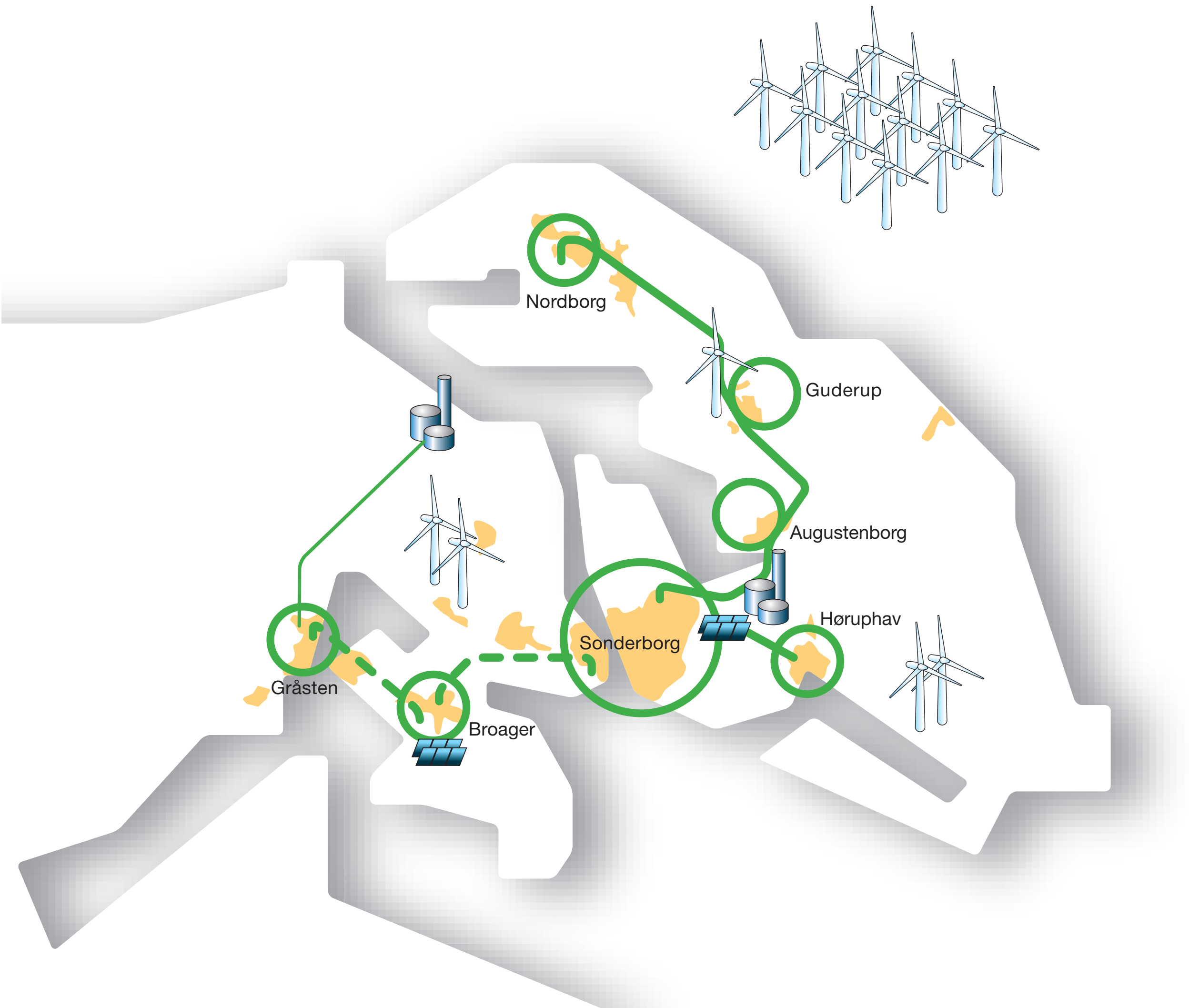
ProjectZero
Masterplan 2029

– for a CO_2-neutral Sonderborg-region



Bright Green Business
ProjectZero

November 2009

Master Plan 2029

ProjectZero for a CO_2 neutral Sonderborg area

This Master Plan has been completed by the consultancy **SRC International**, represented by Thorkild Kristensen and Kirsten Dyhr-Mikkelsen in cooperation with the Energy Plan Group and ProjectZero's Steering Group for the Master Plan process.

The Energy Plan Group consists of:

- Jesper Bang Andersen, DONG Energy
- Ole Damm, Enervision
- Torben Esbensen, Esbensen Rådgivende Ingeniører (Consulting Engineers)
- Lotte Gramkow, Project Zero A/S
- Jens Chr. Hansen, Danfoss
- Steen Kramer Jensen, Energinet.dk
- Vivian Krøll, Sonderborg Kommune (Municipality)
- Steffen Moe, Sonderborg Fjernvarme (District Heating)
- Morten Pindstrup, DONG Energy
- Helge Ørsted Pedersen, Ea Energianalyse
- Peter Rathje, Project Zero A/S

ProjectZero's Steering Group for the Master Plan process consists of:

- Torben Esbensen, Esbensen Rådgivende Ingeniører (Consulting Engineers)
- Lotte Gramkow, Project Zero A/S
- Vivian Krøll, Sonderborg Kommune (Municipality)
- Peter Rathje, Project Zero A/S

Introduction

ProjectZero is the vision of turning the Sonderborg area into a CO2 neutral area not later than 2029. For this purpose **the Master Plan 2029** has been prepared where the overall frames of the process have been defined. The gradual implementation of the Master Plan 2029 results in a number of individual Roadmaps.

The Master Plan 2029 has been prepared by the consultancy SRC International and the Energy Plan Group consisting of both local and external players aiming at utilizing external expertise and at the same time ensuring a real anchoring and endorsement of the identified opportunities and chosen strategies thus the future implementation will be encouraged in the best possible way. The Energy Plan Group was founded in April 2009 and has currently discussed relevant issues based on input from the consultant. Representatives from the ProjectZero secretariat have followed the work along the way and taken an active part in the process to ensure the synergy with relevant activities. Thorkild Kristensen, SRC International, acted as technical manager, and Kirsten Dyhr-Mikkelsen, Ea Energianalyse has acted as process manager.

The Energy Plan Group consists of:

- Jesper Bang Andersen, DONG Energy
- Ole Damm, Enervision
- Torben Esbensen, Esbensen Rådgivende Ingeniører (Consulting Engineers)
- Lotte Gramkow, Project Zero A/S
- Jens Chr. Hansen, Danfoss
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- Morten Pindstrup, DONG Energy
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The steering group for the Master Plan process is generally responsible for the decisions and options made concerning the Master Plan 2029. The steering group consisted of::

- Torben Esbensen, Esbensen Rådgivende Ingeniører (Consulting Engineers)
- Lotte Gramkow, Project Zero A/S
- Vivian Krøll, Sonderborg Kommune (Municipality)
- Peter Rathje, Project Zero A/S

The Master Plan 2029 data basis mainly originates from six task groups, and a demography and projection group. In parallel, Sonderborg Municipality, the local district heating plants and Rambøll have prepared a heating plan motion for the Sonderborg area that was released on November 11, 2009. When the Master Plan 2029 report was finalized, the motion had not yet been heard by the city council. The finally approved heating plan will be designated ”Varmeplan Sonderborg” (Heating plan Sonderborg).

The Steering Group for the Master Plan process and the Energy Plan Groups thank all participants for their engaged professional input.

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1 Summary and conclusions

ProjectZero is the vision of turning the Sonderborg area into a CO_2 neutral area no later than 2029.

The objective concerns the following CO2 emissions:

- CO_2 emission from energy related consumption within the municipal boundary including road traffic but excluding rail transport, sea carriage and air transport.

- The CO_2 content in energy that is imported/exported over the municipal boundary. RE (Renewable Energy) plants are included that are established outside the municipal boundary at the request of local stakeholders such as Sonderborg's own plants (e.g. offshore wind turbine at Pøls Reef).

Thus, the objective does not concern emission of climate gasses through non-energy related activities, and it does not include CO_2 emission from production of imported goods and there will be no deduction of CO_2 emission linked to export of goods.

The methodology is based on the production principle.

The ambition is to achieve a significant CO_2 reduction during the period 2010-2015 (phase 2 + 3) through an active involvement of citizens, educational institutions, industry and municipality, and that the Sonderborg area reaches a 25% CO_2 emission reduction in 2015 compared to the 2007 level. How to reach the CO_2 reduction has been described in the Roadmap 2010-2015 – see separate document.

Private and public players and stakeholders will join in realizing the vision and defining the scopes.

The realization will take place through 1) **substantial energy efficiency measures** and 2) **conversion of the energy supply** to renewable energy (RE). The key issue of a sustainable energy system is however 3) the transformation to a dynamic energy system.

Further to the CO_2 neutrality, ProjectZero also wants to contribute to maintaining and generating workplaces in the knowledge intensive industries.

The Master Plan 2029 presents the overall, long-term strategy for achieving the defined development targets for the Sonderborg area. The gradual implementation of the Master Plan 2029 results in a number of action plans where ”Roadmap 2010-2015” is the first one.

The Sonderborg Area

The Sonderborg area is the sixteenth largest municipality and holds approx. 77,000 inhabitants. Danfoss, one of Denmark’s largest industrial companies, has its headquarters and extensive production facilities in the Sonderborg area. The area also holds an extensive agriculture, focusing mainly on pig farming.

There is a tradition of active know-how dissemination, and through a number of years, Danfoss has been the driving force behind the establishment of sub-suppliers within production and processing in the metal, machinery, and electronic industry. The Sonderborg area has a strong mechatronics cluster, agriculture cluster and an extensive tile production.

The Sonderborg area is characterized by a diversity of educational institutions and a solid research environment with a good connection to the businesses and industry. Syddansk Universitet (University of Southern Denmark) with campus Alsion can be mentioned as one of the educational institutions. The learning project House of Science is an example of the area’s ambition of strengthening the connection between research, development and training with a concurrent science and nature theme from kindergarten to PhD.

Several parties are working on a Southern Danish Centre of Excellence/Cluster driven by the Sonderborg area that is focusing on energy efficiency (sub-section of Cleantech) where Southern Danish companies cooperate in developing climate friendly technologies and solutions.

The Background 2007

Today, the district heating supply in the Sonderborg area is based on natural gas and waste cogeneration. In areas without district heating, oil furnaces, natural gas furnaces and electricity for space heating and production of warm utility water are mainly used. In addition, there is a small amount of heat pumps and biomass furnaces installed.

The industrial manufacturing processes are based on fossil fuel and electricity, while the road transport is exclusively based on oil like in the rest of the country.

In 2007, the gross energy consumption amounted to approx. 2,822 GWh, and the related CO_2 emission was 674,000 tons corresponding to 8.8 tons CO_2 per year per inhabitant. The Danish Energy Agency has calculated the total Danish CO_2 emission per inhabitant to 9.7 tons in 2007 and 9.4 tons in 2008, however the total transport and not only road transport is included/Energy statistics 2008, Danish Energy Agency, 2009/. If sea carriage, rail transport and air transport are included in the calculation of the Sonderborg area's CO_2 emission, the emission will be 9.4 tons per inhabitant in 2007.

The two figures below show the allocation of the actual energy consumption and CO_2 emission on the application categories.

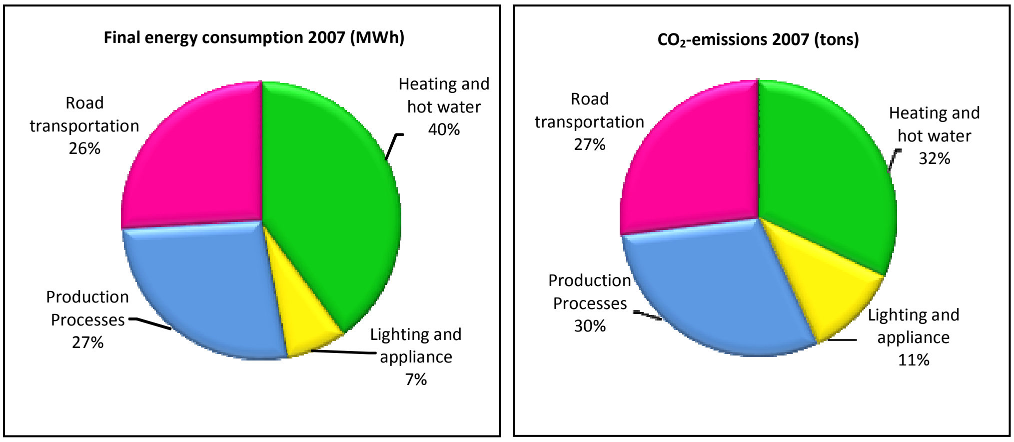

Figure 1: Final energy consumption and CO2 emission 2007 distributed on end user.

Vision and Guiding Stars

Sonderborg has chosen to follow three guiding stars in their effort to achieve CO_2 neutrality:

- Energy efficiency that reduces the area's sensitivity to increasing energy prices and strengthens the industries competitiveness.
- A multi-pronged robust energy supply based on local RE resources in effective interaction with external RE resources that ensures the supply security.
- A dynamic energy system that allows dynamic optimization of the interaction between consumption and supply, thus new market mechanisms will be exploited fully during the phase-in of the RE technologies.

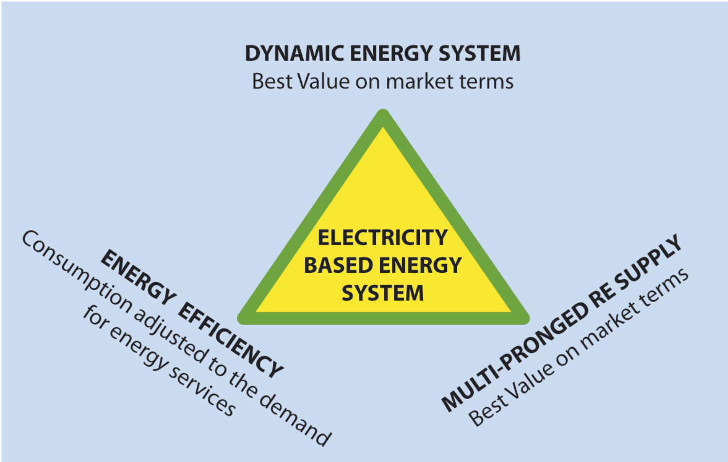

Figure 2: The three main guiding stars of the strategy.

A number of measures will be launched within each of the three guiding stars that contribute to achieving the long-term objective. Two underlying terms for the guiding stars are a continued increasing electrification of society concurrently with an increased expansion of wind turbines, see section 5.3, and that district heating based on RE continues to be a future-oriented sustainable energy solution

In order to achieve the 2029 goal, substantial energy efficiency in all segments is necessary coordinated with a strategic prioritized application of own RE resources. The Master Plan must ensure that overall considerations and long-term possibilities are not lost and that the phase-out of fossil fuel takes place in a targeted and coordinated way. The necessary overall coordinating initiatives within each guiding star are shown in *Figure 3*.

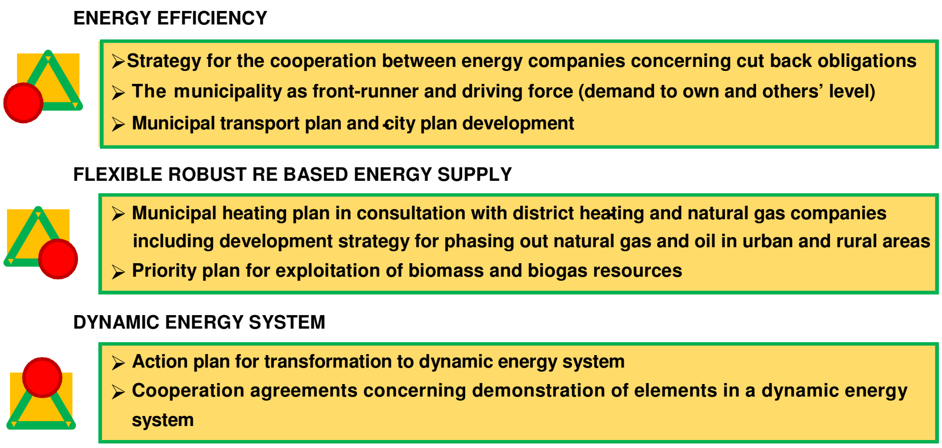

Figure 3: Overall coordinating initiatives for each of the three guiding stars.

The main strategies for each of the three guiding stars are as follows:

- Energy efficiency

   - Timing of messages and quotations, thus it coincides with the natural replacement, entails that the additional investment is minimized, and that it is easier make the consumers listen. E.g. when the refrigerator breaks down or the school needs to be renovated anyway. Thus the support from companies, shops, citizens and energy companies is ensured.
   - The municipality's energy efficiency must be a role model for the effort of the area's companies, shops, agriculture, citizens and institutions.
   - Realization of "easy" savings, but also the "difficult" savings such as energy renovation, industry and transport.
- Multi-pronged RE based energy supply
   - Municipal determined frames for the heating to be chosen:
      - City – District heating based on waste, geothermal energy, biogas, biomass, solar heat and heat pumps.
      - Rural areas – Heat pumps or biomass furnaces; both in combination with solar heat with water accumulator and heating elements.
   - Electricity supply based on cogeneration, wind, biomass and solar cells.
   - Fuel based on biogas and bio ethanol in the long term.

- Dynamic energy system
   - Exploitation of real time price signals – tariffs and taxes.
   - Extension of storage capacity and movable consumption.
   - Showroom with products, hardware and software technology in action and continued development.

Timetable

The plan period has been divided into seven phases. Thus, all the selected devices do not have to be deployed from the first phase. Some technologies must be refined and markets matured before they can be widely spread. Others must be settled quickly thus the Sonderborg area can reach the intermediate aim of a 25% CO_2 emission already in 2015 compared to the 2007 level. This is illustrated in *Figure 4*. The focus areas for the period 2010-2015 have been specified in the Roadmap 2010-2015. The listed focus areas in the subsequent periods must be considered suggestions to some possible focus areas. Research, development and tests are being carried through in a big number of exciting possibilities. Thus it is not suitable now to freeze the technology mix.

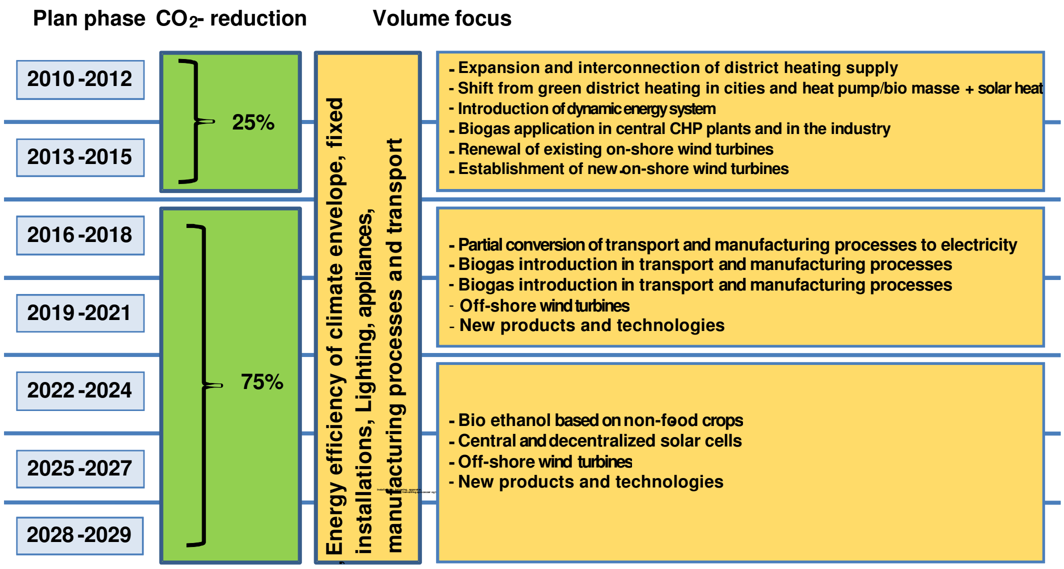

Figure 4: The big volumes distributed on the seven phases of the plan period.

During the two first phases (2010-2015), the following focus areas are expected to be the most effective focus areas:

- Expansion of the district heating systems and establishment of a transmission line from Sonderborg to Nordborg,
- Geothermal heat, solar heat, biogas and biomass in the district heating supply
- Switching from oil furnaces, natural gas furnaces and electric heating to district heating in the urban areas,
- Switching from oil furnaces, natural gas furnaces and electric heating to heat pumps or biomass furnaces combined with solar heat in the rural areas,
- The introduction of a dynamic energy system,
- Biogas application in central plants,
- Renewal of existing on-shore wind turbines, and
- Establishment of new on-shore wind turbines.

These focus areas will altogether contribute to prepare the Sonderborg area for a bigger incorporation of sustainable energy and new technologies both in terms of consumption and supply. i.e. making the system robust and flexible.

In 2012, status on the progress of initiated devices identified in the Roadmap 2010-2015 will be taken, thus the endeavors can be adjusted and new ones added as far as necessary to reach the 2015 goal. However, it might be relevant to take status earlier based on the experiences made with initiated devices, changes in the external frames such as a change in the energy tax system or the emergence of new technologies and products.

A status in 2015 must compare the objective for 2015 to what has actually been achieved, but also form the basis of an action plan for the coming period. The Energy Plan Group has formulated a suggestion on how the Sonderborg area can become CO_2 neutral in 2029 by using its own resources to the greatest extent possible. Thus the Master Plan 2029 features a suggestion on what fulfills this demand. **Those suggestions must however exclusively be considered as theoretical possibilities.** The actual focus areas and devices cannot be identified until further on in the process. It is essential that the endeavors initiated during the period 2010-2015 contribute to robustness and flexibility in the total energy system.

The Master Plan 2029 assumes that during the period 2016-2021 the following devices have had the biggest effect on the energy and CO_2 balance:

- Conversion of part of the consumption of fossil fuel in transport and manufacturing processes to electricity,
- Introduction of biogas in transport and manufacturing processes as a replacement for oil and natural gas,
- Establishment of central and decentralized solar cell panels,
- Establishment of off-shore wind turbines and
- New products and technologies.

During the last period (2022-2029), the Master Plan 2029 assumes that the following devices have the biggest effect on the energy and CO_2 balance:

- Conversion of part of the consumption of fossil fuel in district heating production, transport and manufacturing processes to bio ethanol as a result of an increased production of non-food produces,
- Establishment of central and decentralized solar cell panels,
- Establishment of off-shore wind turbines
- New products and technologies.

All through the plan period 2010-2029 there will be a continued effort to achieve energy efficiencies in all segments. The various elements and devices will vary over time but the strength and the effect will be even and strong. Examples of focus areas to be initiated already during the first phase 2010-2012 are:

- Energy demands for buildings in the Sonderborg area that are one or two classes higher than in the rest of the country.
- Demonstration of package solutions for energy renovation of the building envelope.
- Energy management, energy efficient planning and energy efficiency through production optimization. E.g. as quotation under the communication platform ZEROcompany.

- Energy efficient choice of lighting and electric appliances by means of support from the area's shops through the communication platform ZEROshop
- Tests with special energy saving taxes that increase the incentive to implement efficiencies.

Only the devices for the period 2010-2015 have been identified for the time being, just like the other two guiding stars (multi-pronged RE supply and dynamic energy system). By the end of period, a new action plan must identify actions to be initiated after 2015.

The vision for 2029 sees the Sonderborg area as leading in the field. These years, there is an ongoing global work for solving the issues concerning switching the energy systems to more dynamic systems. Sonderborg is in a unique position due to the business expertise and F&U competences within the area, and due to the dialog between municipality, companies, citizens and other players. Cleantech companies are present locally and can test different solutions in the community and create green jobs. Among other things, this is facilitated by remote read meters for both district heating and electricity that are already installed at the consumers and ready to come into play.

The Sonderborg area's traditions of cooperation between the business world, citizens and municipality – Private-Public Partnership – form also a strong fundament for solving the new challenges in the cooperation.

Thus the Sonderborg area has a unique platform that can be applied to demonstrate how various energy solutions function in practice. If the suggested devices are implemented, the Sonderborg area could function as a showroom for a dynamic energy system, and the Sonderborg area could have an active influence on the development of society both locally, nationally and internationally. Local initiatives and cooperation spread ever-widening circles to the advantage of the whole society.

Sonderborg 2029

The Sonderborg area wants to become pioneer in creating and testing dynamic energy systems that can utilize the energy markets' price signals optimally in proportion to the energy demand. This combined with considerable energy efficiencies and a 100% conversion to RE, can make the Sonderborg area CO_2 neutral not later than 2029. The profit for the area's citizens and companies is a better environment, new competences and new green jobs.

The vision is that till 2029, the Sonderborg area has had a considerable growth within the Cleantech business that is among the most future-proof workplaces. Through ProjectZero, the Sonderborg area has strengthened its profile as a green municipality with core competences within knowledge intensive businesses.

The local community is strengthened by the citizens' and business' active involvement in the realization of the Master Plan vision. Through proactive action, the Sonderborg area has been the front runner for a transformation of Denmark's total energy system and thus contributed to the fulfillment of Denmark's energy political goals. The Sonderborg area has contributed to maintaining Denmark's position as one of the leading countries within sustainable energy systems and participatory planning.

The final energy consumption in 2029 (1,434 GWh) is in the vision expected to be 45% lower than in 2007. See the allocation of applications in *Figure 5*.

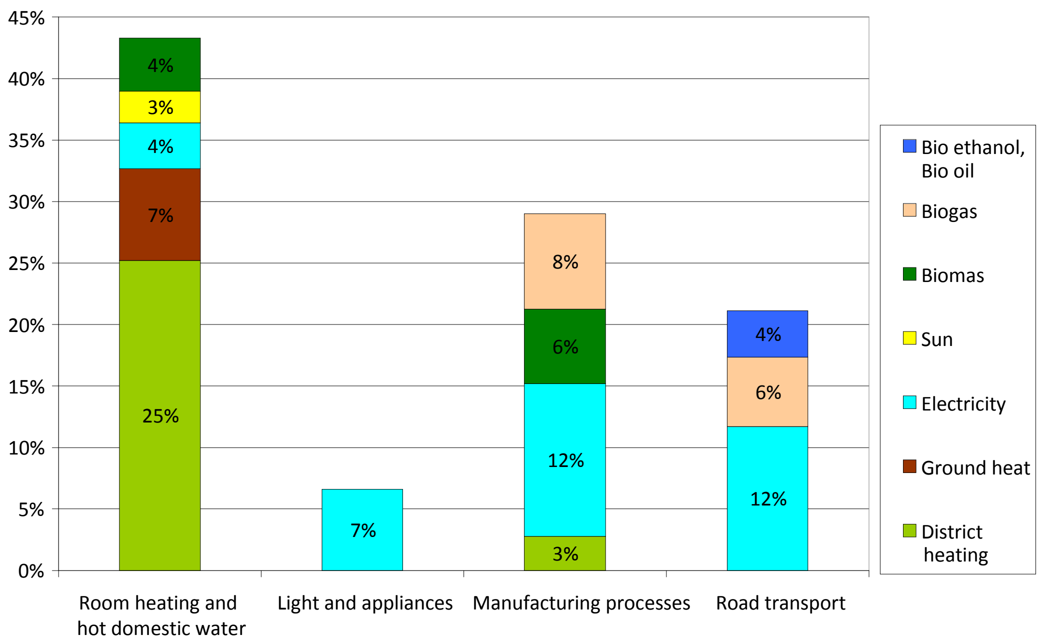

Figure 5: Allocation of the final energy consumption in 2029 calculated on end-consumption and energy types/Energy balance 2029/. The energy consumption for heat pumps is divided between two energy types - geothermal heat contribution and the electricity that powers the heat pumps.

The Master Plan assumes that the district heating is extended to cover 62% of the total net heat demand (see *Figure 6*). In 2029, the net heat demand is assumed to cover the following in the rural districts:

- 65% with individual heat pumps (hereof 1/3 electricity and 2/3 ambient heat).
- 20% with individual biomass furnaces e.g. wood pellet furnaces.
- 15% with solar heat as a supplement to the individual heat pumps and biomas furnaces

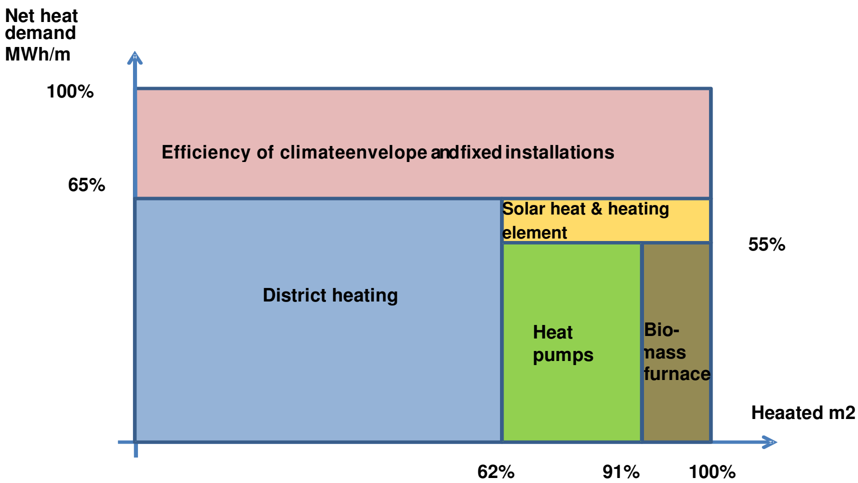

Figure 6: Expected coverage of the net heat demand in the Sonderborg area including Danfoss process /Energy balance 2029//Energibalance 2029/.

A transmission pipe between Sonderborg and Nordborg is assumed established with connection of all towns en route. The district heating systems in Gråsten and Broager are still assumed independent units however they can also be connected to the big transmission system with a view to gain a full-scale utilization of waste heat, geothermic, solar heat and heat from biogas-fired CHP plants – the choice will depend on concrete project estimations. The total district heat production in the municipality is expected to be allocated as shown in *Figure 7*.

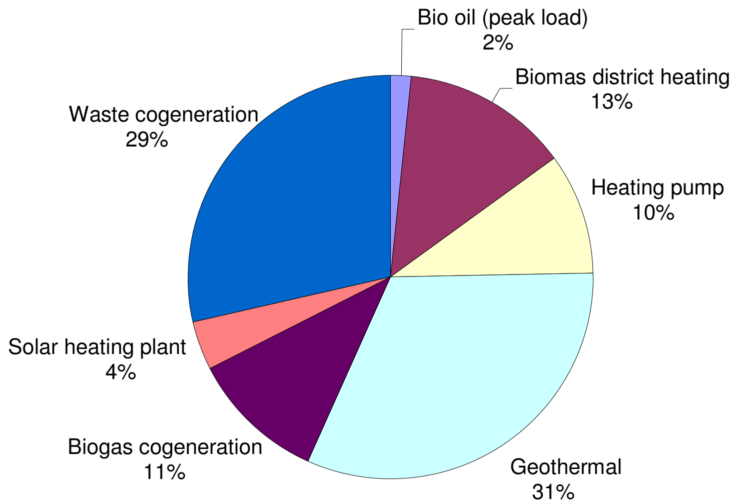

Figure 7: Expected fuel use for district heating production in the Sonderborg area, 2029.

The demand for energy for manufacturing processes and road transport is assumed covered by electricity, biomass, biogas or bio ethanol. The technologies in the Master Plan 2029 have been chosen with the goal in mind that the municipality's total biomass resources must be applied locally. Among other things, this implies that the Master Plan 2029 contains bio ethanol production in 2029.

It is of course uncertain whether such production will become reality or whether it will be more appropriate at that time to apply the resources in another way. Today, there are arguments on the appropriateness of the various technologies in the short run, and this uncertainty with regard to what will be optimal will of course not be less when the technologies are estimated in a 20-year perspective. The suggestion in the Master Plan 2029 must be seen as one of several possible mixes of fuel and technologies where all biomass resources in the municipality are used to cover the Sonderborg area's energy demand in a meaningful manner.

