Ea Energy Analyses

Analysis of the market for bio energy – locally and internationally

Final report, 29 September 2010

  

Report carried out by Ea Energy Analyses on behalf of CMBI as part of an Enercoast project, with support from the Interreg IVB North Sea Region Programme and Region Midtjylland.

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Summary and conclusions

This report aims to describe the market potential for biogas and biomass heat and power applications, and to assess the opportunities and barriers for development of such biomass markets locally and internationally. The project has been commissioned by ENERCOAST whose overall aim is to create a market for bio energy in the North Sea area. The project uses Denmark, Central Denmark Region, and three Danish municipalities (Randers, Norddjurs, and Syddjurs) to illustrate the challenges related to developing a more substantial market for bio energy trade.

SSCM analysis

A parallel study also commissioned by ENERCOAST and carried out by Ea Energy Analyses assessed the sustainability of relevant biomass supply chains related to the resource accessibility in the three municipalities. The primary focus was on biogas, straw, wood residues, and energy crops for combined heat and power production and the results were presented in a report released in July of 2010 entitled 'SSCM Analysis of the Bioenergy Resources in Randers, Norddjurs and Syddjurs' (Ea Energy Analyses, 2010). The data basis for both studies is very similar, and as such the current report incorporates and builds upon many of the SSCM reports findings.

The present report describes the market structures and price developments of the aforementioned biomass resources. The market structures and trade conditions are described on a local (the 3 municipalities), national (Denmark) and regional/international (European/global) level.

Biomass demand

Political climate and energy goals constitute the major demand side drivers. With high European targets for the share of renewable resources in the energy production the demand for biomass is expected to increase dramatically towards 2020. However, the distribution of biomass fired production plants is not keeping pace with this target, which indicates that there are different barriers to be overcome before the utilisation of the various resources is optimal. Particularly local resources such as biogas and energy crops, and to certain extent straw, face challenges related to economy and technology. Concrete recommendations related to these barriers are discussed throughout the report.

Local demand

The three municipalities in focus currently utilise a significant amount of biomass, as on average over 30% of their gross energy consumption comes from biomass, a figure that is more than 3 times the national average. With this in mind, relative to today, the future local heat demand in the three municipalities is still expected to be met by an increasing share of district heating coming from biomass (particularly in Randers where Randers Kraftvarmeværk will continue to replace coal with biomass). The establishment of new biogas plants within the municipalities would also lead to an increased demand for bioenergy.

On the other hand, the municipalities have also set goals of reducing overall heat consumption, which may reduce the demand for bioenergy.

National demand

The use of biomass (and in particular wood pellets) is expected to increase over the coming years in Denmark. In its annual report on Danish energy trends from 2009 (DEA 2009), The Danish Energy Agency (DEA) reports that it expects renewable energy to grow over the coming years. A large part of this growth is due to an increase in the use of wood pellets.

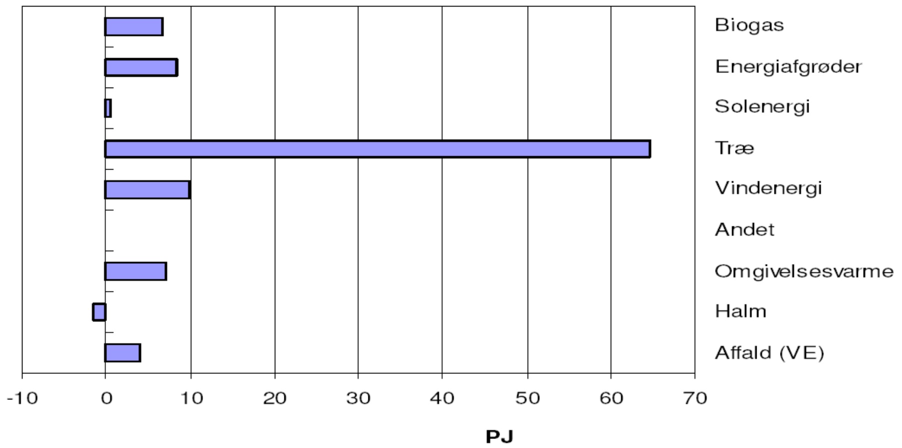

Figure 1: Danish increased use of renewable energy from 2009 to 2020 from the annual report on Danish energy trends from 2009 from the Danish Energy Agency. Biogas, energy crops (energiafgrøder), solar (solenergi), wood (træ), wind (vindenergi), other (andet), heat load for heat pumps (omgivelsesvarme) , straw (halm), and garbage (affald).(DEA, 2009)

The reason that the use of wood is expected to increase dramatically compared to the other resources is due to the fact that several of the central coal-fired power plants are expected to shift from coal to wood pellets within the period. The reason that the use of straw could be expected to decrease is that at least one of the central power plants is expected to replace their straw usage with wood chips or wood pellets. One very recent example of this is Dong Energy who in September of 2010 stated that starting in 2012 they intend to use 25% less straw, and replace it with wood pellets imported from Canada and the Baltic states (Ingeniøren, 2010).

EU demand

Relative to 2007 figures, for the EU to reach its 2020 renewable energy target of 20%, it will require an additional 10,600 PJ of renewable energy by 2020 (in gross consumption terms). In this report it is suggested that 60% of this could come from biomass and waste, equivalent to 6,300 PJ, or roughly 420 million tonnes of additional biomass. Combined with the 2007 EU consumption of biomass and waste of 4,000 PJ, an estimate for the annual gross energy from biomass and waste in 2020 is 10,300 PJ, roughly 690 million tonnes of biomass.

Resource availability

In recent years a variety of studies aimed at quantifying the available biomass resources on a national, regional and global level have been carried out, and the results vary considerably. This is due to the different calculation methods and data, and the different types of resources, and resource inventories utilised. There does however appear to be significant potential to increase the supply of biomass for energy, partly through increased use of residues from agriculture and forestry, and partly via the cultivation of energy crops.

Local resources

Locally, in the three municipalities in focus, roughly 50% of the produced straw is left uncollected in the fields. Thereby there should be a surplus of available straw in the three municipalities, totalling 175,799 tonnes/year. The Central Region Denmark as a whole only has 30% uncollected straw on its fields and uses a far larger share of straw for animal purposes than is the case in the three municipalities.

Compared to the current use of slurry for energy production, there is a significant amount of slurry available. The slurry potential in the three municipalities is estimated to be 838 TJ, as opposed to the 5 TJ that is used today.

National/regional resources

Wood chips from forest residues are more of an intra-nationally traded resource. The Danish Energy Agency estimates a potential of 51 PJ of wood for energy purposes in Denmark, and roughly 80% of this potential is currently being utilised. Other actors however, such as the Forest Industry and wood retailers, claim that the production from forest residues can be more than doubled. Another unknown factor is the future potential for wood chips from energy crops such as willow or poplar. However, before a firm potential figure from energy crops can be arrived at, a number of environmental, ethical and economic aspects will have to be addressed.

International resources

Wood pellets are seen as an international resource, and are imported from as far away as North America. Estimates of the global wood resources vary drastically. The European Environment Agency (EEA) estimates the European biomass resources (including wood, waste and energy crops) to go up from 7.8 EJ in 2010 to 9.5 EJ in 2020 and 11.7 EJ in 2030. These figures are based on the expectation that over the long run over a third of the European biomass potential will come from energy crops. Due to uncertainties related to sustainability, competition with food production, water availability, soil quality, protected areas, etc., estimates for potential global biomass resources vary greatly. Studies based on residues alone cite estimates of 100 EJ/yr, while technical potentials as high as 1500 EJ/yr are to be found at the other end of the spectrum. Best guess estimates meanwhile fall in the range of 200 to 500 EJ (Lysen and van Egmond, 2008). When speaking of global biomass potentials it is also worth noting that there are large regional differences in resource availability.

Sustainability

Though the majority of solid biofuels for energy purposes are currently derived from residues from forestry or agriculture, the expected increase in demand for biomass from the energy sector has given rise to concerns about the sustainability in relation to cultivation methods, biodiversity, displacement of nature reserves and competition with food production. Particularly residues from developing countries can come from non-sustainable forestry. Furthermore, if the biomass does not arise from residues and comes from countries outside of the European Union, there can be additional issues related to competition with food production and biodiversity.

There has been a great deal of discussion within the EU Commission about the development of sustainability criteria for solid biomass, but thus far such criterion is only in place for liquid biofuels.

Summary of resources

The table below summarises biomass resources based on various studies referred to in the present report. As highlighted above, there is great uncertainty about the resource size, so the figures should only be seen as an indication of the possibilities for use of bioenergy in Europe and globally. In addition, the large future resource totals rely on the immergence of considerable amounts of energy crops, and therefore this total potential is not deemed to be realisable until 2030. Furthermore, there are substantial sustainability issues related to utilising the estimated potentials found on the higher end of the spectrum.

Unit: PJ	Utilisation today	Long term resource potential
Global	50,000*	200,000 - 500,000*
EU	4,000*	12,400*
Denmark	82.6	165
3 Municipalities	6.8	6.2

Table 1: Biomass utilisation and resource figures. EU, Danish, and Municipality 'utilisation today' figures include imports. *Indicates that the figure includes waste.

Trade in bioenergy

Bioenergy resources are traded both locally (manure, straw, wood chips), nationally (straw, wood chips and wood pellets) and internationally (primarily wood pellets and wood chips). A barrier towards further expansion of the international market for biomass trade could be the lack of standardisation related to the quality of biomass resources. For example, the import from other countries can make it more difficult to control the quality of the product that will be delivered, and the definitions of biomass are not the same from country to country and the understanding with respect to quality may differ as well. Therefore a certain level of international standardisation or certification would help to address such issues.

Straw

At present straw is primarily a local or regional fuel, infrequently transported intra-nationally between regions, and very rarely internationally. Straw as an energy fuel plays quite a minor role in Europe, but a significant role in Denmark. The two largest actors in the Danish straw market are Dong Energy and Vattenfall, who together account for roughly 68% of the total amount of straw traded for energy purposes.

Straw is traded by either local contract, mostly used by small decentralised energy producers, and by tender, used by the large central producers. The market conditions for trading straw are characterised by local and regional differences. The straw prices thus tend to vary from area to area depending on local conditions such as yield, number of livestock farms and local demand. The Danish Energy agency forecasts the straw price to be moderately increasing from 37.8 DKK/GJ today to 42.2 DKK/GJ in 2015 and 44.1 DKK/GJ in 2025 (all prices in 2010 DKK). The agriculture sector however, expects prices to decrease in the short run due to the rather large surplus of uncollected straw at the moment. This expectation complies with recent statements from one of the largest straw consumers, Dong Energy, saying that they already from 2012 will use 25% less straw than they do today (Ingeniøren, 2010).

Wood chips

Wood chips are both a locally and a regionally traded fuel, however at this point in time they are not traded on a large scale internationally. The majority of the wood chips in Denmark come from the Danish forests, a substantial part comes from the open landscape in Denmark, and a smaller part from import (10-20%). The imported wood chips come primarily from the Baltic States.

Wood chips are purchased either directly through bilateral contracts with local producers or via wholesalers, for instance HedeDanmark, or energy trading companies.

The price of wood chips today lies between 42 and 47 DKK/GJ. The Danish Energy Agency has forecasted that prices will increase from 44.6 DKK/GJ today to 48.3 DKK/GJ in 2015 and 52.5 DKK/GJ in 2025 (all prices in 2010 DKK).

Wood pellets

Wood pellets are traded across all areas, and due to their relatively high energy density they are increasingly traded internationally and across continents. In 2008 Europe had an import of roughly one million tonnes of wood pellets, coming primarily from North America. Almost half of the global forest area is found within four countries: Russia, Brazil, Canada and the Unites States.

Wood pellets are traded either via bilateral long term contracts, mostly used by large and medium scale consumers, or via retailers and wholesalers, mostly used by smaller residential consumers.

The current price for wood pellets (depending on type, quality, and purchase destination) lies between 60 and 80 DKK/GJ, and are considerable higher than the prices for other biomass fuels. The Danish energy agency expects prices to increase from the current level of 67.7 DKK/GJ to 71.3 DKK/GJ in 2015 and 77 DKK/GJ in 2025 (all prices in 2010 DKK).

North Sea trade

The report summarises the most dominant trends in flows of biomass between countries and focuses particularly on the North Sea Region. Wood pellets are often traded internationally, wood chips less so, and straw only quite rarely. While not overwhelming, there is a flow of wood pellet trade between countries in the North Sea Region. In particular, Germany and Sweden export to Denmark, and Sweden exports to the UK. In the future it also appears likely that Norway will begin to export to its neighbouring countries as well. However, the North Sea Region is not an obvious geographical defined boundary for biomass trade, as a great deal of the biomass flow occurs outside of this region.

Looking at Denmark in isolation for example, it is more relevant to talk about a Baltic Sea trade region, as large parts of the imported wood pellets and wood chips arrive to Denmark from Baltic Sea States, with much of the remaining imports coming from North America.

Biomass prices and costs

Historic Costs

Over the past 10 - 15 years the prices for various biomasses in Denmark have been quite steady, particularly when compared to those for fossil fuels. This is reflected in the figure below which displays the price in DKK/MWh for various fuels at the plant gate, exclusive VAT, but including other taxes. The costs listed are nominal values, and as such in real terms the cost of straw (light green), and wood chips (dark green) have stayed quite constant over this time period, with wood pellets (light blue) showing a more gradual increase. Costs for all three biomass forms have grown and fluctuated less than costs associated with natural gas (dark blue), and oil (red).

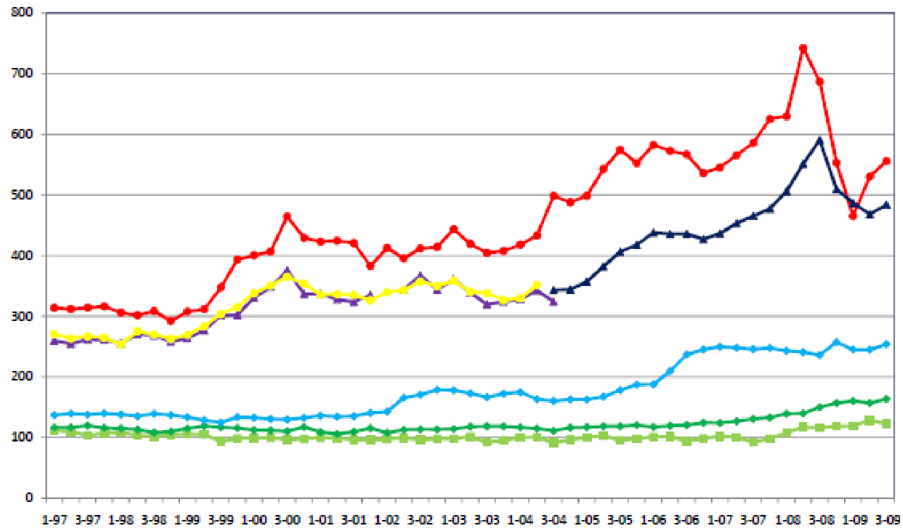

Figure 2: Nominal fuel costs in DKK/MWh at the plant gate, exclusive VAT, but including other taxes from January of 1997, till the 3rd quarter of 2009. The red line depicts oil, the yellow and dark blue natural gas, the light blue wood pellets, the dark green wood chips, and the light green straw. Fossil based fuels incur a tax of roughly 200 DKK/ MWh, while biomass does not incur any taxes (Boldt, 2009).

