both social and company-economic as well as climate and energy-related arguments for the promotion of this technology.

#### Existing strategies, policies and measures for the development of district cooling infrastructure

A strategy to promote the use of district cooling in Denmark does not exist at present. The current regulation considers district cooling to be a commercial activity that is not regulated in terms of its content in the energy legislation. This means that there are no approval requirements for the establishment of district cooling installations, and there is also no price regulation. However, it is the case that district cooling installations over 20 MW with a thermal input capacity must be presented to the Energy Agency for approval (see the requirement concerning a cost-benefit analysis described in Annex IX, part 2 of the Energy Efficiency Directive).

The involvement of municipalities in district cooling in contrast to district heating is limited in terms of legislation. This is due to a desire to protect private district cooling undertakings against unfair competition and to protect heating customers against the financial risks of investing in district cooling undertakings. If a municipality wishes to establish district cooling, the financing for this must take place within the municipality's budget, and the cooling installation must also be placed with an independent company with limited liability.

# 7.1.3 Physical planning

(...) encourage new thermal electricity generation installations and industrial plants producing waste heat to be located in sites where a maximum amount of the available waste heat will be recovered to meet existing or forecasted heat and cooling demand. DA L 315/40 Official Journal of the European Union, 14 December 2012.

New regulations were established by Denmark in 2014 under Article 14(5) of Directive 2012/27/EU to ensure that thermal and other industrial installations with a thermal input of more than 20 MW perform cost-benefit analyses pursuant to Annex IX of the Directive.

No new measures are planned to ensure the location of installations in accordance with the thermal heat demand. Physical planning means that municipalities already have the potential to encourage undertakings to locate any new electrical production installations and new industrial installations

producing waste heat in locations where as much of the waste heat produced as possible can be utilised.

• (...) encourage new residential zones or new industrial plants which consume heat in their production processes to be located where available waste heat, as identified in the comprehensive assessment, can contribute to meeting their heat and cooling demands. This could include proposals that support the clustering of a number of individual installations in the same location with a view to ensuring an optimal matching between demand and supply for heat and cooling.

No new measures are planned to ensure the location of residential areas in accordance with thermal heat generation. The current regulation already provides municipalities with the potential to plan for residential areas through municipal heat plans and the adoption of local plans.

The Danish Planning Act (in Article 15(2)(11)) includes access for municipalities in connection with physical planning and via a local plan to ensure '*the provision of or connection to common installations either inside or outside the area covered by the plan as a condition for the use of new buildings*'. Therefore, the Act provides municipalities with the potential to determine that all new buildings must be connected to the district heating network in a local plan for a new residential area, such that the existing district heating supply is utilised. This potential has been used by a number of municipalities, although this is not compulsory. When the provision is used, this is typically in connection with the preparation of a local plan for a new area that has been zoned for housing through physical planning.

This provision supplements the potential of the Heat Supply Act to impose a connection obligation to district heating supplies for both new and existing buildings.

 (...) encourage thermal electricity generating installations, industrial plants producing waste heat, waste incineration plants and other waste-to-energy plants to be connected to the local district heating or cooling network.

In 2014, Denmark determined regulations under Article 14(5) of Directive 2012/27/EU to ensure that thermal and other industrial installations with a total thermal input of more than 20 MW perform costbenefit analyses in accordance with Annex IX of the Directive.

Similarly, the Danish Electricity Supply Act prescribes that cogeneration installations with a capacity of over 25 MW must have a licence for cogeneration. The licences contain a condition that the owner of the cogeneration installation must maintain the supply of heating to areas zoned for district heating in accordance with the Heat Supply Act. Cogeneration installations where there is a condition to supply district heating to zoned areas may only be closed down after permission has been granted by the Energy Agency. Such permission is only granted if an alternative supply can be established under reasonable financial and energy efficient conditions.

• (...) encourage residential zones and industrial plants which consume heat in their production processes to be connected to the local district heating or cooling network.

Municipal councils may order that buildings be connected to individual natural gas supplies or district heating. This connection obligation means that the supply company may demand a connection fee or a fixed annual charge; however, this does not lead to an obligation to draw energy from the collective installation.

#### 7.2 Primary energy savings

Assignment: (i) an estimate of the primary energy to be saved.

The method and results of the Scenario Analysis have been used in relation to the projection of the primary energy consumption in this analysis. As described in Chapter 3, the Scenario Analysis describes a number of different scenarios for the future energy system in Denmark, and at the same time describes the fuel consumption, level of self-sufficiency and gross energy consumption<sup>10</sup> associated with this.

| Scenario         | Wind   | Biomass | Bio+   | Hydrogen | Fossil |
|------------------|--------|---------|--------|----------|--------|
| Fuel             | 458 PJ | 526 PJ  | 631 PJ | 443 PJ   | 680 PJ |
| consumption      |        |         |        |          |        |
| Self-sufficiency | 74 %   | 68 %    | 57 %   | 77 %     | (*)    |
| Gross energy     | 594 PJ | 606 PJ  | 634 PJ | 590 PJ   | 653 PJ |
| consumption      |        |         |        |          |        |