The gross energy consumption, where the final consumption of electricity and district heating has been converted to fuel consumption, has in the vision been reduced to 1,756 GWh in 2029, i.e. with 38% compared to 2007.

In 2029, the mix of energy resources has changed from a large part of fossil fuel to contain exclusively of local RE and import of CO_2 neutral electricity over the municipal border.

It is assumed that the electricity import is covered by off-shore wind turbines. Whether it is environmentally and financially beneficial to base the electricity import on production from production plants outside the municipal boarder or otherwise, depends on the interaction possibilities with the other electricity systems.

The local production and effective utilization of biomass are expected to increase considerably.

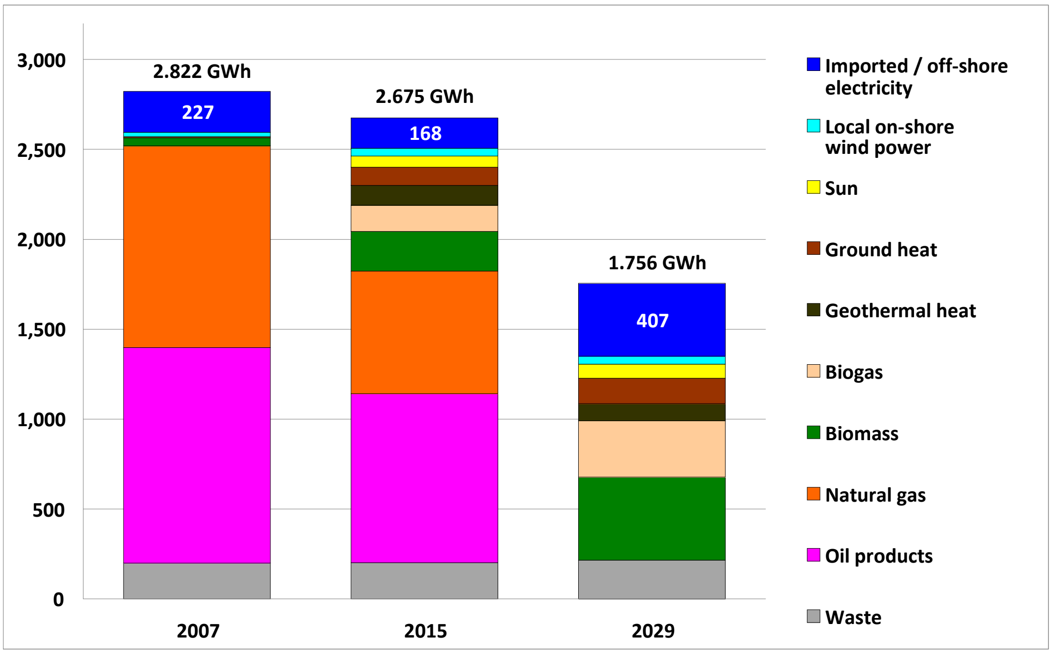

Figure 8: The change in application of energy type from 2007 to 2015 to 2029/Energy balance/.

The economy in the total Master Plan is evaluated by the STREAM model. It can be concluded that using IEA's fuel price forecasts from 2008, the costs in the Master Plan 2029 will generally be identical with the costs in the Reference. The Reference is defined as the physical situation in 2007 but by using the future fuel prices.

The Master Plan 2029 contains many elements. Some will be better than the Reference which is the case for most elements in the heating plan part while others will have a poorer economy than the Reference.

The individual choices of technologies will of course at that time be based on concrete project financial calculations which might imply that some of the elements will not be implemented as outlined in the Master Plan 2029.

Furthermore it must be stressed that the calculations contain a certain amount of uncertainty as the calculations are based on a relatively small physical system where 80% of the electricity is produced by wind turbines. In such a system, the remaining 20% of the current must principally be produced in plants with an effect that can cover the total electricity consumption on days without wind. This is unrealistic due to waste-fired co-generation and biogas-fired engine plants.

Thus it is assumed that plants outside the Sonderborg area will be able to cover the demand during hours where the local plants including wind turbines cannot deliver. The total annual electricity production from local plants must however correspond to the total annual consumption which means that part of the wind turbine current is assumed "stored" in the grid during windy periods and transformed back during windless periods.

”The storage” in the grid has in the Master Plan 2029 been minimized by introducing flexible consumption that can take current in case of a surplus in electricity from the wind turbine production in proportion to the inflexible electricity demands and that can be disconnected in case of electricity shortage in proportion to the inflexible electricity demands. It is about electric cars, individual heat pumps at the consumers and central heat pumps in the district heating system. All together the flexible electricity consumption amounts to 44% of the total electricity consumption in the Sonderborg area in 2029.

In the socio-economic calculations it is assumed that flexible electricity consumptions together with the exchange with the surroundings can ensure that the total annual production from wind turbines can be applied locally. The accordance between consumption and production on minute and hourly basis must be ensured through the establishment of a dynamic energy system that is specified in the Roadmap 2010-2015.

IEA expects in a future scenario that the CO_2 quota price in 2030 will be 110 USD/tons CO_2 corresponding to 640 DKK/ton. The actual CO_2 quota price is 100 DKK/ton, thus the future CO_2 bill with the existing energy system in the Sonderborg area will be 540 DKK/ton x 674,000 ton/year = 364M DKK/year, if the IEA scenario becomes reality.

For the evaluation of the Master Plan 2029, a CO_2 price of 640 DKK/ton has been applied – and of course this contributes to the conclusion that the costs are not bigger than in the Reference.

The key word for the Master Plan and the Sonderborg area's vision is *interaction*. It is through cooperation and dialogue that local and common strengths and resources are utilized in the best possible way. It is through common development and exchange of flexible and robust solutions that the common goal of a sustainable society can be realized. Thus local responsibility and changes in the Sonderborg area can contribute to encourage responsibility and changes in the rest of the world for mutual benefit.

2 Introduction

The current dependency on fossil fuel is not sustainable and conversions and energy efficiency measures are important in order avoid climate changes and dependency on imported energy, and to ensure continued economic growth both nationally and internationally.

The Government has appointed a Climate Commission in order to ensure the fulfillment of these goals. Prior to the end of 2010, the Climate Commission must suggest how Denmark can become CO_2 neutral in the long term.

ProjectZero is the vision of making the Sonderborg area CO_2 neutral not later than 2029. This is only possible if everybody pulls together: City council, municipal institutions, companies, educational institutions, energy companies, citizens etc.

The Master Plan 2029 is ProjectZero's best bid on the concrete activities that ought to be initiated thus the Sonderborg area can:

- realize its ambitious goal of CO_2 neutrality not later than 2029,
- assert itself among the front runners for a sustainable future and
- maintain and further develop its commercial positions of strength.

To a great extent, it is about finding a common ground by coordinating the efforts and utilizing the possibilities of cooperation thus the great perspectives are met and intermediate solutions are realized when possible. Furthermore, it will be necessary to develop and test new technologies. In the Master Plan it has been emphasized to stress the possibilities and the demand for interaction between relevant players seen in a time perspective – thus Sonderborg can realize the wanted activities and CO_2 savings within the wanted period.

2.1 ProjectZero

ProjectZero (PZ) is phrasing, anchoring and realizing the Sonderborg area's Master Plan.

The ProjectZero Secretariat drives the vision of CO_2 neutrality not later than 2029 through substantial energy efficiency measures, conversion of the energy supply to renewable energy (RE) and the establishment of a dynamic energy system. Further to CO_2 neutrality, the project expects also to maintain and create new workplaces within the Cleantech industries.

The ProjectZero Secretariat is anchored in the Project Zero Fund and the subsidiary Project Zero A/S. The composition of the boards can be seen in enclosure 1.

The Project Zero Fund was founded in spring 2008 with the support of Sonderborg Municipality, Bitten & Mads Clausen's Fund, SYD ENERGI, DONG Energy and the Nordea-Fund. Project Zero A/S is the operational company that drives the area's development towards CO_2 neutrality.

The specialty about the Sonderborg area's work towards CO_2 neutrality is the solid anchoring in the local industry and the cooperation between public and private companies (PPP – Private-Public Partnership).

2.2 The Master Plan's function

The Master Plan 2029 is the result of the cooperation between main players and stakeholders who jointly have defined a future vision for Sonderborg and the frames for the realization of this vision.

The function of the Master Plan is to maintain the vision and outline the overall long term strategy and guidelines for the work in order to achieve the jointly defined development goal for Sonderborg within the desired time frame. Thus, the Master Plan is a tool for all stakeholders and decision makers of the area that must ensure the maintenance of important values, and that critical choices are made in time thus the ambitious and visionary goal is achieved. The concrete gradual implementation of the Master Plan 2029 results in a number of Roadmaps of which Roadmap 2010-2015 is the first one.

The Roadmap 2010-2015 is an action plan that states the activities to be initiated in the short run to achieve a 25% CO_2 emission reduction in the Sonderborg area by 2015 in proportion to the starting point in 2007, and thus it will form an important working foundation for fulfilling the vision that has been set in the Master Plan 2029.

Thus the Master Plan outlines the overall and more general intentions and recommendations and identifies the main components in Sonderborg's development strategy, while the individual Roadmap gives a more detailed presentation of the individual devices and working phases – i.e. an action plan for a given number of years – and follows up on the general recommendations specified in the Master Plan.

At the same time, the Master Plan will act as a dialogue platform thus Sonderborg has a proactive impact on the development nationally and internationally. An example could be a dialogue concerning the work of the Climate Commission that must report to the

Government prior to the end of 2010 on how Denmark can become fossil-fuel-free (see more in section 5.3).

2.3 Work process of the Master Plan 2029

ProjectZero´s Master Plan process was initiated after preliminary considerations during autumn 2008 where a number of primary Danish consultants/experts were invited to a dialogue on the challenge.

In spring 2009, a number of local anchored work groups were established to handle the actual Master Plan work (see enclosure 2). This included the preparation of the Reference (baseline 2007) for the development of the Sonderborg area's CO_2 emission and catalogue of measures for buildings (including permanent installations and appliances), manufacturing processes, transport, agriculture, and RE (including waste). As part of the municipal heating plan work, the preparation of a proposal for a heating plan was commenced.

Figure 9 outlines the mutual relation between the documents of the Master Plan process including the proposal for a heating plan.

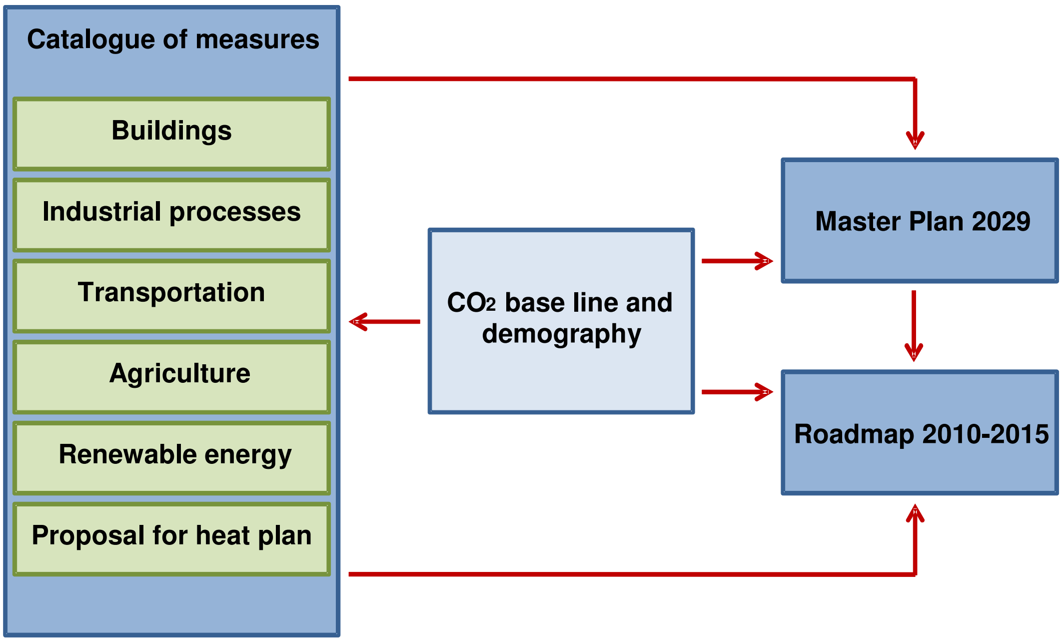

Figure 9: Sketch of the documents of the Master Plan process.

The devices that are planned to be launched in the plan period 2010-2015 can be divided into technical devices and implementation devices. The technical measures are the technical solutions that must be launched in order to achieve a 25% reduction in the CO_2 emission compared to the 2007 level. The implementation devices are the initiatives necessary to ensure interest and support in the technical devices. E.g. energy efficient renovation – energy renovation – of existing buildings is a technical device that must be supported by Sonderborg Municipality's decisions and campaigns and professional co-operation in order to ensure owners' of buildings support to offer and carry out energy efficient renovation.

The device groups also had to recommend a number of devices that all together could lead to a 25% reduction in the CO_2 emission in the Sonderborg area by 2015 compared to 2007. They are included in the Roadmap 2010-2015.

The Energy Plan Group has collected the contributions from each of the other work groups and the heating plan work, and analyzed them in a total context based on the recommendations of the groups. Fields that have not been covered by the other work groups have been handled by the Energy Plan Group. Thus, the Energy Plan Group has contributed cross-disciplinary elements such as overall considerations concerning a dynamic energy system and calculation of the consequences. The Energy Plan Group's work with the Master Plan 2029 and Roadmap 2010-2015 has concurrently been discussed with ProjectZero´s Steering Group for the Master Plan process. The Steering Group consists of Managing Director Torben Esbensen from Esbensen, Plan Manager Vivian Krøll from Sonderborg Municipality and Managing Director Peter Rathje and Project Manager Lotte Gramkow from Project Zero A/S.

Each work group consists of an external process consultant and one or two external technical consultants supplemented by an advisory group mainly consisting of local stakeholders (see enclosure 2). This combination aimed to utilize external expertise and to ensure real anchoring and support behind the identified devices and chosen strategies thus the later implementation was encouraged in the best possible way. Representatives from the ProjectZero Secretariat have taken part in all work groups in order to ensure synergy. The responsible for the management of the various work groups and the written material are presented in *Figure 10*.

CO_2 base line and forecast (the reference)		
Task Manager	Trine Hadrup Mikkelsen	Enervision
Buildngs including fixed installations and appliances		
Process Man.	Gert Johannesen	CREO Architects
Tech. Manager	Signe Antvorskov	Esbensen Rådgivende Ingeniører
Manufacturing processes		
Process Man.	Peter Maagøe Petersen	Viegand & Maagøe
Tech. Manager	Per Mikael Pedersen	Enervision
Transport		
Process Man.	Michael Aakjær Nielsen	Grontmij|Carl Bro
Tech. Manager	Hanne Hansen Wrisberg	Rambøll
Agriculture (resources and saving options)		
Process Man.	Peder Damgaard	Gråsten Landbrugsskole (Agricultural school)
Tech. Manager	Gert Schneider	Sloth Møller Rådgivende Ingeniører (Consulting
Tech. Manager	Jens Bo Holm-Nielsen	Center for Bioenergi, AAUE
Vedvarende energi (including waste)		
Process Man.	Ejvin Beuse	PlanEnergi
Tech. Manager	Per Alex Sørensen	PlanEnergi
Energy plan (Master Plan 2029 and Roadmap 2010-2015)		
Process Man.	Kirsten Dyhr-Mikkelsen	EA Energianalyse (EA Energy Analysis)
Tech. Manager	Thorkild Kristensen	SRCI

Figure 10: The process of the work groups and technical managers.

The preliminary work made by these work groups form the basis of the considerations behind the Master Plan work. The Master Plan describes the elements the Sonderborg area should bring into play in the short run and in the long run.

A follow-up on the Roadmap 2010-2015 and an evaluation of the progress of the initiated devices must, if necessary, take place again before 2015.

Status on the realization of the Master Plan progress will concurrently be taken in order to evaluate whether it is necessary to adjust the guiding stars. First planned status will take place in 2012 and repeated in 2015, 2018, 2021, 2025, and 2030. It might turn out to be necessary to take status at other times e.g. due to harvested experiences with initiated devices or changes in the outer frames such as alterations in energy taxes. Furthermore the catalogue of measures will be updated, if relevant.
The ProjectZero Secretariat is responsible for this process .

The socio-economic analyses of the device portfolio that must lead to a realization of the Master Plan's vision have been carried through by means of the model tool STREAM[a].

[a] Sustainable Technology Research and Energy Analysis Model, see http://www.tekno.dk/subpage.php3?article=1074&toppic=kategori7&language=dk

The STREAM tool was originally developed for the Technology Council's project "The Future Danish Energy System" and later on further developed as part of EU's technology estimation unit's (STOA) project "The future Energy Systems in Europe" in a cooperation between Technology Council, DTU/ RISØ, EA Energy Analysis, and European parliamentarians and representatives from the energy industry and professional organizations. This Excel based tool has originally been developed for inter-European scenario analyses that can expound how EU's goals on supply security and CO_2 reduction can be achieved in a cost effective way and give an understanding of the energy sector's challenges, barriers and possibilities´.[b] The model is included in the training at DTU (Technical University of Denmark).

The STREAM model which development has been partly financed by Bitten and Mads Clausens Fund among others can handle integrated scenario analyses of energy and CO_2 scenarios including the transport sector and contains basic data on country level.

2.4 Reading Guide

The Master Plan report starts with an introduction of the Master Plan's function and organizational setup in chapter 2 and a short presentation of the Sonderborg area in chapter 0.

There are a lot for interpretations of the term CO_2 neutrality, thus Sonderborg's definition has been described in detail in chapter 4.

The Master Plan takes an analysis of Sonderborg's situation in 2007 as the starting point. This has been reported in chapter 5 and an analysis of the outer frames: What happens nationally and internationally that can be relevant for Sonderborg's endeavors to achieve zero CO_2 (chapter 6).

Sonderborg's vision has in chapter 6 resulted in a future picture based on three overall guiding stars. One guiding star is the direction in which Sonderborg expects society to move in order to realize the goals.

Subsequently, the expected result of the Master Plan work is presented in chapter 8, namely the energy balance, the CO_2 balance for 2029, and in chapter 9 a socio-economic estimation of the Master Plan.

In the report the sources are outlined with slashes – /source/.

[b] www.streammodel.org

The ”Sonderborg area” and ”Sonderborg Municipality” refer to the geographical area covered by the city of Sonderborg while ”Sonderborg Municipality” refers to the municipality as a public company.

3 Sonderborg in brief

The Sonderborg area is after the latest municipality reform the sixteenth biggest municipality of a total of 98 municipalities and is included in Region Syddanmark (Sothern Denmark region). Sonderborg Municipality includes the former municipalities Augustenborg, Broager, Graasten, Nordborg, Sundeved, Sydals and Sonderborg.

The Sonderborg area holds some of the most beautiful natural resorts of the country with a stretch of coast of approx. 200 kilometers and vast forests, among others the forest around Graasten and Denmark's longest coastal forest on the eastside of Als (Nørreskoven). The area is 497 km^2 and geographically it covers the whole of Als and a radius of approx. 15 kilometers into Jylland /Municipal web/.

Figure 11: The Sonderborg area /municipal web/.

The Sonderborg area has approx. 76,800 citizens thus a population density of 154 citizens/km^2. The population figure is not expected to change very much during the period up to 2029. /Work group for CO2 base line and demography /. In the latest prognosis, Sonderborg Municipality expects approx. 1,400 new housings to be established during the period 2009-2021. 35% of the area's citizens live in the city of Sonderborg and 9% live in Nordborg. Approx. 12% live in the rural districts (defined as towns smaller than 200 inhabit-ants).

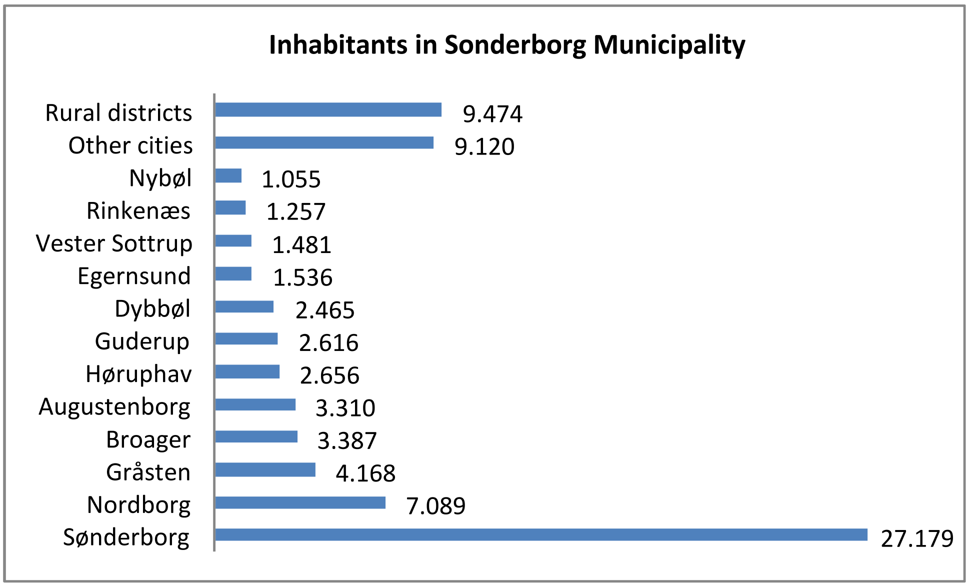

Figure 12: Population divided between cities in Sonderborg Municipality /Danmarks Statistik (Statistics Denmark)/.

The Sonderborg area has a dynamic business environment within high technology, machinery and food industry, and it has many educational institutions and dormitories. Campus Alsion, Syddansk Universitet (University of Southern Denmark) are situated in Sonderborg.

In 2003, the occupation in the businesses in the Sonderborg area was allocated as follows: 31% within industry, 30% within public service, and 17% within trade and service while 3% were employed in agriculture /Catalogue of measures for buildings/.

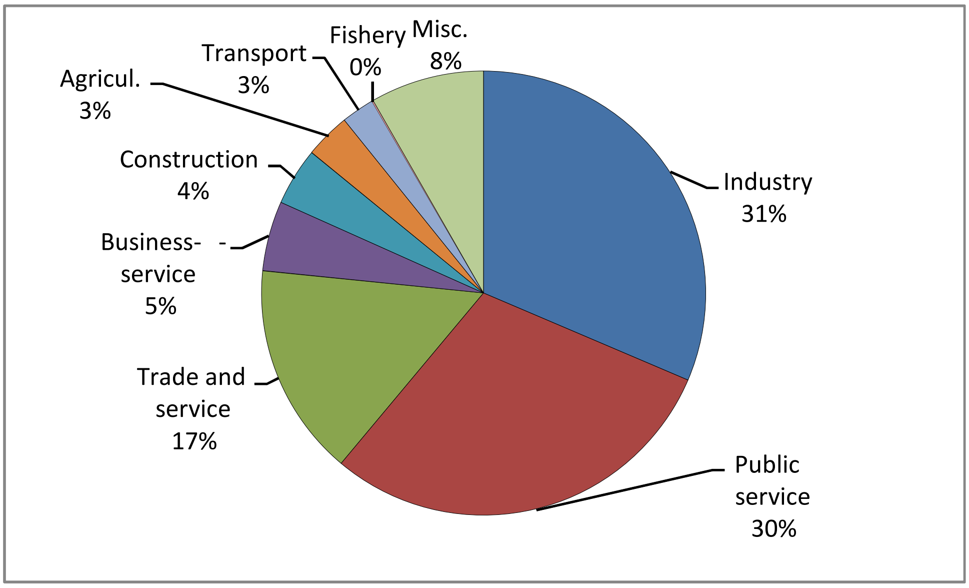

Figure 13: Allocation of businesses in the Sonderborg area/ National Association of Municipalities /.

The agricultural production is mainly based on pig production, and at the moment the pig stocks amount to 43,173 animal units corresponding to more than 2 million pigs /Catalogue of measures for agriculture/. The size of livestock farms and location are shown in *Figure 14*.

Danish Crown has a slaughter plant in Blans with approx. 725 employees who slaughter approx. 56,000 pigs/week /Danish Crown, October 2009/.

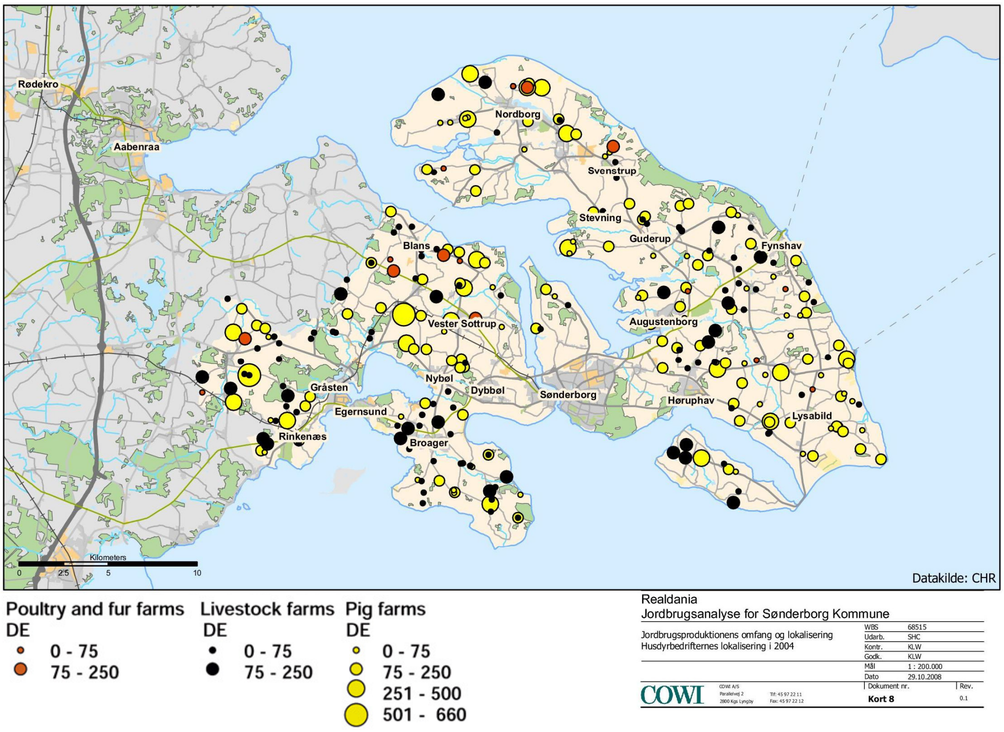

Figure 14: Livestock farms' location and sizes. /Catalogue of measures for agriculture/

A counting reveals a total of 234 industrial businesses in the Sonderborg area. These are allocated as shown in *Figure 15* / Catalogue of measures for process of production/.

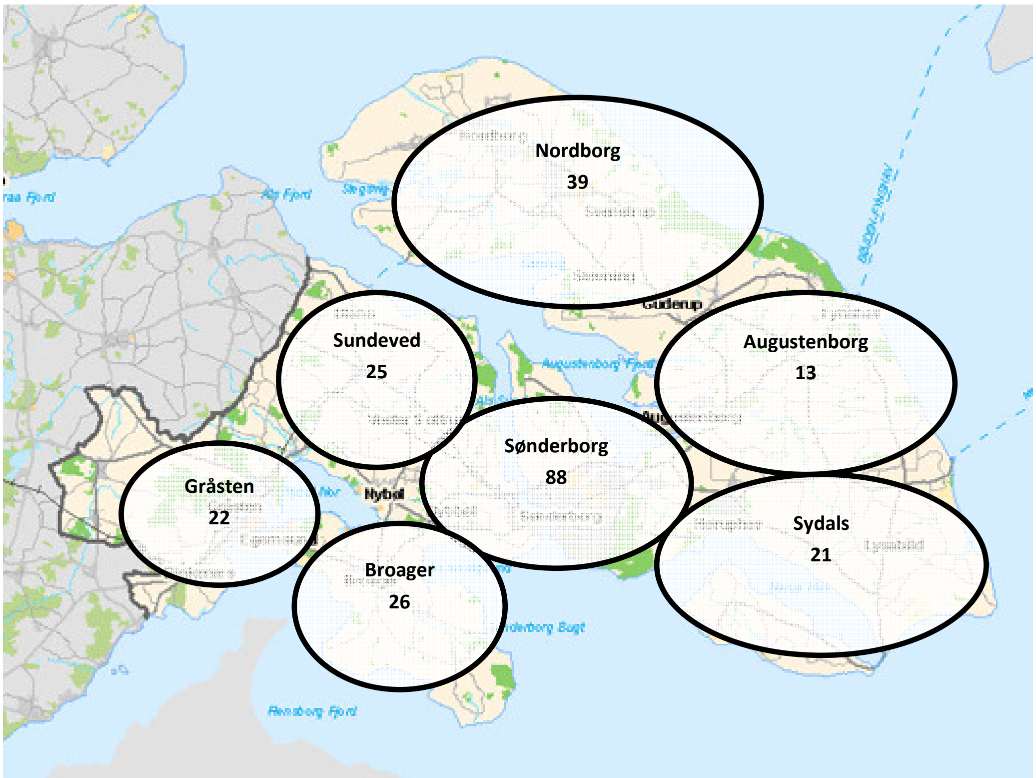

Figure 15: Geographical location of the 234 industries in the Sonderborg area /Catalogue of measures for processes of production /.

Historically, the business community in the Sonderborg area has been marked by Danfoss' activities way back to the 1930s. Danfoss has been instrumental in creating the basis for the establishment of smaller businesses as sub-suppliers to these industries. Thus, 133 businesses are today registered under the categories production and processing of metal, machinery industry and electronics industry. In addition to that there are businesses within food and tile works. Furthermore, Danfoss has worked actively with spreading know-how and offered good conditions for development and establishment of new businesses.

The Sonderborg area is characterized by a diversity of educational institutions and has a solid research environment with links to the business community such as Syddansk Universitet (University of Southern Denmark) located at Alsion. House of Science (HoS) is an example of a link between research, development and education – so to speak from Kindergarten to PhD. House of Science is a co-operation between Sonderborg Municipality, ProjectZero, the area's four upper secondary educational institutions and Danfoss Universe. The aim of the project is to create a strong learning environment that ties formal and informal educational opportunities effectively together with the business community. Competence development in a broad sense – from responsibility to professional core competences – is necessary to achieve the vision and it will create workplaces.

ProjectZero contributes in creating the demand-based basis that is necessary for the Sonderborg area to become a center of excellence and establish one or more clusters within Cleantech that is an overall term for the solutions and technologies that are necessary to solve the climate challenges. Energy and water saving equipment and green energy and water supply belong to Cleantech. The Sonderborg area has special competences within cooling, heating, lighting and process controlling that can be compounded in products leading to energy efficiency. Several of the area's businesses are involved in district heating, solar, heat pumps, solar cell and hydrogen technologies also called RE technologies.

Today, the public energy supply of the Sonderborg area is mainly based on natural gas and waste cogeneration supplemented by a minor part of on-shore wind and electricity import across the municipal boundary. Areas without district heating, natural gas and fuel oil are mainly used for heating production of hot water. Totally, the district heating coverage of the area is 34% of the net heating demand which is relatively low compared to the national average. Industrial processes of production are mainly based on fossil fuel and electricity while transportation, like in the rest of the country, is solely based on petrol and diesel oil. In Sonderborg, there is an unexploited potential for biomass and biogas utilization and waste heat from industrial processes. In addition to that solar heat and geothermal power could be utilized.

In terms of transport, the Sonderborg area is characterized by a big country oriented municipal where Sonderborg city is the center of gravity with Gråsten and Nordborg as the other urban anchor points.