Looking at Figure 2 it is interesting to note the difference between wood chip and wood pellet costs. Based on 2009 figures, they were roughly 160 DKK/MWh (45 DKK/GJ) and 250 DKK/MWh (70 DKK/GJ) respectively for wood chips and wood pellets. This relationship is interesting, because wood chips can be used to make wood pellets, and if this can be done for less than 25 DKK/GJ, it is possible that the difference in these two prices will converge somewhat in the future, thereby reflecting this production cost.

Cost Drivers

On a country by country basis there are different cost drivers for biomass. In Denmark for example biomass is exempt from energy taxes, considered CO_2 neutral, and receives subsides for the portion that it is utilised in electricity production. The figure below displays how EU CO_2 prices and Danish tax exemptions and subsidies for biomass affect the fuel costs in Denmark for a CHP plant such as Randers kraftvarmeværk.

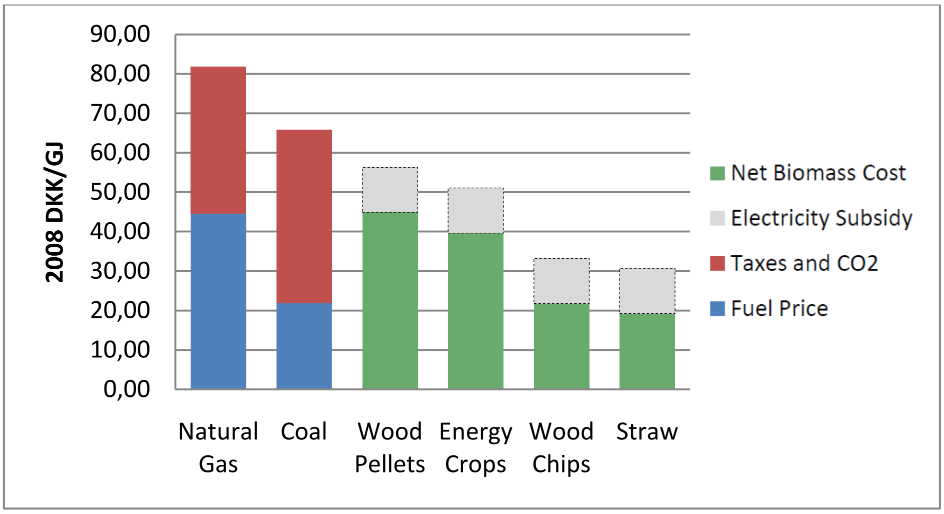

Figure 3: Role of CO_2 prices, energy taxes, and subsides on fuel costs in Denmark for a CHP plant such as Randers kraftvarmeværk based on 2010 figures (DKK/GJ/Fuel). Blue portion indicates the underlying fuel price, red the additional taxes and CO_2 related costs, grey box the value of the electricity subsidy, and green the cost for biomass after the electricity subsidy has been subtracted. Fuel and CO_2 costs and are courtesy of the Danish Energy Agency (DEA, 2010). [1]

As can be seen from the figure, in the absence of taxes and subsidies, the most attractive fuel choice for energy providers would otherwise be coal.

Subsidies for biomass and other renewable energy resources are not solely a Danish concept. Many European countries have introduced economic incen-

[1] Calculations in the figure are based on an electrical efficiency of 27% and a heat efficiency of 59%. Coal and natural gas taxes are 72.1 and 66.1 DKK/GJ respectively. Utilising the V formula and a 59% heat efficiency, this corresponds to a fuel tax of 34.0 and 31.2 DKK/GJ respectively for coal and natural gas. CO_2 quota prices are based on DEA forecasts, and CO_2 contents of 95 and 57 kg/GJ for coal and natural gas. With an electrical efficiency of 27%, electricity subsidies for biomass of 41.7 DKK/GJ correspond to a subsidy of 11.4 DKK/GJ. Sulphur and NO_x taxes are not included. For further details on underlying figures please see Ea Energy Analyses (2010).

tives to motivate energy producers to invest in biomass technologies instead of fossil fuels.

One example is Germany where electricity production based on renewable resources such as biomass receives a feed-in tariff depending on the resource and the size of the plant. The tariff is reduced every year and the current tariff is roughly 572 DKK/MWh electricity (161 DKK/GJ) produced at a 20 MW decentralised CHP plant. (BMU, 2009)

Another example is Sweden, where renewable energy production is encouraged by a market for RE certificates that was introduced in 2003. The spot price for RE certificates has been roughly 228 DKK/MWh electricity (63 DKK/GJ) during the period 2008-2010 (SKM, 2010).

The above examples all reveal that at this point in time biomass based fuels are highly reliant on subsidies and the lack of energy and CO_2 taxes in order to be competitive with fossil fuels such as coal and natural gas. In addition, political goals expressed through subsidies and taxes can influence the development of the biomass prices.

Case analyses

The present report shows that existing biomass CHP have low heat production costs compared to other technologies. Natural gas fired plants meanwhile have high costs compared to biomass and coal.

Three different possibilities for concrete fuel shifts within the three municipalities are discussed in this report and the consequences of the described development of the biomass markets for the concrete cases are evaluated. The selected cases represent biogas for CHP production, locally produced solid biomass for CHP production in smaller district heating plants, and imported solid biomass for CHP production in a larger central CHP plant.

Biogas

The report shows that there is a large resource potential available for biogas production in the three municipalities. Having the highest costs for energy production, natural gas plants are the most obvious to be replaced with biogas. Relative to the other two municipalities, Randers Municipality has a high share of natural gas based district heating from its 6 gas fired CHP plants. These plants were all built in the early nineties and in the absence of any major upgrades would therefore require replacing within the next 10 years or so. As such capital investment decisions will have to be made within the next few years. The heat costs might be reduced by 50-60% by building a new biogas CHP plant as opposed to a new natural gas fired plant. Replacing the existing straw or wood fired boilers in Syddjurs and Norddjurs with biogas CHP would however not be economic.

It should also be noted that while there has been a great deal of focus on developing additional biogas plants, there still exist a number of barriers that first must be overcome before cost savings in the range mentioned above can be realised. Possible enablers to overcome problems with high investment risks and neighbour scepticism are loans guaranteed by the municipalities and clear political signals related to the selection of locations for new biogas plants.

Wood chips

An obvious concrete fuel shift case in the three municipalities is replacement of the remaining coal utilisation at Randers Kraftvarmeværk and thereby bringing the plant up to 100% biomass utilisation. Being located near a harbour, the plant is able to import wood chips from the Baltic States at a lower cost than the average Danish price level for wood chips. The plant is today capable of utilising 85-90% biomass and the transformation to 100% biomass capability is expected to be completed by 2011. It is anticipated that the biomass usage at the plant in the future will consist of 60-80% wood chips and 20-40% wood pellets and alternative biomass. A shift away from fossil fuels is economically attractive for Randers Kraftvarmeværk under the current regulatory conditions. Wood chips and alternative forms of biomass are currently a more cost effective fuel choice for Randers Kraftvarmeværk than wood pellets.

Local biomass

Two possibilities of fuel shifts to greater utilisation of locally produced biomass are described in the report: Either to replace natural gas CHP plants with straw or wood chip fired CHP plants, or to replace the coal fired production at Grenaa Kraftvarmeværk with straw. Straw is the most obvious choice to increase the consumption of local biomass within the three municipalities, as there exists a surplus of straw locally. However, most of these natural gas fired CHP plants are quite small, and therefore there is some uncertainty whether biomass fired CHP units of this size will be economical.

The Grenaa Kraftvarmeværk is from 1991 and is therefore expected to have a remaining lifetime of roughly 10 years. Furthermore, the current CFB technology can only utilise up to 60% straw. One possibility is therefore to replace the plant with a new straw fired CHP plant able to utilise 100% straw. At the present time the investment costs for such a CHP plant would be around 600 – 1,200 MDKK. Depending on the future demand for process heat in Grenaa, the plant could be dimensioned to use up to 2-3,000 TJ of straw. This is a significant increase of straw use corresponding to more than the available resource within the three municipalities. However, relative to other fuels the straw price is expected to increase at a lesser rate, and may in fact not see much of an increase at all if demand from the biomass CHP sector decreases.

Conclusions on future perspectives and recommendations

- The report demonstrates that due to political goals and regulative incentives the demand for biomass for energy purposes is expected to increase dramatically in the upcoming years. Particularly the demand for biomass from wood, such as wood pellets and wood chips, are expected to increase. The increasing demand is expected to result in higher biomass prices, particularly for woody biomass.

- Wood will very likely be increasingly traded internationally, both between continents, and within. Given current and expected trade patterns, the defining of a North Sea trading region is not a natural choice. Trade between the North Sea countries occurs to a smaller extent, but the largest exporters of woody biomass to Denmark are the Baltic States and North America. In the future, the largest biomass producers are expected to be North America, Russia and Brazil.
- Straw as an energy fuel is mainly a Danish concept and in the short term the demand for straw is expected to decrease. Competition with woody biomass, and its more amicable product qualities for power plants, is seen as the main reason for this. Over the longer run the pressure on the world's wood resources is however expected to restore or increase the national demand for straw and thus increase the fuel prices.
- Another factor that could influence the demand and price development for straw is the erection of 2nd generation bioethanol plants. This technology is still in the early demonstration phase but in the future could become more widespread as a consequence of political goals to reduce fossil fuel dependence. Liquid bio fuels for transport such as bioethanol have to fulfil the criteria for sustainability listed in the RES directive. The EU commission is expected to present a new report on indirect changes in land use by the end of 2010 that is anticipated will lead to a tightening of the current sustainability criteria.
- Faced with national emission reduction targets, and desires to increase the use of renewable energy resources, it has become evident for many nations that importing biomass is one of the most cost-effective ways of achieving these goals. This is of itself is a driver for growth in international biomass trade. As the markets for biomass resources evolve it is likely that standards for biomass quality and certification of sustainability will develop. Sustainability criteria for the utilisation of solid biomass resources should be set on a European level as is already the case with liquid biofuels. The market actors can help facilitate this process by requesting and implementing such standards.
- The price development of the local, national and international biomass resources are determinate for the investments in new production facilities. Taxes and subsidies are keeping the biomass fuel prices on a higher competitive level than that of fossil fuels.
- The uncertainties of the price development of particularly imported biomass will perhaps make it attractive for energy producers to build power plants that are very versatile in terms of what fuel they can use, i.e. multifuel plants, as is the case with Randers Kraftvarmeværk.

1 Introduction/Background

The project has been commissioned by ENERCOAST whose overall aim is to create a market for bio energy in the North Sea area. The project uses Denmark, Central Denmark Region, and three Danish municipalities (Randers, Norddjurs, and Syddjurs) to illustrate the challenges related to developing a more substantial market for bio energy trade.

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In 2007, renewable energy constituted 8% of the total gross energy consumption of the EU. Reaching the goal of 20% renewable energy in 2020 requires significant growth in the renewable energy sector including bio energy resources. The bio energy sector is faced with special organisational and logistic challenges due to the small average size of the producers of biomass and biogas. There is also room for improvement and optimisation of the entire chain from biomass and biogas production to energy use. At the same time, the economic difficulties of the agricultural sector force the farmers to look for alternative sources of income such as the production of energy resources.

Definition of terms

Within the report the term 'local' will refer to within a Danish municipality or Danish Region. 'National' will refer to within a country's borders, while 'regional' will refer to trade within a particular grouping of nation states, for example the North Sea Region, Baltic Region, etc. Meanwhile, 'international' can encompass both trade between nations that are close to another (thereby within the same 'region', as well as long distance trade, for example from North America to Europe.

From the perspective of the energy sector - including the local energy production utilities and the municipalities – a key question is to what extent and at what prices different types of bioenergy resources will be available in the future. This question is key to decisions regarding investment in new energy generation facilities and to the future heat planning by the municipalities, as well as business opportunities related to the agricultural sector.

Bio energy resources are limited resources and are at times in competition with food production. Local municipalities and national governments must apply a holistic view of resources and demands and in cooperation with local stakeholders prepare plans for cost-effective deployment of local resources and competences. Based on these plans, the regulatory framework can be modified to further the intended development and create well functioning markets (agriculture, energy, transport). Prices and taxes will drive the markets, and a solid grasp of the economic drivers is critical for understanding the incentives of the individual stake-holder businesses.

2 Randers, Norddjurs and Syddjurs municipalities

The municipalities of Norddjurs, Syddjurs and Randers are located in the north-eastern part of Central Denmark Region. In the figure below, the Central Denmark region is highlighted in blue, while the 3 municipalities in the region are highlighted in green.

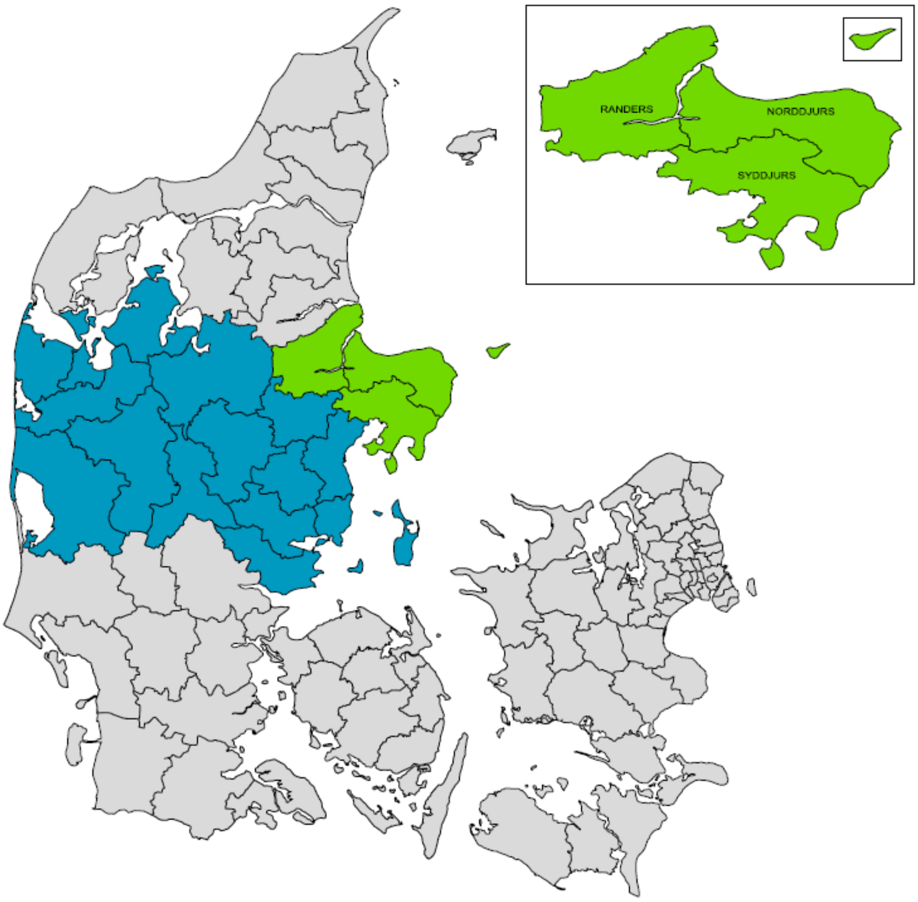

Figure 4: Municipalities in Central Denmark Region.

The population of the Central Denmark Region is 1.25 million and its total area is 13,124 km^2, corresponding respectively to 23% of the total Danish population, and around 30% of the total area of Denmark. According to 2010 figures, Randers is the largest of the three municipalities with an area of 800 km^2, and a population of 94,744 (Randers Municipality, 2010). Norddjurs has an area of 721 km^2, and a population of 38,427, while Syddjurs is 696 km^2 and has a population of 40,193 (Norddjurs Municipality, 2010 Syddjurs Municipality, 2010).