Table 7.1. Key figures from the scenario calculations for 2035. (\*) is dependent on Danish fossil fuel generation in 2035.

| Scenario         | Wind   | Biomass | Bio+   | Hydrogen | Fossil |
|------------------|--------|---------|--------|----------|--------|
| Fuel             | 255 PJ | 443 PJ  | 710 PJ | 192 PJ   | 483 PJ |
| consumption      |        |         |        |          |        |
| Self-sufficiency | 104 %  | 79 %    | 58 %   | 116 %    | (*)    |
| Gross energy     | 575 PJ | 590 PJ  | 674 PJ | 562 PJ   | 546 PJ |
| consumption      |        |         |        |          |        |

Table 7.2. Key figures from the scenario calculations for 2050. (\*) is dependent on Danish fossil fuel generation in 2050.

Gross energy consumption was 784 PJ in Denmark in 2012. The following annual primary energy savings have been estimated, depending on the scenario realised:

| [PJ] | Wind | Biomass | Bio+ | Hydrogen | Fossil |
|------|------|---------|------|----------|--------|
| 2035 | 190  | 178     | 150  | 194      | 131    |
| 2050 | 209  | 194     | 110  | 222      | 238    |

Table 7.3. Primary energy savings in relation to 2012 (784 PJ).

The scenario that is realised (and therefore the size of the primary energy savings), will amongst other things be an issue of political priorities, the planning of which will take place in connection with the organisation of the Danish energy policy for the period following 2020.

#### 7.3 Support measures and impact assessment

**Assignment:** (*j*) an estimate of public support measures to heating and cooling, if any, with the annual budget and identification of the potential aid element. This does not prejudge a separate notification of the public support schemes for a State aid assessment.

<sup>&</sup>lt;sup>10</sup> Gross energy consumption describes the total input of primary energy into the energy system. The input of primary energy into the Danish energy system is a mixture of fuel and fuel-free energy in the form of wind, solar and geothermal.

# 7.3.1 Cogeneration support<sup>11</sup>

The PSO costs associated with environmentally friendly electricity generation during previous years are shown below in Table 1, divided into wind, biomass, etc. and decentralised cogeneration. Amongst other things, this shows that the PSO costs for high-efficiency decentralised cogeneration amounted to DKK 1.8 billion in 2014.

|               | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  |
|---------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Wind          | 1 665 | 678   | 1 227 | 1 140 | 1 482 | 2 232 | 3 103 | 4 084 |
| Biomass, etc. | 409   | 255   | 436   | 485   | 625   | 641   | 868   | 974   |
| Decentralised | 1 186 | 185   | 1 267 | 619   | 507   | 1 289 | 1 189 | 1 813 |
| cogeneration  |       |       |       |       |       |       |       |       |
| Total         | 3 260 | 1 119 | 2 931 | 2 244 | 2 613 | 4 161 | 5 160 | 6 870 |

Table 7.4. PSO costs for environmentally friendly electricity generation (DKK million).

A so-called electricity generation subsidy was previously paid for electricity produced at decentralised (high-efficiency) cogeneration installations with a 25 MW electricity capacity or less and waste-based cogeneration installations. These costs were financed through the Appropriations Act, and in previous years were as follows:

|                   | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013             | 2014 |
|-------------------|------|------|------|------|------|------|------------------|------|
| Natural gas-based | 100  | 129  | 104  | 92   | 108  | 109  | 51 <sup>12</sup> | -    |
| cogeneration      |      |      |      |      |      |      |                  |      |
| Waste-based       | 79   | 117  | 99   | 0    | -    | -    | -                | -    |
| cogeneration      |      |      |      |      |      |      |                  |      |
| Total             | 179  | 246  | 203  | 92   | 108  | 109  | 51               |      |
|                   |      |      |      |      |      |      |                  |      |

Table 7.5. Costs financed through the Appropriations Act for decentralised cogeneration (DKK million).

Support for waste-based cogeneration was abolished with effect from 1 January 2010.

The payments through the Appropriations Act for natural gas-based cogeneration were converted to the Basic Amount financed as PSO contributions with effect from 1 July 2013.

#### Heat pump initiative

The Danish Appropriations Act for 2015 includes a fund for DKK 27.5 million for the establishment and expansion of knowledge in the use of large electrically-driven heat pumps for district heating supplies.

<sup>&</sup>lt;sup>11</sup> Obtained from Danish reports pursuant to Article 6(3) and Article 10(2) of Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC (2011).

<sup>&</sup>lt;sup>12</sup> Covers the period January – June 2013.

# 8 References

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ENS [2014, b] Energy supplies in the period leading up to 2020, 2035 and 2050 (*Energiscenarier frem mod 2020, 2035 og 2050*), prepared by the Danish Energy Agency (*referred to as the Scenario Analysis*).

ENS [2014, c] Analysis of the Danish cooling potential (Analyse af det danske kølepotentiale), prepared for the Danish energy Agency by Rambøll et al. (referred to as the District Cooling Analysis) – unpublished.

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