There are two main roads from Sonderborg city to Aabenraa and Krusaa/Padborg. During the next 10 years, a new highway connection between the highway E45 near Kliplev to Sonderborg city is expected to be established. The aim is to increase accessibility between Sonderborg and the highway network and at the same time reduce the traffic congestion on the two existing westbound traffic corridors.

The Sonderborg area holds a large number of areas with bicycle tracks, and in the years to come focus will be on creating a bicycle network where the big bicycle and moped flow can be offered a good accessibility and safety. Sonderborg Municipality has prepared a bicycle route plan that defines the future bicycle route networks. In 2010, Sonderborg Municipality plans to prepare a bicycle action plan that describes the initiatives Sonderborg Municipality plans in order to promote bicycling in the Sonderborg area.

There are three ferry routes in the Sonderborg area; the Als route (Fynshav-Bøjden), the Ærø route (Mommark-Søby) and Hardeshøj-Ballebro (owned by Sonderborg

Municipality). In the near future, the Ærø route will stop the ferry ride to Mommark Harbor and instead move it to Fynshav ferry port. All three ferry routes have a huge local and regional impact.

The air traffic to the Sonderborg area is handled by Sonderborg Airport owned by Sonderborg Municipality.

Today, the airport is open for all types of aviation and is used both for scheduled flights, charter flights, private flights and helicopter service.

4 CO_2 Neutrality

There are several ways of settling Sonderborg's climate impact. Objectives assume clarification and principle determination of what ”zero CO_2” means. Must the greenhouse gases be included? Must all sources be taken into account? How is the exchange of goods and transport across the borders handled? How is the electricity import/export handled? Is it possible to buy indulgences for lacking reduction in the CO_2 emission?

4.1 Energy Related and Non-Energy Related Climate Impact

Greenhouse gases are a contributory factor in the global warming. Greenhouse gases include besides CO_2 also methane (CH4), nitrous oxide (NO2), hydro fluoric carbons (HFC gases), per fluorocarbons (PFC gases) and sulfur hexafluoride (SF6). For comparability all gases are often converted to CO_2 equivalents, where the gas impact on the atmosphere is taken into consideration as some are stronger than others.

In Sonderborg's Master Plan 2029 **only CO_2 from energy related purposes** are included due to a wish of focusing the effort on energy related devices and the possibility of acting as showroom for a dynamic energy system and relatively large energy savings through public-private-partnership.

Thus Sonderborg's Masterplan 2029 does not address methane from waste disposal sites and industry gases, and methane and nitrous oxide from agriculture. The emission from methane and nitrous oxide from agriculture is influenced by the size of pig production, the number of dairy cattle, feed efficiency, extraction of agricultural acreage, afforestation and biogas production.

Agriculture is important in terms of greenhouse gases. In Denmark, 24% of the greenhouse gas emission is calculated in CO_2 equivalents, non-energy related (see below *Table 1*). Sonderborg has a relatively large share of agriculture thus it might be assumed that Sonderborg's share in non-energy related emission is bigger than the national average.

Table 1: Danmark's greenhouse emission 2005 divided in sectors and sources (million tons CO2 equivalents) /Environment and economy 2009, The Economic Council, page 270/.

		Energy related CO_2	Non-energy related CO_2	Total	
Covered by quotas		**24.5**	**1.9**	**26.4**	*41%*
Electricity and heat production etc.		21.8	1.9		
Other industries		2.7			
Not covered by quotas		**23.7**	**13.6**	**37.3**	*59%*
Industry	Agriculture	3.5			
	Construction	0.7			
	Industry	1.0			
	Private service	0.7			
	Public service	0.7			
Households, heat		3.6			
Transport	Private cars (households)	5.8			
	Freight on road	5.3			
	Other transport	2.4			
Methane and nitrous oxide from agriculture			10.0		
Other greenhouse gas emission			3.6		
Total		**48.2**	**15.5**	**63.7**	*100%*
		76%	*24%*	*100%*	

4.2 Production Perspective or Consumption Perspective

In the Sonderborg Master Plan 2029 CO_2 statement, the same view on the CO_2 load has been taken as in the Kyoto agreement however the area has been limited to Sonderborg Municipality instead of the borders of Denmark. This is called a "production perspective" /IDA's Climate plan 2050, page 67/.

Thus the target of CO_2 neutrality includes **the direct energy consumption** but not the indirect energy consumption. I.e. that the consumption of energy for watching television is included but not the energy consumption of energy for producing TV sets if they are produced outside Sonderborg's borders.

Thus the energy consumption for **production** e.g. industrial processes of production is included in the CO_2 balance no matter whether the manufactured products are used in the Sonderborg area or outside the area.

The energy content in other goods sold is not included in the considerations in the Master Plan 2029.

There are no figures for the Sonderborg area's real transport consumption. Thus, the transport consumption is estimated based on data from Denmark's transport consumption. That means that the Sonderborg area's share of the transport consumption is estimated to correspond to the Sonderborg area's share of the total Danish population.

Taken into account that Sonderborg has a limited influence on shipping industry, train transport and air transport policies, these have been left out in the CO_2 balance and the CO_2 target. The statement in *Table 2* shows the importance of this decision. Road transport accounts for more than ¾ of both the energy consumption and the CO_2 emission of the total transport. The left out transport consumption accounts for approx.7% of Sonderborg's total CO_2 emission including all transport (see enclosure 4).

Table 2: Sonderborg's share of the total Danish transport estimated on the basis of the relative share of Denmark's population.

Transport	Energy source MWh						CO2 emission (tons)	
	JP2 (avgas)	Motor petrol	Diesel-/gas oil	Fuel oil, petroleum coke	Total			
Road transport		307.125	370.828		677.953	78%	179.501	78%
Rail transport			11.983		11.983	1%	3.192	1%
Domestic shipping			13.289	4.275	17.564	2%	4.741	2%
Domestic aviation	5.769				5.769	1%	1.495	1%
International aviation	146.187				146.187	17%	37.892	17%
Miitary transport	6.719		2.645		9.364	1%	2.446	1%
Final consumption for transport	**158.675**	**307.125**	**398.745**	**4.275**	**868.820**	100%	**229.267**	100%
	18%	35%	46%	0%	100%			

4.3 Sonderborg as Integrated Part of an International System

Sonderborg is part of a global community and is part of an internationally coherent system with mutual exchange of goods; among others also electricity, waste and biomass.

Firstly, Sonderborg will endeavour to utilize the possibilities within the geographical borders of Sonderborg Municipality. This reflects the wish of being a visible driving force in a development away from fossil fuel (front-runner) and not a wish of being independent of the other energy system (a "bubble"). A "bubble" perspective can lead to sub-optimization. An essential part of the solution on the environmental challenge can be found in the interaction with initiatives and development in society. A dynamic interaction with the rest of the country and Europe will lead to a better utilization of RE as the supply profile can be adapted to the demand in a better way.

This is reflected in the Master Plan and in the choices that will be made.

At the same time, Sonderborg wishes to take responsibility for its share of the global environmental impact caused by CO_2 emission from energy related purposes and not only export the problems (*Figure 16*). Energy efficiency measures that can lead to reduction in the energy consumption are an important element in the limitation of the CO_2 emission.

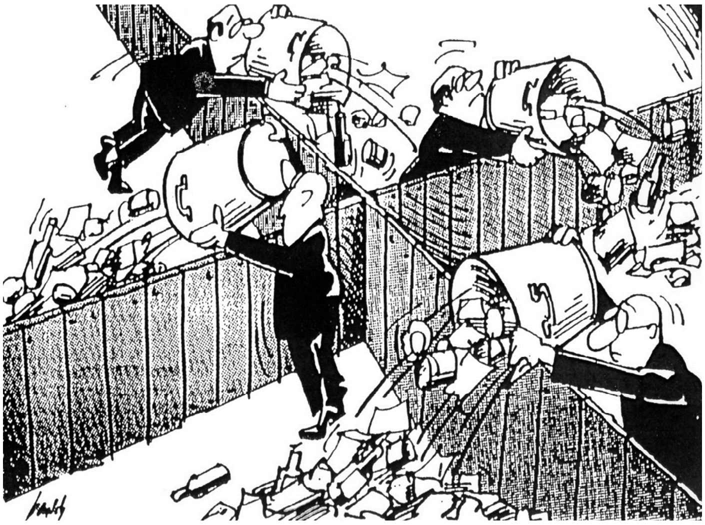

Figure 16: What went wrong? /Rabo Bank presentation, Paris, 2007/.

The CO_2 content in the external imposed energy resources are included in Sonderborg's CO_2 balance as mentioned in section 4.1., just like the CO_2 content in the export of energy has been included.

The content of CO_2 in electricity imported over the municipal border depends highly on conditions outside Sonderborg's influence. To the extent that there is a demand for net import over the municipal border, it is a goal for the Master Plan 2029 that the import is counterbalanced by initiatives organized by Sonderborg possibly outside Sonderborg's borders. These could include:

- Extraordinary **binding** of greenhouse gases, e.g. through establishment of forests or wetlands, extraction of drained ground of farming, reduction in nitrogen surplus in the agriculture, better feeding practices, increased amount of organic agriculture and different kinds of ”carbon-capture storage” (CCS) .
- Investments in **RE production outside the municipal border** such as wind turbine plants, biomass production etc. This does not lead to less CO_2 in the short run but it can in the long run if we assume that the next quota allocation is adjusted according to the possibilities of RE. However, it is important to ensure that purchase of ”green” current etc. actually leads to additional establishment of RE plants and not only leads to the establishment of smaller RE by other players.
- **Acquisition and destruction of** CO_2 **quota**. It will reduce the amount of quotas in the current quota period and thus increase the quota price and contribute to

increasing the share of RE ”here and now” (and not first in the next quota period).

The establishment of RE plants such as off-shore wind turbines near Sonderborg is given priority. Demonstration of a dynamic energy system, where the interaction between RE based supplies, energy consumption and the possibility of storage of energy is utilized in the best possible way, could lead to an adaptation of a higher share of RE in Sonderborg. It is also expected to be of value to the expansion of dynamic energy systems and RE in Denmark and the outside world.

Extraordinary binding of CO_2 is not precluded but has not been prioritized in the Master Plan right now for two reasons: firstly, Sonderborg wants to contribute to total avoidance of CO_2 emission secondly, the number of well tested binding possibilities is not sufficient.

Acquisition and destruction of CO_2 quotas also have low priority.

The text box below summarizes in brief how the CO_2 balance for Sonderborg is defined.

The CO_2 reference:

- The calculated CO_2 emission in 2007.

The CO_2 reduction goal includes:

- CO_2 emission from energy related purposes outside the municipal border including road transport.
- The CO_2 content in energy imported/exported over the municipal border. By request of the Sonderborg area, RE plants established outside the municipal border are included as own plants (e.g. off-shore wind turbines).

The CO_2 reduction goal does not include:

- CO_2 emission from rail and sea transport and aviation.
- The CO_2 content in imported goods.
- CO_2 emission from non-energy related purposes.

Figure 17: CO2 emission from non-energy related purposes.

5 Frames – Challenges and Possibilities

The climate targets are the overall challenge in the decades to come. At all levels – internationally, nationally and locally – focus is on how supply systems and energy consumption can be adapted to meet the global warming (see *Figure 18*). But also energy political subjects such as security of supply and financial growth will be central issues in the years to come.

Efforts must be made at several levels and it is the interaction between a number of actions that altogether can ensure that the energy political objectives are achieved. A common EU minimum standard can e.g. lead to a limited electricity consumption of refrigerators and a common EU labeling may facilitate the consumers in evaluating the energy quality of the refrigerators; however national and local efforts ensure that energy efficient refrigerators are available in the stores and that the sellers support their customers in choosing energy efficient products.

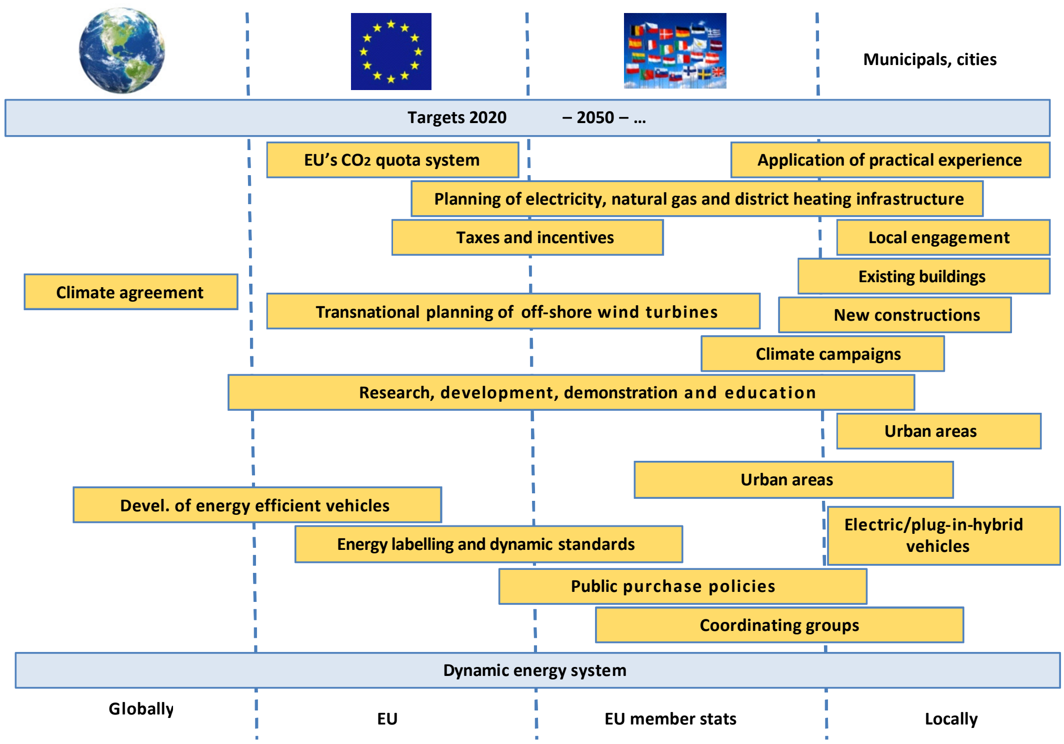

Figure 18: Examples of interaction level internationally, nationally and locally concerning eco-friendly development of energy system and energy consumption.

In the same way, a fully dynamic energy system in Denmark cannot be fully utilized if the transmission network to our neighboring countries is not sufficiently expanded to allow exchange with the Norwegian and Swedish CHP plants (combined heat and power plants). In the future energy systems there will be a demand for a wide range of different energy storage technologies thus the naturally given fluctuations in the energy production from wind and sun can be coped with. These storage technologies must be developed through international research and development and local entrepreneurship.

5.1 International Objectives and Initiatives

Work is ongoing internationally to reach a long-term agreement at the climate conference COP15 in Copenhagen in December 2009 that also includes the world's big emitters of greenhouse gases. This will be a big step forward in combating climate changes – and it will have an impact on the future frames for new initiatives both at international, national and local level.

During the last years, the EU has been a very active player in the energy and climate policy and this development is assumed to continue.

In April 2009, The European Council passed a climate and energy package that implies a number of binding targets for the EU in general up to 2020:

- 20% reduction of greenhouse gas emissions,
- 20% RE in the EU's total energy consumption,
- 20% less energy consumption through energy efficiency measures,
- 10% RE in each Member State's transport energy consumption.

In everyday speech these targets are called ”20-20-20 targets”.

The package also determines the initiatives agreed upon in EU with a view to achieve the common targets for 2020. Among other things, the package contains a new RE directive with binding targets, a revised quota trading system, decision on a 10% reduction of the greenhouse gas emissions in the sectors not covered by quotas, a directive on CO_2 accumulation and storage in the underground. According to the RE directive, the countries must present national action plans for RE not later than mid 2010.

Obviously, comprehensive and long-term efforts are necessary to combat the climate changes. There is an increasing focus on which binding targets must be established after 2020. The EU's ambition is to reach a reduction of 60-80% of the total European greenhouse gas emissions in 2050. This will take place as the available knowledge of the consequences of global warming becomes more specific.

Besides the climate and energy package, the EU has taken a number of initiatives to encourage energy savings and energy efficiency measures, among others the determination of minimum demands for the energy efficiency of products, advance the utilization of cogeneration, district heating, cooling etc.

CO_2 quota trade system in the EU

The EU has established a trade system for CO_2 quotas to make the value of environmental impact from CO_2 emission visible, and to help ensure that the most polluting energy production plants are taken out of operation first.

The EU's CO_2 quota trade system must ensure a cost effective CO2 reduction within *the quota-regulated market*.

Players within the quota-regulated market will get a certain amount of CO2 for a given period. The purpose is that the allocated amount of quotas will be reduced for each new period. Electricity and district heating will be produced at quota-regulated plants. Allocation of fewer quotas in 2012-20 will lead to higher CO2 quota prices thus RE (and energy efficiency measures) will be in a better competitive position.

Thus the emission in the EU will not be reduced if e.g. Gråsten District Heating changes from fossil fuel to RE in 2010 as the amount of quotas does not change within the current quota period. However, this only lasts on the short run. A reduction of the consumption of energy can in the long term contribute to the fact that a lower quota allocation becomes politically possible in the next period.

The quota-regulated market contains the following types of industries:

- Electricity and heat-producing plants of 20 MW thermal effect and above.
- Energy-producing industrial plants of 20 MW thermal effect and above however not energy production from waste.
- Refineries and coke plants.
- Industries within production and ferrous metals processing above a certain size.
- Concrete, glass and tile companies above a certain size.
- Paper and cardboard industries above a certain size.
- As of January 1, 2012 also aircraft operators.

For Sonderborg's part, 11 companies are covered by the quota regulation. These companies are shown in below *Table 3*.

Table 3: Allocated quota in the Sonderborg area during the 5-year period 2008-2012 (tons CO2 equivalents).

Quota companies	Amount	Share
Gråsten District Heating	66,441	*8.2%*
Broager District Heating	52,995	*6.6%*
Sonderborg District Heating	5,404	*0.7%*
Sonderborg CHP plant	363,123	*45.0%*
Total energy supply	**487,963**	***60.5%***
Gråsten Teglværk (tileworks)	20,616	*2.6%*
Petersen Tegl Egernsund (tileworks)	48,499	*6.0%*
Tychsens Teglværk (tileworks)	20,513	*2.5%*
Carl Matzens Teglværker (tileworks)	22,423	*2.8%*
Bachmanns Teglværk (tileworks)	24,701	*3.1%*
Vesterled Teglværk (tileworks)	58,027	*7.2%*
Total tileworks	**194,779**	***24.1%***
Danfoss	124,325	*15.4%*
Total	**807,067**	***100.0%***

The common energy system

The climate challenges and the consideration for the supply security imply a great political wish for giving RE a more central position in the energy system in the years to come. Politically goals have been set for the total share of RE in 2012 and 2020. According to the proposal for burden sharing in the RE directive from the EU Commission, Denmark must be supplied by 30% RE in 2020. Thus RE cannot be considered a supplement to the conventional energy production any longer but as a main source that must be adapted to ensure the continuous functioning of the system.

However, today's energy system is very much based on a 20th century technology, planned and built-up prior to the invention of the microprocessor. This implies limitations in the flexibility and potentially implies problems in terms of environmental safety, supply security and safety in general.

This calls for reconstruction of the energy system from a past centralized manufacturing controlled system to a decentralized and more consumer interactive system. The reconstruction will involve energy producers, supply companies, producers of equipment, and suppliers of energy services, installers, consumers, controllers, and other authorities.

For Energinet.dk the operation becomes more and more comprehensive and complex. A great number of fluctuating and distributed electricity productions must be adapted in the system and the efficiency in both production and consumption is increased in the total system and losses reduced. This requires new technologies and communication in the system. This is called **a dynamic energy system**.

The development of the dynamic energy system is a task that has been compared to the establishment of the national and international freeway systems in the last century and the development of the Internet during the last decades.

Denmark is not the only country facing this challenge, and there is a great commercial export potential for the regions that are on the forefront in the endeavors.

5.2 National Objectives and Initiatives

In its energy political statement 2009 to the national parliament of Denmark, the government describes the objectives and visions of the climate and energy policy in Denmark as follows:

The Vision

- 100% independent of fossil fuels.

International binding objectives

- 30% RE in the final energy consumption in 2020, 10% RE in transport.
- 20% reduction in 2020 in non-quota greenhouse gas emissions compared to 2005.
- 21% reduction of greenhouse gas emissions on average during the period 2008 – 2012 compared to 1990 (Kyoto).

National objectives

- 20% RE in the gross energy consumption in 2011.
- Annual energy savings of 1.5% of the final energy consumption in 2006.
- 4% reduction in the gross energy consumption in 2020 compared to 2006.

Figure 19: The energy and climate vision of the Danish Government /Energy political statement 2009/.

As appears from the statement, new energy and climate political initiatives are necessary in Denmark in order to reach the objectives of RE share and reduction in the gross energy consumption. According to the latest forecasting from the Danish Energy Agency, 2% is missing to reach the objective of 30% RE in the gross energy consumption in 2020 and with the current initiatives only half the objective of a 4% reduction in the gross energy consumption in 2020 will be reached.

The Government has appointed a national Climate Commission based on the vision of a fossil fuel free Denmark that prior to the end of 2010 must suggest how Denmark in the long run can liberate itself from the dependence of fossil fuel. Among other things, the commission must suggest coherent energy systems that ensure improved energy efficiency, reduced energy consumption, an increased share of RE, and that increase the competition in the energy markets. Furthermore, the government has announced that –

within the current election period – based on the report of the Climate Commission – specific proposals on when and how Denmark will be fossil fuel independent will be presented.

Among the most important initiatives already initiated to reach the objectives are:

- **the energy agreement** from February 2008 that improves the frames for expanding with RE and increases the energy saving liabilities of the energy companies,
- **tax reform**, that increases energy and environmental taxes and
- **the strategy for reduction of the energy consumption** in new buildings. The requirements to the energy consumption in new buildings are suggested to be tightened with 25% in 2010 and 57% in 2015 combined with a factor for district heating of 0.8.

The expansion of district heating in the form of power plant heat is emphasized in the government's Energy political statement 2009 as an essential reason for the Danish energy political success, just like the district heating is mentioned as a key player in the development of the green growth community. The conversion from individual natural gas supply to district heating is in some cases socio-economically beneficial and promote-worthy. In January 2009, The Minister for Climate and Energy has encouraged the municipalities to initiate projects for this conversion. The utilization of big heat pumps in the district heating supply is examined right now.

According to the Energy political statement, the biomass including biodegradable waste in Denmark amounts today to ¾ of the RE share of the energy consumption. According to the statement, only approx. half of the Danish biomass resources are utilized. An international market is building up for biomass and especially wood pellets and industrial waste.

The government expects that the termination of rest-in-itself regulations for the power plants' waste incineration will make it more attractive for the power plants to replace coal with waste which would reduce the amount of waste that is sent to the dedicated waste incineration plants.

Finally, the government considers the utilization of geothermic in the heat supply as a great potential. The Ministry of Climate and Energy has just prepared a statement on geothermic that expounds the potential, socio-economics, barriers etc. /Geothermic heat from the interior of the Earth, October 2009/.

According to the National Association of Municipalities, the legislation on the municipal heat plans is expected to fall into place in 2010, thus the municipalities must have the plans ready in the next municipal plan period. Cooperation across the municipal borders, holistic thinking and long-term thinking by the municipalities will be highly emphasized.

In the government's green transport policy from January 2009, focus is on reduction of the CO_2 emission from transport by letting the public transport perform most of the future growth in traffic and encourage bicycle transport. The energy agreement from 2008 implied that electric and hydrogen cars were exempted from taxes up to 2012, and that a pool of 35M DKK was allocated to a pilot project for electric cars during the period 2008-2012./Catalogue of measures for transport/

5.3 Danish Visions/Future Images

During these years, work is ongoing from several sides to develop long-term strategies for future energy systems. Four strategies will be presented in brief below that have been published by the Danish energy industry, the Danish system operator, the research environment, and the Danish engineering association.

Danish Energy – CO2 neutral energy system in 2050 (June 2009)

Danish Energy has with its vision ”Power to the people”, June 2009 prepared scenarios for an energy system that is CO_2 neutral in 2050. The objective of the vision is that the emission of greenhouse gasses must be reduced thus the total CO_2 emission in Denmark is zero in 2050, and that Denmark's security of supply must be increased with a reduction of the dependence on imported oil and gas.

According to Danish Energy, it can be implemented through an efficient energy market, and by an electricity share that is increased from 20% of the energy consumption to more than 50%. Danish Energy's 2050 scenario shows how the future can be with technology solutions such as electric cars, heat pumps, application of electricity in the industry, application of biogas from agriculture and CO_2 storage (CCS = Carbon Capture Storage). Further to this are massive energy efficiency measures and energy savings.

Energinet.dk – integration of wind power (March 2009)

In the report "Effective application of wind power-based electricity in Denmark", March 2009, Energinet.dk has described the challenge of integrating huge amounts of wind power in the electric system, primary with focus on balancing the system. In the report it is emphasize that electrically based solutions are very energy effective and RE electricity can be effectively and flexibly transformed in both the heating and transport sector with regard to heat pumps and electric cars. This requires a development of a dynamic interaction between the electric system, heat pumps and electric cars. Electricity meters with two-way communication are prerequisite.

Furthermore, the report suggests an extension of exchange links, strengthening of the network, and geographical spreading of offshore wind turbine farms, flexible electricity production and consumption, and in the long run electricity storage as well as application of hydrogen in the transport sector and gas network as possible devices.

IDA's Climate plan 2050 (August 2009) (IDA = The Danish Society of Engineers)

IDA's Climate plan 2050 is part of the international climate project ”Future Climate – Engineering solutions”, where engineering organizations from 12 countries work on developing national climate plans and other initiatives that can contribute to reducing the emission of greenhouse gases.

IDA's Climate plan 2050 describes how Denmark can reduce the emission of greenhouse gases by 90% during the first part of the 21st Century. The socio-economic calculations show that a conversion of the energy supply will imply savings of 13bn DKK already in 2015. Hereafter the savings will increase up until 2050 thus the savings will reach 25bn DKK per year.

IDA's Climate plan 2050 contains nine central recommendations that reflect an offensive strategy where society through large investments adapts and future-proofs the Danish energy and infrastructure. The strategy is based on a number of different devices with focus on increased demands, innovation and market development and knowledge building.

Examples of suggested changes in the energy consumption and energy supply are:

- Wind turbines deliver 70% of the total electricity.
- The remaining 30% comes from biogas (15%), solar energy (10%) and wave energy (5 %).
- The district heating supply is expanded, fuel cells and heat pumps (both based on wind energy) deliver heat.
- The energy consumption in the business world and housing and property lot is reduced by half before 2050.
- The business world must reduce its energy consumption by 30% before 2015. New financial incentives and guidance on energy savings must encourage the development.

Research and development strategy for biogas (August 2009)

In the research strategy for biogas from August 2009, the trade association for Biogas, EUDP and Energinet.dk have suggested focus areas where there is a primary demand for development:

- Biogas plants only based on manure – focus on concentration of liquid manure and fibres.
- Operational economic optimisation - minimisation of costs per m3 processed biomass.
- Gas yield optimization and minimization of residual methane emission from de-gassed liquid manure.
- Preliminary processing and opening of manure fibres and plant material to in-crease the gas production.
- Process understanding and operational process optimization – monitoring, con-trolling and regulation.
- Models for optimal adaption of biogas in the future energy system e.g. by inte-gration of the electricity and gas sectors.

5.4 Local and Regional Political Objectives and Initiatives

Setting objectives and launching new initiatives to future-proof the Danish energy sys-tem must not only be done centrally. Regions, municipalities, cities, industries and popu-lation are actively engaged in the work. Below, the objectives of Sonderborg Municipali-ty and Syddansk Vækstforum (Southern Danish Growth Forum) are presented.

Sonderborg Municipality – Energy Policy and Energy Strategy (March 2008)

Sonderborg Municipality's "Energy policy and energy strategy, 2008" outlines the vision that the Sonderborg area must be CO_2 neutral not later than 2029. Already in 2009, the municipal energy consumption must be reduced by 20% compared to 2007, and the energy consumption in the households, industries and the municipal business in the area must be reduced by half in 2020 compared to 2007.

The efforts necessary for reaching these objectives are described for the following areas:

- **Municipal business,** where a large number of initiatives within the municipali-ty's own buildings, institutions, procurement and transport are carried through;
- **Urban and municipality structure,** where focus is on energy efficient urban structure, architecture, and green areas;
- **Construction,** where low energy buildings, class 1 for both municipal and pri-vate new constructions were a demand already in 2008;
- **Transport and infrastructure** with initiatives for minimization of transport de-mand and optimization of transport, car-pooling, focus on vulnerable road us-

ers, collective transport and estimation of possibilities of loading stations for electric cars;

- **Industry and agriculture,** where the scene is set for supporting energy saving initiatives and public-private partnerships, and cooperation on the establishment of biogas plants;
- **Energy resources and recycling** with possible application of bio fuel in the energy production and cooperate with Danfoss on micro cogeneration plants;
- **Tourism and leisure** with focus on CO_2 neutral holidays offers and energy tourism; and
- **Education** with focus on science subjects and events on science and hydrogen technology.

For more information about objectives and activities for the municipal business (item 1) see section 7.4.

Syddansk Vækstforum (Southern Danish Growth Forum)

Syddansk Vækstforum is an industrial political cooperation between businesses, knowledge and educational institutions, labor market's partners, the municipality of the region and Region Syddanmark. According to the Action Plan 2009-2010 of Syddansk Vækstforum, the objective - up to 2012 within the energy area in the region - is a 10% higher value increment within off-shore, energy systems and mechatronics that are strengths in the region, and a 50% increased energy efficiency in the garden centers through development and implementation of new technologies.

ProjectZero Initiatives and ZERO Communication Platforms

The ProjectZero Secretariat has launched a number of communication platforms that aim at getting businesses and private citizens to communicate and visualize their efforts in contributing to a CO_2 neutral future:

- **ZEROfamily** – More than 100 families who are working on reducing the family's CO_2 emission by changing habits. The families are front runners who show the way to the rest of the Sonderborg area's families. The ProjectZero Secretariat supports the families with activities and tools and by the end of 2009 the most spirited family will be rewarded.

- **ZEROcompany** – Businesses lead the way in the work of making Sonderborg CO_2 neutral not later than 2029, so-called front runners. The companies have made an ambitious and measurable climate strategy aiming at reducing the CO_2 emission by minimum 10% within the first year. The ProjectZero Secretariat supports the companies with a branding package and an involvement package; access to ProjectZero arrangements and offer for a learning process.

- **ZEROambassador –** The ambassadors must be instrumental in showing the rest of Denmark that Sonderborg has the empowerment to create the new intelligent climate solution necessary for both the Sonderborg area and globally. The ambassadors must initiate two activities during one year and send a description of why they support the ProjectZero vision, how and the objectives. The ProjectZero Secretariat supports the ambassadors with a branding package, a leaflet to the employees, a catalog of measures and a workshop free of charge.
- **ZEROshop –** The shops must be display windows for the Sonderborg area's effort on the climate area, and with the effort of the shops' climate endeavors, the customers and visitors will be reminded of the difference made by the area. The ambition is to reward 25 shops during 2009. The goal is that a minimum of 100 shops in the Sonderborg area can be appointed ZEROshops in 2010/11. The shops must appoint an energy responsible person in the shop and carry through all energy efficiency measures with less than a two-year payback time.

The programs have been initiated to anchor ownership for the vision at both companies and private citizens.

The Programs represents a good foundation for new concrete devices pointed out in the Roadmap 2010-2015, but also to transform the overall visions and devices to actions and references to the everyday life of the companies and citizens.

6 The Starting Point in 2007

An essential assignment in the Master Plan work has been to set up an energy balance and a CO_2 balance for the Sonderborg area. The balances will make it possible to assess the advances and measure the effect of the initiated devices measured in energy and CO_2 emission.