2.1 Current energy use and production units

The following section will briefly introduce the energy consumption profiles in the municipalities in Norddjurs, Syddjurs and Randers.

Data

The data is primarily based on an analysis undertaken by PlanEnergi on behalf of Central Denmark Region in a regional development project. The analysis of data in this project was done with a focus on the municipalities. An energy balance was made for the region, and for 13 of its 19 municipalities, among these were the municipalities of Norddjurs, Syddjurs, and Randers.

The primary source of data for the collective heat supply and electricity production in the energy balances is the Danish Energy Agency's data on energy producers in Denmark from 2007, which was divided into electricity, heat, type of fuel and plant, etc. Final energy consumption is then calculated by deducting the estimated plant efficiency and distribution losses.

Fuels for individual heating purposes are calculated based on the amount of small local boilers from chimney sweepers and general estimates of their fuel consumption e.g. straw, firewood, wood chips, etc. The consumption of diesel and petrol is calculated on the basis of the amount of motorised vehicles, while fuel consumption for trains, ships and planes is allocated according to the number of inhabitants in proportion to the total Danish consumption.

Energy consumption in Norddjurs

In 2007, the gross energy consumption and the final energy consumption in the Municipality of Norddjurs was 5,379 and 4,599 TJ respectively.

Gross energy consumption

The figure below displays the gross energy consumption (fuel consumption and other types of energy, for example wind power) in the Municipality of Norddjurs for 2007.

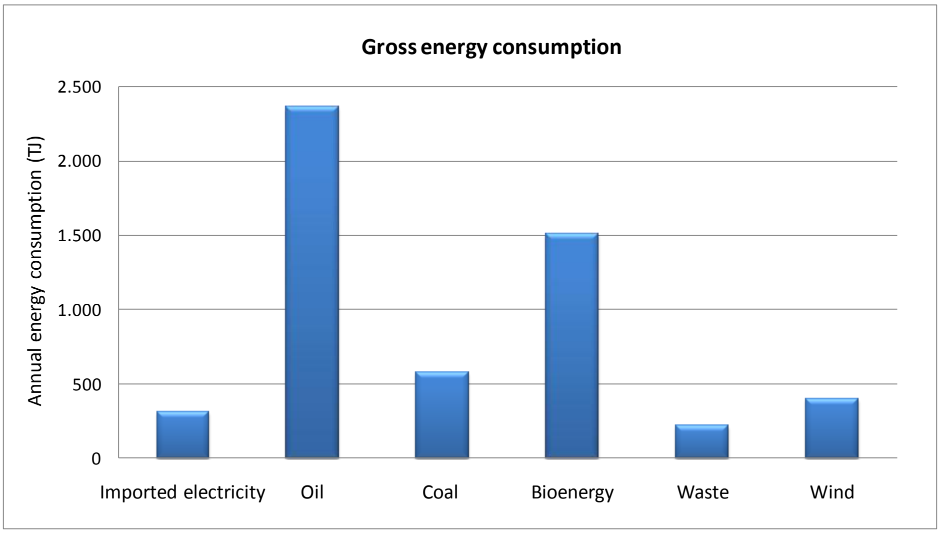

Figure 5: Gross energy consumption, Municipality of Norddjurs 2007.

The consumed bioenergy resources consist of straw, firewood, wood chips, wood pellets and waste wood. The share of bioenergy is significant (nearly 28%) with 1,500 TJ out of 5,379 TJ of the total gross energy consumption, thus helping to contribute to an overall high share of renewable energy in the municipality. The amount of renewable energy in the gross energy consumption is about 2,000 TJ, which depending on the amount of non-biodegradable material in the waste, corresponds to a share of renewable energy of ca. 40%. Most notable is the high consumption of oil, roughly 2,300 TJ. It should also be noted that there is no consumption of natural gas in the municipality, because there is no natural gas grid in Djursland.

Final energy consumption

The final energy consumption (end-use) allocated according to sector and energy products in the municipality of Norddjurs, is shown in the figure below. The final energy consumption covers energy supplied to the final consumer for all energy uses.

The figure reveals that the transport and household sectors are the sectors with the largest consumption, representing ca. 1,600 and 1,400 TJ respectively in 2007. Furthermore, it is worth noting that there is a relatively high share of renewable energy and oil used in the household sector, which is most likely primarily used for individual heating.

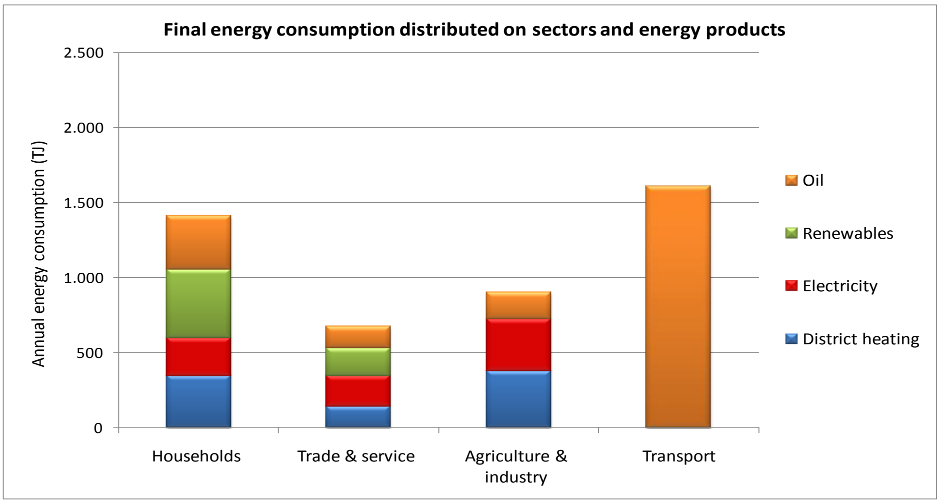

Figure 6: Final energy consumption distributed on sectors and energy products, Municipality of Norddjurs 2007.

The total fuel consumption for heating purposes is shown in the figure below. Over 2/5 of the heat is supplied from district heating, roughly 1/4 by oil, and slightly less than 1/3 from bio energy in form of individual heating (primarily firewood and wood chips). The consumption of electricity, solar power and heat sources for heat pumps (air or ground heat) is marginal. The bioenergy used for individual heating is primarily local firewood, wood pellets and straw.

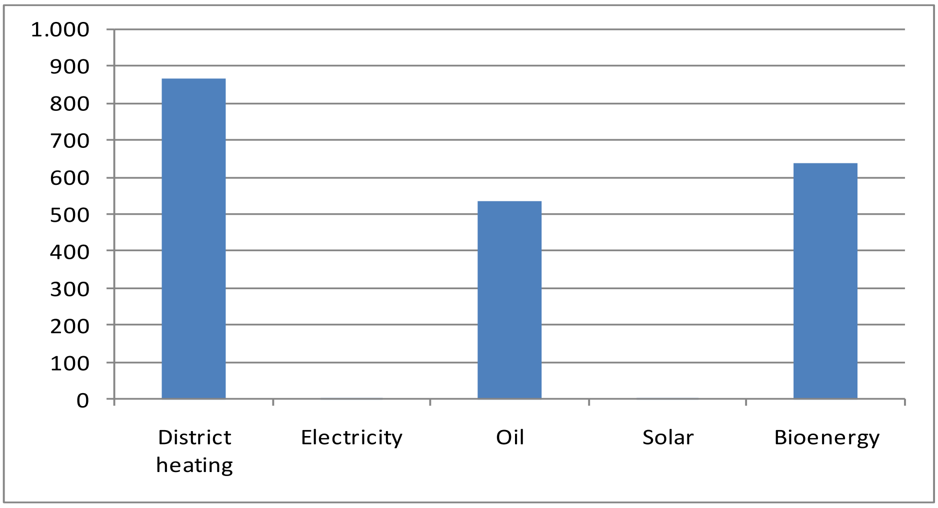

Figure 7: Heat consumption by energy source (TJ final energy), Municipality of Norddjurs 2007. Heat consumed in industries is not included.

A high share of both bioenergy and oil is used for individual heating purposes. With respect to the district heating production, well over half comes from bio-energy, with the majority of this consisting of straw. As such bioenergy covers over half of the total heat production (individual and collective) in Norddjurs.

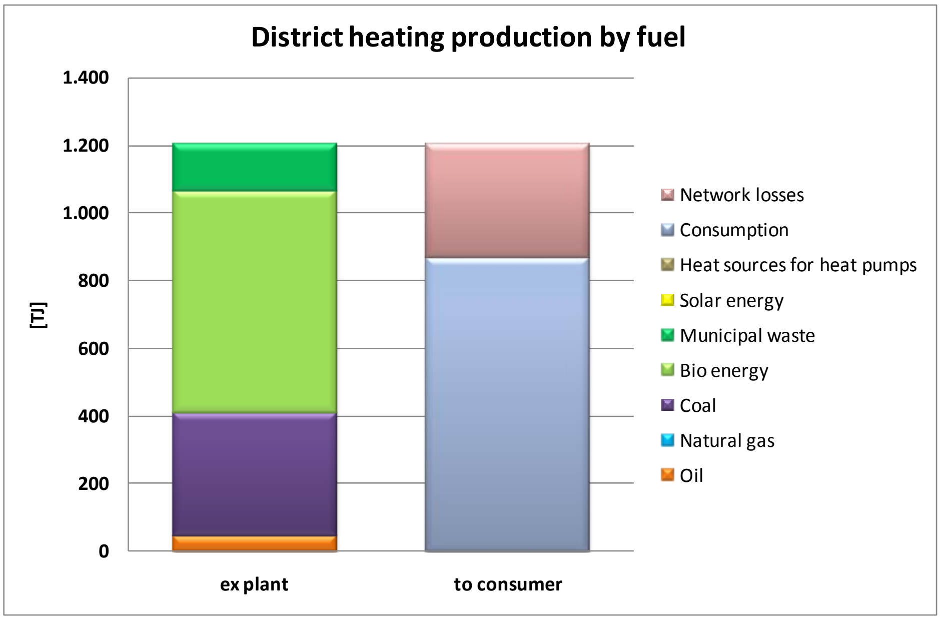

Figure 8: Total district heat production by fuels, Municipality of Norddjurs 2007. Of the district heating figure, well over half is produced via biomass. As such, over 50% of the total heat con-sumption (individual and collective) is derived from bioenergy

District heating plants in Norddjurs

The largest district heating plant is Grenå Kraftvarmeværk, which uses straw and coal. The other district heating plants in Norddjurs are mainly smaller dis-trict heating boilers that utilise wood chips. The district heating plants include:

	Coal (TJ)	Fuel oil (TJ)	Gas oil (TJ)	Straw (TJ)	Wood Chips (TJ)	Wood and biomass waste (TJ)	Waste (TJ)	Gross Fuel (TJ)
Allingåbro Varmeværk			0.7		54.6			55.3
Anholt Elværk			16.9					16.9
Auning Varmeværk				116.0				116.0
Gjerrild					20.7			20.7
Glesborg Fjernvarmeværk					21.5			21.5
Grenå Forbrændingsanlæg							231.0	231.0
Grenå Kraftvarmeværk	526.9	17.7	5.1	563.4		9		1,122.1
Ørsted Fjernvarmeværk				55.5				55.5
Ørum Varmeværk			0.8		23.8			24.6
Stenvad varmeværk			0.4		9.5			9.9
Trustrup-Lyngby Varmeværk					40.3			40.3
Vivild Varmeværk			2.3		47.3			49.5
Voldby Varmeværk					11.3			11.3
Total	**526.9**	**17.7**	**26.2**	**734.9**	**229**	**9**	**84.2**	**1774.6**

Table 2: Fuels used in district heating plants in Norddjurs in 2007

Energy consumption in Syddjurs Municipality

Gross energy consumption

The figure below displays the gross energy consumption (fuel consumption and other types of energy, for example wind power) in the Municipality of Syddjurs for 2007.

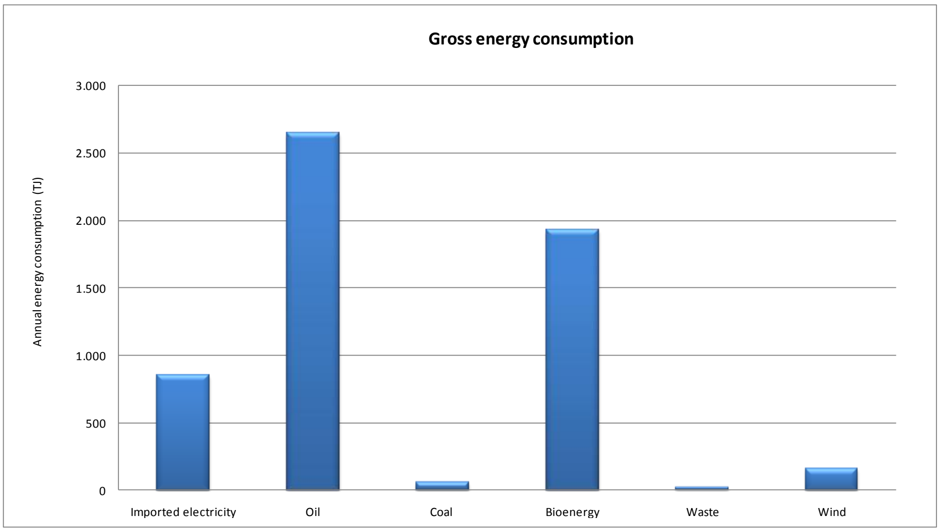

Figure 9: Gross energy consumption, Municipality of Syddjurs 2007.

The share of bioenergy is significant with 1,931 TJ out of 5,676 TJ in the total gross energy consumption, thus contributing to a high share of renewable energy in the municipality overall. The consumed bioenergy resources consist of straw, firewood, wood chips, wood pellets and waste wood.

Final energy consumption

The final energy consumption (end-use) distributed over sectors and energy products in The Municipality of Syddjurs, is shown in the figure below. The final energy consumption covers energy supplied to the final consumer for all energy uses.

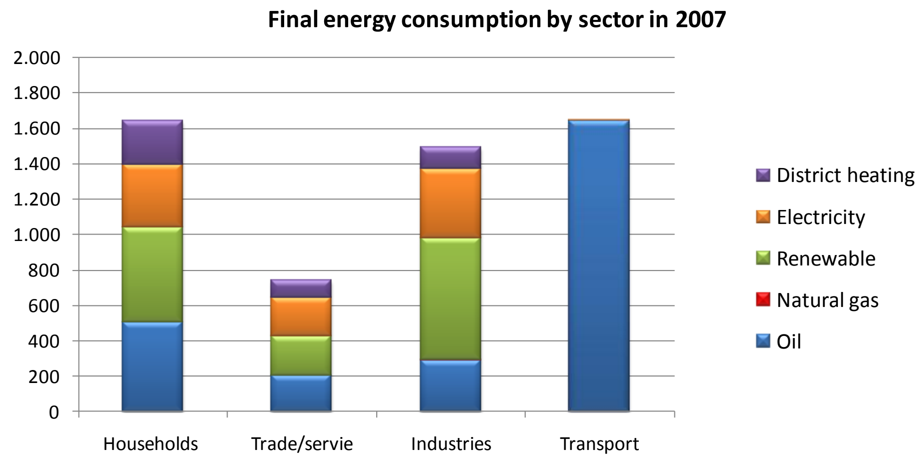

Figure 10: Final energy consumption distributed via sectors and energy products, Municipality of Syddjurs 2007.

The figure reveals that the transport and household sectors are those areas with the largest consumption, with approx. 1,600 TJ each in 2007. Furthermore, it appears that there is a relatively high share of both renewable energy and oil used in the household sector, a great deal of which is likely from individual heating.