Below items account for how the energy balance for the Sonderborg area in 2007 has been set up. The energy balance for 2007 forms basis of the CO_2 balance for 2007 that poses the reference for the Master Plan for 2029.

The energy balance is set up in a spread sheet where the columns show fuel/energy sources, electricity and district heating. Fuel/energy sources are: Petrol, diesel/gasoil, natural gas, waste, different kinds of biomasses, biogas, geothermic heat and ground heat, sun, wind and imported electricity.

The rows in the energy balance can be divided into four groups:

1. 1. ”Gross energy consumption” which is the total energy consumption of all consumers in the area i.e. both CHP plants and end consumers.
2. 2. ”Conversion sector” which shows the energy consumption on CHP plants and district heating plants converting fuel to electricity and/or district heating. Also e.g. local wind turbines, central and decentralised solar cells and bio ethanol production are included in the “conversion sector” in 2029.
3. 3. ”Distribution losses” for electricity and district heating.
4. 4. ”Final energy consumption” which is the energy supply at the doorstep of the end consumers. It can be petrol for the car, electricity to industrial process-es or district heating for heating.

I de nationale energibalancer er endeligt energiforbrug normalt opdelt på kategorierne husholdninger, handels- og serviceerhverv, produktionserhverv og transport. Energiba-lancen for Sønderborg-området opererer med følgende kategorier af endeligt energifor-bru In the national energy balances the final energy consumption is normally divided into the categories households, trade and service businesses, production, and transport. The energy balance for the Sonderborg area operates with the following categories of final energy consumption:

1. Heating and hot domestic water in all building categories
2. Light and appliances in housings and trade and services

3. Manufacturing processes in agriculture and industry
4. Transport.

Below the final energy consumption has been accounted for in the four consumer categories. Then the fuel consumption in CHP plans and other plants in the conversion sector are calculated, and finally the gross energy is calculated.

6.1 Heating and Hot Domestic Water

The Net Heat Demand Allocated on Building Categories and Kind of Heating

The net heat demand is the amount of heat buildings need to keep a room temperature of 20°C and to cover the demand for hot domestic water. Thus the net heat demand is independent of the kind of heating. The net heat demand in all buildings in the Sonderborg area is calculated by multiplying:

- BBR's (Enterprise and Construction Authority) information on the area (m2) of heated buildings allocated on application type, year of construction and kind of heating with
- Specific net heat demand (MWh/year/m3) for the same building categories. The figures have originally been calculated by the Danish Energy Agency to be used in the heat planning and lately refined and calibrated by Aalborg University, thus applied on Denmark's total building mass they give the final energy consumption that can be demonstrated in Denmark.

The total net heat demand in the Sonderborg area is 935 GWh/year (3.366 TJ/year). Included is a heat demand in Danfoss' buildings of 27 GWh/year (97 TJ/year).

Danfoss district heating stations produce further 61 GWh/year (220 TJ/year) primary for process conditional ventilation. Thus Danfoss' plant delivers a total of 88 GWh/year (317 TJ/year), and due to their size, they are included in the conversion sector together with the district heating plants of the area in the statement belo .

Table 4: Net heat demand in the Sonderborg area calculated on the basis of BBR, and process conditional ventilation at Danfoss, 2007 (MWh).

	Gas oil	Natural gas	Straw	Wood-chips, Wood pellets, firewood, wood waste	Heat pumps	Elec-tricity	District heating	Total
Residents	155.284	164,861	6.856	23,708	5,662	63,199	264,018	683,587
Agriculture and forestry	3.975	448	919	1,084	6	488	26	6.948
Manufac., construction	20.674	29,025	1	2,488	99	2,187	8,356	62,830
Trade & service, street lights	28.824	36,334	238	3,202	769	7,611	105,148	182,125
Total	208.757	230,668	8.14	30,482	6,536	73,485	377,548	935,490
Danfoss process conditional venti.							61,151	61.151
Total	208.757	230,668	8.014	30,482	6,536	73,485	438,699	996,642

Figure 20 shows the net heat demand allocated on building categories. For comparison, the allocation in Denmark is 64% in housings, 16% in buildings for manufacturing industries, construction and agriculture while the remaining 20% are in trade and services. /Heat plan Denmark, s.20/. Thus the Sonderborg area has relatively more housings and less business buildings.

Figure 21 shows the allocation of the net heat demand on the kind of heating.

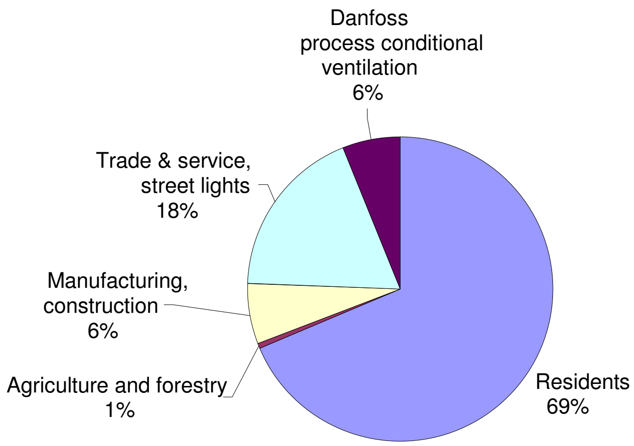

Figure 20: Net heat demand in the Sonderborg area 2007: 935 GWh (3.368 TJ/year) including 27 GWh (97 TJ) for Danfoss heating + 61 GWh (220 TJ) for Danfoss process = 997 GWh (3.588 TJ/year) including Danfoss process .

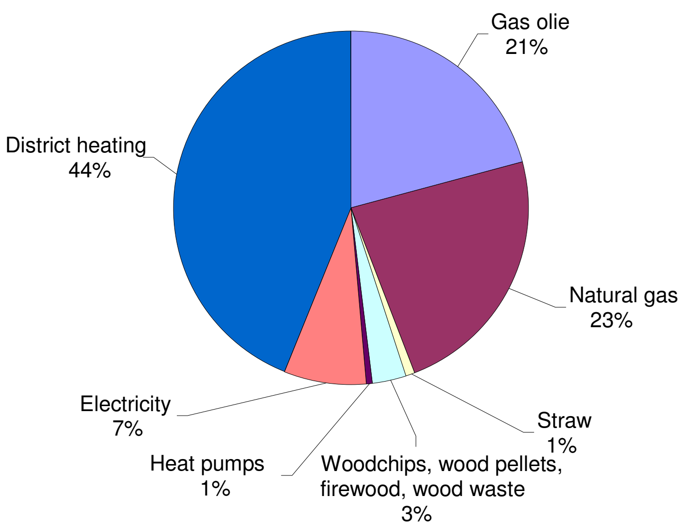

Figure 21: Net heat demand in the Sonderborg area 2007 allocated on the kind of heating.

Net Heat Demand Allocated Geographically

In connection with the preparation of the proposal for the heating plan, the net heat demand in the Sonderborg area has been allocated in energy districts after street names. This has not been possible in connection with the preparation of the Master Plan. Thus the mapping of the heat planning has been used cf. *Table 5*. The table does not include the process energy demand at Danfoss.

Table 5: Net heat demand geographically allocated, 2007 (MWh).

	Sønder-borg	Augusten-borg	Guderup	Svenstrup	Nordborg	Sønder -> Nordborg	Graasten	Broager	Cities total	Rural districts	Total
District heating	202,731	20,963	138	0	35,294	259,126	24,000	17,307	300,433	0	300,433
Heat pumps	1,828	13	373	47	838	3,100	720	355	4,175	6,212	10,386
Straw/wood pellets	1,972	1,070	1,337	438	2,892	7,709	2,790	890	11,388	28,918	40,306
Solar panels	13	1	4	14	31	64	11	10	85	239	324
Misc. Ind. Uniden.	138	15	8	0	22	184	330	2	515	323	839
Natural gas furnace	53,253	1,521	17,574	4,028	28,521	104,897	24,074	59	129,030	113,872	242,902
Oil furnace	24,458	5,166	5,460	1,486	30,210	66,780	10,033	5,968	82,780	127,053	209,833
Electric oven	6,614	986	1,765	282	4,116	13,764	3,739	2,248	19,751	46,526	66,277
Total	291,008	29,736	26,659	6,295	101,925	455,622	65,696	26,838	548,156	323,143	871,300
District heating ex. Wo	258,000	25,643	180	-	45,836	329,659	32,142	22,979	384,780		
Net loss	55,269	4,680	41	-	10,542	70,533	8,142	5,672	84,347		
Net loss	21%	18%	23%	-	23%	21%	25%	25%	22%		

The total amount (871 GWh) is not consistent with the above stated amount (935 GWh), which is due to the fact that the proposal for the heating plan operates with actual district heating sale instead of the theoretically calculated sale based on BBR.

The fact that the actual (degree-day adjusted) district heating demand deviates quite a lot from the theoretical demand should be addressed in the future heating plan work as the heat demand statement should be made on equal conditions for buildings with district heating and buildings without district heating.

For the further heating plan work a new heat atlas should be prepared where all buildings in the Sonderborg area are redefined based on the location in the energy district. This requires a thorough definition of the borders of all existing and potential district heating areas by street name and number.

Høruphav and all urban communities with more than 200 inhabitants belong to potential district heating areas or "near-heating" areas. The cities have been listed in Enclosure 5 in the Roadmap 2010-2015. The heat atlas of the villages can together with maps be put at local forces' disposal if they want to examine the possibilities of "near-heating".

Finally the following should be clarified:

- to what extent Danfoss' considerable heat demand for process conditional ventilation can be covered by district heating,
- whether there is a demand for process energy in other companies that could be covered by district heating,

- whether there is a surplus heat production from industrial processes near the district heating network or transmission pipes that can be used for district heating production.

Figure 22 illustrates the geographical allocation of the net heat demand that is shown in *Table 5*. *Figure 23* shows the location of cities with district heating and natural gas in the Sonderborg area.

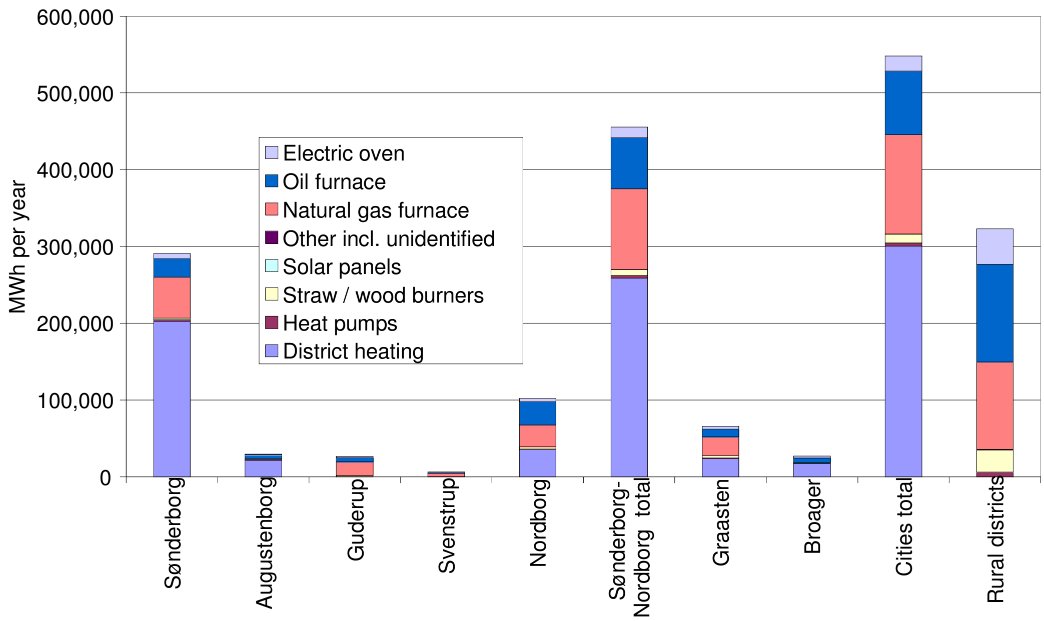

Figure 22: Net heat demand 2007 geographically allocated (Danfoss is included under oil furnace and natural gas furnace).

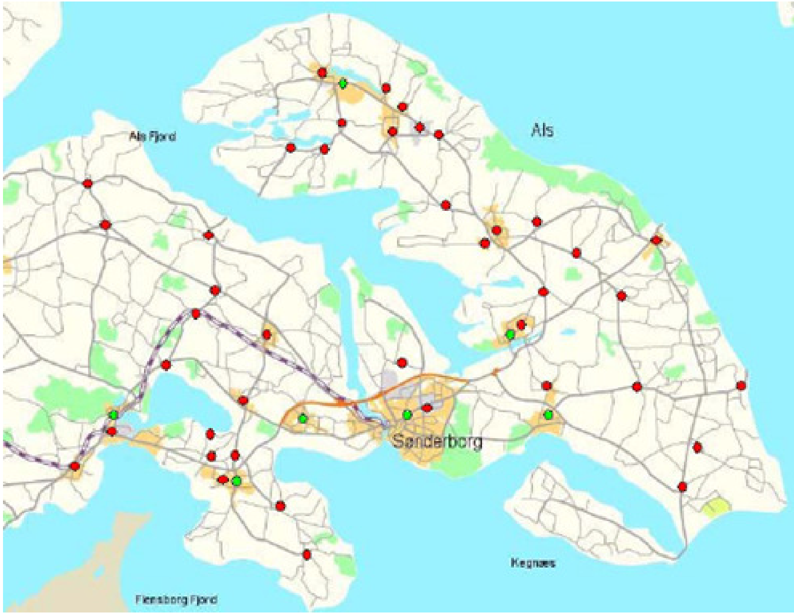

Figure 23: The red spots show towns with natural gas. The green spots show towns with district heating. A project for converting Høruphav to district heating has been approved however the towns have not yet been supplied with district heating.

6.2 Lighting and Appliances

SYD ENERGI has stated the electricity consumption on a number of end-user categories in 2007. If the consumption of direct electric heating and heat pumps (according to the heat atlas) is subtracted from the total electric consumption, you get the consumption for light and appliances and manufacturing processes. The result appears from *Table 6*.

Table 6: Electric consumption in the Sonderborg area allocated on building categories and purpose, 2007 (MWh).

	Direct electric heat	Electricity for heat pumps	Light Appliances, processes	Electric consumption total	Direct electric heat	Electricity for heat pumps	Light Appliances, processes	Electricity consumption total
Housing	54.990	2.519	71.519	129.029	11	1%	15%	27%
Trade & service, street light	7.227	384	117.678	125.289	1%	0%	24%	26%
Agriculture and forestry	5.863	315	30.429	36.607	1%	0%	6%	8%
Manufacturing, Builders and construction	2.137	50	191.643	193.829	0%	0%	40%	40%
Final consumption total	70.217	3.268	411.269	484.753	14	1%	85%	100%

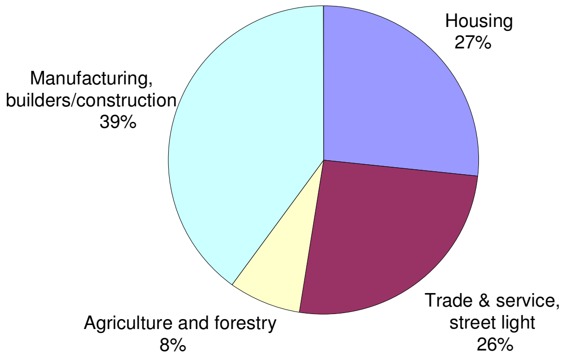

Figure 24: The electric consumption in the Sonderborg area allocated on consumption categories, 2007 (100% = 485 GWh).

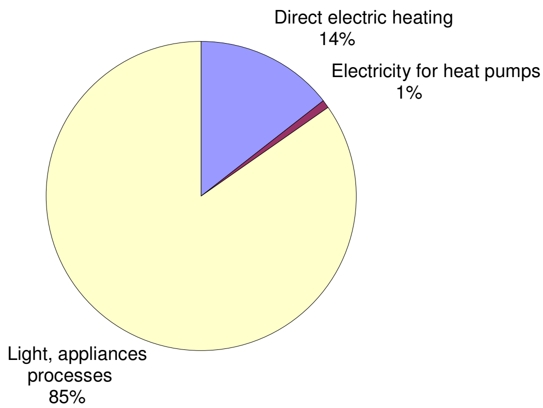

Figure 25: The electric consumption in the Sonderborg area allocated on application, 2007 (100% = 485 GWh).

Figure 25 shows that 14% of the total electricity sale was used for direct electric heating.

43% of the total electricity sale for housing was used for electric heating (54.990 / 129.029), if the BBR registrations and the specific net heat demand are correct.

6.3 Manufacturing Processes

Allocations of the energy consumption statements for manufacturing processes in the Sonderborg area are not available – apart from the allocation of the electricity consumption. However, numbers of the fuel consumption for manufacturing processes nationwide are available. The fuel consumption in the Sonderborg area has been calculated as the area's share of the electricity consumption on industry level multiplied by the national fuel consumption in the industries in question. The tile works are an exception. It has been possible to obtain the actual consumption. The result appears from *Table 7*. Danfoss' district heating consumption for process conditional ventilation (61.151 MWh) is included in this table and in *Table 4*. However, it is of course only included once in the energy balance.

Table 7: Final energy consumption for manufacturing purposes in the Sonderborg area, 2007 (MWh).

	Petrol	Diesel oil/ Gas oil	Natural gas	Coal coke	Electricity	District heating	Total
Agriculture and forestry	2.160	78.831			30.429		111.420
Manufacturing, builders and Construction	26.062	121.200	146.880	31.429	191.643	61.151	578.364
Final consumption total	28.223	200.031	146.880	31.429	222.072	61.151	689.785
Final consumption total	4%	29%	21%	5%	32%	9%	100%

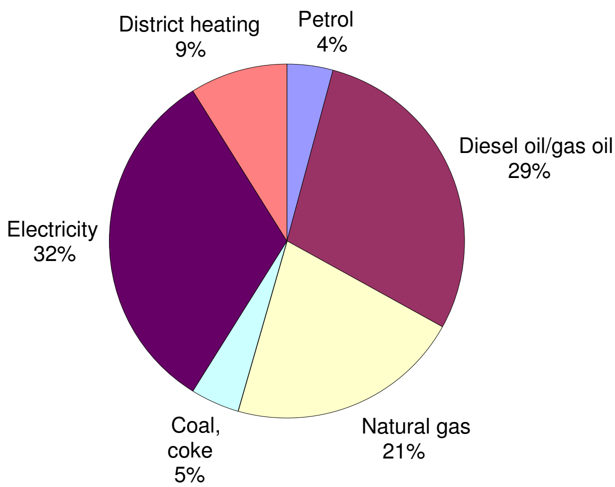

Figure 26: Final energy consumption for industrial processes in the Sonderborg area, 2007 (100% = 690 GWh).

Calculated like this, the final energy consumption for manufacturing purposes amounts to 26.4% of the final total energy consumption in the Sonderborg area in 2007, against 26.2% nationwide.

6.4 Road Transport

Transport energy consumption statements for the Sonderborg area are not available. Thus, it is assumed that the area's share of the transport energy consumption in Denmark corresponds to the population figure namely 1.4%. Thus, the energy consumption for road transport is calculated as follows:

- 307 GWh petrol, corresponding to 33.7M liter petrol
- 371 GWh diesel oil, corresponding to 37.2M liter diesel oil
- 678 GWh total.

The energy consumption for rail transport, domestic shipping, domestic aviation, international aviation and the Defense's transport is not included in the energy balance for the Sonderborg area as this consumption takes place outside the municipality borders. The consumers altogether accounted for 191 MWh in 2007, if they were calculated in the same way as road transport corresponding to 22% of the total transport energy demand of 869 GWh.

6.5 The Conversion Sector

Table 8 shows how the calculated district heating demand per consumer of 439 GWh/year (1.580 TJ/year), cf. *Table 4*, and a net loss of 82 GWh/year (295 TJ/year) are covered by CHP units and boilers at the district heating plants in the area and at Danfoss.

Table 8: Energy consumption and electricity and district heating production in the Sonderborg area 2007 (MWh/year).

	Cogeneration units			Boilers		District heating		
	Waste/ Natural gas	Electricity	District heating	Natural Gas	District heating	Ex works	Net loss	An consumer
Sonderborg waste	198.876	41.872	138.611			138.611		
Sonderborg gas	340.068	162.188	130.386	19.114	18.158	148.545		
Sonderborg total	538.944	204.060	268.998	19.114	18.158	287.156	51.266	235.890
Gråsten district heating	38.420	15.717	20.375	16.708	15.873	36.248	11.612	24.636
Broager district heating	28.188	11.952	14.485	12.254	11.641	26.126	5.550	20.576
Augustenborg district heating	18.709	7.570	9.635	19.696	18.711	28.346	6.886	21.460
Nordborg (a)	60.282	23.220	30.364	25.233	23.972	54.336	6.313	48.023
Danfoss	32.292	13.169	16.146	75.757	71.969	88.115	0	88.115
Total	716.836	275.688	360.003	168.762	160.324	520.326	81.627	438.699
- hereof gas fired plants	517.960	233.816	221.391	168.762	160.324	381.715		

(a) Nordborg CHP plant + Østerlund district heating station (Sonderborg heat supply) + Housing association Danbo's district heating stations: Havnbjerg, Langesø and Th. Brorsons.

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The stated heat production ex plant covers the waste part of Sonderborg CHP plant (SKVV) and Danfoss actual figures for 2007. For the other plants it is the actual values for 2007 plus 17% thus the total heat supply per consumer corresponds to the net heat demand calculated on the basis of information in BBR. The fuel consumption and electricity production are also increased by 17%.

The correction corresponds to 9% of the actual total heat production ex plant. The correction can be justified by the fact that 2007 was warmer than the average year that has been the basis for determining the specific net heat demand that is used to calculate heat atlas.

Figure 27 shows the district heating production in the Sonderborg area distributed on plants.

It appears that the net heat demand covered by district heating in Gråsten + Broager totals 12% of the total district heating covered net heat demand in the area, while in Augustenborg + Danfoss + Nordborg total 32%.

This large district heating covered net heat demand on Als is the rational basis behind the recommendation of preparing a project proposal for establishment of a transmission pipe for the distance Sonderborg-Nordborg, before a possible project proposal for the distance Sonderborg- Gråsten is prepared.

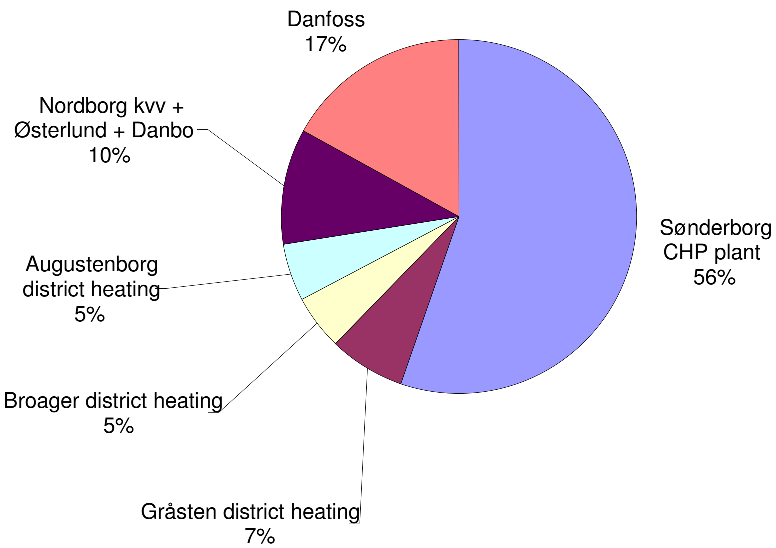


Figure 27: District heating production ex works in the Sonderborg area, 2007 (100% = 520 GWh).

Figure 28 shows that Sonderborg CHP plant covered 8 +31 = 39% of the Sonderborg area's total electricity consumption in 2007, while the CHP plants in the other district heating towns covered 14%.

Today, 21 wind turbines are installed in the Sonderborg area with a total installed capacity of approx. 10 MW. No additional capacity has been established since 2000. The wind turbines produced 23,503 MWh in 2007 and production has remained at this level since 2000. The production in 2007 was equal to 4% of electricity consumption in the Sonderborg area in 2007.

The remaining 43% of the electricity consumption was ”imported” over the municipal border.

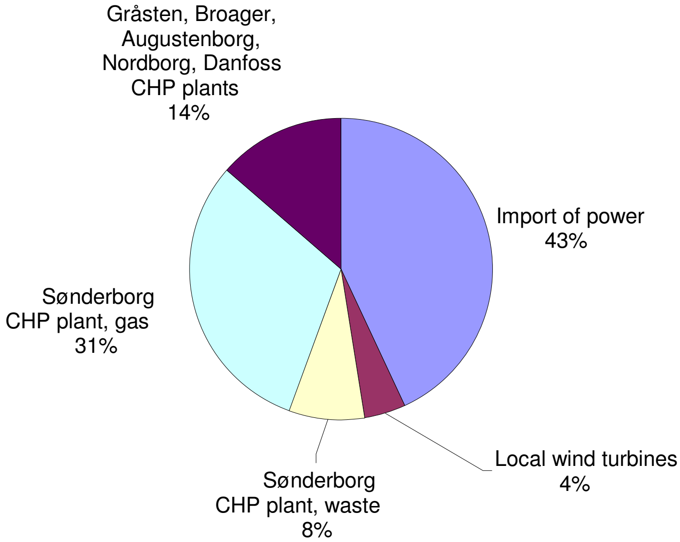


Figure 28: Electricity production an distribution network in the Sonderborg area, 2007 (100% = 526 GWh).

6.6 Energy Balance for 2007

Based on the above exposition, the energy balance for the Sonderborg area in 2007 can be calculated, cf. *Table 9*.

Table 9: Energy balance for the Sonderborg area, 2007 (GWh).

	Oil	Natural gas	Coal	Waste	Straw	Wood and fire-Wood	Ground heat	Wind	Imported Electricity	Electricity	District heating	Total
A: Gross energy cnsump.total	1.167	1.122	31	199	8	38	7	24	227	-	-	2.822
B1: Imported electricity	-	-	-	-	-	-	-	-	-227	227	-	-
B2: Local wind turbines	-	-	-	-	-	-	-	-24		24	-	-
B3: CHP plants total	-	-518	-	-199	-	-	-	-	-	276	36	-81
B4: Big boiler plants total	-	-169	-	-	-	-	-	-	-	-	16	-8
B: Conversion total	-	-687	-	-199	-	-	-	-24	-227	526	52	-90
C: Distribution loss	-	-	-	-	-	-	-	-	-	-41	-	-123
D: Final consump .: A+B+C	1.167	435	31	-	8	38	7	-	-	485	43	2.610
- Room heating	-261	-288	-	-	-8	-38	-7	-	-	-73	-378	-1.053
- Light and appliances	-	-	-	-	-	-	-	-	-	-189	-	-189
- Manufacturing processes	-228	-147	-31	-	-	-	-	-	-	-222	-61	-690
- Road transport	-678	-	-	-	-	-	-	-		-	-	-678
D: Final consumption total	-1.167	-435	-31	-	-8	-38	-7	-	-	-485	-439	-2.610

Reading guide for table: It is seen that 1.122 GWh natural gas is imported. Hereof 687 GWh is used on CHP plants and big boiler plants in the conversion sector which leaves 435 GWh for the final consumption. The final consumption is used for room heating (288 GWh) and manufacturing processes (147 GWh).

The gross energy consumption in 2007 was allocated as follows:

- 90% imported oil, natural gas, coal and electricity.
- 10% local fuel: waste, straw, wood, geothermal heat and wind.

The Master Plan must account for how the demand that today is covered by imported fossil fuel and electricity in future can be covered by local resources or RE plants that municipal players have set up outside the municipality borders.

Figure 29 and *Figure 30* show some of the figures in a graphic representation in *Table 9*.

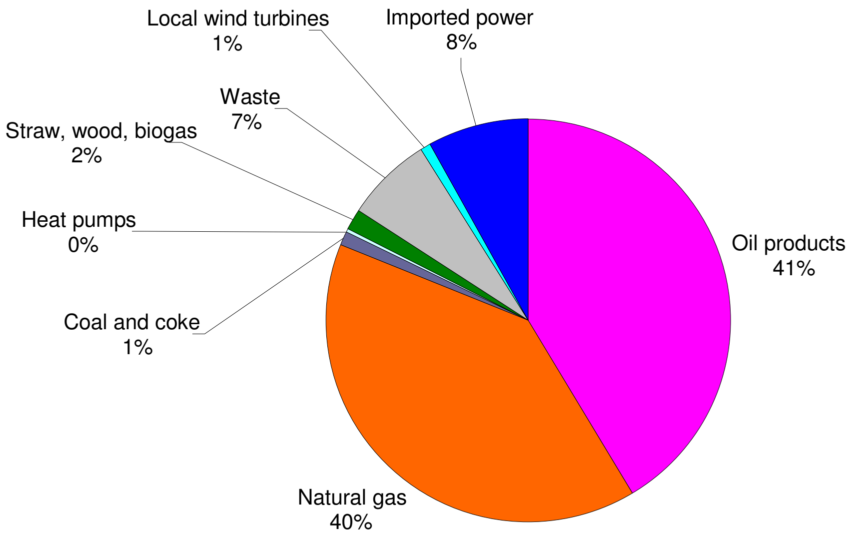


Figure 29: Total gross energy consumption in the Sonderborg area, 2007 (100% = 2,822 GWh).

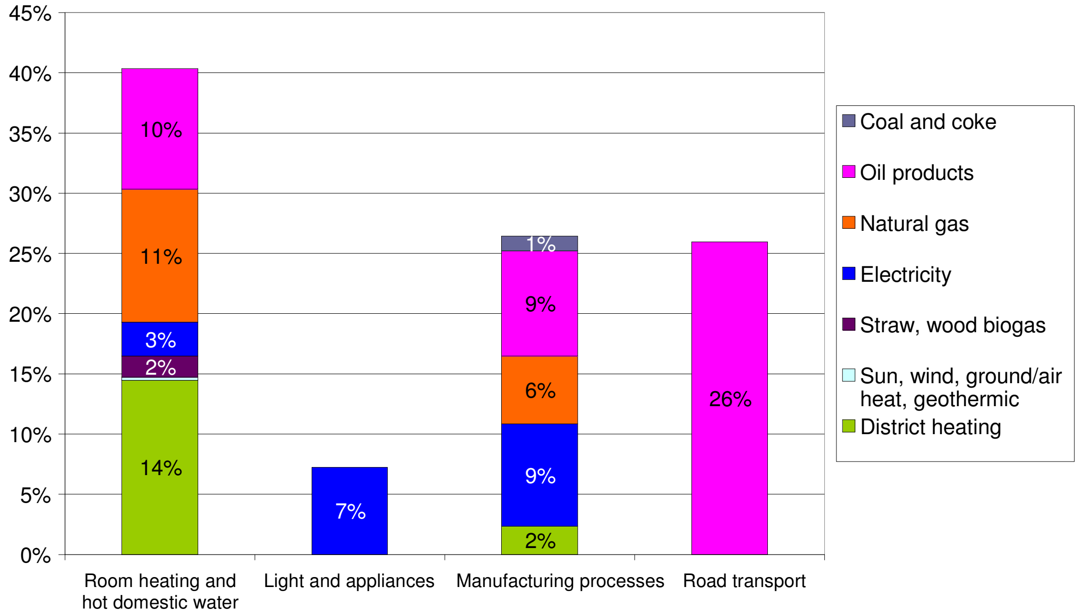


Figure 30: Final energy consumption in the Sonderborg area, 2007 (100% = 2,610 GWh).

6.7 CO_2 Balance for 2007

The CO_2 emission can be calculated based on the energy balance for 2007, cf. *Figure 31*. The calculation is based on the Danish Energy Agency's emission factors and assuming an emission factor of 445 kg CO_2 per MWh net electricity import where the net electricity import is calculated as the total electricity consumption in the Sonderborg area minus electricity produced by wind turbines and CPH plants in the area.

Making up the CO_2 emission from the area's CHP plants, the fuel consumption for heat production is calculated as heat production divided by 200% while the rest is allocated to electricity production.

The mentioned 445 kg CO_2 per MWh is the average emission from electricity delivered in West Denmark in 2007. The electricity consumption average in the Sonderborg area in 2007 is 411 kg CO_2 per MWh with this emission factor.

The energy related CO_2 emission in 2007 was 674.000 tons (excluding rail transport, shipping and air transport), which corresponds to 8.8 tons CO_2 per inhabitant, which corresponds to the average for Denmark[c]. The figure shows that the road transport sector contributes considerably to the total CO_2 emission.

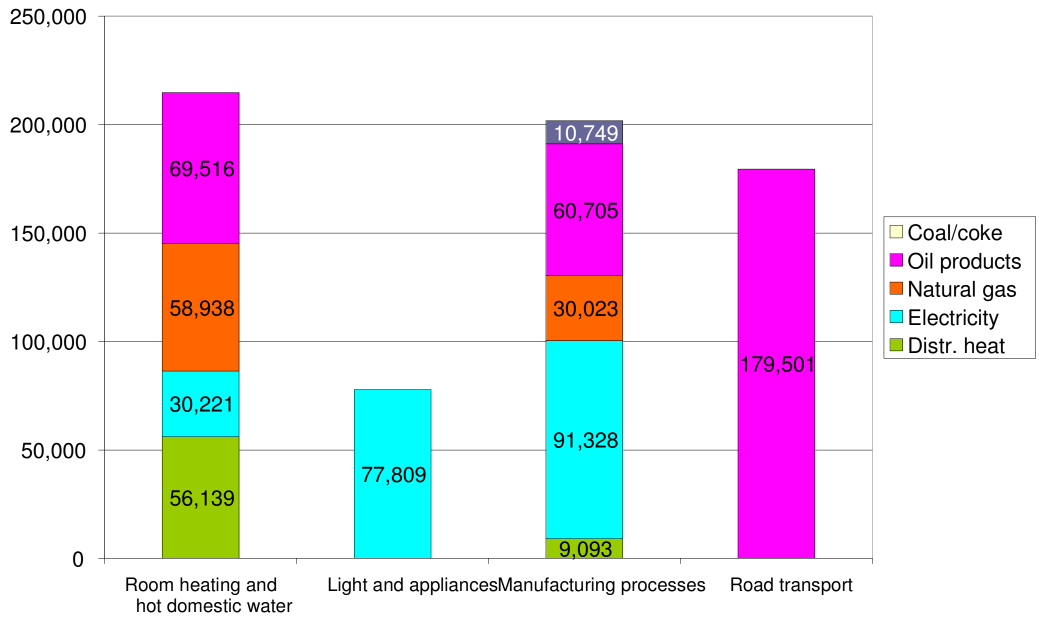


Figure 31: The Sonderborg area's energy related CO2 emission 2007 (674,000 tons) (excluding air, rail transport and shipping).

[c] According to Environment and Economy 2009, Denmark's greenhouse gas emission was 2005 63.7M tons CO2 equivalents in 2005, of which 48.2M tons were related to energy. According to the National Allocation Plan for Denmark during the period 2008-12, the expected greenhouse gas emission for Denmark is 63.7M tons CO2 equivalents per year during the period 2008-2012. The population is 5,447,000.

7 Vision and Guiding Stars

7.1 Vision

The vision is a CO_2 neutral Sonderborg area that acts as dynamo for education and industrial development. CO_2 neutrality is a means to ensure a sustainable future where Sonderborg will have impact on the national and international development.

7.2 Guiding Stars

The Master Plan 2029 is based on three overall guiding stars in effort to achieve CO_2 neutrality. A guiding star is the direction society is expected to move to achieve sustainability, supply security and financial growth. The three guiding stars are:

- Energy efficiency that reduces the area's sensitivity to increasing energy prices and strengthens the industry's competitiveness.
- A multidimensional robust energy supply based on local RE resour CO_2ces in effective interaction with external RE resources that ensures supply security.
- A dynamic energy system that allows dynamic optimization of the interaction between consumption and supply thus new market mechanisms can be fully utilized in the phasing in of the RE technologies.

Within each of the three guiding stars a number of initiatives are initiated that contribute to the long-term objective. An underlying premise for the guiding stars is a continued electrification of society and that public energy systems such as district heating will be a sustainable energy solution.

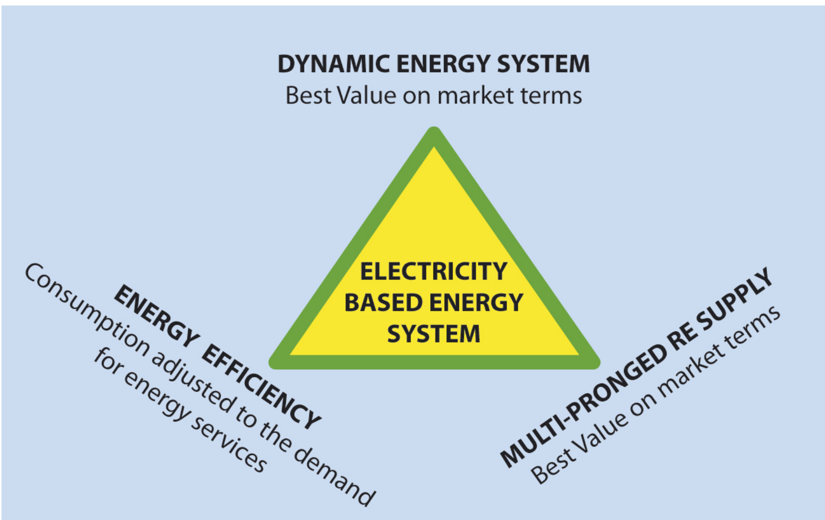


Figure 32: The three overall guiding stars of the strategy Figure.

7.3 The Challenge

A sustainable development without the use of fossil fuels requires both energy efficiency measures and conversion from fossil fuels to RE resources. In below principle sketch, the scope of the task has been illustrated (*Figure 33*). The gross energy consumption of fossil fuels amounted to 82% of the total consumption in 2007. This consumption must be reduced by means of efficiency measures and RE for covering the remaining consumption.

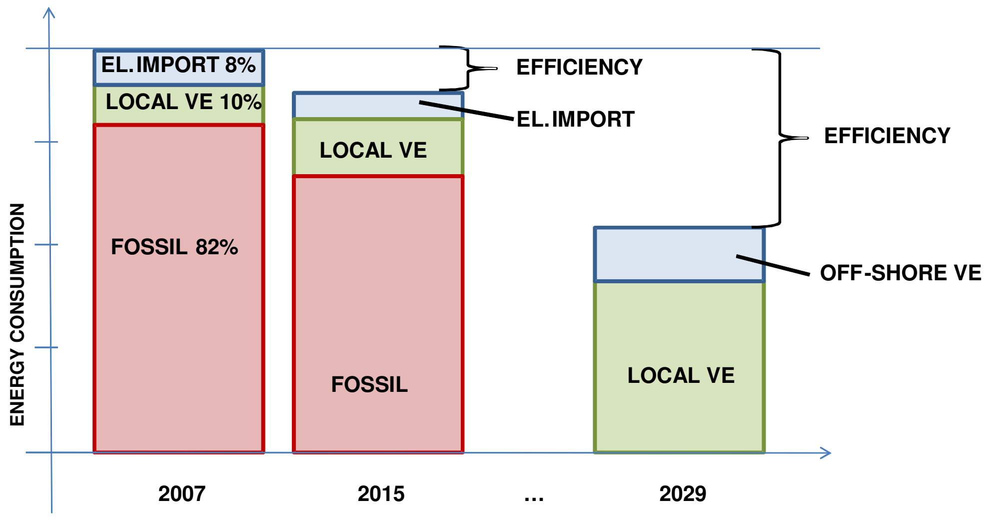


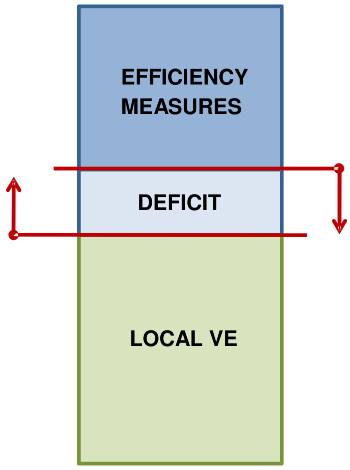
Figure 33: Principle sketch of the development strategy for Sonderborg's energy system. RE includes waste utilization.

Please note that off-shore RE – that is wind turbine capacity – is also considered a local resource as it is assumed established at the request of the Sonderborg area.

A critical aspect for achieving the 2029 objective are substantial efficiencies in all links coordinated with a strategic prioritized utilization of own RE resources.

The amount of RE resources internally in the Sonderborg area is limited and the goal is to use the available RE resources delivering the biggest profit per invested DKK, contemporary with the maintenance of a robust energy system. It will be necessary to prioritize between the different resources and demands. A reduced demand will contribute to long lasting local RE resources. The importance of energy efficiencies is illustrated in *Figur 34*. If local resources are not sufficient, energy will be imported.

Even with significant efficiencies and full utilization of local RE resources, it will be necessary to import electricity. The idea is that in 2029 this electricity will be produced in own plants outside the municipal borders - e.g. off-shore wind turbines established in interaction with the other energy systems. Thus the ambition is a drastic reduction of the energy consumption within all four consumer segments (room heating and hot domestic water, lighting, appliances, manufacturing processes and transport) and 100% utilization of own local resources supplemented with own off-shore wind.



Figur 34: Principle sketch of the balance between savings and off-shore wind production.

The future heating plan for the Sonderborg area is vital for not losing the overall considerations and long-term opportunities and for a focused and coordinated development of oil and natural gas.

The vision will be realized through cross-functional co-operations and holistic thinking – locally but also in dialogue with other municipalities thus the potentials and synergies are utilized for the mutual benefit. The linkage of consumption and production in a dynamic energy system is important for the interaction with other areas' position of strength.

Whether Sonderborg achieves its goals depends on a variety of factors at local, regional, national and international level - some are entirely inside Sonderborg's own control, while others are more or less susceptible. Sonderborg is bound to act within the existing framework, but can also contribute actively to influence and alter the framework conditions.

7.4 Guiding Star – Energy Efficiency

Energy efficiency is a key element in a CO_2 neutral future. There are many private economic and socioeconomic profitable opportunities that for different reasons are not realized and possible synergies are sometimes lost. The ProjectZero partnership has declared that it sees energy efficiencies as a considerable part of Sonderborg's effort to achieve CO_2 neutrality.

In an attempt to realize the efficiency potentials, the available leverages must be utilized. Examples are:

- the obligation of the energy companies to contribute to the realization of energy savings at the consumers,
- the role of the municipality as administrator of the Heat Supply Act and other rules,
- the natural replacement rate and
- external subsidy schemes.

The leverages will be explained below.

As of 2010, the Danish energy companies are instructed to realize 5.4 PJ energy savings per year at the consumers according to the energy political agreement dated February 21, 2007. The goal of the agreement is, with a new energy saving agreement between the Ministry of Climate and Energy signed on November 20, 2009, to further increase with 0.8 PV in order to compensate for the share of non-additional savings (saving that are independent of the companies' effort). Totally, the energy companies must realize 6.1 PJ/year.

SYD ENERGI, DONG Energy and the local district heating plants hold the supply area in the Sonderborg area and they are committed energy companies. In 2010, the companies will prepare a strategy for how they can realize a substantial part of their saving commitments within the Sonderborg area in a cooperation that ensures that possible synergies are utilized and that the efficiencies interact in a reasonable way with the conversion of the energy supply to RE (central and decentralized) and the establishment of a dynamic energy system.

Sonderborg Municipality is authorized to define the framework for the local heat supply and climate envelope, fixed installations, streetlights and local transport. Thus Sonderborg Municipality has a great responsibility but at the same time good opportunities to influence the local development in a direction that meet the vision in the Master Plan 2029.

Sonderborg Municipality is preparing a heating plan. As of November 11, 2009 a suggestion for a heating plan is available that must be approved by the city council. Important choices are made including the choice of heat sources with a view to comply with the objectives of CO_2 neutrality in 2029. Thus Sonderborg Municipality is an absolute key player in the heating area.

Another example of Sonderborg Municipality's initiatives to encourage the realization of efficiency potentials is that the local plans of the municipality from 2008 posit that new constructions must be built as low energy class 1 – this requirement is still not standard nationwide but it is expected to become a nationwide standard not later than 2015.

Furthermore Sonderborg Municipality is also a consumer of energy – a large-scale consumer who can influence the consumption in a large number of contexts. In March 2008, Sonderborg Municipality passed an energy policy and energy strategy and has established a Climate Secretariat whose main task is to initiate and coordinate municipal initiatives. Sonderborg Municipality has also entered a curve breaker agreement with the Electricity Saving Trust aiming at a 20% reduction of the energy consumption within the period 2008-2011. Among other things, Sonderborg Municipality has obtained energy labeling of all municipal buildings (210 buildings) and set a target to implement all proposals in the energy labeling report during five years that have a payback period below 20 years. In 2009, 86 MDKK have been granted to start this work – the so-called Energy Fund in the municipality.

A third leverage is the natural replacement of appliances, vehicles and renovation of buildings e.g. refrigerators. The energy renovation of the climate envelope is relatively expensive. If on the other hand it is possible to utilize the natural replacement to realize efficiencies, the costs are minimized. If the natural replacement rate is not utilized, the chances for involving the consumers and obtaining efficiencies in the cheapest way are missed.

Especially the realization of efficiencies in existing constructions can be difficult to launch. The popular and professional anchoring of ProjectZero can contribute to Sonderborg becoming one of the municipalities making the first visible progresses in this area. Banks, Credit Associations etc. will be involved thus financing products are available that can support the increasing interest in energy efficient solutions and choices.

The concepts ZEROfamily, ZEROshop, ZEROcompany and ZEROambassador launched by ProjectZero's Secretariat can advantageously be used as communication platforms for the realization of energy efficiencies. A formalized and focused cooperation on energy efficiencies and technology development in three business groups: energy heavy businesses, other businesses, and private and public trade and service businesses are expected to influence the realization considerably.

Finally, it must be expected that there will be different knowledge and support programs nationally and under EU auspices that can be utilized during the plan period. Presumably, an enhanced effort towards buildings will be launched in the coming years –

perhaps a new renovation pool with energy focus. Another example is the newly established "Knowledge center for energy savings in buildings" (www.byggeriogenergi.dk). Their task is to gather and communicate knowledge about concrete and practical possibilities on how to reduce the energy consumption in buildings. Furthermore there are research pools such as EUDP and PSO.

The catalogue of measures groups have appointed a large number of measures for realization of energy efficiencies with climate envelope, fixed installations, lighting, electric appliances, manufacturing processes and transport. They are listed in enclosure 3 and include in brief the following:

- Energy requirements for buildings in the Sonderborg area are minimum one class higher than in the rest of the country
- Integrated energy design of buildings
- Energy renovation of climate envelope
- Energy improvements of fixed installations (e.g. technical additional insulation, heat recovery and energy effective central heating pumps)
- Adjustment of fixed installations (e.g. optimal district cooling)
- Energy efficient outdoor lights and streetlights
- Energy efficient indoor lighting and electric appliances
- Reduction of stand-by consumption
- Energy management, energy efficient designing, energy efficiencies through production optimization
- Special energy saving subscriptions
- Planting and green roofs
- Energy efficient and CO_2 friendly transport and urban development (including road pricing)
- Energy efficient driving

The efficiency strategies are in brief as follows:

- Utilize economy of scale and synergies through cooperation and coordination, also including the energy saving obligations of the energy companies.
- Address the end consumption in all four main segments; heating and hot domestic water, lighting and appliances and transport.
- That the municipality as front runner and motive force makes demands on own and others' level of efficiency.
- Incorporate the zero CO_2 vision in municipal transport and urban development.
- Modify and time the devices thus possible efficiencies in connection with new buildings, new purchases and natural replacement are utilized optimally and concurrently with changes in the supply system.
- Utilize potential ambassadors and influencers – front runners can inspire others, companies can influence the employees, installers and retail can influence

the consumers, schools and education environments can influence the pupils, students and teachers can influence "the home front" etc.

- Ensure a supply of financing products modified to the interest of energy efficient solutions.

7.5 Guiding Star – Multidiractional Robust Energy Supply

The municipal heating plan will, when finally passed, define the guidelines for a focused extension of the district heating in the urban areas and a focused phase-out of natural gas and oil in the rural areas. In the future energy system a collective infrastructure will also be required for heat supply. District heating will be the main element in the heat supply for the urban areas while individual solutions or small-scale district heating system solutions will be relevant in the rural areas.

Both supply areas will be built up on a range of RE resources. In terms of district heating, it will be waste, biomass, geothermic, solar heating and heating elements. In the long term, biogas will also be included. Heating elements will also be established in order to utilize periods with cheap electricity for the heat production. In the rural districts the heat supply will be concentrated on heat pumps in combination with solar heating, and biomass furnaces in combination with solar heating. With the conversion from natural gas and oil boilers, the aim is to establish a large enough water tank capacity thus it can utilize cheap electricity in interaction with heating elements like with district heating.

Below *Figure 35* illustrates the expected spilt between collective and individual heat supply and the importance of the efficiency effort.

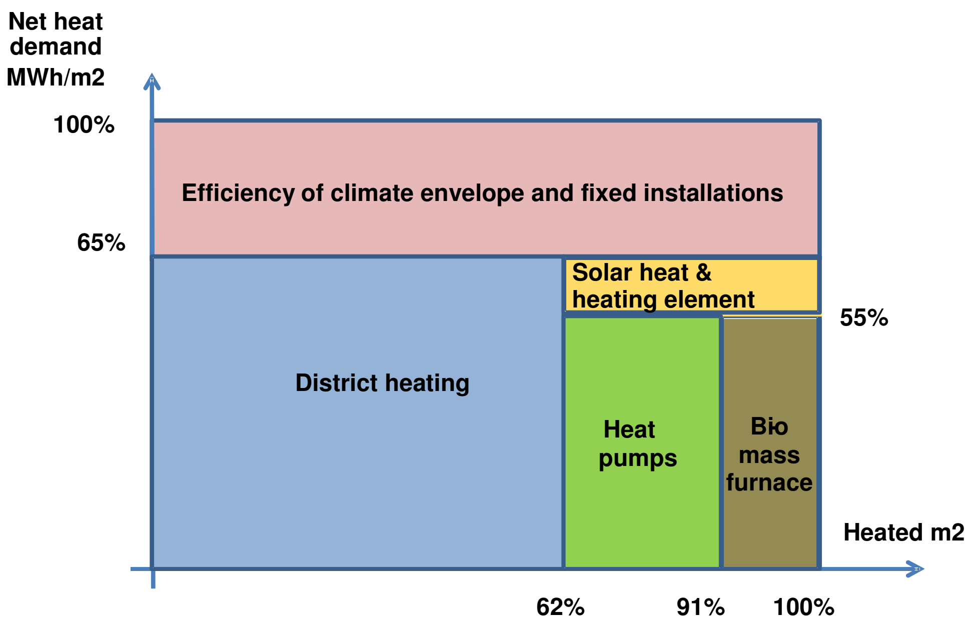


Figure 35: Sketch of the supply structure for buildings in 2029 (heating and hot domestic water and Danfoss process).

The planned key technologies are well-known and well-tested solutions.

The challenge is much bigger when it comes to covering the electricity demand and the fuel demand for manufacturing processes and transport with own production. Part of the electricity production will take place through cogeneration production and on-shore wind turbines, while the rest will be imported over the municipal border – in the long term from own off-shore wind turbine plants. It will not be possible to redistribute all manufacturing processes and transport to electricity thus it is necessary to introduce alternative fuels.

A number of possible technical solutions have been pointed out of which most are described in the catalog of measures and the proposal for a heating plan. In brief they include the following:

- Central plants with geothermic, solar heating, heating elements and solar cells.
- Central biogas plants with focus on the utilization of liquid manure energy.
- Decentralized plants based on heat pumps, biomass, solar heat, heating elements and solar cells in buildings, agriculture and industries.
- Application of surplus heat from manufacturing processes.
- Demonstration plants of small-scale district heating system solutions and local heat solutions based on solar heat and biomass.
- Demonstration plants for solar cells.
- On-shore and off-shore wind turbines.

The energy supply strategies in brief are as follows:

- Bring both central and decentralized RE solution in play.
- Phase-out natural gas and oil for the benefit of RE based district heating and individual RE solutions.
- Ensure RE based electricity production through renewal of existing on-shore wind turbines, establishment of off-shore wind turbines and PV.
- Prepare a priority plan for the utilization of biomass/biogas resources, especially in view of the supply for district heating, manufacturing processes and transport.
- Ensure RE based fuels through an increased production of energy crops and retrieval of own and others experiences with biogas and bio ethanol plants in order to be able to estimate to what extent they can be included in the portfolio of resources in the long run

7.6 Guiding Star – A Dynamic Energy System

According to the vision, Sonderborg must actively contribute to create growth and business opportunities through implementation of an innovative strategy for a dynamic energy system that is efficient and coherent. A system that can react real-time on the market price signals and handle all types of technologies among others an active application of the consumer side and a further adaption of renewable and decentralized energy production. The total energy system – consisting of hardware, communication systems and markets – must be environmentally appropriate, economically efficient and must maintain a high supply security. It is necessary to think system solutions rather than only technology specific products.

There are several different elements that can contribute to ensuring flexibility in the energy system among other things communication systems and efficient markets for the coordination of supply and demand in both the short and long run. The work of developing and establishing a dynamic energy system must take place on many different fronts and requires a targeted, constructive interaction between end users, installers, (plumbing, electricians), the IT business, equipment manufacturers, suppliers of the energy system and operators, educational institutions, municipalities, regional forums etc.

For the time being, there is no total Danish strategy for system solutions for the energy system. Different projects have illustrated different aspects within the area[d], however a whole testing and demonstration has not yet taken place.
The aim is to establish Sonderborg as a full-scale showroom that can be the spearhead of competence building and experience gathering and thereby function as show case for system solutions and a dynamic energy system both technically, organizationally, nationally and internationally. Furthermore, Sonderborg could contribute in creating a national market pull for the requested development.

The demonstration will be interesting also beyond Denmark's borders and the activities could usefully link up with international frontrunner knowledge.

Sonderborg is in the lead due to the fact that all district heating customers of Sonderborg District Heating's area have remote read meters. Each customer's district heating consumption can be followed thus the identification of problems (such as poor cooling) can be detected quickly and systematically. Sonderborg District Heating has already a routine of spotting areas with poor cooling and addressing these by means of remote read meters.

[d] IDA's Climate plan 2050, May 2009; Power to the People, Danish Energy, June 2009 – A vision of a CO2 neutral society 2050; Scenario report, Energinet.dk, 2007 – Four scenario analysis for illustration of the robustness of decisions compared to different future challenges; The Technology Council – The future energy system 2007 and projects such as Development of strategic partners in the field of intelligent energy systems (EUDP project 2009), EcoGrid (ForskEL No. 7816), "The energy city Frederikshavn 100% RE supply without imbalances" (ForskEL No. 10134), EDISION consortium (integration of electric cars in the electric system), (ForskEL No. 10224), Demand response medium sized industry consumers (ForskEL, No. 10252), Systems with high level integration of renewable generation units (DSF No. 2104-05-0043), Control and regulation of a modern distribution system (ForskEL No. 6316), Efficient district heating in the future energy system (EFP), Electricity consumption as frequency controlled reserve (PSO), Practical test with the future energy system

Furthermore Sonderborg is in the lead as all electricity consumers have remote reading thanks to SYD ENERGI´s visionary rolling out of remote read meters. Each customer's electricity consumption can be followed with quarterly readings that allows for spot price based customer rates, load disconnection and quick and systematic identification of abnormal consumption. Thus, it is possible to introduce hourly rates based on spot prices and the charges could also be adjusted to fit the consumption. Sonderborg could take a large and important step towards a dynamic energy system by means of the possibility of storing cheap RE based current.

Some examples of technologies that can "move the electricity consumption" are heating elements (5-15,000 kWh/year), heat pumps (3-7,000 kWh/year, thermal storage) and electric cars (3,000 kWh/year). Individually and collectively they can move the consumption – i.e. store the cheap RE current for later heat consumption when the price goes up due to a more spares production. Today, industry and business have typically BMS[e], plants that easily could be adjusted to react to possible prices signals. As something new, disconnection or connection of different categories of electric appliances could be added on demand (e.g. do the laundry at a cheaper time of day).

Since the development of dynamic energy systems face increasing attention, support and cooperation will be possible.

In the summer of 2009, The Council for Technology and Innovation was invited to bid on innovative community solutions that can ensure a flexible energy system and by means a grant, DEA (Danish Energy Agency) invited 300 private house owners to participate in a test with heat pumps.

Sonderborg will consider how these possibilities of financial support and professional interaction can be beneficially used in the local work with ProjectZero, but also how the ProjectZero work can act as inspiration for others.

A catalogue of measures has not been prepared for products and technologies that can benefit the development of a dynamic energy system however below some examples of subjects for possible product development and demonstration are briefly mentioned:

- Heat consumption as balancing the electricity system both in proportion to the spot market and the regulating power market (district heating, heat pumps, water tanks and heating elements) and better utilization of RE resources locally, nationally and internationally).

[e] CTS – Central Tilstandskontrol og Styring. (Central Inspection and Control).

- Electricity consumption as balancing the electricity system both in proportion to the spot market, the regulating power market and the frequency controlled reserve.
- Electric vehicles as means of reserve, balancing and CO_2 savings.
- Dynamic electricity rates reflecting real-time prices.
- Dynamic charges (without which the impact of dynamic pricing will be reduced).
- Visibility of actual energy consumption (savings and attention through sensitization of the consumers = what does it mean that I turn off/on here?).
- New expense types/forms.
- Visibility of unusual prices.
- Visibility of unusual consumption.
- Derivative products such as alarm, temperature regulation, energy monitoring etc.

The preparation of an overall strategy for Sonderborg as showroom for dynamic energy systems and matching products and technologies is in this context important for a coordinated effort and attracting projects from home and abroad. The strategy is determined by private and public key players in a dialogue with Energinet.dk. Both own but also international experiences are linked up within the subject.

A result of the strategy process will be a clarification of the above listed activities. Next step in the strategy process is the set-up of an international workshop where interested parties are invited to Sonderborg to formulate demonstration and product development projects. The possibility of strengthening the individual company and graduates within the area by using arrangements for industrial PhD, knowledge coupon and knowledge-pilot will be utilized targeted and thus contribute to the competence building in the individual company and in Sonderborg and in Denmark as a whole.

It is expected that the strategy process will identify a need for development and test of new technologies such as product development of internal and external control units – demands that beneficially can be accomplished by Cleantech companies in Sonderborg leading to a strengthening of Sonderborg’s knowledge resources and jobs. Centre for Software Innovation (CSI) at Alsion/Sonderborg plays an important role that propels the companies’ inspiration and competence development in connection with an energy systematic approach to the new challenges.

As experiences from the initiated activities are harvested, workshops presenting the experiences and master classes can be offered later on.

The strategies in brief are as follows:

- Preparation of an action plan for the area's role in the demonstration of a dynamic system and establishment of partnerships with internal and external stakeholders of demonstration and product development projects.
- Create market reliable price signals for rates and charges through test application of different types of rates and charges supporting a dynamic system.
- Expansion of storage capacity and movable consumption (e.g. electric vehicles) for a better utilization of RE resources and balancing of the energy system.
- Development of new products as well as hardware and software technologies for the dynamic energy system.

7.7 Recap

As described in the sections above, great changes within all three guiding stars have been planned. In short, it is the necessary overall coordinated initiatives as shown in *Figure 36*. These initiatives are critical for the overall success.

ENERGY EFFICIENCY

- **Strategy for the energy companies' cooperation in terms of saving commitments**
- **The municipality as front runner and mainspring (demand on own and others level)**
- **Municipal transport plan and city plan development**

FLEXIBLE ROBUST RE BASED ENERGY SUPPLY

- **Municipal heat plan in consultation with district heating and natural gas companies including a strategy for development of natural gas and oil in urban and rural districts**
- **Priority plan for exploitation of biomass and biogas resources**

DYNAMIC ENERGY SYSTEM

- **Action plan for transformation to dynamic energy system**
- **Cooperation agreements concerning demonstration of elements in a dynamic energy system**

Figure 36: Overall coordinative initiatives for each of the three guiding stars.

A wide range of measures must be implemented fast in order for Sonderborg to reach the intermediate aim in 2015 of a 25% CO_2 emission reduction compared to the 2007 level and the final aim of a zero CO_2 emission in 2029. However, they must not be rolled out parallel but with different weight in the seven phases of the Master Plan period. This is illustrated in *Figure 37*.

The focus areas for the period 2010-2015 are specified in the Roadmap 2010-2015. The listed focus areas during the following periods must be considered proposals for some possible focus areas.

A wide range of exiting possibilities are being researched, developed and tested in recent years. Thus, it is not suitable to lock the technology mix already now.

Furthermore, it must be expected that both the government and the EU will make decisions during the coming years that will influence the possibilities of implementing the Sonderborg area's Master Plan 2029 and which measures to activate first. It could e.g. be the implementation of the government's "Strategy for reduction of the energy consumption in buildings" from April 2009 that sees energy demands as leverage for a product development within construction.

Another example is the bill introduced on October 8, 2009 concerning amendments on advancing savings in the energy consumption, law on state subsidies for product-oriented energy savings and law on charges for electricity and abatement of the law on the Electricity Saving Trust.

As late as November 12, 2009, the Climate and Energy Ministry announced that a pool of 400M DKK has been allocated to support the replacement of oil furnaces before the heating season 2010 with more modern and climate friendly systems such as district heating, heat pumps or solar heating systems. The Finance Agreement entered between the government and The Danish People's Party includes also a pool of 260M DKK for energy renovation of public buildings.

All these things affect the Sonderborg area's options and the individual device's relevance and profitability.

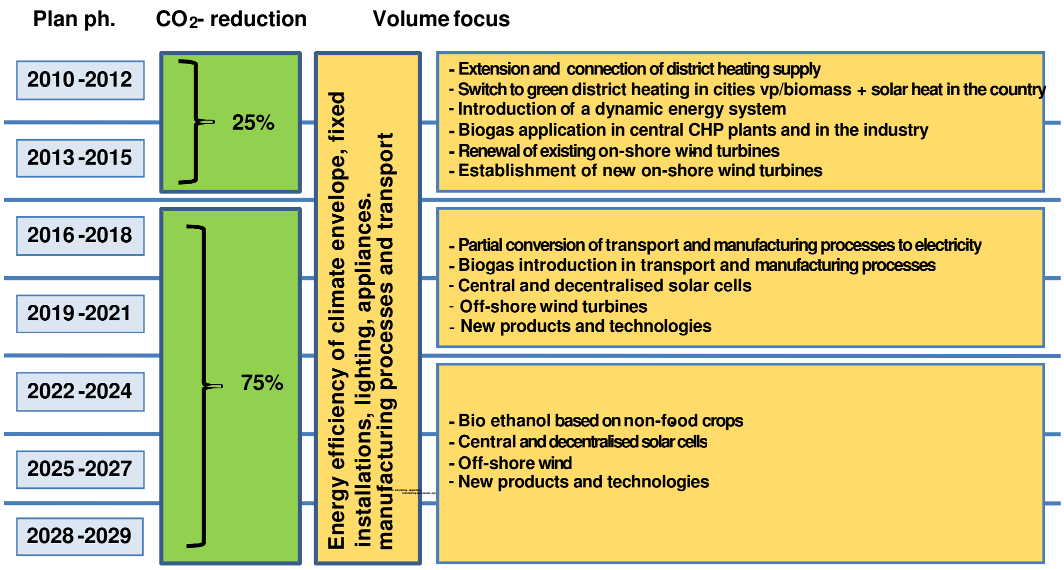


Figure 37: The large volumes spread on the phases of the plan period.