The total heat consumption divided on energy sources is shown in the figure below. Roughly 1/4 of the heat is supplied from district heating and 37-38% each by oil and bio energy in form of individual heating. The consumption of electricity, solar power and heat sources for heat pumps (air or ground heat) is marginal. The bioenergy used for individual heating is primarily local firewood, wood pellets and straw.

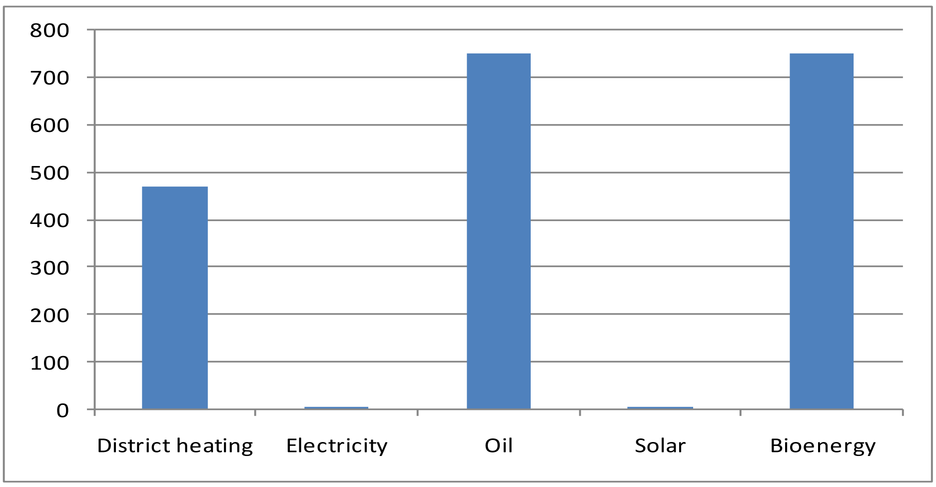

Figure 11: Heat consumption by energy source (TJ final energy), Municipality of Syddjurs 2007. Heat consumed in industries is not included.

The district heating production by fuels is shown in the figure below. In addition to the individual heating, of the district heating portion, well over 75% comes from biomass. Therefore the total heating (individual and district) in Syddjurs is nearly 60% derived from bioenergy.

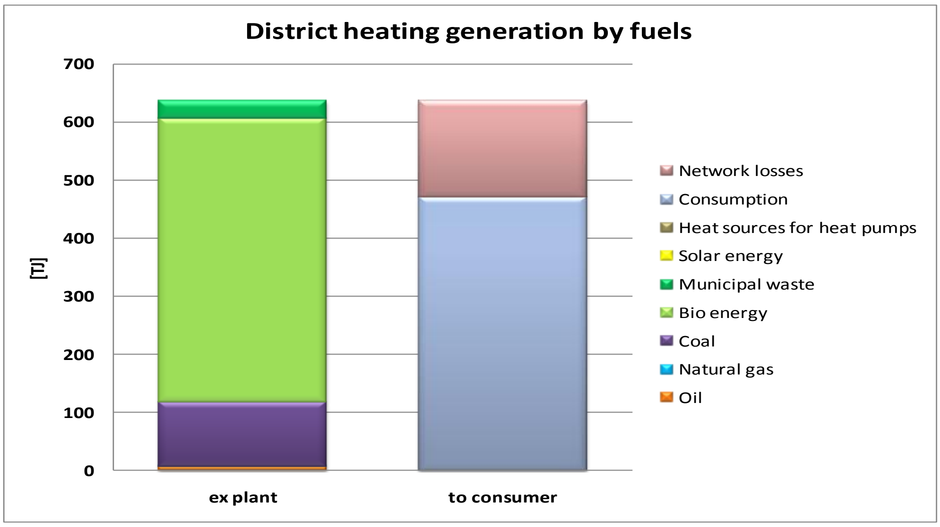

Figure 12: Total district heat production by fuels, Municipality of Syddjurs 2007. Of the district heating, over 75% is from bioenergy. As a result, nearly 60% of the total heat demand (individual and district) is met via bioenergy in Syddjurs. The coal fired district heating is heat imported from Århus (Studstrupværket to Hornslet).

District heating plants in Syddjurs

A more comprehensive breakdown of the district heating plants in Syddjurs is provided below. They consist of one large industrial provider, and a number of smaller district heating boilers using wood chips or straw. The district heating plants include:

	Coal (TJ)	Fuel oil (TJ)	Gas oil (TJ)	Straw (TJ)	Wood Chips (TJ)	Wood and biomass waste (TJ)	Wood Pellets (TJ)	Gross Fuel (TJ)
Balle Varmeværk (Glatved Losseplads)		0.3	10.4		8.4		5.0	24.1
Ebeltoft Fjernvarmeværk					190.0			190.0
Kolind Halmvarmeværk				41.2				41.2
Mesballe							5.2	5.2
Mørke Fjernvarmeværk					12.0			
Nimtofte Fjernvarmeværk				50.8				50.8
Novopan Træindustri A/S	120.2	1.1				710.9		832.2
Rosmus Varmeværk		0.2					5.3	5.5
Ryomgaard Fjernvarmeværk				61.6				61.6
Rønde By's Fjernvarmeværk				94.2				94.2
Thorsager Fjernvarmeværk				24.9				24.9
Tirstrup Varmeværk					17.6			17.6
Total	**120.2**	**1.6**	**10.4**	**272.7**	**228.0**	**710.9**	**15.5**	**1359.3**

Table 3: Fuels used in district heating plants in Syddjurs in 2007. Wood and biomass waste for Novopan also includes a significant amount of wood chips. Novopan produces heat for industrial

processes as well as some surplus heat (~ 30 TJ) for Pindstrup Varmeværk. Pindstrup Varmeværk is not mentioned in the table as it uses very little fuel but receives surplus heat from Novopan. Hornslet Fjernvarme imports coal-fired heat from Århus but has no own production and is therefore not included.

It is worth noting that the largest heat supplier in Syddjurs is Novopan, a particle board manufacturer, thus the heat generated here is process heat, not heat primarily generated for household heating purposes.

Energy consumption in Randers Municipality

For Randers municipality as a whole, data for 2007 has been utilised. However, in recent years, Verdo (formerly Energi Randers), the main heat and electricity producer in Randers, has made a conversion from coal to biomass at the Randers CHP. Therefore, fuel use and production for Energi Randers is based on data for 2009. Due to the fact that the majority of other data has not changed drastically, all other data is from 2007. The decision to integrate more recent data for Randers CHP is based on the desire to present an accurate picture of the current energy usage situation.

Gross energy consumption

The figure below displays the gross energy consumption (fuel consumption and other types of energy for example wind power) in the Municipality of Randers for 2007.

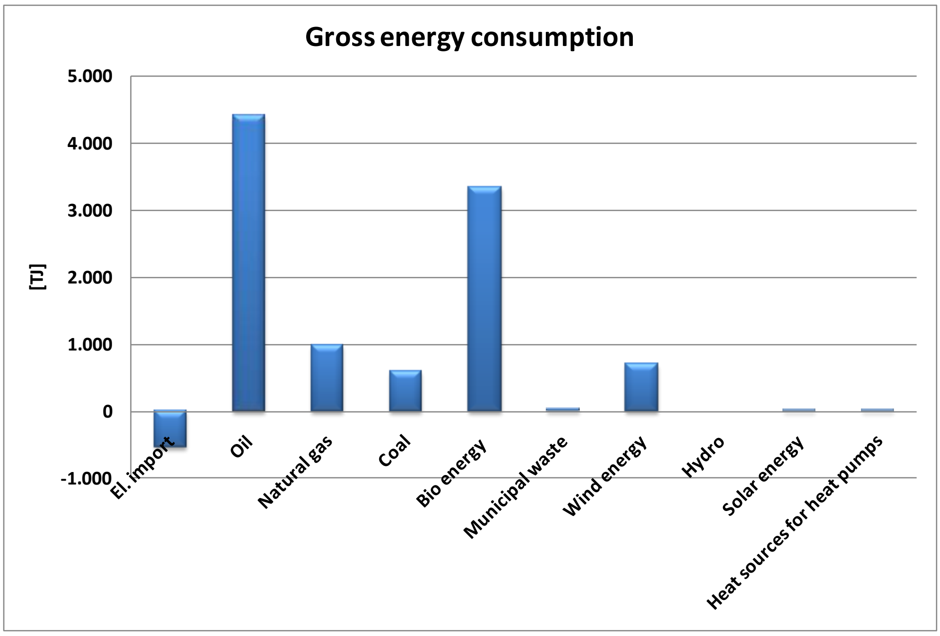

Figure 13: Gross energy consumption, Municipality of Randers 2007 (Energi Randers 2009 data).

The share of bioenergy is around 3,400 TJ out of approx. 9,700 TJ in the total gross energy consumption, corresponding to a 35% share. The consumed bioenergy resources consist of straw, firewood, wood chips, wood pellets and waste wood. Most of the biomass is used at the Randers CHP plant.

The municipality of Randers was a net exporter of electricity in 2007, which explains the negative figure for electricity import.

Final energy consumption

The final energy consumption (end-use) distributed via sectors and energy products in the municipality of Randers, is shown in the figure below. The final energy consumption covers energy supplied to the final consumer for all energy uses. The total final energy consumption in Randers was 8,345 TJ.

The figure reveals that the transport and household sectors are the sectors with the largest consumption, with approx. 3,600 and 2,500 TJ respectively in 2007. Furthermore, there is a relatively high share of renewable energy used for heating in the household sector.

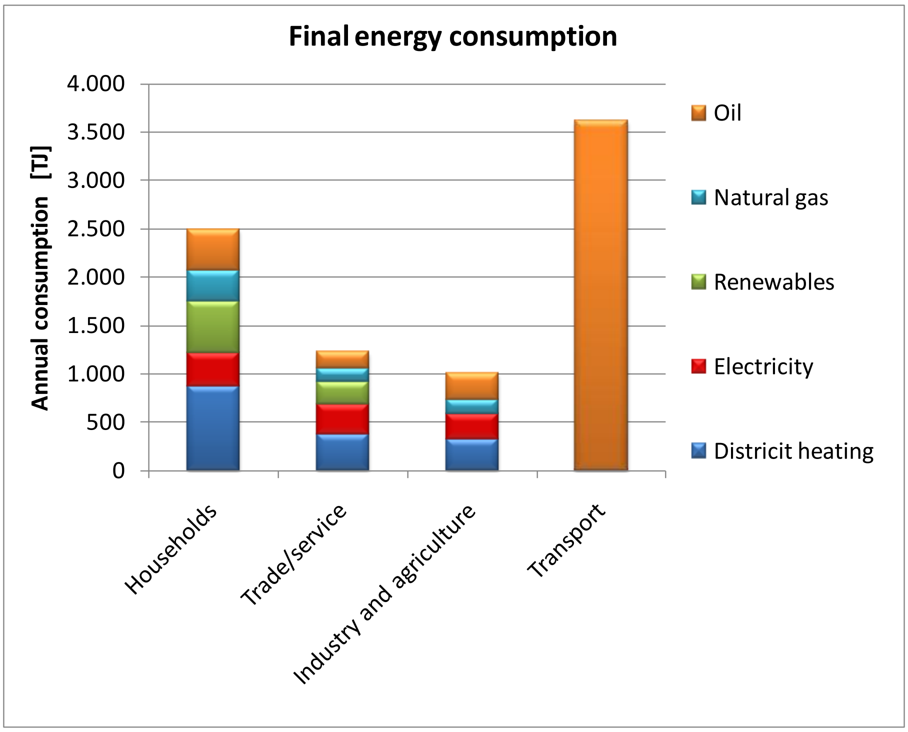

Figure 14: Final energy consumption distributed on sectors and energy products, Municipality of Randers, 2007.

The heat consumption by energy source is shown in the figure below. Roughly 45% of the heat is supplied from district heating and 17% each by oil and natural gas, and 21% from bio energy in form of individual heating (primarily firewood and wood chips).

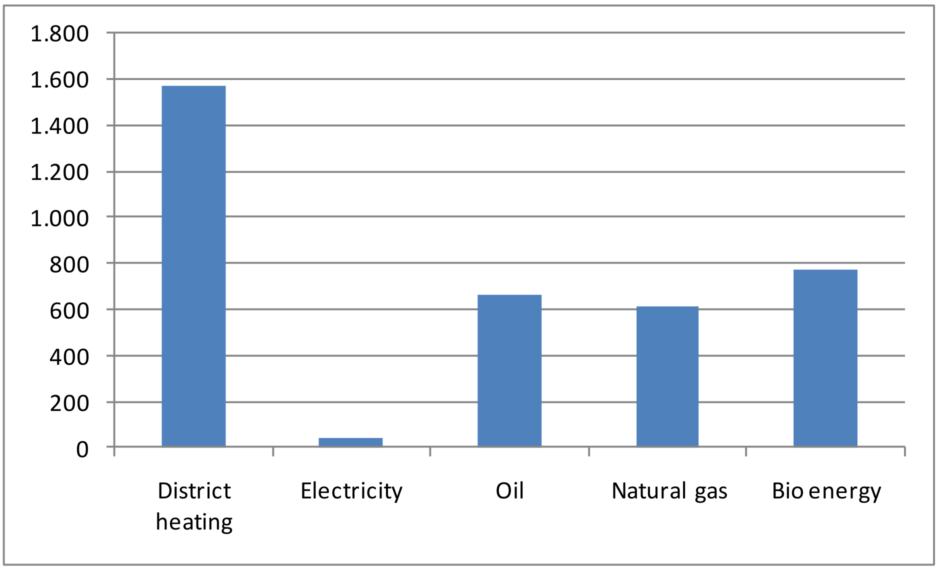

Figure 15: Heat consumption by energy source (TJ final energy), Municipality of Randers 2007 (Energi Randers 2009 data). Heat consumed in industries is not included.

Most of the district heat is generated at the combined heat and power plant Randersværket, which uses a combination of coal and various forms of biomass. It is worth noting that since 2007 the fuel use has shifted to considerably more biomass and less coal. This is reflected in the figure below as data for 2009 are used for Energi Randers. In addition to the individual heating, of the district heating portion, over 70% now comes from biomass. Therefore the total heating (individual and district) in Randers is nearly 55% derived from bioenergy.

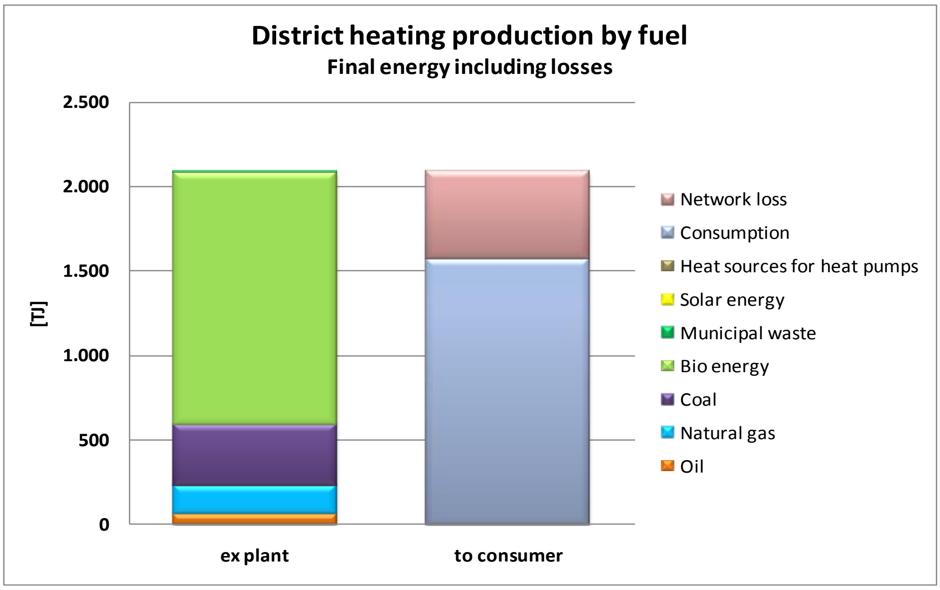

Figure 16: District heating generation and consumption by energy source, Municipality of Randers 2007 (Energi Randers 2009 data). Consumption includes heat used as process energy in industries.