According to the Roadmap 2010-2015, the following measures are expected to contribute to the essential changes in the Sonderborg area's energy system and CO_2 emission during the first two phases (2010-2015):

- Expansion of the district heating systems and establishment of a transmission pipe from Sonderborg to Nordborg,
- Geothermal heat, solar heat, biogas and biomass in the district heating supply,
- Changing from oil furnaces, natural gas furnaces and electric heating to district heating in the urban areas,
- Changing from oil furnaces, natural gas furnaces and electric heating to heat pumps or biomass furnaces combined with solar heat in the rural areas,
- Introduction of a dynamic energy system,
- Biogas application in central plants,
- Renewal of existing on-shore wind turbines and
- Establishment of new on-shore wind turbines.

All these focus areas will altogether contribute to preparing the Sonderborg area for a greater adaption of renewable energy and new technologies both in terms of consumption and supply and thus making the system robust and flexible.

In 2012, status will be made on the progress of the initiated measures thus the focus areas can be adjusted and new added to the extent necessary for obtaining the 2015 goal. It might be relevant to make status earlier due to harvested experiences with initiated measures, changes in the outer frames such as changes in the energy tax system or the generation of new technologies and products.

A status in 2015 must compare the objective for 2015 with the actually achieved and form basis of an action plan for the coming period. The Energy plan group's task has been to put forward a suggestion on how the Sonderborg area can become CO_2 neutral in 2029 by exploiting own resources as much as possible. Thus the Master Plan 2019 includes suggestions on what is necessary to fulfill this demand. **However, these suggestions must be seen as theoretical possibilities.** The actual focus areas and measures can first be identified at a more advanced stage. The essential part is that the focus areas that are initiated during the period 2010-2015 contribute to robustness and flexibility in the whole energy system.

During the period 2016-2021, it has been assumed in the Master Plan 2029 that the following measures within the guiding stars "multidirectional RE supply" and "dynamic energy system" have the greatest effect on the energy and CO_2 balance:

- Conversion of part of the consumption of fossil fuels in transport and manufacturing processes to electricity,

- Introduction of biogas in transport and manufacturing processes for the replacement of oil and natural gas,
- Establishment of central and decentralized PV plants (Photovoltaic)
- Establishment of off-shore wind turbines and
- New products and technologies.

During the last period (2022-2029), it has been assumed in the Master Plan 2029 that the following measures have the greatest effect on the energy and CO_2 balance:

- Conversion of part of the consumption of fossil fuels in district heating production, transport and manufacturing processes to bio ethanol due to an increased production of non-food crops,
- Establishment of central and decentralized PV plants (Photovoltaic),
- Establishment of off-shore wind turbines and
- New products and technologies.

All through the plan period 2010-2029, there will be a continuous effort to achieve energy efficiencies at all stages. The individual elements and measures will vary over time but the strength and effect will be even and strong. Examples of focus areas to be established already during the first phase – i.e. in 2010-2012 are:

- Energy demands on buildings in the Sonderborg area that are one or two classes higher than in the rest of the country.
- Demonstration of package solutions for energy renovation of buildings' climate envelope.
- Energy management, energy efficient design and energy efficiencies through production optimization e.g. as an offer under the communication platform ZEROcompany.
- Energy efficient choice of lighting and electric appliances by means of support from local shops through the communication platform ZEROshop
- Tests with energy saving charges that increase the incentive to realize efficiencies.

Just like the two other guiding stars (”multidirectional RE supply” and ”dynamic energy system”) only measures for the period 2010-2015 have been identified for the time being. At the end of the period, a new Roadmap will point out the activities planned for the period after 2015.

8 Sonderborg 2029

Master Plan is based on an evaluation of:

- which efficiency measures can realistically be expected in the individual energy consumption sectors during the plan period, and
- how the reduced energy consumption – sector for sector – can be replaced with local RE resources by the end of the plan period in the best appropriate way.

In the following section, the expected consequence of vision and efforts in terms of implementation of the Master Plan 2019 is presented. Firstly, the local energy resources are presented, secondly, how they may be applied in the individual consumption sectors in 2029.

8.1 Local Energy Ressources

Most of the local energy resources are limited by the available areas.

The solar radiation in Denmark is approx. 1,000 kWh/year/m2 on a horizontal surface; 20% more on a south facing surface with an incline of 40. Solar panels can on the average deliver 456 kWh/year/m2, and for each square meter of solar panels, 2.5 m2 land must be available. As a supposition, the necessary acreage can be calculated that is needed for covering the Sonderborg area's net heat demand with solar heat for 935 GWh/year / (456/2.5) kWh/year/m2 = 510 ha = 1% of the area's acreage.

However, it is difficult to store the heat from summer to winter (unless Sonderborg District Heating's efforts to establish seasonal storage in connection with the geothermic unit turns into a success), and furthermore, there is energy consumption that cannot be covered by heat.

Thus, it is relevant to examine which other energy can be utilised from the area's acreage. *Figure 38* shows how the municipality's 49,657 hectares are assumed utilised in 2012, 2015, 2021 and 2029 in the Master Plan.

The following changes from 2012 to 2029 are assumed – measured in percentages of the area's total acreage:

- Corn totally -18%
- Rapeseed -11%
- Grass and clover -3%
- Fallows -3%
- Forage crop -1%
- Remaining areas: town, road +1%
- Forest areas +7%
- Natural areas +8%
- Energy crops totally +20%

The mentioned area changes have been estimated by the Agriculture Group with representatives from Centre for Bio Energy and the agricultural organizations. The scenario implies that approx. 20% of the agricultural area will be converted to energy crops. The scenario is subject to great uncertainty. The development of the agriculture - among others the pig production and biomass production – will of course especially depend on the development in food prices and energy prices.

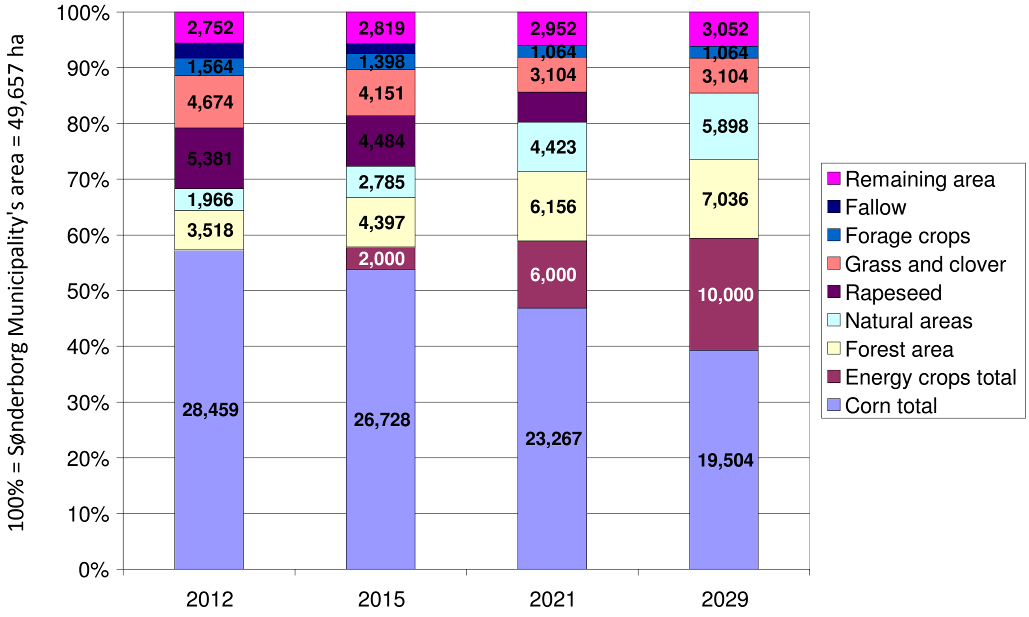


Figure 38: Assumed development in the utilisation of the acreage in the Sonderborg area, 2012-2029 (100% = 49.657 hectares).

All things being equal, the food production must be expected to continue for a longer time in the Sonderborg area than in the neighboring areas due to the fact that the ground has better site quality thus import of biomass will take place from these areas to the Sonderborg area.

However, provided that the energy sector is willing to pay the necessary price for the energy crops and that the production reaches the outlined level that must be considered the maximum scenario.
Below, the assumptions for calculating the potential energy production from each individual area type are described. The resulting production of biomass for combustion and biogas production are shown in *Figure 39* and
Figure 40. *Figure 41* shows the total energy potential. The figure includes rapeseeds, oil seeds that however are not expected to play a role in the energy supply of the Sonderborg area.

Corn - Straw

It is assumed that the number of animals will drop and that the need for corn products for forage also will decrease. Thus, the energy potential of straw will decrease in the plan period by approx. 30%.

The energy content of straw is assumed to be 4 tons/acre x 14.5 GJ/tons = 58 GJ/acre. Furthermore it is assumed that only half of the amount of straw will be available for the energy sector.

Energy Crops

It is assumed that corn and green rye are seeded on half of the areas with energy crops and that willows will be planted on the other half of the area. The energy crops mentioned are chosen to illustrate the energy potential other combinations might turn out to be better during the plan period.

The corn is seeded in May and harvested in September where the green rye is seeded in September and harvested in May. Corn is a whole crop produce like grass and other roughage. Both corn and green rye are used for biogas production. The yield is:

- corn: 15 tons/acre x 300 m3 biogas/ton x 23 MJ/m3 = 104 GJ/acre
- green rye: 3 tons/acre x 250 m3 biogas/ton x 23 MJ/m3 = 17 GJ/acre
- total: 121 GJ/acre – or twice as much as for straw.

In Germany approx. 350,000 acres are used for corn for biogas. The area is 7 times bigger than the Sonderborg area.

The harvest yield from willows that is used for combustion is 10 tons/acre x 16 GJ/tons = 160 GJ/acre, which is 1/3 more than from corn/green rye. The productivity of energy crops is expected to increase in general during the next years; e.g. the yield from willow could probably increase from 10 to 12 tons dry material per acre within short.

The farmers prefer annual rather than biennial crops as long as sales of biennial crops are uncertain. If the energy sector wants willow in the future energy supply, it is necessary to enter contracts of a 20-25 years' duration with the farmers.

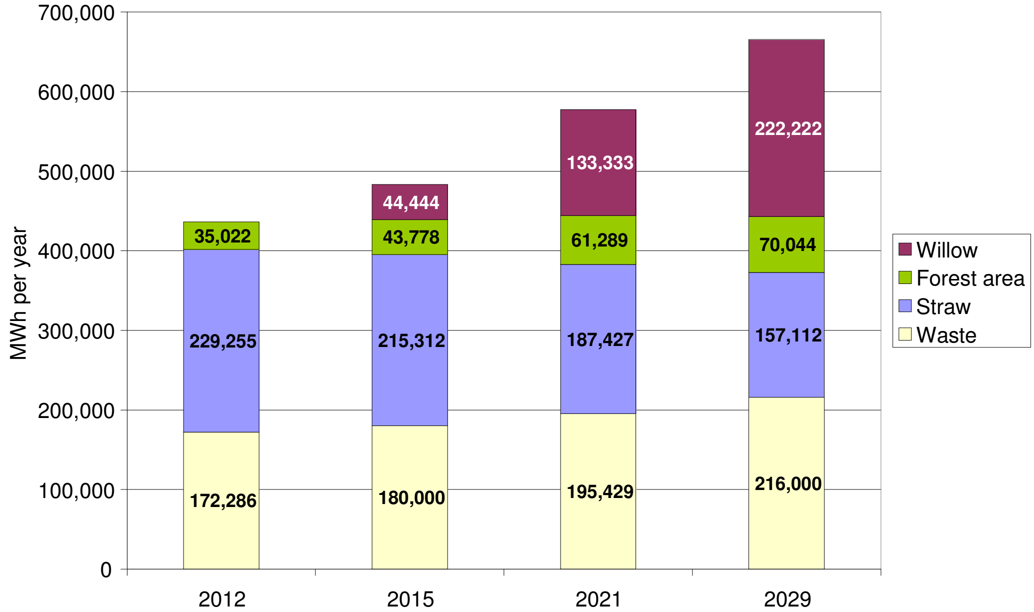


Figure 39: Potential production of biomass in the Sonderborg area for combustion.

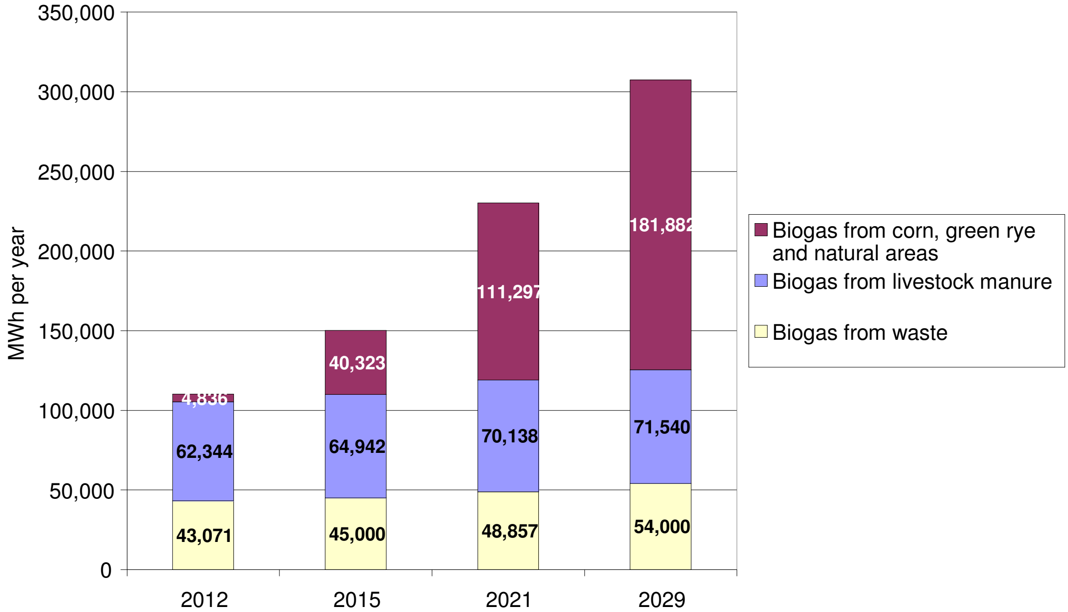


Figure 40: Potential production of biogas in the Sonderborg area.

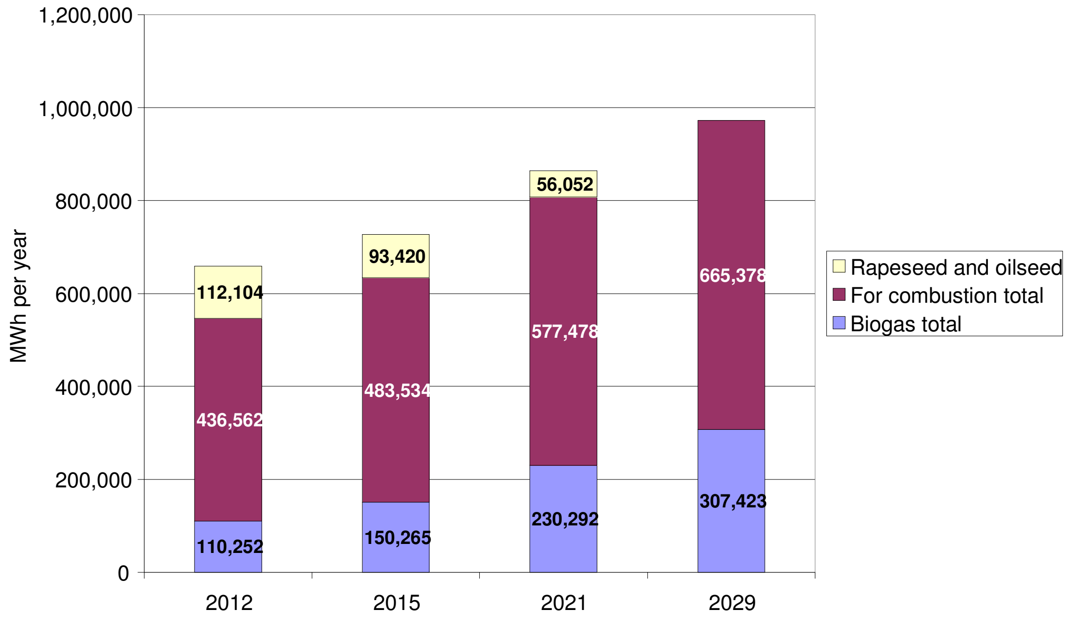


Figure 41: Total energy potential from biogas in the Sonderborg area.

Natural Area

Care of natural areas is estimated to contribute with 3 tons/acre x 9.5 GJ/tons x 30% = 8.6 GJ/acre. In addition, there will be a constant contribution of 167 MWh/year from weed cutting along streams. Both will be used for the biogas production.

Forest Areas

From the total felling of trees from the forests, half of it is expected to be used as fire-wood and energy wood while the other half is used as timber e.g. furniture etc.

The potential in energy wood:

- Hardwood tree: 82% x 5 m3/acre x 660 kg/m3 x 19.0 GJ/tons = 63 GJ/ acre forest
- Coniferous trees: 18% x 5 m3/acre x 460 kg/m3 x 19.2 GJ/tons = 44 GJ/acre forest
- Total: 107 GJ/acre.

It is estimated that:

- 10% of the timber after the processing procedures can be used for energy purposes,
- windbreaks etc. can contribute with an amount of energy corresponding to 15% of the energy content of the total felling from the forests.

Today, approx. 38 GWh wood is used in the area cf. *Table 5*, that is the net heat demand (after loss in biomass furnaces) of 40 GWh covered by straw/wood.

Biogas from Manure

The exploitable energy potential in biogas from manure is in *Table 10* calculated to 71,540 MWh in 2029. The potential is based on an assumption that the number of animals is decreased by approx. 1/3 compared to today and that it is possible to produce biogas on 85% of the manure from these animals. If the production takes place in a steady flow over the hours of the year, the energy amount corresponds to a power of 8 MW. As shown in

Figure 40 waste and corn/green rye etc. will however increase the biogas potential considerably.

Table 10: Udnytteligt energipotentiale fra biogas fra husdyr Exploitable energy potential from biogas from manure.

					2012	2021	2029
				Livestock units:	100%	75%	67.5%
				Utilization rate.	50%	75%	85%
	DE: livestock units	ton/ DE	m3/ ton	Potential, MWh, #	MWh	MWh	MWh
Pigs	43,173	17	22	103,159	51,580	58,027	59,188
Cattle	6,464	15	22	13,629	6,814	7,666	7,819
Poultry	3,365	4.9	75	7,901	3,950	4,444	4,533
Total	53,002			124,689	62,344	70,138	71,540

#: 23 GJ/m3 biogas

Waste

In 2007, 68,186 tons waste was incinerated at Sonderborg CHP plant. Approx. 57% hereof originated from the Sonderborg area while 43% originated from Aabenraa municipality. The energy content of the incinerated waste was 199 GWh, jf. *Table 8*.

According to DEA's basic projection of Denmark's energy consumption, the energy content of incinerated waste will increase from 14 PJ in 2009 to 19 PJ in 2030. I.e. an increase of 36% is expected. Based on this projection, the energy content in waste for incineration at Sonderborg CHP plant is estimated to 270 GWh in 2029 (225 GWh in 2015).

According to the Agriculture Group's mapping, approx. 20% of the energy content in the waste (54 GWh in 2029) can be extracted as biogas while the remaining part (216 GWh) must be used for combustion.

DEA has determined the emission coefficient for waste to 32.5 kg CO_2/GJ, corresponding to a plastic content of approx. 10% measured on the weight. As we assume an unchanged emission coefficient for 2029, the CO_2 emission by combustion of waste will be 270,000 MWh * 3.6 GJ/MWh * 32.5 kg/GJ = 31,600 tons CO_2.

8.2 Room Heating and Hot Domestic Water 2029

Specific Net Heat Demand

The proposal for a heating plan is based on an assumption that the specific net heat demand decreases by 25% from 2009 to 2020. Hereafter it is assumed to be constant.

The Master Plan is more ambitious and presupposes that the specific net heat demand decreases by 35% up to 2029. The Master Plan expects the improvements in climate envelope and fixed installations to be bigger than estimated in the proposal for the heating plan due to extraordinary support from building owners, construction industry, and district heating companies, municipality and other players. The specific devices are described in section 7.4 and in the catalogue of measures for buildings. These correspond to the prerequisites in IDA's Climate plan 2050.

IDA's Climate plan 2050 assumes that the energy consumption for room heating is decreased by 78 PJ in 2030 corresponding to 37% of the consumption in 2007 (approx. 210 PJ). The measures are among others consumer information, continuing education, tightening of building regulations, consumer-oriented incentive schemes, the public sector as front runner, differentiated taxation of housing, favorable mortgage financing and public subsidies of 675M DKK/year during the period 2010-2020 for the construction sector including lighting and electric appliances .

District Heating Coverage

The proposal for the heating plan for the Sonderborg area prepares for a considerable expansion of the district heating supply by:

- connecting all buildings to district heating that are within or close to the district heating supply areas and not yet connected to district heating
- establishment of a transmission pipe from Sonderborg to Nordborg, and switching all buildings in Guderup and Svenstrup to district heating over a number of years.

The Master Plan assumes the same district heating coverage in 2029 as the proposal for the heating plan, i.e. a district heating coverage of 462,944 / 75% * 65% = 401,218 MWh (the proposal for the heating plan assumes a heat demand in 2029 of 75% of the heat demand in 2007, i.e. a 25% reduction while the Master Plan assumes 65%, i.e. a 35% reduction).

Assigned a total net loss of 126,560 MWh, according to the heating plan, the heat demand ex plant will be 527,778 MWh.

The remaining net heat demand in the Sonderborg area (246,599 MWh) in 2029 is assumed to be covered as follows:

- 65% with individual heat pumps (hereof 1/3 electricity and 2/3 geothermal heat).
- 20% with individual biomass furnaces e.g. wood pellet furnaces.
- 15% with solar heat as a supplement to the individual heat pumps and biomass furnaces

The result of this plan appears from *Figure 42*. The district heating coverage increases by 18% points from 44 to 62% (the figures include Danfoss' process energy consumption).

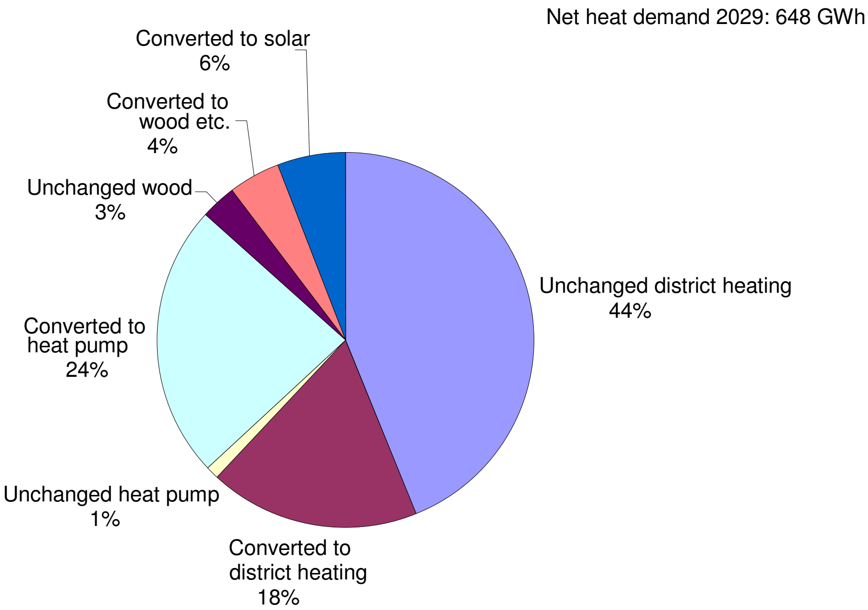


Figure 42: Coverage of the net heat demand in 2029 compared to today (100% = 648 GWh).

Individual Heating

The biggest change is however that 24% of the net heat demand in the Sonderborg area is assumed to change from oil furnaces, natural gas furnaces and electric ovens to individual heat pumps.

Buildings with central heating systems are assumed to change to earth/water or air/water heat pumps while buildings with direct electric heating change to air/air heat pumps.

5% of the net heat demand in the Sonderborg area is assumed to change from oil furnaces, natural gas furnaces and electric ovens to biomass furnaces.

District Heating Production

The district heating is assumed produced in the following three district heating systems:

- The district heating networks in Sonderborg, Vollerup, Augustenborg, Guderup, Svenstrup, Danfoss and Nordborg are assumed interconnected with a transmission pipe,
- Gråsten district heating,
- Broager district heating.

Figure 43 shows the relative size of the three district heating networks.

It is recommended to examine whether it is cost-effective to extend the transmission pipe from Sonderborg to Broager and Gråsten with a view to a better exploitation of cheap base-load units (waste heat, geothermal heat, heat based on biogas and solar heat) and a possible utilization of surplus heat from industries on the route.

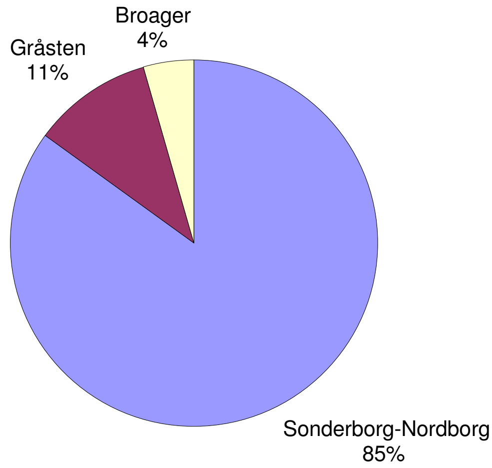


Figure 43: District heating production ex plant, 2029 (100% = 528 GWh).

Table 11 shows how the district heating could be produced for the three district heating systems in 2029.

The units' annual production is for all three systems calculated on the basis of duration curves with a utilisation time of 4,171 hours/year, corresponding to the utilisation time for a district heating system with 50% fixed consumption (25% net loss + 1/3 of the net heat demand is assumed to be domestic water etc).

Table 11: Coverage of district heating demand ex works, 2029 (GWh). The red figures show the used amount of energy while the black figures show produced electricity and district heating.

	Plant effect: MW	Waste	Straw	Wood	Willow, Corn, green rye	Remaining prod. ethanol product.	Bio ethanol & -oil	Biogas	Solar energy	Geo-thermal	Ground heat (v.p.)	Elec-tricity	District heating
Transmission system Sonderborg-Vollerup-Augustenborg-Guderup-Svenstrup-Danfoss-Nordborg													
Bio oil	27.6	0	0	0	0	0	-6	0	0	0	0	0	6
Biomass district hea-ting	14.0	0	0	0	-25	0	0	0	0	0	0	0	21
Heat pump	14.0	0	0	0	0	0	0	0	0	0	-34	-17	51
Geothermal	29.0	0	0	0	-86	0	0	0	0	-96	0	-6	169
Biogas kv	4.0	0	0	0	0	0	0	-74	0	0	0	28	35
Solar panel	1.8	0	0	0	0	0	0	0	-16	0	0	0	16
Waste kv	17.2	-216	0	0	0	0	0	0	0	0	0	45	151
Total	107.6	-216	0	0	-111	0	-6	-74	-16	-96	-34	51	449
Gråsten district heating													
Bio oil	4.4	0	0	0	0	0	-2	0	0	0	0	0	2
Biomass district hea-ting	6.5	0	0	0	-38	0	0	0	0	0	0	0	32
Biogas kv	2.5	0	0	0	0	0	0	-46	0	0	0	18	22
Total	13.4	0	0	0	-38	0	-2	-46	0	0	0	18	56
Broager district heating													
Bio oil	2.0	0	0	0	0	0	-1	0	0	0	0	0	1
Biomass district hea-ting	3.0	0	-20	0	0	0	0	0	0	0	0	0	17
Solar heat	0.5	0	0	0	0	0	0	0	-5	0	0	0	5
Total	5.5	0	-20	0	0	0	-1	0	-5	0	0	0	23

In all three systems the peak load (30-40% of the maximum power demand ex plant with 3-7% of the annual production) is covered by bio oil or bio ethanol fired boilers.

The load distribution in 2015 and 2029 in the transmission system Sonderborg-Nordborg appears in*Figure 44* and *Figure 45*.

The differences are as follows:

- The total heat production ex works has decreased from 535 to 449 GWh
- The heat from waste combustion has increased from 141 to 151 GWh
- The heat from the geothermal plant has decreased from 195 to 169 GWh due to the smaller heat basis (assuming that heat storage has not been established)
- The gas fired CHP plant (the gas turbines) is replaced by 14 MW heat pumps on the average (that uses 17 MWh electricity a year, cf. Table 11) and 14 MW bio-mass fired boilers
- The natural gas fired peak load boilers are replaced by bio oil and bio ethanol fired boilers.

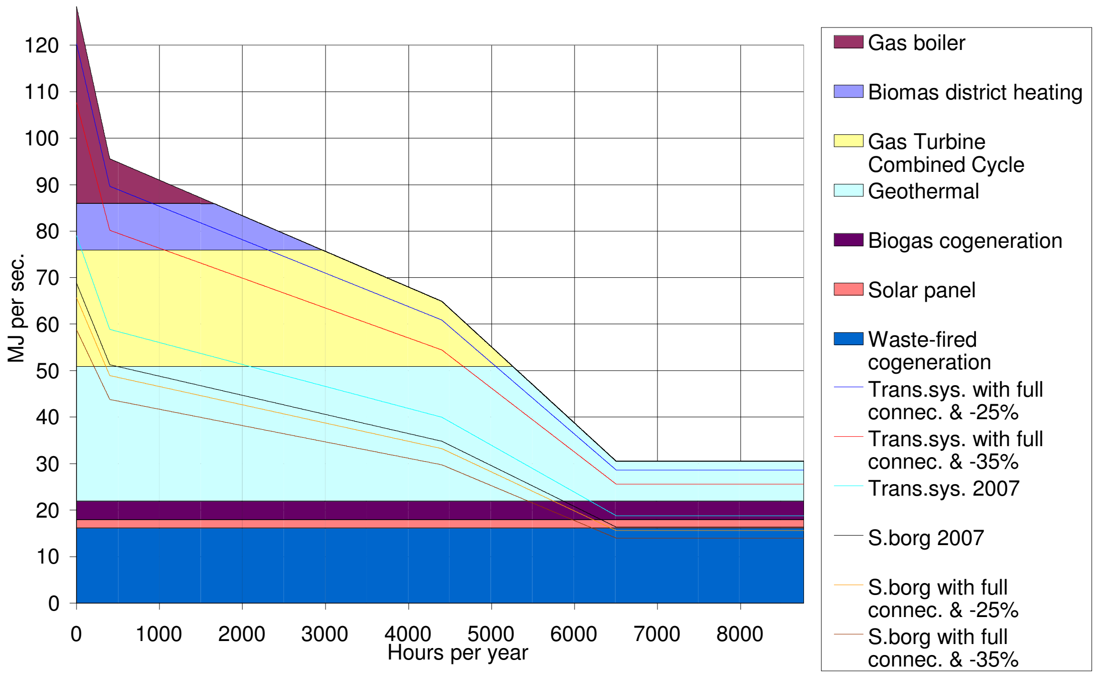


Figure 44: Duration curve of the interconnected transmission system 2015.

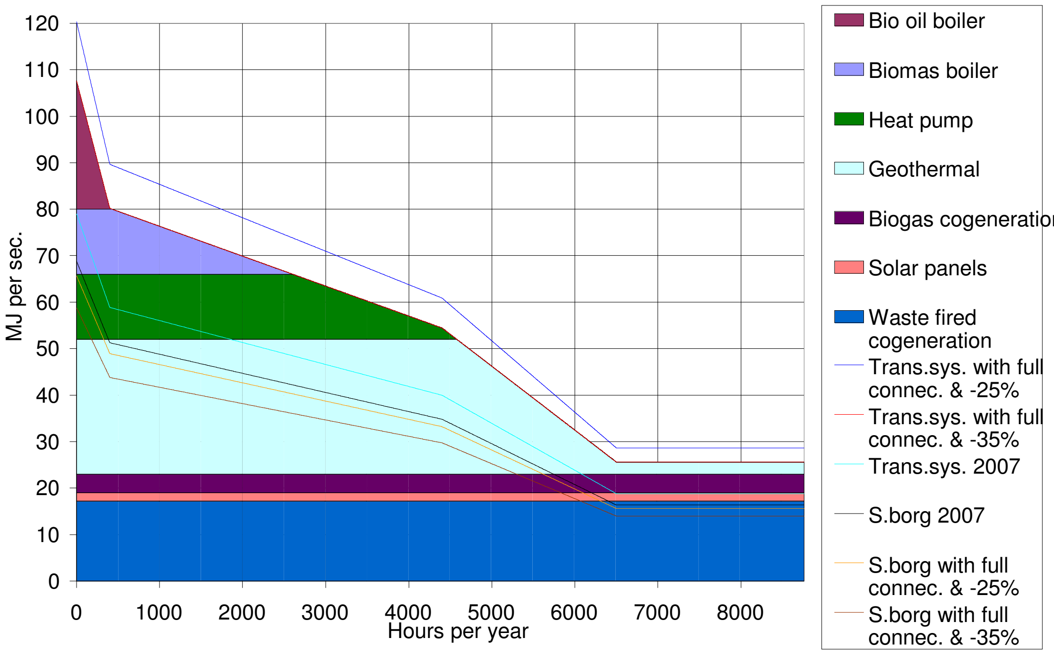


Figure 45: Duration curve of the interconnected transmission system 2029.

The allocation of the resulting district heating and electricity production ex works on fuels is shown in *Figure 46* and *Figure 47.*

Figure 48 shows that approx. 43% of the electricity consumption is flexible: 30% goes to electric cars, 3% to central district heating pumps and 10% to individual heat pumps with heat accumulators that are also used for the solar heating systems.

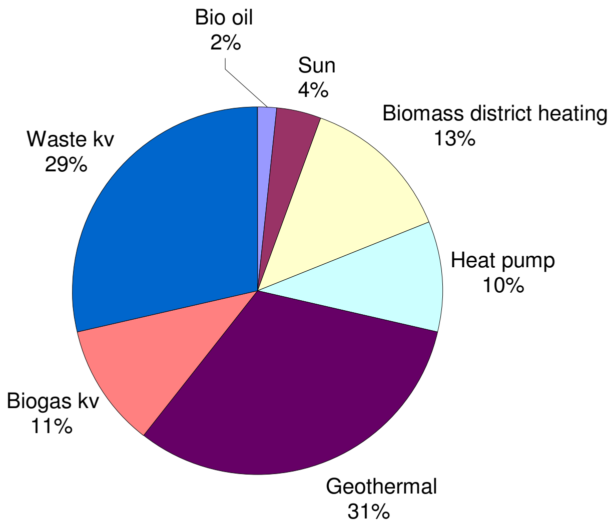


Figure 46: Allocation of district heating production ex plant on energy sources, 2029 (100% = 528 GWh).

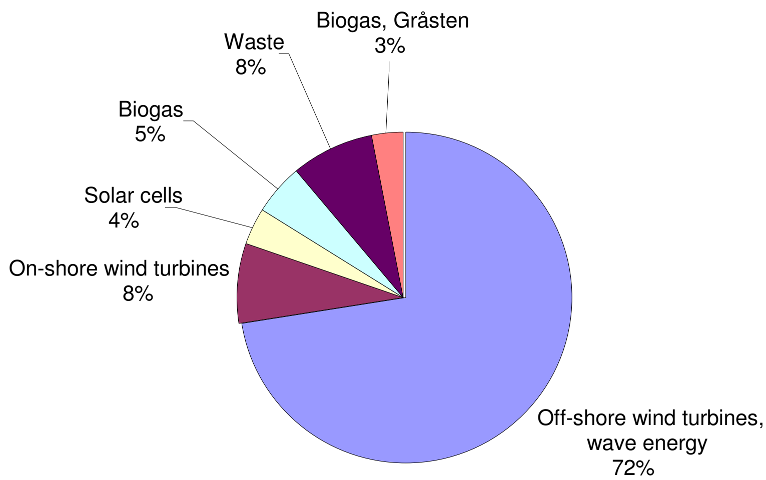


Figure 47: Allocation of electricity production on energy sources, 2029 (100% = 562 Gwh

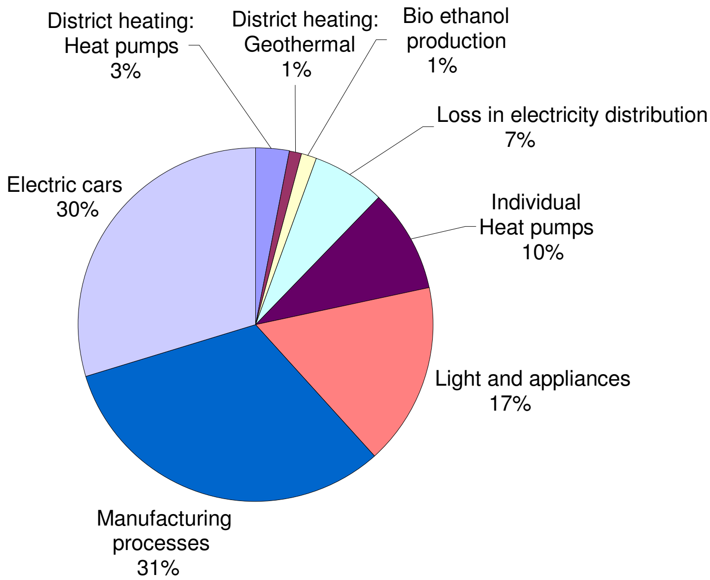


Figure 48: Allocation of electricity production on application (1005 = 562 GWh)

The base load is covered in the interconnected transmission system Sonderborg-Nordborg as follows:

- After separation of waste for biogas production, the energy content in the waste is 216,000 MWh. This results in a heat and electricity production of 151,000 and 45,000 MWh/year. The calculation is made according to the same electricity and heat efficiency as today: 21% and 70%.

- Prior to 2015, a central solar heating system of 35,000 m2 is established with an annual production of 16,000 MWh .

- In 2013 a biogas plant is established that delivers gas to an existing gas motor in Augustenborg that is converted to biogas. The gas motor delivers 4.0 MW heat during all hours of the year. With a total efficiency of 85% and Cm = 0.8 (heat efficiency 47.2%) the thermal biogas amount will be 8.5 MW or 74,000 MWh/year. The bio gas production will be based on organic waste and manure.

- A geothermal plant with a heat efficiency of 29 MW is established in Sonderborg. The heat comes from the earth (16 MW) and transmission heat from the biomass fired boilers (13 MW).

- 14 MW central heat pumps with an efficiency factor of 3 is established. The heat pumps are primary in operation in periods with low electricity prices which will often happen in an electric system with much wind energy.

- The biomass fired boilers (85% efficiency) that run the geothermal plants are made 14 MW bigger than necessary for the operation of the geothermal plant in preparation for heat supply to the district heating network. The biomass can be wood, straw or residues from the bio ethanol production.

The specific market prices of biomass and electricity determine whether the heat pumps or the biomass fired boilers must cover the intermediate load. The two types of plants are established each with an efficiency of approx. 30 MW as they usually will be in operation at the same time but separately.

The efficiency and annual production of the various district heating production plants appear from *Table 11*.

Thus the base load is covered by Gråsten district heating:

- In 2013, a biogas plant is established that delivers gas to an existing gas motor in Gråsten that is converted to biogas. The gas motor delivers 2.5 MW heat during all hours of the year. With a total efficiency of 85% and Cm = 0.8 (heat efficiency 47.2%) the thermal biogas amount will be 5.3 MW or 46.000 MWh/year. The bio gas production will be based on organic waste and manure.

- A biomass fired district heating plant is established with a heat efficiency of 6.5MW (85% efficiency).

The efficiency and annual production of the various district heating production plants appear from *Table 11*.

Thus the base load is covered by Broager district heating:

- A central solar heating system of 10.000 m2 is established with an annual production of 4,560 MWhf[f].

- A biomass fired district heating plant is established with a heat efficiency of 3.0 MW (85% efficiency).

The efficiency and annual production of the various district heating production plants appear from *Table 11*.

[f] Such plant was established and taken into use on September 1, 2009.

8.3 Lighting and Appliances

The electricity consumption for lighting and appliances in buildings (housing and trade and service businesses) is assumed to decrease by 50% which is in accordance with IDA's expectations for 2030 in the Climate plan 2050, however 20 years earlier in Sonderborg due to the focused efforts on energy efficiencies. The measures are among others consumer information, consumer campaigns, labeling, and EU standards for maximum allowed energy consumption.

8.4 Manufacturing Processes

The Manufacturing industries are agriculture, industry and construction companies. These industries' energy consumption (fuels and electricity) is expected to be reduced by 35% during the plan period due to energy savings and structural changes such as relocation of certain energy demanding industries to other countries.

This is in line with IDA's Climate plan 2050 that expects the industry's fuel consumption to be reduced by 31% in 2030 while the electricity consumption will be reduced by 43%. Both Sonderborg's Master Plan 2029 and IDA's Climate plan 2050 emphasize a great need for development of new incentive structures that will encourage the companies' investments in energy efficiencies.

The reduced energy consumption is assumed to be redistributed to RE resources as follows:

- The requirements that are today covered by petrol and diesel oil (32% of the total process energy consumption including electricity) are redistributed to biogas (75%) and electricity (25%).

- The requirements that are today covered by natural gas and coal (36% of the total process energy consumption including electricity) are redistributed to solid biomass (residues from ethanol production, straw, wood or non-food crops (75%) and electricity (25%)).

8.5 Transport

In the Master Plan it is assumed that the road transport requirement (person km and ton km) will increase with 18%, but the growth will be fully compensated by the energy efficiency (9%) thus the energy consumption will be unchanged.

The petrol and diesel oil consumption is assumed redistributed to RE as follows:

- 80% is replaced by electricity
- 12% is replaced by biogas
- 8% is replaced by bio ethanol or alike.

This fuel mix is a possibility in 2029 but hydrogen / fuel cell cars or hybrid cars might have a large market share.

8.6 Energy Balance 2029

Table 12 sums up the consequences of the above listed efficiency measures and fuel conversions and adds three new elements to the energy balance for 2029:

On-shore Wind Turbines in the Sonderborg Area (B2 in the Table)

Today, 21 wind turbines have been erected on-shore in the Sonderborg area with an installed capacity of 10 MW. Until now, it has been the city council position that some of this capacity must be replaced by bigger wind turbines but other capacity will be cut down thus no net growth will take place in the totally installed capacity.

The Master Plan assumes that this policy will be changed and that it will be possible to establish further 10 MW wind turbine capacity on-shore during the plan period thus the total on-shore based wind turbine capacity will be 20 MW. The production from this is expected to be 44,000 MWh/year.

Central and Decentralized Solar Cells (B3)

The production is expected to be 20,000 MWh in 2029. If the application time is 1,000 hours/year, it corresponds to an installed capacity of 20 MW. The 20,000 MWh correspond to 3.6% of the electricity consumption in the distribution network in the Sonderborg area.

In its Climate plan 2050, IDA calculates with 5% coverage of buildings' electricity consumption in 2050 by the building integrated (decentralized) solar cells. IDA assumes that in 2030 the total production of central and decentralized solar cells will be able to cover 0.9 TWh / 31.1 TWh = 2.9% of the electricity consumption.

Bio Ethanol Plant (B4)

With a view to providing liquid fuels to heavy vehicles in the transport sector, part of the straw and non-food energy resources are used for the production of bio diesel and bio ethanol in second generation bio ethanol plants that are not necessarily situated in the Sonderborg area.

The plant allows the biomass amounts that cannot be used in CHP plants, individual biomass furnaces or manufacturing processes to be used in a meaningful way – based on the overall premise that the local biomass resources must be used locally.

It is assumed that 4% electricity must be used for a “firing” energy unit biomass. The output is 30% bio ethanol, 27% solid residue that can be used for combustion in boiler units, and 43% loss (hereof 12% are included in a residue that can be used as animal feed).

In the Master Plan 2029 it is assumed that the CO_2 emission from the ethanol production is zero as the production is based on residues (biomass) and CO_2 free electricity. Furthermore it is assumed that the energy crop harvest is made with machines driven by CO_2 free energy.

Imported Electricity (B1)

For the energy balance to go up, it is necessary to import 407,000 MWh electricity in 2029. If this electricity must be produced in off-shore wind turbine farms with an application time of 3,600 hours/year, the necessary capacity must be = 113 MW. Wave power plants could also be an option. Off-shore wind turbines could be established in the waters between Als and Ærø – alternatively in the Kattegat or the North Sea.

Table 12: Energy balance for the Sonderborg area, 2029 (MWh).Negative values are marked with red.

	Waste	Straw	Wood	Willow, corn, green rye	Re-maining product ethanol product	Bio ethanol & oil	Biogas	Solar energy	Geo-thermal	Ground Heat (v.p.)	Wind	Offshore wind, wave energy	Elec-tricity	District heat	Total
Local resources	216	157	70	222			307								973
Import		5	-8	-15	31	-0	5					407			783
A: Net energy consum.	216	163	62	207	31	-0	313	78	96	141	44	407			1,756
B1: Imported (Impor-												-407	407		
B2: Local wind turbines											-44		44		
B3: Central/decentralized Solar cells								-20					20		
B4: Bio ethanol plant		-142		-57	56	62							-8		-89
B5: Transmission system	-216					-6	-74	-16	-96	-34			51	449	58
B6: Gråsten district heating						-2	-46						18	56	25
B7: Broager district heating						-1		-5						23	17
B: Conversion sector total	-216	-163		-207	56	54	-121	-41	-96	-34	-44	-407	531	528	-159
C: Distribution loss													-37	-127	-164
D: Final energy consump:A+			62		87	54	192	37		107			494	401	1,434
- Room heating			-62					-37		-107			-53	-361	-620
- Lighting/appliances													-95		-95
- Manufacturing processes					-87		-111						-178		-376
- Transport						-54	-81						-168		-303
D: Final energy consump.			-62		-87	-54	-192	-37		-107			-494	-401	-1,434

Reading guide to the table: 70 GWh wood resources are available. 62 GWh hereof are used in the Sonderborg area while 8 GWh are not used or exported. The 62 GWh wood are used for room heating and hot domestic water.

IDA bases the Climate plan 2050 on an extensive expansion of the wind turbine capacity in Denmark combined with storage possibilities in fuel cells and batteries in e.g. electric cars and utilisation of electricity in heat pumps. Electric cars and central and decentralized heat pumps are also included as central elements in the Master Plan 2029. *Figure 49* and *Figure 50* illustrate the gross energy consumption and the final energy consumption as shown in *Table 12*.

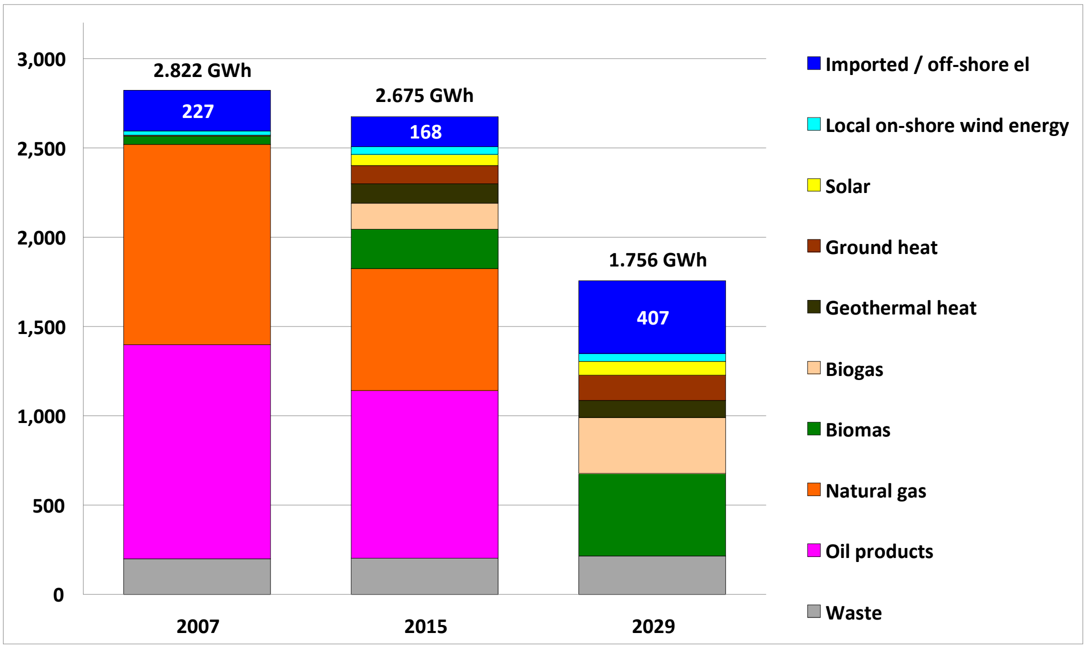


Figure 49: Gross energy consumption in the Sonderborg area (GWh/year).

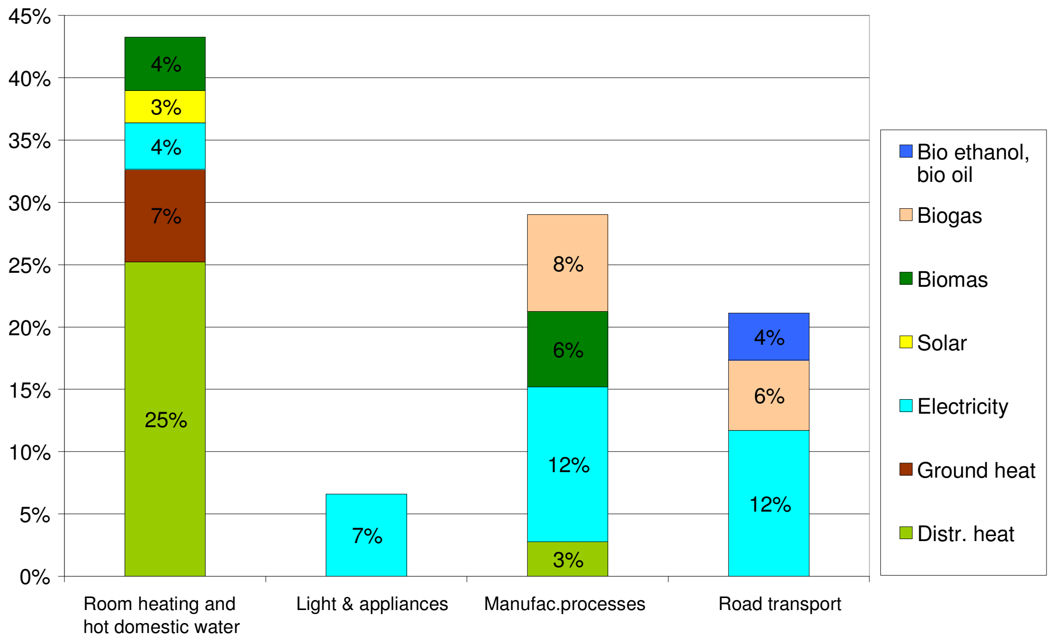


Figure 50: Final energy consumption in the Sonderborg area, 2029 (100% = 1.434 GWh).

The gross energy consumption decreases from 2,822 GWh in 2007 to 1,756 GWh in 2029. The Sonderborg area changes from being highly dependent on fossil fuels – especially natural gas and oil products – to cover 77% of its gross energy consumption with energy produced within the area borders. The rest of the consumption (23%) is covered by electricity produced in own plant outside the area.

The final energy consumption in 2029 is 1,434 GWh. District heating, heat pumps and biomass boilers cover the major part of the consumption for room heating and hot domestic water. Bio ethanol is produced for road transport and the residues are used in industrial manufacturing processes. Biogas is used in district heating production but also in manufacturing processes and in road transport. In the manufacturing processes and road transport it amounts to 27% of the segment's total energy consumption.

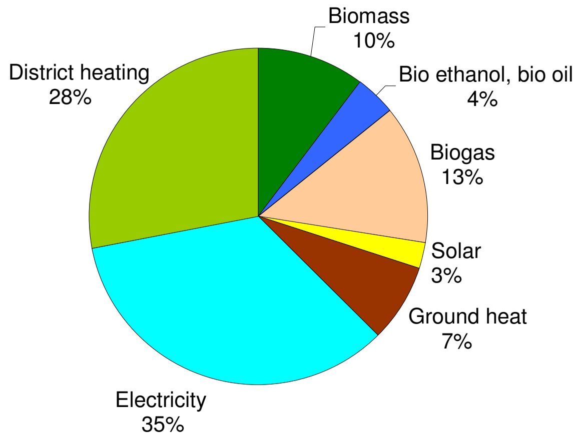


Figure 51: Final energy consumption allocated on fuels, 2029 (100% = 1.434 GWh).

8.7 Application of Local Energy Resources

With the mentioned assumptions, all energy resources available in the Sonderborg area are applied in 2029. Furthermore, the energy balance is based on a continuous disposal of the waste from Aabenraa municipality by Sonderborg CHP plant.

The composition of the biogas potential and the biogas consumption in 2029 is shown in *Table 13*.

It is assumed that in 2015 the manufacturing industries have a biogas consumption of 24,395 MWh after conversion of 15% the oil and natural gas consumption in 2007 to electricity (25%) or biogas (75%).

In 2029, the whole oil and natural gas consumption of the manufacturing industries has been redistributed and biogas is furthermore used in the transport sector.

Table 13: Biogas potential and application, 2015 and 2029 – MWh/year.

	2015	2029	2015	2029
Potential for biogas production				
Waste	45,000	54,000	30%	18%
Manure	64,942	71,540	43%	23%
Corn, green rye, nature	40,323	181,882	27%	59%
Total	150,265	307,423	100%	100%
Application of biogas				
Cogeneration for I transport system*	74,202	74,202	51%	24%
Cogeneration For Gråsten *	46,376	46,376	32%	15%
Manufacturing processes	24,395	111,274	17%	36%
Transport	0	80,923	0%	26%
Total	144,973	312,775	100%	100%

*: 85% total efficiency and Cm = 0.8 i.e. electricity and heat efficiency are 47.2% and 37.8%.

Table 14 shows a corresponding application of the biomass resources that are estimated to be available in 2029. A great part (31%) is used in a bio ethanol factory in or outside the Sonderborg area that produces fuels for the transport sector.

Table 14: Biomass potential and application, 2015 and 2029 – MWh/year.

	2015	2029	2015	2029
Potential for biomass production				
Straw	215,312	157,112	71%	35%
Willow	44,444	222,222	15%	49%
Forest areas	43,778	70,044	14%	16%
Total	303,534	449,378	100%	100%
Application of biomass				
Bio ethanol plant (transport)	0	143,444	0%	31%
Trans.sys. biomass DH.	27,207	25,022	15%	5%
Trans.sys. geothermal	99,865	86,476	54%	19%
Gråsten, biomass DH	0	38,045	0%	8%
Broager, biomass DH	0	20,406	0%	4%
Room heating and vv	59,126	61,650	32%	13%
Manufacturing processes	0	86,925	0%	19%
Total	186,197	461,968	100%	100%

9 Socio-Economic Evaluation of the Master Plan

In the previous chapters it has been described how the Sonderborg area technically can bring the CO_2 emission to zero in 2029. An obvious question now will be what will it cost?

Below we have made a bid on the cost however it must be emphasized that it is rough calculations with great uncertainty incorporated. No one today can predict with certainty the extent of the climate problems the world community will be facing in 10 years and how Denmark and the EU will react to such problems with regulations. Furthermore, no one can with certainty predict how the prices for fuel and energy will develop when the CO_2 emission becomes more expensive and what technologies will be most competitive by then.

9.1 The Gross Energy Consumption in 2029 will be Covered Like This

There are some few constants and one of them is the area of the municipality. If the Sonderborg area must achieve CO_2 neutrality in 2029 based on own resources, it must be done by using the area of the municipality in the best possible way for biomass and energy crop production. This production must take place in competition with the agriculture's food and feed production.

The Master Plan 2029 is based on an annual consumption of 721 GWh local biogas and biomass, which is almost the maximum that can be expected gained from the soil. Further 270 GWh will come from waste, assuming that the waste from Aabenraa (43%) will be sent to combustion in Sonderborg. Thus the total local fuel resources are 991 GWh, corresponding to 56% of the expected gross energy consumption of 1,756 GWh in 2029.

Thus the remaining 44% must come from energy sources above and below ground. The Master Plan 2029 suggests the following possible allocation:

- 6% from geothermal heat applied in the district heating systems,
- 8% from ground heat applied in individual heat pumps,
- 4% from solar heat and solar cells in central and decentralized plants,
- 3% from local on-shore wind turbines where the power is assumed doubled compared to the existing 10 MW and
- 23% from off-shore wind turbines.

This means that 23% of the gross energy consumption in the Sonderborg area in 2029 must come from off-shore wind turbines. This is even with maximum utilization of the expected local biomass and waste resources and assuming that the very ambitious saving targets will be realized.

The 23% off-shore wind energy corresponds to 407 GWh/year or 113 MW wind turbine capacity if the plants have a utilization time of 3,600 hours/year. Off-shore wind turbine farms cost approx. 19M DKK/MW including grid connection etc. thus the investment will be estimated to 2.1bn DKK.

The ambitious saving targets consist of the following changes compared to 2007:

- 35% reduction of the net heat demand t,
- 50% reduction of need for electricity for lighting and appliances in housing, trade and service,
- 35% reduction of the energy consumption for manufacturing industries and
- 9% higher road transport requirement and switching from petrol and diesel oil to electricity (applied through batteries and fuel cells, bio ethanol and biogas.

9.2 Heating Savings

It is assumed that the heating savings cost 18,900 DKK/(MWh/year) on the average excluding VAT if 35%[g], must be saved with a longevity of 40 years.

A single-family house from the 1960s (27% of all single-family houses in the municipality) has typically a net heat demand of 143 kWh/year/m2 x 130 m2 = 18.6 MWh/year. If the heat demand must be reduced by 35% (6.5 MWh/year), the investment will be 123,000 DKK excluding VAT.

The total heat demand in the building stock in the Sonderborg area is 925,000 MWh/year. If the demand must be reduced by 35%, the total investment will be 324,000 MWh/year x 18,900 DKK/(MWh/year) = 6.1bn DKK. Savings that size will not be profitable with the actual energy prices however the savings are expected to be profitable in ten years as the CO_2 and fuel prices are expected to increase considerably (see below).

However, it is possible that a 35% saving will not be private economically profitable when the oil and natural gas furnaces have been replaced by district heating connections, individual heat pumps and biomass furnaces that are characterized by low varia-

[g] SBI 2009:05: "Potential energy savings in the existing construction" (page 26) states the costs by reducing the heat demand in the Danish building stock with 37% on average. Applied on the Sonderborg areas building stock, the costs will be 22,000 DKK per saved MWh/year on average, if the energy renovation cannot take place together with an already planned building renovation, and 6,200 DKK per saved MWh/year, if the energy renovation can take place together with a planned building renovation (marginal cost). Weighted 80/20, the average cost will be 18,900 DKK per saved MWh/year.

ble costs. In this case, the weighting between reduction and production of heat will be different however it will not move the overall economy fundamentally.

In Roadmap 2010-2015 it is assumed that the heat consumption will be reduced by 5% during the period 2010-2015. This corresponds to a 35% reduction of the heat consumption before 2015 made by 1/7 of the building stock. However, all combinations of more buildings and less savings per building are of course possible. The cost can be estimated to 1 / 7 of the above amount i.e. totally 900M DKK or approx. 150M DKK/year .

9.3 Electricity Savings

It is assumed that the electricity savings have 10 years longevity and that the approx. prices are:

- 10.000 DKK/(MWh/year) if the savings for lighting and appliances must be 50%,
- 6.000 DKK/(MWh/year) if the savings for manufacturing processes must be 35%.

The total consumption of electricity and appliances in housings and all other buildings apart from buildings in the manufacturing industry was in 2007 72 + 118 = 190 GWh/year. If the need must be reduced by 50% before 2029 as assumed in the Master Plan 2029, the total additional investment will be 50% x 190 GWh/year x 10M DKK/(GWh/year) = 950M DKK compared to the reference at that time.

For the manufacturing industries the price will be 35% x 222 GWh/year x 6M DKK/(GWh/year) = 470M DKK.

In total, the investments in electricity-saving measures (additional costs compared to the reference at that time) will add up to approx. 1,420M DKK or approx. 142M DKK/year during the period 2020-2029, as the investments are assumed to have 10 years longevity.

9.4 Individual Heat Pumps and Biomass Furnaces

The user economy by investing in individual heat pumps in the rural districts as replacement for existing oil furnaces or natural gas furnaces is presented in the Roadmap 2010-2015. A heat pump can be installed for 75,000 DKK excl. VAT. Based on today’s electricity and oil prices the saving will be approx. 3,700 DKK/year incl. VAT compared to an oil furnace.

With a wood pellet furnace to 50,000 DKK excl. VAT, the saving will be approx. 3,000 DKK/year incl. VAT compared to an oil furnace.

From the Roadmap 2010-2015 it appears that it is expected to switch to heat pumps and approx. 2,300 biomass furnaces before 2029 in approx. 10,200 buildings in the rural districts. With the mentioned capex, the total investment will be 880M DKK excl. VAT. Half the investment is expected to take place before 2015 .

9.5 The STREAM Model

In order to get an estimation of the total financial consequences of the Master Plan 2029, the plan has been analyzed using the STREAM model[h]. Originally, the model was developed for a project with the title "The future Danish energy system" that the Technology Council has carried through during the period 2004-2007 in cooperation with players within the Danish energy sector.

The STREAM model for the Master Plan consists of four Excel files with the preconditions for the final energy consumption (including the expected reduction of the consumption in the scenario), the composition of the conversion sector (electricity and district heat producing plants etc.), and duration curves for both reference and alternatively with time data for on-shore and off-shore wind turbine production, solar heat and solar cell production, electricity consumption, heat consumption etc.

Furthermore, the STREAM model contains a number of condition assumptions on prices for and technical characteristics of the various electricity and heat production technologies. Some of these have been applied unchanged while others have been adjusted to this project.

An essential input in the model is the choice of technologies for the conversion sector. The energy balance for 2029 shows how the energy demand in the Sonderborg area can be covered with a certain set of technologies in specific district heating plants, wind turbines, solar cells etc. Based on this balance, the percentages in *Table 15* have been chosen as input for the STREAM:

[h] www.streammodel.org

Table 15: Electricity (including cogeneration) and district heat production divided on energy sources.

	Electricity production		Boilers for district heating	
	Reference	MP 2029	Reference	MP 2029
Import (coal)	43%			
Natural gas	44%		100%	
Waste	8%	8%		
Wind	5%	80%		
Biogas		8%		
Solar		4%		8%
Biomass				29%
Geothermal				63%
Total	100%	100%	100%	100%

Table 15 shows that the regulated electricity-generating units (the waste-fired CHP plant and the biogas-fired engines) only cover 16% of the annual electricity consumption.

If the Sonderborg area should manage the electricity supply independently of the outside world, the waste-fired CHP plants and the biogas-fired engines should be able to deliver the maximum power demand on a windless day. This would mean that the plants overall would get a 16% utilization, where one usually expects a utilization of approx. 90% for technical operational and financial reasons. As 16% is not realistic it is assumed, that plants outside the Sonderborg area will be able to cover the demand in hours where the local plants (including the wind turbines) cannot cover the demand. The total annual electricity production from local plants must correspond to the total annual consumption.