District heating plants in Randers

The remaining district heating plants in Randers are mainly smaller natural gas fired CHP plants. The district heating plants in Randers include:

	Coal (TJ)	Gas oil (TJ)	Natural Gas (TJ)	Biogas (TJ)	Straw (TJ)	Wood Chips (TJ)	Wood and biomass waste (TJ)	Gross Fuel (TJ)
Energi Randers Produktion A/S* (2009)	597						2450	3047
Gassum-Hvidsten Kraftvarmeværk			47.3					47.3
Gjerlev Varmeværk		1.1			23.1			24.2
Havndal Fjernvarme A.m.b.a.		0.7			32.3			33.0
Langå Varmeværk			148.1					148.1
Mejlby Fjernvarmecentral			21.8					21.8
Mellerup Kraftvarme			44.9					44.9
Overgaard Biogasanlæg				43.8				43.8
Randers Central Renseanlæg			42.6	26.1				68.7
Uggelhuse-Langkastrup			32.2					32.2
Værum-Ørum Kraftvarmeværk			39.6					39.6
Total	**597**	**1.8**	**376.5**	**69.9**	**55.4**	**0**	**2450**	**3550.5**

Table 4: Fuels used in district heating plants in Randers in 2007. * For Energi Randers the fuel use is for 2009. It is worth mentioning that the largest supplier, Randers Produktion, has increasingly switched over to greater biomass usage, and less coal. This trend is anticipated to continue throughout the next few years as the plant aims to utilise 100% biomass. It is also worth noting that a significant portion of the 'wood and biomass waste' for Randers is in fact wood chips, and to a lesser extent wood pellets. Overgaard biogasanlæg and Randers Renseanlæg have biogas facilities and produce power but no heat according to the available data. The biogas is produced from sludge, industrial waste, slurry and energy crops.

Summary

The table on the following page summarises the energy situation in the three municipalities and compares them with the energy situation in Denmark. Use of municipal waste is not included in the table.

The total gross energy use in the 3 municipalities is 2.4% of the Danish total gross energy consumption. The 3 municipalities have a much higher share of bioenergy use (28-35%) than that of the national average for Denmark (9.5%). The main reason is that there is a very high share of biomass use in both individual and district heating systems. Furthermore, Syddjurs has the large industrial manufacturer Novopan, which uses biomass for the production of process heat and power.

Indicator	Norddjurs	Syddjurs	*Randers	3 munici-palities	Denmark	Municipali-ties share
Gross energy (PJ)	5.4	5.7	9.7	20.8	863.5	2.4%
Final energy (PJ)	4.6	5.5	8.3	18.4	685.2	2.7%
Total biomass (PJ)	1.5	1.9	3.4	6.8	82.2	8.3%
Total biomass (% of gross energy)	27.7%	33.3%	35.0%	32.6%	9.5%	-
Straw (PJ)	0.74	0.31	0.15	1.2	18.3	6.6%
Wood (PJ)	0.77	1.62	3.17	5.6	60.0	9.3%
Biogas (PJ)	0	0.005	0.07	0.075	3.9	1,9%
District heating production (PJ)	1.21	0.64	2.09	3.9	121.5	3.2%
District heating production from biomass (PJ)	0.66	0.49	1.49	2.6	19.7	13.4%
Individual heating (PJ)	1.17	1.50	2.05	4.7	115	4.1%
Individual heating from biomass (PJ)	0.64	0.75	0.77	2.2	N/A	-
Other biomass (PJ)	0	0.71	0	0.7	N/A	-

Table 5: Summary of energy use in the three municipalities compared with the Danish consumption in 2007 (*data for Energi Randers from 2009). Biomass does not include municipal waste.

2.2 Climate and Energy Plans of the 3 municipalities

The 3 municipalities are all working to reduce greenhouse gas emissions and increase the use of renewable energy.

Municipality of Syddjurs and Norddjurs

The municipalities of Norddjurs and Syddjurs have been co-operating in the field of climate energy and in the initiative called Djurs Energiland. The collaboration started in 2007, and in 2008 a think-tank for ideas and initiatives dubbed Energirådet was created. In 2009, an energy and climate action plan was drawn up.

On the basis of statistics from 2007, the action plan presents a vision for a possible energy future with radically lower CO_2 emissions. The action plan encompasses 9 concrete initiatives with focus on energy savings, increased use of renewable energy and restructuring of the transport sector.

The action plan among other things includes the following collaborative visions:

- 20% reduction in heat consumption
- 75% reduction in oil consumption for heating
- Establishment of 2 new biogas plants
- Offshore wind turbines totalling 40 MW in capacity

In terms of CO_2 emissions, the plan estimates a reduction in Norddjurs from a 2007 value of 270,000 tonnes (7.0 tonnes per person) to 150,000 tonnes by 2025. If displaced CO_2 from electricity exports is subtracted, this will result in 2025 emissions of roughly 90,000 tonnes (approx. 2.3 tonnes per person).

Meanwhile, in Syddjurs, 2007 CO_2 emissions were just under 310,000 tonnes (7.5 tonnes per person), and are estimated to be 180,000 tonnes in 2025, equal to 4.5 tonnes per person and a reduction of roughly 40%.
(Norddjurs and Syddjurs Municipalities, 2009)

Municipality of Randers

In 2009, the Municipality of Randers published a plan describing its measures for mitigating climate change in 'Climate Action Plan 2030'. The plan consists of both short term (2010), and long term targets (2030), for reducing greenhouse gas emissions in the municipality.

The major long term targets of the municipality are:

- 75% reduction of CO_2 emissions relative to the 1990 level by 2030
- 75% renewable energy in the energy supply by 2030

The plan consists of 54 specific initiatives which are to be launched in the next 5 years. The targets and initiatives in the plan are mainly focused on the following three areas:

- Establishment of new wind turbines on land, and continuous replacement of existing turbines with larger and more efficient ones
- Increased use of renewable energy in the collective heat supply
- Establishment of new wood and wetlands, and securing roughly 250 hectares from crop rotation.

Furthermore, the plan lays the groundwork for a heat plan, and a plan for biogas. The plan is currently in hearing at the moment, and thereafter will have to seek political approval.
(Randers Municipality, 2010b)

In 2007, the 92,984 inhabitants and the municipality as a geographical area emitted approximately 530,800 tonnes of CO_2, corresponding to ca. 6 tons of CO_2 per capita. With the vision put forward in the action plan, the average emission per capita is estimated to be 2.4 tonnes of CO_2.

2.3 Future Demand for Bioenergy

When assessing the 3 municipalities potential future demand for bioenergy there are a number of factors to consider.

On the one hand we expect to see an increasing proportion of district heating to come from biomass (particularly in Randers where Randers Kraftvarmeværk will continue to replace coal with biomass). The establishment of new biogas plants within the municipalities would also lead to an increased demand for bioenergy. From an individual heating standpoint the municipalities are particularly interested in shifting away from individual oil furnaces, and if this shift manifests itself in the installation of wood pellets furnaces this will also lead to an increase in bioenergy demand.

On the other hand, the municipalities have also set goals of reducing overall heat consumption, which may reduce the demand for bioenergy. With respect to the concrete goal of reducing oil consumption from heating, a likely result could be the replacement of individual oil furnaces with heat pumps. In addition, owners of existing low efficient biomass based individual heating may also switch over to more efficient heat pumps.

3 Danish existing and future demand for bioenergy

3.1 Current Danish biomass usage

Use of biomass in Denmark

The Danish use of biomass for energy is shown in the table below (from "Energistatistik 2008"). The use of solid biomass was 78 PJ. Furthermore, waste (30 PJ) and biogas (4 PJ) was used.

It is worth noting that wood waste has its own category, whereas some other sources include a large majority of this as wood chips, and thus have total wood chip utilisation of roughly 14 PJ (HedeDanmark, 2009).

TJ	Straw	Wood chips	Wood pellets	Fire-wood	Wood waste	Total
Central el and heat prod.	4,002	3,040	6,215	0	1,093	14,350
Decentralised CHP	3,103	1,905	0	0	470	5,478
District heating plants	3,417	4,407	1,985	0	457	10,266
CHP from Industrial Process	0	549	0	0	135	684
Heat from Industrial Process	0	0	0	0	454	454
Agriculture and Forestry	1,937	27	0	0	0	1,964
Industrial Processes	0	1,081	945	0	3,319	5,345
Private and Public Service	0	148	919	0	0	1,067
One family houses	2,905	81	8,245	27,198	0	38,429
Total	**15,364**	**11,238**	**18,309**	**27,198**	**5,928**	**78,037**
(Of which is import)	0	3,371	15,928	2,176	0	21,475

Table 6: Biomass use in Denmark 2008 (Energistatistik 2008)

The table reveals that in 2008, 19 PJ (roughly 1 mil. tonnes) of wood pellets were used in Denmark. Of this about half was used for heating in households and about half was used for power and district heating production. The Avedøre Power Plant alone used 5.95 PJ of wood pellets (DONG Energy, 2008), or about one third of the Danish consumption of wood pellets.

3.2 Danish goals and future biomass usage

Integration of more renewable energy in the years ahead is a political priority, and Denmark as well as the EU has adopted targets for the share of renewable energy in 2012 and 2020. In 2020, 30% of Danish energy supply is to be renewable energy - a substantial share of total energy production. This challenge will be even greater in the long term, when fossil fuels are to be entirely phased out of Danish energy production. The Danish government has committed to setting/suggesting a timeframe for when Denmark can become independent of fossil fuels, as well as a strategy for how this aim can be achieved. One such indicator of this is the Danish Commission on Climate Change Policy

(Klimakommission), a panel of leading scientific experts, tasked with presenting suggestions as to how Denmark can in the future phase out fossil fuels.[2]

As such, the use of biomass (particularly wood pellets) is expected to increase over the coming years in Denmark. In its annual report on Danish energy trends from 2009 (Danish Energy Agency 2009b), The Danish Energy Agency explains that it expects renewable energy to grow over the coming years, as is displayed in the figure below. The light blue bars are solid biomass, and its annual use is expected increase to about 165 PJ by 2025. A large part of this increase is due to an increase in the use of wood pellets.

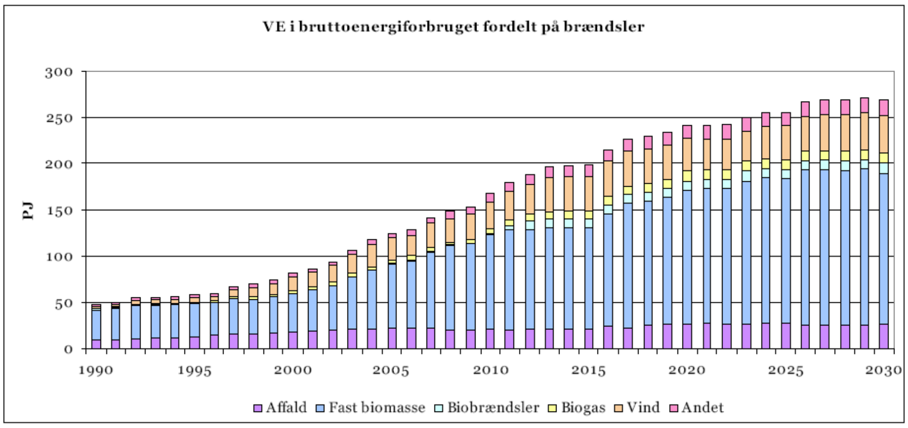

Figure 17: Renewable energy in the yearly report on Danish energy trends from 2009 from the Danish Energy Agency (2009). Waste (Affald), Solid Biomass (Fast biomasse), Biofuels (Bio-brændsler, Biogas, Wind (Vind), and Other (Andet).

The figure below comes from the same report and shows the expected increase in the use of renewable energy from 2009 to 2020 (Danish Energy Agency 2009b).

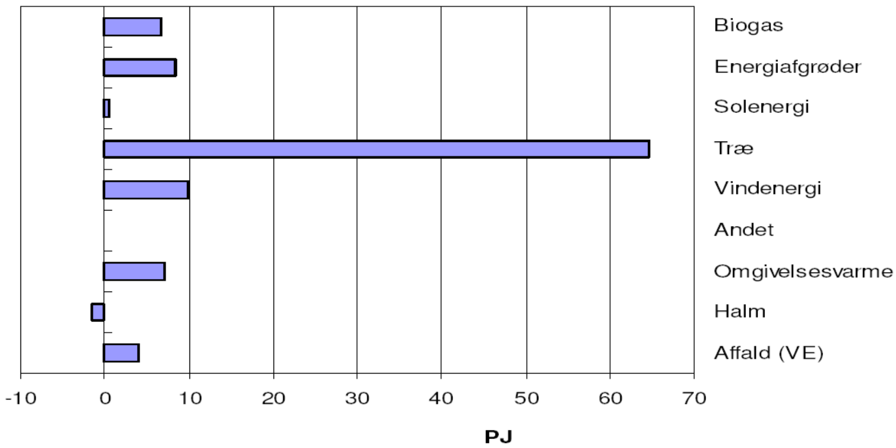

Figure 18: Danish increase of the use of renewable energy from 2009 to 2020 from the annual report on Danish energy trends from 2009 from the Danish Energy Agency. Biogas, energy crops (energiafgrøder), solar (solenergi), wood (træ), wind (vindenergi), other (andet), heat load for heat pumps (omgivelsesvarme) , straw (halm), and garbage (affald).(DEA, 2009b).

[2] http://www.klimakommissionen.dk/en-US/AbouttheCommission/Sider/Forside.aspx

The reason that the use of wood is expected to increase dramatically compared with the other resources is that several of the central power plants are expected to shift from coal to wood pellets within the period. A possible explanation for an expected decrease in straw use could be due to the fact that at least one of the central power plants is expected to replace their straw usage with wood chips or wood pellets. Dong Energy for example as recently as September of 2010 stated that starting in 2012 they intend to use 25% less straw, and replace it with wood pellets imported from Canada and the Baltic states (Ingeniøren, 2010).

3.3 Danish energy incentives and regulations

Meeting the aforementioned national targets requires economic and tax incentives, and in Denmark there are a number of different taxes and subsidies in place for both the heating and electricity sectors. Understanding the rationale for their implementation, how they work in practice, and thereby how they influence fuel choice decisions, is particularly relevant for actors within the heat and power sector.

There are a number of different taxes and subsidies that are relevant for the heat and power sector, including:

- Energy taxes
- CO_2 taxes
- CO_2 quotas
- Electricity subsidies
- Sulphur and Nitrogen Oxide taxes
- Waste taxes

The most relevant taxes and subsidies for this study are the energy and CO_2 taxes, as well as CO_2 quotas and electricity subsidies, and as such each will be described below.

Energy and CO_2 taxes

Generally speaking, energy taxes for heat are placed directly on the fuel, whereas for electricity it is normally placed on the end-user and not in the production stages. The main reason for the difference in how heat and electricity is taxed is due to the fact that heat is more of a local good (i.e. it is used relatively close to where it is produced), whereas electricity is a good that is traded internationally across borders and regions. As such, the allocation of electricity taxes on the end-user, as opposed to the producer, helps to maintain the competitive balance with neighbouring countries.