This means that part of the wind turbine current is “stored” in the grid on windy periods and used in windless periods.

The ”storage” in the grid is minimized by introducing flexible consumption that can purchase current in case of surplus electricity from the wind turbine production in relation to the inflexible electricity demand that can be interrupted in case of shortage in relation to the inflexible electricity demand .
Figure 48 Figure 48 shows that the electricity consumption in 2029 is divided by 30% for electricity cars, 10% for individual heat pumps at consumers, and 3% for central heat pumps in the district heating system. Together, the flexible electricity consumption represents 44% of the overall electricity consumption.

In the socio-economic calculations it is assumed that the flexible electricity consumption together with exchange with the surroundings can ensure that the overall annual production from the wind turbines can be used locally. The consistency between consumption and production right from minute to annual basis must be ensured through the establishment of a dynamic energy system, which is mentioned in the Roadmap 2010-2015.

It is possible that later more detailed calculations will show a need for further flexibility in the system e.g. through electrolysis and fuel cells however these technologies have not been included.

9.6 Fuel Prices

IEA's fuel price assumptions from World Energy Outlook 2008 form basis of the calculations. The prices for 2030 (5.81 DKK/USD) are as follows[i]:

- Crude oil: 122 USD/barrel = 548 DKK/MWh
- Coal: 110 USD/ton = 178 DKK/MWh
- Natural gas: 344 DKK/MWh
- Straw and wood waste: 188 DKK /MWh
- Energy crops: 295 DKK/MWh

The actual crude oil price is 75-80 USD/barrel thus the mentioned 122 USD/barrel is approx. 60% higher than today's prices.

9.7 CO_2 Price

The International Energy Agency (IEA) has published World Energy Outlook 2009, where two scenarios for the development in the energy consumption and supply have been analyzed. In the reference scenario it is assumed that new policies will be introduced. This implies that the world energy related CO_2 emission reaches 40.2 Gton CO_2 in 2030.

As an alternative, IEA has prepared a scenario (”the 450 scenario”), that takes a starting point in a wish that the global average temperature must only increase by 2 °C corresponding to 450 ppm of CO_2 equivalents in the atmosphere in 2030.

In order to meet this goal, the global energy related CO_2 emission in 2030 must not be higher than 26.4Gton CO_2 which is 34% less than in the reference scenario[j]. The reduction will be provided through efficiency measures (57% hereof 51% in the end consumption), renewable energy (20%), bio fuel (3%), nuclear energy (10%), and binding of CO_2 (10%).

[i] Danish Energy Agency: “Preconditions for cost benefit analysis in the energy area”, May 2009.

[j] “Copenhagen provides an opportunity to take prompt action. Each year of delay before moving to a more sustainable emissions path would add around 500 billion USD to the global investment cost of delivering the required energy revolution (some 10.5 trillion USD for the period 2010-2030 in the 450 scenario). A delay of just a few years would render a 450 scenario completely out of reach.”(s.167). Se iøvrigt Boks 5.2, Tabel 5.4 og Figur 5.8..

The establishment of a common CO_2 quota market for all OECD countries and all non-OECE countries in Europe as of 2013 is an essential measure for obtaining the reductions.

From 2013, the large economies that are not members of OECD (China, Russia, Brazil, South Africa and the states in the Middle East) are expected voluntarily to enter agreements of CO_2 emission reductions and as of 2021 to establish CO_2 quota markets.

In the alternative scenario, IEA expects the CO_2 quota price to reach **110 USD/tons** CO_2 in 2030 in the OECD market and 65 USD/tons CO_2 in the large economies' markets.

The 110 USD/tons CO_2 corresponds to 640 DKK/ton[k], and EU's Impact Assessment of the Climate and Energy agreement estimates that the price will be 240 DKK/ton or 30 EUR/ton[l] in 2013, which is in the next framework period.

Based on the actual CO_2 price, the future CO_2 bill would be (640 – 100) DKK/ton x 674,000 ton/year = 364M DKK/year higher than today with the existing energy system in the Sonderborg area.

For the evaluation of the Master Plan 2029, a CO_2 price of 85 EUR/ton has been applied. This price has been estimated by IEA. The price is 6½ times higher than today and almost 3 times higher than EU expects for 2013 however the price is regarded realistic for the situation in 2029 where the consequences of the climate changes are likely to be more visible than today.

9.8 Calculation Results

Based on these preconditions, the total costs in the Reference and the Master Plan 2029 have been calculated. *Figure 52* Based on these preconditions, the total costs in the Reference and the Master Plan 2029 have been calculated.

However, there will be major shifts between the cost types: the Master Plan 2029 will lead to fuel savings of 1,312M DKK/year, primarily due to exchanging expensive oil and natural gas with "free" wind energy etc.

The operation and maintenance costs are 110M DKK/year higher in the Master Plan 2029 than in the Reference, while the capital costs are 1,195M DKK/year higher. The reason for this is to find in the massive investments in heat and electricity savings as well as wind energy as explained above.

[k] The Danish Energy Agency: "Prerequisite for socio economic analysis on the energy field", May 2009, 5.81 DKK/USD
[l] http://www.nordpool.dk/System/FinanceMarket/emissions/ and 7.45 DKK/Euro.
[m] The Danish Energy Agency: "Prerequisite for socio economic analysis on the energy field", May 2009, page 7.

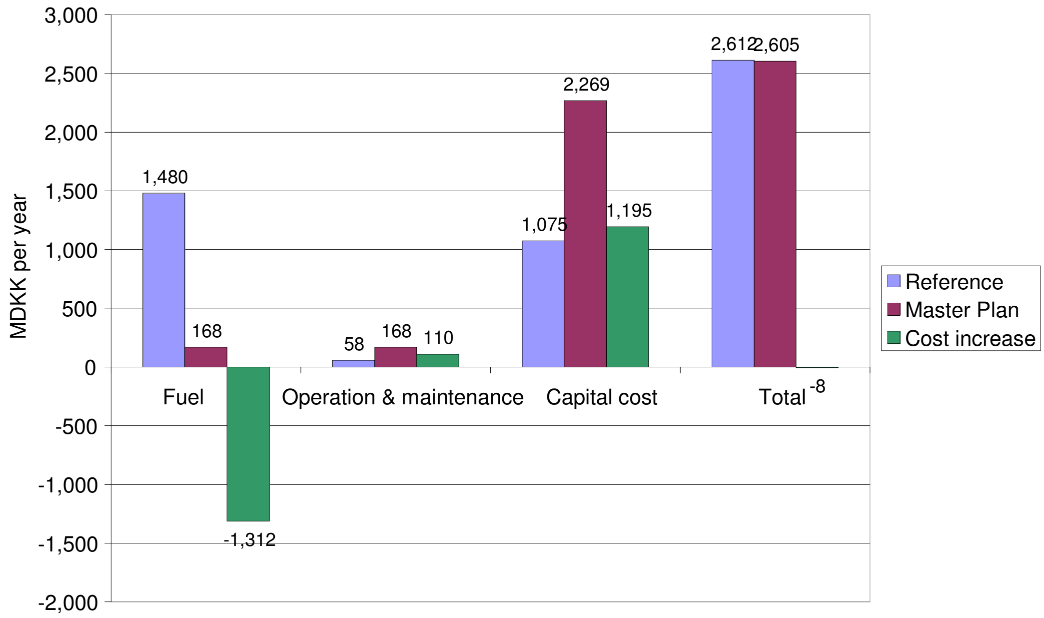


Figure 52: Annual costs in the Reference and Master Plan 2029 – divided on cost types.

Figure 53 shows the allocation of the total costs in energy sectors: electricity production, district heating, individual heating, transport, energy savings and infrastructure.

The Master Plan 2029 is only more expensive than the Reference in one area, namely energy savings. The reduction of the need for electricity, district heating and individual heating is so big that the costs within all these cost areas are lower in the Master Plan 2029 Master Plan 2029 than in the Reference.

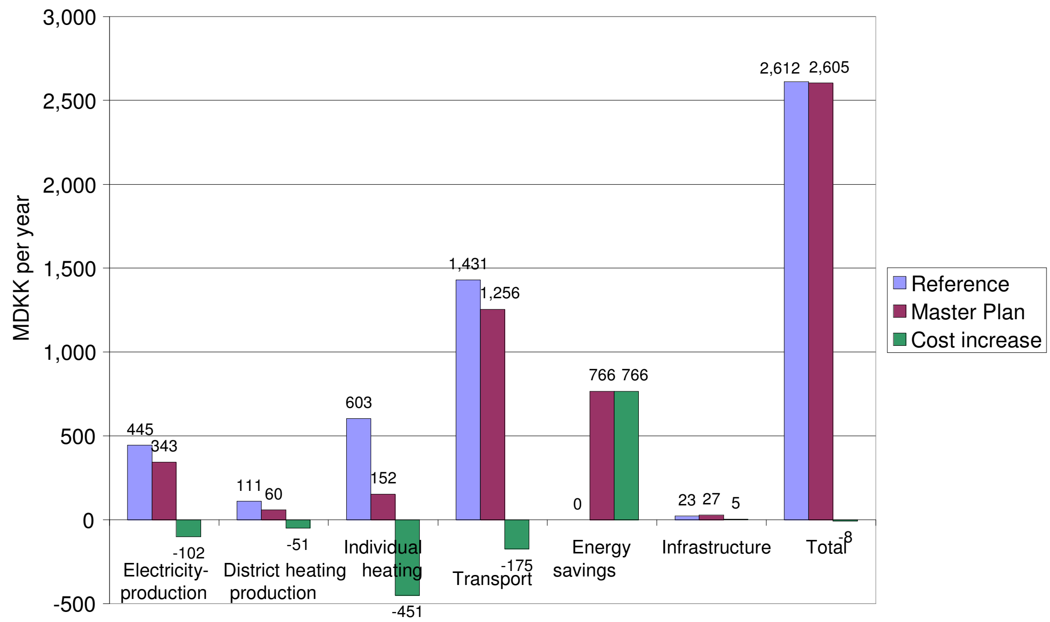


Figure 53: Annual costs in the Reference and Master Plan 2029 – divided on energy sectors.

Note that the costs for district heating production are lower in the Master Plan 2029 than in the Reference in spite of the fact that the district heating covered net heat demand is 40% higher.

The transport sector has the largest costs both in the Reference and in the Master Plan 2029, however the net saving is 12% compared to the Reference. In the Reference the same vehicle fleet is assumed as today (petrol and diesel cars) just a bit more effective while the Master Plan 2029 assumes that 80% of the driving need is covered by electric cars, 12% by biogas driven cars, and the last 8% are covered by bio ethanol and bio diesel. The share of the electricity's final energy consumption for transport is less than 80% as the electric cars have a higher efficiency than cars with internal combustion engines.

9.9 Sensitivity Calculations

Sensitivity calculations have been made with a variation of the CO_2 price, fuel prices and the interest rate.

Figure 54 shows the net costs as function of the CO_2 price that by default has been set to 85 EUR/ton = 640 DKK/ton.

With the current CO_2 price of 13 EUR/ton, the Master Plan 2029 causes a net expense of approx. 400M DKK/year compared to the Reference.

With the CO_2 price of 30 EUR/ton in 2013 estimated by the EU, the Master Plan 2029 will cause a net expense of approx. 300M DKK/year compared to the Reference.

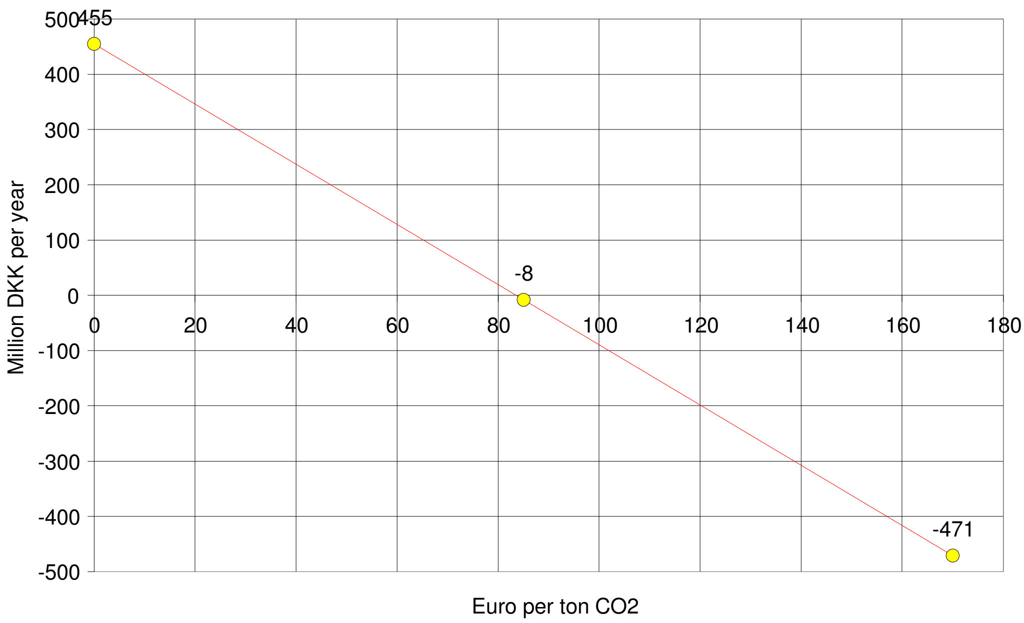


Figure 54: Annual additional costs in the Master Plan 2029compared to the Reference – as function of the CO2 price.

Thus it is clear:

- that the Master Plan 2029 is not cost-effective with the current CO_2 prices but
- that it will be cost-effective with the future expected prices and therefore it is a good guideline of the direction the Sonderborg area has to go.

More than half of the costs in the Reference consist of fuel expenses and the cost-effectiveness of the Master Plan 2029 depends very much of the future oil and natural gas prices. The coal prices too are important as they form basis of the calculations of the electricity price in the Reference.

Figure 55 shows the net costs as function of the energy prices where 100% corresponds to IEA's price assumptions from World Energy Outlook 2008 for crude oil, coal and natural gas in 2030 (prices of local straw and biomass fuels are kept constant). If the prices of fossil energy is only half as high as expected by the IEA, the net costs will increase from approx. zero to nearly 500M DKK/year.

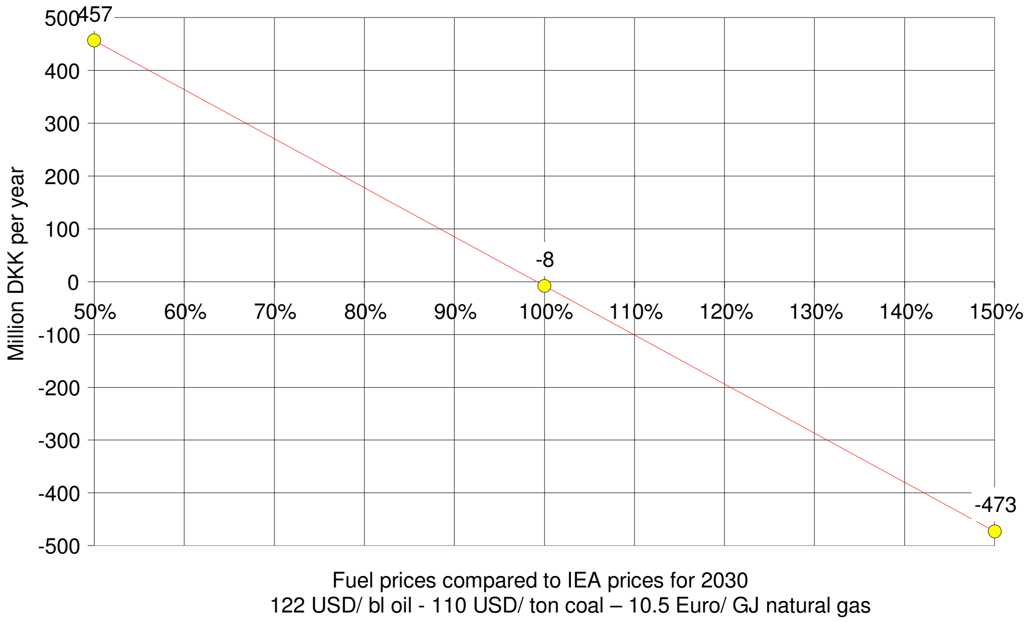


Figure 55: Annual additional costs in the Master Plan 2029 compared to the Reference – as function of the energy prices.

84% of the costs in the Master Plan 2029 consist of investments, and the cost-effectiveness of the Master Plan 2029 depends very much on the interest rate. *Figure 56* shows the net costs as function of the interest rate that by default has been set to 6%. If the interest rate is set to e.g. 3%, the Master Plan 2029 causes a net saving of 200M DKK/year.

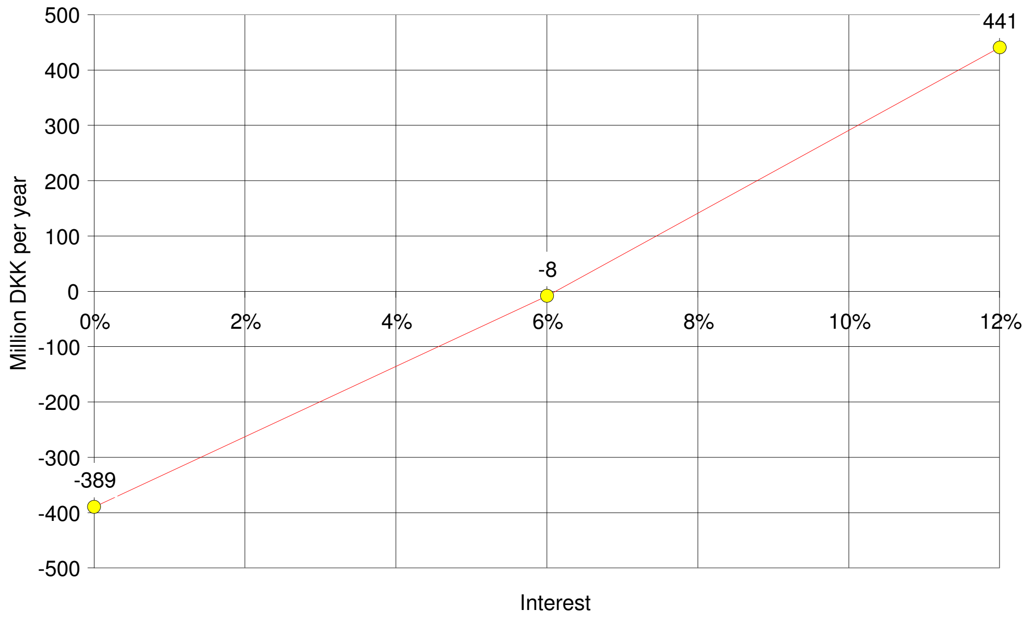


Figure 56: Annual additional costs in the Master Plan 2029 compared to the Reference – as function of the interest rate.

9.10 Conclusion

The Master Plan 2029 has been formulated from a premise that local energy needs must be covered by local energy sources.

The Master Plan 2029 consists of a number of technical solutions that are considered relevant for the Sonderborg area to carry through during the next 20 years in order to reduce the CO_2 emission to zero in 2029. Many options can be discussed, e.g. giving priority to energy efficiency measures or to heat/electricity production and prioritizing between electricity and biogas/bio ethanol used in the road transportation in 2029.

None of these issues seems to be fundamental to the direction defined in the Master Plan the 2029.

The Master Plan 2029 confirms the validity of the measures that are included in the Roadmap 2010-2015. Some of the most important are:

- A project proposal for establishment of a transmission pipe between Sonderborg and Nordborg should be prepared with a view to a thorough illustration of the socio-economics and corporate economics and organizational issues around the pipe;

- The district heating areas should be extended including the district heating cities' peripheral regions and the towns the transmission pipe passes through;

- It should be considered to establish connection commitment to the district heating systems where the connection must be done prior to a certain year unless it is demonstrable that it will lead to unreasonable costs;

- It should be considered how a shift from oil furnace, natural gas furnace and electric ovens can be encouraged in the rural districts – e.g. by developing standard packages together with local craftsmen;

- It should be considered how the establishment of big offshore wind turbine farms or wave energy plants can be carried through. If the Sonderborg area only wants to document CO_2 neutrality in 2029, massive investments will be necessary.

Enclosure 1 – The Board of directors for Project Zero Fund and Project Zero A/S

Status per 4th quarter 2009

The Project Zero Fund Board		
Position	**Name**	**Company**
Formand	Peter Clausen	Bitten & Mads Clausens Fund, Chairman
	Niels Bergh-Hansen	DONG Energy, Group Managing Director
	Claus P. Bjergaard	Nordea Danmark, Regional Manager
	Ole Damm	Enervision A/S, Manager
	Niels Duedahl	SYD ENERGI, Managing Director
	Asger Gramkow	Tænketanken (the think tank) Futura Syd, Chairman
	Jan Prokopek Jensen	Sonderborg Byråd (city council), Mayor
	Aase Nyegaard	Sonderborg Byråd, (city council) Vice-Mayor
	Bjarne Graabech Sørensen	Syddansk Universitet, (Southern Danish University) Vice-Rector
	Lars Tveen	Danfoss A/S, Manager

Project Zero A/S Board		
Position	**Name**	**Company**
Formand	Ole Damm	Enervision A/S, Managing Director
	Lars Tveen	Danfoss A/S, Manager
	Inge Olsen	Sonderborg Municipality, Manager
	Charles Nielsen	DONG Energy, Development manager
	Bendt Olesen	Sonderborg Municipality, Head of Strategy and Plan Committee
	Per Munk Jensen	SYD ENERGI, Vice-director

Enclosure 2 – Steering Group and Task Groups

Steering group for the Master Plan Process		
Position	**Name**	**Company**
Chairman	Peter Rathje	ProjectZero, Director
	Torben Esbensen	Esbensen, Director
	Lotte Gramkow	ProjectZero, Project manager
	Vivian Krøll	Sonderborg Municipality, Plan Manager

CO2 baseline and projection(Reference)		
Position	**Name**	**Company**
Task Man.	**Trine Mikkelsen**	**Enervision**
Co-players	Marianne Friis Ajer	Sonderborg Municipality
	Thorkild Bruhn	Sonderborg Municipality
	Tina Callesen	Sonderborg Municipality
	Lotte Ebbesen	Dong Energy
	Arne Hurup	Grontmij | Carl Bro
	Leo Jørgensen	Danfoss
	Anders Grum Kjærgaard	Sonderborg Kraftvarme (cogeneration)
	Frederik Krog	Grontmij | Carl Bro
	Helge Lorenzen	LandboSyd
	Morten Menné	Sonderborg Municipality
	Martin Mogensen	Sonderborg Municipality
	Tina Aagaard Mørkeberg	Sonderborg Municipality
	Flemming Lynge Nielsen	Danfoss
	Lisa Nielsen	ASA
	Lena Nørskov-Jensen	Sonderborg Fjernvarme (District Heating)
	Jacob Sandholt	Dong Energy
	Erik Ravn Schmidt	DONG Energy
	Karin Spillemose	SYD ENERGI
	Mikkel Vestergaard	Sonderborg Municipality
	Martin Østergaard	Center for Bioenergi, (Bio energy) SDU/AAUE

Buildings incl. installations and appliances

Position	Name	Company
Process man	Gert Johannesen	CREO Arkitekter (Architects)
Tech. Man.	Signe Antvorskov	Esbensen Rådgivende Ingeniører (consulting engineers)
Focus Group	Gert Backman	Botjek
	Carl Bock	Ingeniørgruppen Syd (Engineer group)
	Harald Christensen	Creo Arkitekter (Architects)
	Helge Fynsk	EUC Syd
	Maria Gaardsted	Esbensen Rådgivende Ingeniører (consulting engineers)
	Thorkild Chr. Hansen	Arkitektfirmaet a78 (Architect)
	Nina Kaubak	Sonderborg Municipality
	Henning Lesch	SIB
	Bjarne Baun Madsen	Salus Boligadministration (Property administration)
	Mike Vinge Madsen	Grontmij | Carl Bro
	Esben Molsted	Grontmij | Carl Bro
	Frederik Nors	Esbensen Rådgivende Ingeniører (consulting engineers))
	Robin Roost	Sonderborg Municipality
	Thomas Bulow Schmidt	Alpha-Innotech

Manufacturing Processes

Position	Name	Company
Process Man	Peter Maagøe Petersen	Viegand & Maagøe
Tech.Man.	Per Mikael Pedersen	Enervision
Focus Group	Andreas Christensen	Vesterled Teglværk (Tilework)
	Henrik Dalsgard	Viegand & Maagøe
	Christian Eriksen	ProjectZero
	Kenneth Kristensen	Viegand & Maagøe
	Hans Chr. Nielsen	Danfoss
	Leif Petersen	Servodan
	Thomas Bulow Schmidt	AS AP
	Lene Stensdorf	Sonderborg Municipality

Transport		
Position	**Name**	**Company**
Process Man.	**Michael Aakjær Nielsen**	**Grontmij|Carl Bro**
Tech. Man.	**Hanne Hansen Wrisberg**	**Rambøll**
Focus Group	Jørgen Fischer	Syd Trafik (Syd Traffic)
	Maria Grove Jørgensen	Sonderborg Municipality
	Niels Larsen	EUC
	Ejlif Steen Petrat-Laursen	Sonderborg Municipality
	Anders Sørensen	Sonderborg Lufthavn (airport)

Vedvarende energi inkl. affald		
Position	**Name**	**Company**
Process Man.	**Ejvin Beuse**	**PlanEnergi**
Tech. Man.	**Per Alex Sørensen**	**PlanEnergi**
Focus Group	Mikael Kjer Jensen	Esbensen Rådgivende Ingeniører
	Lisbeth Møller Jensen	Sonderborg Municipality
	Anders Grum Kjærgaard	Sonderborg Cogeneration
	Vivian Krøll	Sonderborg Municipality
	Jesper Møller Larsen	Rambøll
	Martin Frank Mogensen	Sønderborg Municipality
	Lisa Nielsen	ASA
	Jørgen Lindgaard Olesen	PlanEnergi
	Steen Pedersen	Grontmij|Carl Bro
	Lars Blædel Riemann	Sønderborg Forsyning

Agriculture		
Position	**Name**	**Company**
Process. Man.	**Peder Damgaard**	**Gråsten Landbrugsskole (agricul. school)**
Tech. Man.	**Gert Schneider**	**Sloth Møller Rådgivende Ingeniører**
	Jens Bo Holm-Nielsen	**Center for Bioenergi, AAUE**
Focus Group	Anders Andersen	LandboSyd
	Jens Bondesen	Center for Bioenergi, SDU/AAUE
	Henry Grosmann	Sonderborg Municipality
	Jan K. Jensen	DGC
	Merwyn Lopes	ProjectZero
	Helge Lorenzen	LandboSyd Rådgivning (consultancy)
	Martin Frank Mogensen	Sonderborg Municipality
	Erik Ravn Schmidt	DONG Energy
	Martin Østergaard	Center for Bioenergi, SDU/AAUE

Energy plan		
Position	**Name**	**Company**
Process. Man.	**Kirsten Dyhr-Mikkelsen**	**EA Energianalyse (Energy Analysis)**
Tech. Man.	**Thorkild Kristensen**	**SRCI**
Focus Group	Jesper Bang Andersen	DONG Energy
	Ole Damm	Enervision
	Torben Esbensen	Esbensen Rådgivende Ingeniører
	Lotte Gramkow	ProjectZero
	Jens Chr. Hansen	Danfoss
	Steen Kramer Jensen	Energinet.dk
	Vivian Krøll	Sonderborg Municipality
	Steffen Moe	Sønderborg Fjernvarme (SFV)
	Morten Pindstrup	DONG Energy
	Helge Ørsted Pedersen	EA Energianalyse (Energy Analysis)
	Peter Rathje	ProjectZero

Enclosure 3 – Portfolio of Measures

The five measures groups have identified and described a broad portfolio of measures that the Sonderborg area can draw upon in the realisation of the vision of CO_2 neutrality.

An overall survey of the analyzed technical measures is shown in below table. Potential estimations and CO_2 displacement price are not included as the calculation methods used by the measures groups vary and in some cases include the costs for implementation measures necessary to realize the technical solutions and in other cases they are not included. For further information, we refer to the catalog of measures.

Renewable energy (near-by and individually):

Plants for block heat (so-called near-by heat)

- Wood pellet boiler (shift from oil)
- Wood pellet boiler with solar heat (shift from oil)
- Straw boiler in bigger villages (shift from oil)
- Straw boiler in smaller villages (shift from natural gas)
- Wood chips (shift from oil)
- Wood chips and Stirling engine (shift from oil)
- Heat pump (shift from oil)
- Heat pump for cold district heating (shift from oil))

Individual heat supply

- Wood pellet furnace (shift from oil)
- Heat pump (shift from oil)
- Solar heat (shift from oil)
- Additional solar heat

Delivery to public electricity, heat and natural gas grid and electricity storage

- Solar panels replace roofs in new constructions, deliver to district heating grid (replace natural gas based cogeneration)
- Solar cells integrated in buildings however connected to the electricity grid?
- Solar cells integrated in buildings however connected to the electricity grid in 2015
- Field placed PV deliver to electricity grid
- Field placed PV 2015 deliver to electricity grid
- Household wind turbines deliver to electricity grid
- 2 MW wind turbine on-shore

Plants for production of bio fuels

- Large farm biogas plants (shift from natural gas)
- Biogas common plants with ManuPower and NIX (shift from natural gas)

Buildings:

Climate envelope and permanent installations:

- Conversion of oil furnace and gas furnace to RE

- Conversion of electric heat to heat pumps
- Solar heat
- Re-insulation of attics and roofs
- Re-insulation of facades
- Re-insulation of basement outer walls
- Renovation and replacement of windows
- Insulation of floors
- Insulation of bases
- Technical re-insulation, utility water
- Replacement of hot-water furnaces (outside collective supply)
- Replacement of heat exchangers (district heating)
- Regulation of central heat system and hot utility water
- Renovation/establishment of ventilation units with heat recovery
- Reduction of air flows in residential ventilation systems (demand control)
- Cooling (natural exhaust, thermal mass)
- Plants (wind, sun)
- Green roofs (cooling)
- LEK1 rather than BR08 in new constructions
- LEK0 rather than BR08 in new constructions
- Integrated energy design in new constructions

Lighting and electric appliances:

- Replacement of central heating pumps
- Replacement of incandescent bulbs to A-bulbs
- Replacement of refrigerators to A++
- Replacement of tumble driers to natural drying
- Laundry (machine and temperature)
- Dishwasher routine
- Minimizing standby consumption
- Replacement of TV plasma screen to LCD screen
- Replacement of stationary computers to laptops
- Solar cells

Manufacturing Processes:

- Energy management
- Biomass utilization (tileworks)
- Optimization of production
- Energy conscious design
- ECO design and green products
- District heating for process purposes
- Surplus heat from district heating
- Tax changes

Transport:

Measures for reduction of the need for transportation

- Planning in cities
- Planning in rural districts

Measures for conversion of transport habits

- Mobility planning
- Bicycle traffic

• Public traffic • Road-pricing • Tourism • Industry Measures for transport efficiency • Electric vehicles • Energy-efficient driving • Energy-efficient public transport • Energy in the transport infrastructure
Agriculture: Energy resources • Development of biomass resources • Development of biogas resources • Roof solar cells on existing and new buildings • Heat pumps (geothermal heat) easures for reduction of the consumption in operating buildings • Re-insulation • Reduction of pigsty/cowshed temperature • Liquid manure cooling or room heating by means of surplus heat from floor channels • Energy efficient fan or fan maintenance • Control and management Measures for reduction of the consumption in field production • Optimization of the driving • Optimization of area locations • Optimization of agricultural machinery

Enclosure 4 – Energy Balance and CO_2 Balance 2007 and 2029

Can be ordered as separate sheet according to agreement.