The table below sets out the Danish heat related energy and CO_2 taxes applicable for 2010. The CO_2 tax has been raised from 90 DKK/tonne to 150 DKK/tonne and is given in DKK/GJ for each fuel. It is worth noting that biomass is exempt from these taxes and this is the main reason why biomass usage in the Danish heating sector is so prevalent.

Fuel	Energy tax (DKK/GJ)	CO_2 tax (DKK/GJ)
Coal	57.3	14.8
Natural gas	57.3	8.9
Fuel Oil	57.7	12.2
Gas Oil	57.3	11.5

Table 7: Danish heat related applicable taxes for 2010. The fee payable is the portion of the fuel attributed to heat generation. For industrial uses other than comfort heating and air conditioning lower taxes are applied. Heavy industry which is covered by the quota system is exempt from taxes (other than the minimum EU taxes).

For pure heat the taxation is relatively simple. For combined heat and power however, it is more complex, as it is only the portion of the fuel that is utilised in heat generation that is taxable, and electricity is exempt from taxation at the production level.

Previously there were different ways of determining how the taxes should be allocated between electricity and heat, both for central and decentralised plants, however this changed as of January 1st, 2010. Now the same rules apply for both centralised and decentralised plants, and the allocation of heat and electricity is done via either the so called 'E' or 'V' formulas:

- E formula: 1 – (electricity production / 0.65)
- V formula: Heat production / 1.25

Each year the plant can decide which of the two formulas should be utilised. Typically plants with high electrical efficiency will make use of the E-formula, while decentralized systems with low electrical efficiency will utilise the V-formula.

CO_2 quota system

Within the EU a CO_2 quota system has been in place since 2005. The quota system covers large energy production units and industries representing roughly 50% of European CO_2 emissions. The first few years were a trial period, and the first real period runs from 2008 – 2012. Each year, all entities covered by the quota system must have emission allowances equal to the total amount of CO_2 emitted.

For energy production, all plants over 20 MW thermal are covered by the quota system, and allowances (also known as permits or quotas) can be acquired via purchase on the market, or from the state via the applicable allocation mechanism (free quotas or auctioning).

The price of CO_2 allowances are currently around 100 DKK/tonne, but the Danish Energy Agency estimates that it will gradually rise to 238 DKK/tonne by 2025. For coal and natural gas this amounts to approx. 22.6 and 13.6 DKK/GJ respectively.

Electricity subsidies

There are electricity subsidies for natural gas-fired decentralised heat and power plants as well as electricity production from renewable sources. The rationale for this is a desire to encourage the usage of more environmentally friendly fuels in electricity production. In the absence of such subsidies, and due to the abovementioned exemption of biomass from heat taxes, there would be a significant incentive to solely use biomass for heating.

For natural gas-fired decentralised CHP units under 25 MW_e there is a subsidy of 80 DKK/MWh (22.2 DKK/GJ) up to a maximum production of 8,000 MWh. In addition, through to 2019, existing plants over 5 MW_e receive a production based subsidy, while existing plants under 5 MW_e have the option to continue to get a subsidy via the 'three step tariff', or the same subsidy that the larger plants receive.

For electricity produced via biomass, the electricity supplement for all CHP plants is 150 DKK/MWh (41.7 DKK/GJ) over and above the electricity market price. Meanwhile, electricity produced from biogas receives a fixed 745 DKK/MWh (206.9 DKK/GJ).[3]

Heat Supply Act – Restrictions regarding fuel choice

In Denmark replacement of the heat production in the district heating plants is regulated by the Heat Supply Act ("Bekendtgørelse om godkendelse af projekter for kollektive varmeforsyningsanlæg"). The act sets out restrictions for municipalities' approval of new district heating plants.

Following the restrictions of this Act, the municipalities must not approve a biomass heat plant (non taxed fuels) in an area that is currently fired with fossil fuels (taxed fuels). This means that only biomass fired CHP plants can displace the production of existing natural gas-fired CHP plants.

However, a biomass fired boiler can be approved if it is built to cover an increased heat demand and the boiler is dimensioned solely to cover this increased heat demand.

Forecasted fuel costs

The figure on the following page presents the Danish Energy Agency's forecasted fuel costs for delivery at the plant gate. The prices are in 2008 DKK/GJ, and do not include taxes.[4]

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[3] Depending on whether the electricity is produced via biogas alone, or in combination with another fuel, electricity producers can also chose a to receive the market price for electricity, plus a supplement of 405 DKK/MWh (112.5 DKK/GJ).

[4] The DEA's forecasted fossil fuel prices are based on the IEA's World Energy Outlook from November of 2009. In particular they are based upon the baseline scenario which assumes that we will continue along the current trajectory, an underlying assumption that is rather unlikely and may have a significant effect on forecasted prices, particularly for natural gas. In addition, the DEA's forecasted prices for biomass appear to have a strong coupling to oil prices, another underlying assumption that can be debated, as historic biomass prices do not appear to be highly correlated with oil prices.

The figure clearly reveals that in the absence of taxes and subsidies, the most attractive fuel choice for energy providers will continue to be coal, which only sees a gradual price increase over the next 20 years. Meanwhile the price of natural gas is anticipated to increase greatly, while wood pellets, wood chips, and straw all see more gradual increases. Energy crops are anticipated to see a slight decline (in real prices) based on the assumption that advances in energy crop cultivation will more then compensate for increase in fuel input prices.

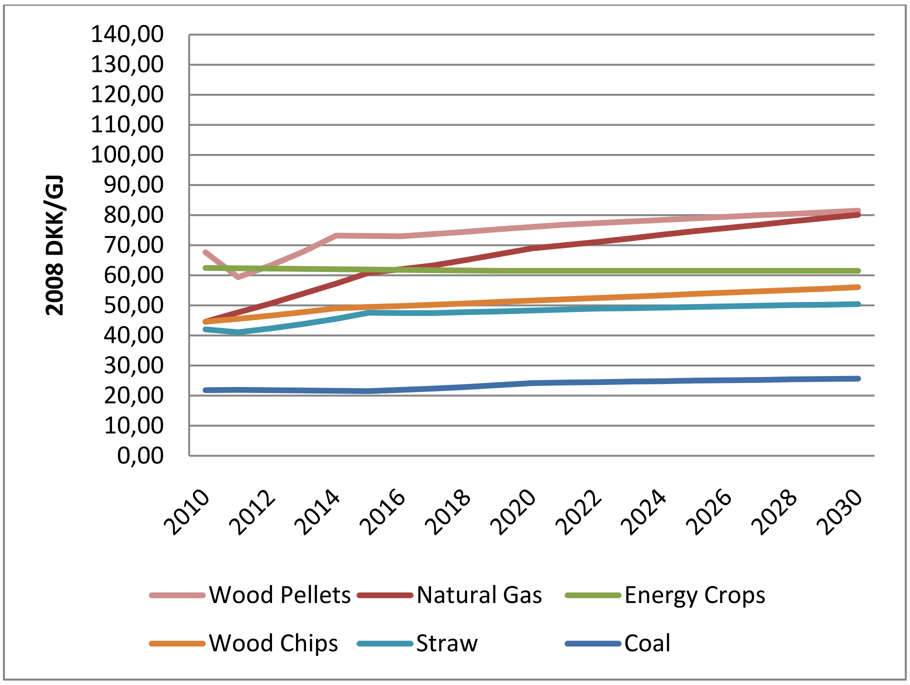

Figure 19: Danish Energy Association forecasted fuel prices, at the plant gate, exclusive VAT (DEA, 2010).

The figure does not take into account current taxes on fossil fuels, the value of CO_2 quotas needed to cover their emissions, nor subsidies for electricity produced via biomass. When these factors are introduced for the Randers kraftvarmeværk for example, the cost picture for input fuels looks quite different. A concrete example of the affect of these factors will be presented in section 7.3 .

4 Regional/International existing and future demand for bioenergy

The following section outlines the current use of bioenergy, as well as expectations regarding the increase in regional, European, and global demand for bioenergy.

4.1 EU biomass usage and goals

Current EU biomass for use in energy sector

On a whole the EU as of 2007 utilised 7.8% renewables in its energy mix, with nearly 70% coming from biomass and waste, representing over 4.000 PJ.

EU Goals

The primary driver for renewable energy use within the EU is the renewable energy directive, which establishes the mandatory target of at least a 20% share of energy from renewable sources in overall Community energy consumption by 2020, and that by 2020 at least 10% of transport fuel in each member state must be from renewable sources (green electricity, hydrogen, and biofuels all qualify, with second generation biofuels counting double) (EU, 2009).

In addition, the EU has also announced that it is willing to strive after even more ambitious targets. For example, prior to the COP 15, in Copenhagen in December of 2009, the EU put forward an offer to reduce greenhouse gas emissions by 30% in 2020 and up to 95% in 2050, provided an international agreement could be reached at the conference. While this did not come to fruition, it does indicate the political will within the EU to further reduce GHG emissions.

EU future demand for bioenergy

Given increases in overall energy demand resulting in a 2020 EU gross inland consumption of 82,400 PJ, to reach the 20% target the EU therefore requires an additional 10,600 PJ of renewable energy by 2020 (in gross consumption terms).[5]

However, given that over the next 10 years there will be used approx. 10,600 PJ more renewable energy, and within this timeframe the most feasible options for large-scale renewable energy production are biomass and wind, it is possible to develop potential scenarios for future EU biomass usage. A realistic scenario for achieving the EU renewable target could be:

- Renewables such as hydro, solar, wave, and geothermal constitute 20% of this required renewable energy

[5] 2020 EU gross inland consumption of 82.400 PJ is based on DG Tren's 2008 figures (DG Tren, 2008).

- 20% comes from wind, (this corresponds to approximately 196 GW of new capacity, and is approx. 15 to 20 GW more than the European Wind Energy Association (EWEA) forecasts).[6]
- Biomass and waste cover the rest, equivalent to 6,300 PJ, or roughly 420 million tonnes of additional biomass.

Combined with the aforementioned 2007 EU consumption of biomass and waste of 4,000 PJ, an estimate for the annual gross energy from biomass and waste in 2020 is 10,300 PJ, roughly 690 million tonnes of biomass.

In comparison, coal consumption in the EU27 in 2005 was 13,400 PJ, equivalent to around 890 million tonnes of biomass. This indicates that if the objective is to be achieved, over the next 10 years there would need to be a very significant substitution of coal with biomass in large power plants.

4.2 Global biomass usage

Current global use of biomass for energy

According to the International Energy Agency, the global use of biomass for energy is currently about 1,200 Mtoe or 50.2 EJ, corresponding to roughly 10% of the total global energy use (IEA, 2009).[7]

Primary energy

Expectations for the use of global biomass are based on scenarios from the IEA's World Energy Outlook 2009. In their publication the IEA presents two scenarios, the baseline scenario and 450 ppm scenario. In the baseline scenario, global projected energy consumption in the world is forecasted according to a business-as-usual approach, that is to say a continuation of current trends and policies. The 450 ppm scenario meanwhile involves a projection where policies are put into place with the aim of limiting global temperature rise to two degrees. This requires a substantial effort in the energy system via energy efficiency, increased renewable energy, etc. In this report we will refer to projections from the 450 ppm scenario in order to estimate future biomass utilisation.

In their 450 ppm scenario, the IEA forecasts that in:

- 2020 nearly 1,500 Mtoe (62,800 PJ) – corresponding to 12% of global primary energy demand, will be met by biomass.
- 2030 roughly 2,000 Mtoe (83,700 PJ) corresponding to 16% of global primary energy demand, will be met by biomass.

These biomass figures, as well as other primary energy demand sources under the 450 ppm scenario, are shown in Figure 20 below.

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[6] EWEA forecasts total installed capacity of 230 GW by 2020 (EWEA, 2010).

[7] The report "Biomass Assessment - Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy" refers to a total global consumption of 46 EJ, of which 37 EJ is non commercial uses of coke, wood and dried manure for cooking and heating, mainly in the developing world. 9 EJ is used in so-called modern bioenergy, for industries, power generation and transportation fuels, and this proportion is growing.

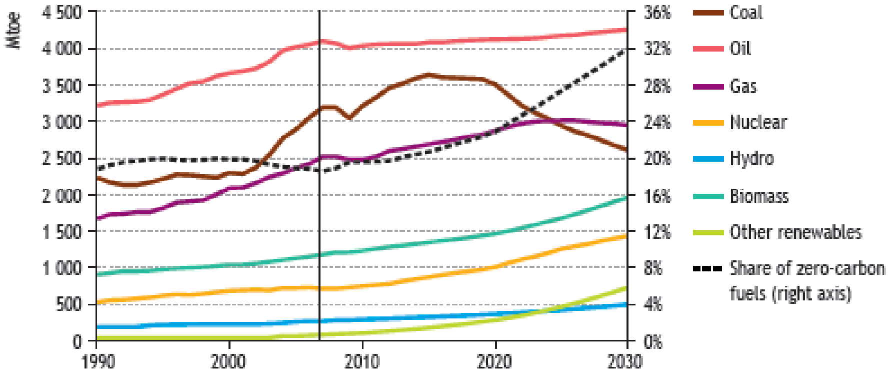


Figure 20: *World primary energy demand in 450 scenario.*

Electricity production

In terms of electricity production from biomass, the WEO 450 ppm scenario envisions roughly 1,450 TWh will come from biomass in 2030, up substantially from the less than 300 TWh in 2007. Even in the WEO reference scenario, which does not assume the implementation of any new CO_2 reduction policy, electricity generation from biomass is forecasted to be 840 TWh in 2030 (IEA, 2009). The majority of this is from combined heat and power plants, while co-firing from coal-based plants and landfill gas also see significant growth. It is estimated that demand for 'traditional biomass', that is, biomass that is used directly for cooking and heating in many developing countries, will decrease over the forecast period. However, this will be more than offset by increased demand for 'modern biomass', particularly from OECD countries (IEA, 2009).

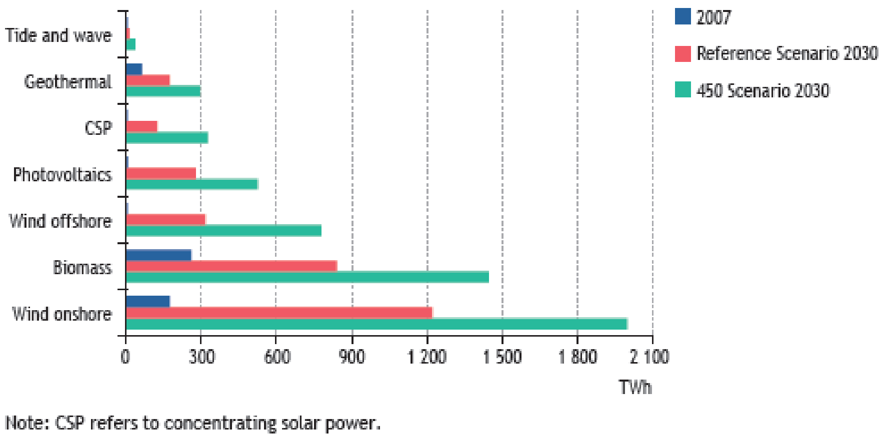


Figure 21: World renewable electricity generation in 450 ppm scenario.

5 Existing and future bioenergy resources

5.1 Local resources

In the following section the current availability of local energy resources in the municipalities of Randers, Norddjurs and Syddjurs will be presented. Local resources are in this chapter defined as the resources that are produced within the three municipalities and include straw, forest wood chips and biogas.

Data for straw is provided by Conterra and Danmarks Statistik. Data for biogas resources are provided by Plan Energi. Calculations on the energy content in energy crops and manure is done on the basis of Kristensen & Jørgensen (2008). Data for local forest wood are based on Danmarks Statistik.

Local straw resources

The table below shows the current production and use of straw in the three municipalities based on recent figures from Conterra. The straw is categorises as either for energy production, animal feed and bedding, or not collected.

Tonnes/year	Total straw production	Energy production	Animal feeding and bedding	Not collected/ unavailable
Norddjurs	114,611	31,961	25,477	57,173
Syddjurs	140,583	41,399	26,288	72,896
Randers	86,729	22,329	18,670	45,730
Total	**341,923**	**95,689**	**70,435**	**175,799**
-10%	34,192			141,607

Table 8: Production and use of straw for different purposes in the three municipalities (Conterra, 2010).

The table shows that roughly half of the straw produced in the three municipalities is currently used for either energy production or for animal purposes. The remaining 50% of the straw produced in the last column is ‘not collected’ or ‘not available’.

As can be seen from the table, there appears to be a surplus of available straw in the three municipalities, totalling 175,799 tonnes/year. As not all straw can be gathered in it is said that approximately 10% of the straw is technically not possible to gather in (The Centre for Biomass technology, 1998). Subtracting 10% from the total straw production as uncollected straw from the municipalities, a surplus of 141.607 tonnes is available. With a calorific value of 14.5 GJ/tonne this equals 2.05 PJ.

The straw use of the three municipalities is illustrated in the figure below.

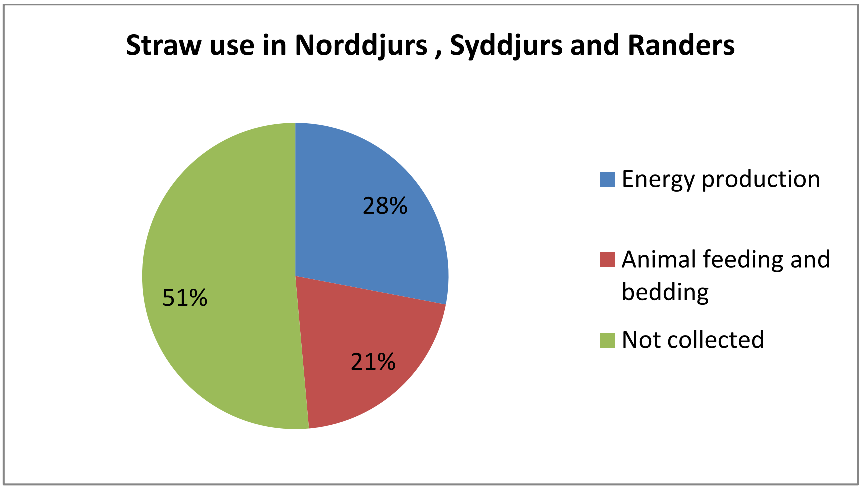


Figure 22: Combined straw use in the three municipalities (Conterra, 2010).

Looking at the entire Central Region Denmark the picture is very different. The region as a total only has 30% uncollected straw and uses a far bigger share of straw for animal purposes than is the case in the three municipalities. This could indicate a higher concentration of livestock farms in this region compared to the specific three municipalities. Figures from Conterra imply that the livestock farming in the municipality of Randers is not as intensive as in other municipalities of Central Region Denmark (Conterra, 2010). However, it is also possible that the figures from Conterra and Denmark's statistic are simply not comparable due to different years of measurements, different methods, etc.

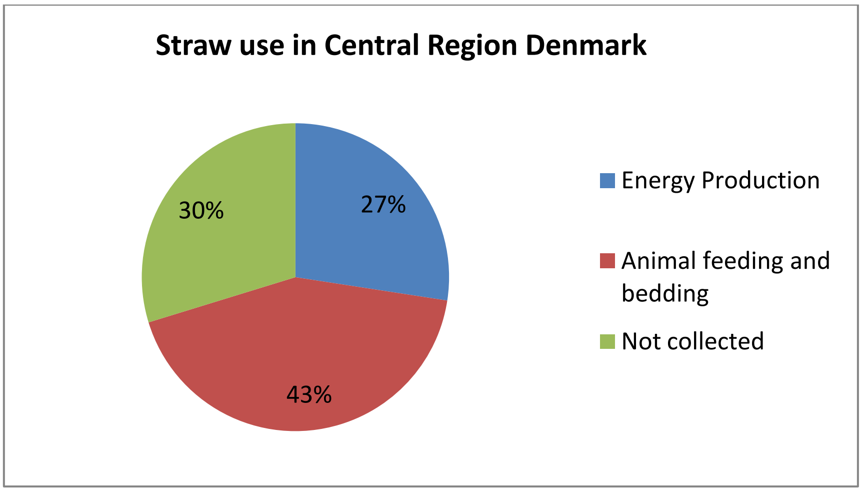


Figure 23: straw use in Central Region Denmark in 2008 (Danmarks Statistik, 2010).

Resources for biogas production

The size and intensity of live stock farms are of great importance for the availability for slurry/manure for biogas production. As mentioned above, the livestock farming in the municipality of Randers is not as intensive as in other municipalities of Central Region Denmark. However, compared to the current use of slurry for energy production, there is a significant amount of slurry available:

Municipality	Slurry potential (TJ)
Norddjurs	286
Syddjurs	252
Randers	293
Total	**831**

Table 9 – Primary energy potential from slurry in the municipalities of Randers, Norddjurs and Syddjurs (PlanEnergi 2008/2009).

The table presents the estimated primary energy potential from slurry (PlanEnergi, 2008/2009). According to PlanEnergi (2008/2009) there is currently not any slurry being used for energy production in Norddjurs, while 7 TJ is being used in Randers and 5 TJ is being used in Syddjurs for the production of heat alone.

Local forest wood resources

According to Danmarks Statistik, in 2000 the total forest area within the three municipalities amounted to 30,190 hectares (Danmarks Statistik, 2010). Looking at the municipality level, Randers Municipality has a much smaller forest area than those in Norddjurs and Syddjurs:

	Forest land (ha)	Energy potential (PJ)
Norddjurs	11,470	0.3
Syddjurs	12,629	0.3
Randers	6,091	0.2
Total	**30,190**	**0.8**

Table 10: Forest land in the three municipalities in 2000 (Danmarks Statistik, 2010). The energy potential is derived from a yield of 1.5 tonnes of dry matter per hectare and a calorific value of 18 GJ/tonne dry matter.

It has earlier been estimated by the Research Center for Forest and Landscape (Forskningscenter for Skov og Landskab) that the yield of biomass for energy from the forests are 1.5 tonnes of dry matter per hectare per year (Kristensen & Jørgensen, 2008). For the three municipalities that amounts to 45,285 tonnes of dry matter a year. Converted into energy this gives a current potential of 0.8 PJ, given a calorific value of 18 GJ/tonne dry matter.

In some scenarios, the yield of 1.5 tonnes dry matter per hectare is increased to 2.25 tonnes dry matter per hectare. As such, the overall potential for the three municipalities with a yield of 2.25 tonnes dry matter per hectare would amount to 1.2 PJ (Ea Energy Analyses, 2010).

5.2 National resources

Potential Danish biomass utilisation for energy purposes based on 2008 data are available on the Danish Energy Agency's website, and from Uffe Jørgensen of the Faculty of Agricultural Sciences. The table below shows the potential for biomass residues, the actual usage, as well as the potential and actual use of energy crops. The usage figures for biomass are based on 2010 DEA figures, while the Danish potential figures are based on a 2010 Danish government security of supply study (Ministry of Climate and Energy, 2010). Released on Feb 26th of 2010, the report estimated the Danish potential for energy crops to be 69 PJ. As indicated in the table, a large portion of Danish biomass residues are currently utilised, particularly wood. Meanwhile, up to this point, biogas and energy crops have only seen a slight portion of their potential utilised.

PJ	Danish Potential	2008 Actual Use	2008 Import
Straw	55	15.4	0
Wood and wood waste	51	62.7	21,5
Biomass for biogas	39	3.9	0*
Biodegradable waste	29	23.6	0
Energy crops	69	0.6	0
Total	**243**	**106.2**	**21.5**

Table 11: Danish biomass resource potentials and actual use figures from 2008 (Ministry of Climate and Energy 2010, DEA 2010, Kristensen & Jørgensen 2008). *It is worth noting that due to the significantly higher subsidy for biogas in Germany, over 200,000 tonnes of corn for use in biogas production were exported from Southern Jutland to Northern Germany in 2009, a number that is expected to grow to 400,000 tonnes in 2010 (Politiken, 2010). **Due to overlaps, i.e. energy crops potentially coming at the expense of straw for example, the total figure is likely overestimated.

Overall the resource is quite large, however there is uncertainty regarding whether the entire resource can be exploited in the short to medium term, particularly when economic barriers are taken into consideration. It should also be noted that the figures in the table cannot be seen independently from each other. The potential for energy crops is based on the displacement of agricultural land and may therefore reduce the amount of available straw. Thus, the number for the total Danish potential presented in the table should be viewed with caution, and is in all likelihood somewhat lower. With most of the growth in Danish biomass use over the coming years expected to occur through the use of wood fuels in central CHP plants, it is extremely likely that woody biomass imports will increase substantially in the coming years.

5.3 Regional/International resources

European biomass resources for energy purposes

An assessment of the European biomass resources is largely based on the European Environment Agency report entitled: "How much bioenergy can Europe produce without harming the environment?" The main findings from the report are highlighted in the below clip from its conclusions:

> **'The study concludes that significant amounts of biomass can be technically available to support ambitious renewable energy targets, even if strict environmental constraints are applied**.' The *environmentally-compatible* primary biomass potential increases from around 190 million tonnes of oil equivalent (Mtoe) (8.0 EJ) in 2010 to around 295

Mtoe (12.4 EJ) in 2030. This compares to a use of 69 Mtoe (2.9 EJ) in 2003 (of which the *environmentally-compatible part* is included in the 295 Mtoe). The potential is sufficient to reach the European renewable energy target in 2010, which requires an estimated 150 Mtoe (6.3 EJ) of biomass use. It also allows ambitious future renewable energy targets beyond 2010. The bioenergy potential in 2030 represents around 15-16% of the projected primary energy requirements of the EU-25 in 2030, and 17% of the current energy consumption, compared to a 4% share of bioenergy in 2003.' (EEA, 2006)

The figure below illustrates these conclusions.

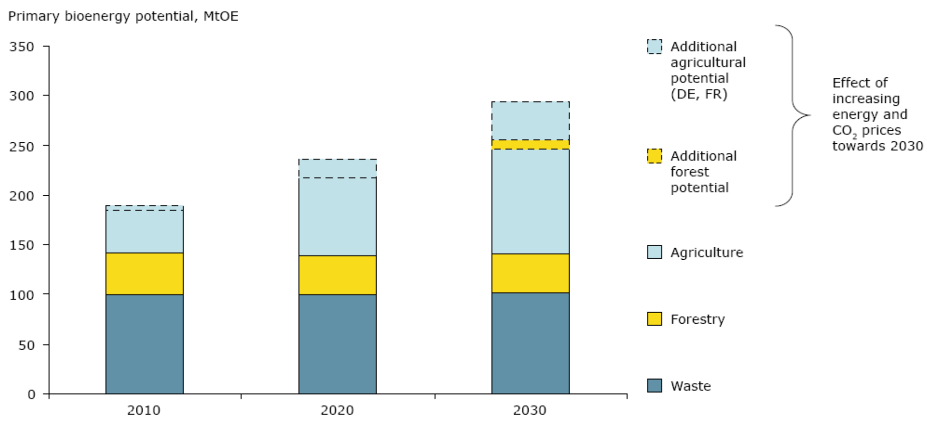


Figure 24: European biomass resources (EEA, 2006).   Note: The agricultural potential comprises dedicated bioenergy crops plus cuttings from grassland and was calculated for EU-25 without Cyprus, Luxembourg and Malta. Agricultural residues, such as straw and manures, are included in the category 'waste' (covering all EU-25 Member States). The forestry potential was calculated for EU-25 except Cyprus, Greece, Luxembourg and Malta. It consists of residues from fellings and complimentary fellings. The additional forestry potential takes into account the reductions in the black liquor potential as a result of wood directed from pulp and paper to energy production. It strongly depends on the assumed carbon permit and oil price. The additional agricultural potential due to higher prices paid for bioenergy was modelled only for Germany (DE), and France (FR).

The table below shows more detailed results from the study. Over the longer term the study concluded that greater than a third of the potential will come from energy crops, which at the moment are relatively limited. To reach this potential, a portion of agricultural land will have to be converted from food to energy production.

	2003		2010		2020		2030	
	Mtoe	EJ	Mtoe	EJ	Mtoe	EJ	Mtoe	EJ
Wood direct from forest	0	0	43	1.8	43	1.8	55	2.3
Waste and residues	67	2.8	100	4.2	100	4.2	102	4.3
Energy crops from agriculture	2	0.1	44	1.8	85	3.6	122	5.1
Total	**69**	**2.9**	**187**	**7.8**	**228**	**9.5**	**284**	**11.7**

Table 12: European biomass resources (EEA, 2006)

Global biomass resources

A number of Dutch institutions collaborated to release a 2008 report entitled 'Biomass Assessment – Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy'. In the study, Utrecht University, amongst other institutions, reviewed a number of global biomass resources studies. The overall assessment was that in the long term there is a potential for an annual biomass utilisation of 200-500 EJ, consisting of:

- Residues from agriculture, forestry, waste - 100 EJ /year
- Increased use from forests - 60 to 100 EJ/year
- Energy crops:
    - Agricultural land - 120 EJ/year
    - Marginal lands - 70 EJ/year
    - Improved cultivation technology - 140 EJ/year

The figure below shows the main findings from the study.

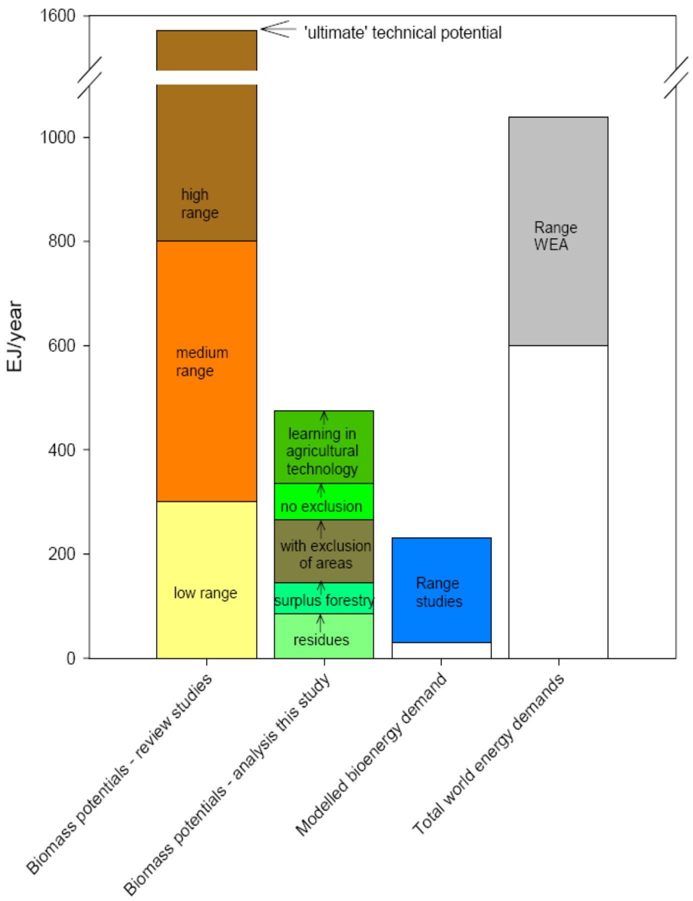


Figure 25: *Global biomass resources (NEAA, 2008)*

In the long term it would appear as though there are relatively large global bio-mass resources available, and as such, biomass can represent a significant share of global energy supply in the long run. However, there are large regional differences in biomass resource availability, and many sources are not located close to potential load centres. The aforementioned government security of supply study from 2010 included the following figure which highlights this point.

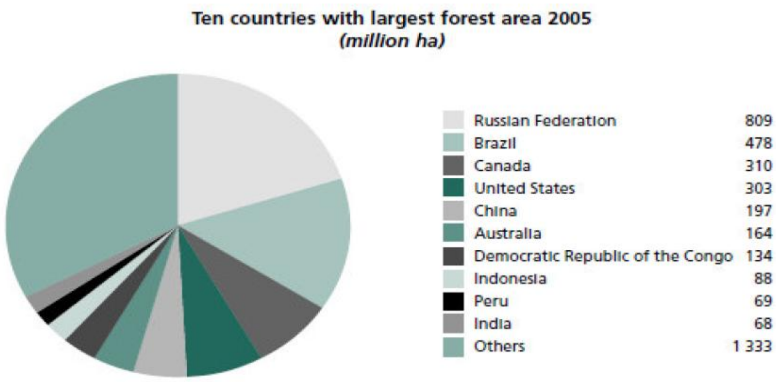


Figure 26: Global forest areas in 2005 (DEA, 2010).

Almost half of the global forest area is found in just 4 countries, namely Russia, Brazil, Canada, and the United States, all of which have abundant biomass resources and a very large portion of the global biomass resource.

5.4 Sustainability issues

The majority of solid biomass for energy purposes is directly or indirectly derived from residues from forestry or agriculture. However the expected increase in demand for biomass from the energy sector has been given rise to concerns about changes in cultivation methods, for example that too large quantities of wood from forest thinning will be removed from the forests. In extreme scenarios the total quantity of wood can decrease as a consequence of younger trees having greater economic value. Such a development could negatively affect both the biodiversity and overall amount of CO_2 sequestered in the forest.

The demand for sustainability in relation to biomass resources has arisen due to examples of situations where increased demand for farmland and tropical wood materials have led to gigantic losses of forest areas in tropical areas. Particularly residues from developing countries can be products from non-sustainable forestry. In several countries the increasing demand for biomass has therefore lead to pressure on retailers and power plants to ensure that the biomass that is utilized for energy production is sustainable. For that reason there has been a development of various certification systems.

In the EU RES directive there are sustainability criteria for liquid biofuels but not for solid biofuels. The EU Commission has been working on sustainability criteria and certification of solid biomass and in February of 2010 they published a report on the topic. The report recommends that criteria for solid biomass should not be binding but merely guiding. One of the reasons given is that the forestry and agriculture within the EU today is already considered to be sustainable, and significant effort in implementing criteria should therefore not be undertaken for the relatively small amount of solid biomass that is currently imported into the EU. The Commission's report has however taken criticism for this stance, as this overlooks the fact that the majority of expectations point to increased import of solid biomass from countries outside of the EU.

5.5 Chapter Summary

In recent years a variety of studies aimed at quantifying the available biomass resources have been carried out, and the results vary considerably. This is due to the different calculation methods and data, and the different types of resources, and resource inventories utilised. For instance, very high figures are seen in the theoretical resource inventories which are based on total global biomass growth potentials. Meanwhile other studies, which take into account the technical and economic limitations, as well as environmental and sustainable aspects, produce significantly lower figures. There does however appear to be significant potential to increase supply of biomass for energy, partly through increased use of residues from agriculture and forestry, and partly via the cultivation of energy crops. However, it should be kept in mind that particularly the larger resource potential estimates face increasingly important sustainability issues related to deforestation, loss of biodiversity and displacement of food production.

The table below summaries biomass resources based on the aforementioned studies. There is considerable uncertainty about the resource size, so the figures should only be seen as an indication of the possibilities for use of bioenergy in Europe and globally. The large future resource totals rely on the immergence of considerable amount of energy crops, and therefore this total potential is not deemed to be realisable until 2030.

Unit: PJ	Utilisation today	Long term resource potential
Global	50,000*	200,000 - 500,000*
EU	4,000*	12,400*
Denmark	82.6	165
3 Municipalities	6.8	6.2

Table 13: Biomass utilisation and resource figures. . EU, Danish, and Municipality 'Utilisation today' figures include imports. *Indicates that the figure includes waste

The reason why the local long term potential is lower than the utilisation today is that the 3 municipalities import large amounts of biomass from abroad (for example wood chips to Randers Kraftvarmeværk) and from other municipalities. As such, there may very well be unused resources within the municipalities in spite of the imbalance in the table above.

6 Trade in bioenergy

This chapter will summarise the results from the demand and resource chapters and conclude on the trade of bioenergy locally, nationally and internationally. Furthermore it will include a description of the international market for bioenergy.

6.1 Biomass in Europe today

The majority of biomass utilised for energy production in Europe today comes from forestry. Straw plays a very minor role in Europe, but a significant role in Denmark. As can be seen from the table below, straw only amounts to around 1% of the biomass used for energy production in Europe. In Denmark the use of wood is approx. 60 PJ and the use of straw is around 20 PJ. This is half of the total European supply of solid by-products from agriculture for use in energy consumption.

2007 Supply of biomass for energy in Europe	Mtoe	PJ
Agriculture:		
Energy crops for liquid (biofuels 1st generation)	8	334
Energy crops for biogas (maize, grass, etc.)	2	84
Energy crops for solid (willows…)	0.3	13
By-products, solid (straw, industrial residues...)	1	42
By-products, biogas (manure, industries…)	3	125
Forestry:		
Direct (logging residues)	20	836
Indirect (Industrial by-products)	52	2,174
Total	~ 86	~3,600

Table 14: Supply of biomass for Energy (excluding waste). From the homepage of AEBIOM, The European Biomass Association, http://www.aebiom.org/?cat=16

At present straw is mainly a local or regional fuel, rarely transported nationally between regions and very seldom traded internationally. Wood chips are both a local and a regional traded fuel, however at this point of time it is not traded on a large scale internationally. Wood pellets meanwhile are traded across all areas, and due to their energy density are increasingly traded internationally.

Import to / export from Europe is at present a relatively small part of the production/consumption of biomass for energy purposes (see figure below). This is however expected to change in the coming years.

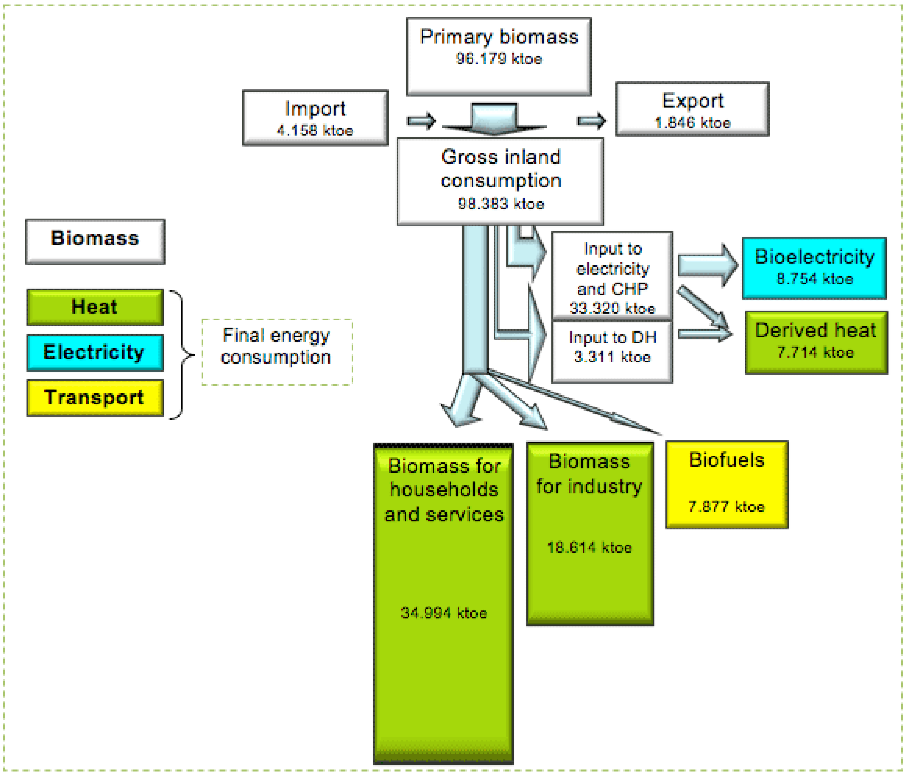


Figure 27: Bioenergy balance in 2007 for EU27. From the homepage of AEBIOM, The European Biomass Association (AEBIOM, 2010).

6.2 Local - Municipalities and Central Denmark Region

Trade in bioenergy on a local level consists mainly of straw and wood chips. Wood chips, however, are also considered be more of a national and international resource as well, and as such will be treated so in the following chapters.

6.2.1 Trading of straw

Straw is primarily a local or national resource. There is no specific limit on how far straw is transported from farm to plant. The price of straw is sensitive to the transport distance, which is why contracts are most often entered with farms close to the plant. The large energy producers, such as Dong Energy for example, have a computer optimization system that chooses the most optimal deliverers of straw depending on price and distance (Palm 2010). This is further explained in the following sections.

Market actors

The actors in the straw market are the farmers on the one side, organised via the Danish Straw Suppliers Association (Danske Halmleverandører), and the energy producers on the other side. Dong Energy and Vattenfall are the largest consumers of straw for energy purposes, purchasing roughly 950,000 tonnes per year. With average national straw for energy figures of ca. 1,400,000 tonnes, these two energy producers purchase roughly 68% of the total average (Holst, 2010b).

Export of straw from the municipalities

Based on the available material, it is not possible to create an import/export balance for the three municipalities in focus. However, a few estimates can be done on the basis of the available figures.

Based on the data from Conterra, the amount of straw that is collected in the municipalities for energy production can be ascertained. These figures include straw collected within the municipalities but used for energy purposes outside the municipalities.

We also have information about the actual use of straw at the specific district heating plants from the data collected by PlanEnergi in 2008/2009.

As such, by subtracting the actual use of straw in the three municipalities from the amount of straw collected for energy purposes, we get a picture of the net export of straw to other municipalities.

	Straw collected for energy purposes (Conterra, 2010)		Straw use in district heating plants in 2007 (PlanEnergi, 2008/2009)		Net export of straw from all three municipalities	
	Tns./year	TJ/year	Tns./year	TJ/year	Tns./year	TJ/year
Norddjurs	31,961	463.4	51,034	740.0	-19,073	-276.6
Syddjurs	41,399	600.3	21,379	310.0	20,020	290.2
Randers	22,329	323.8	10,345	150.0	11,984	173.8
Total	**95,689**	**1387.5**	**82,758**	**1200.0**	**12,931**	**187.4**

Table 15: Calculations of net export of straw from the three municipalities. Conterra 2010 and PlanEnergi, 2008/2009.

As can be seen from the table, there seems to be a net export of straw of roughly 12,931 tonnes/year or187.4 TJ/year. As the figures does not indicate whether there is any import of straw to the municipalities, nothing certain can be said about the import/export balance.

Trading of straw

Straw is traded between the local farmers and the energy producer. There exists no ‘straw exchange’, and the market conditions are characterised by local and regional differences. Smaller district heating companies typically buy their straw from local farmers within a radius of 30-50 km, while the larger energy producers such as Dong Energy or Vattenfall purchase their straw from a farther distance within a radius of approximately 75 km (Boldt, 2009 and Holst, 2010). The 2010 telephone interviews amongst the district heating plants in the municipalities of Randers, Norddjurs and Syddjurs showed that all plants that replied purchase their straw from local farms within their own municipality or the surrounding municipalities (Ea Energy Analyses, 2010).

There are two kinds of ways to trade straw: Local contracts and tenders.

Local contracts

Smaller amounts of straw are mostly traded in local contracts between the farmer and the energy producer. The local decentralised district heating companies enter into contracts with one or more of the local farmers regarding the delivery of a certain amount of straw to a certain price. These types of contracts typically run for 3-5 years. (Holst, 2010)

Tenders

The larger energy producers such as Dong Energy and Vattenfall purchase straw for the centralised power plants by tender (Holst, 2010). According to Dong Energy they have entered a 'code of conduct' with the Danish Straw Suppliers Association (Danske Halmleverandører) in which they commit themselves to purchase the main part of their straw by tendering procedure. Only 6% can be bought by local contracts. Other large straw consumers like Vattenfall have entered similar code of conduct agreements. There are no specific rules for when the Straw Suppliers Association takes the initiative for these agreements, but as Dong Energy and Vattenfall account for roughly 68% of the total amount of straw traded for energy purposes they are the most dominant actors on the market and thereby obvious candidates for such agreements. (Holst, 2010b)

In practice the energy producer puts out a tender containing information about which plants demand a certain type of straw for the following period. The tender does not reveal the amounts of straw needed. Afterwards the farmers submit their bids on how much straw they can deliver to the specific plant at what price. With respect to the transport costs, the farmer can chose to let the energy producer pick up the straw at the farm, or to deliver the straw himself. The farmer can also choose to receive a smaller amount of money per tonne of straw and avoid the obligation of receiving the return ash. The size of the ash price reduction can vary, but in a Dong Energy tender for East Denmark for the fall of 2010, the avoided ash price reduction is 27 DKK/tonne of straw or roughly 5% of the average straw price. When all the farmers have submitted their bids, the energy producer can chose among the most favourable bids. (Dong Energy, 2010)

Straw prices

Straw prices tend to vary from area to area depending on local conditions such as yield and local demand. In the 2010 telephone interviews amongst the district heating plants in the municipalities of Randers, Norddjurs and Syddjurs (Annex 1), all plants were asked how much they pay for their straw. 9 straw fired plants answered, of which the lowest reported price was 30.3 DKK/GJ and the highest was 41.1 DKK/GJ. In the table below the prices from the enquiry are compared to the estimated average price from the Danish Energy Agency and with the actual average price on a national level paid by the district heating companies in the third quarter of 2009. The future straw prices are forecasted by the Danish Energy Agency. The table below shows the expected future straw prices as they were forecasted in April of 2010.

Price of straw	2010 DKK/GJ
Current prices	
Telephone interviews, 2010 (Annex 1)	30.3 – 41.4
Danish Energy Agency, 2010	37.8
Danish District Heating Association, 2009	33.4
Prognosis	
Danish Energy Agency 2015	42.2
Danish Energy Agency 2020	43.0
Danish Energy Agency 2025	44.1

Table 16: Current and future forecasted straw prices, converted to 2010 DKK via DEA inflation factors Danish Energy Agency (2010), Ea Energy Analyses (2010), Boldt (2009).

In terms of the forecasted prices, many factors can influence the actual development of the straw price. Regional and local variations in straw prices can occur due to local surpluses or shortfalls in the straw yield from year to year.

The demand side is one obvious controlling factor in relation to the straw price, which is why the Danish agricultural sector expects the straw price to fall in the short run due to the rather large surplus of uncollected straw at the moment. This expectation is bolstered by the recent Dong Energy release, stating that they expect to buy 25% less straw from 2012, and import wood pellets from Canada and the Baltic States instead. With Dong Energy and Vattenfall's substantial market shares, in the absence of other increased demand, a 25% reduction by Dong is likely to affect the market price. In the long term, it is expected that the future increases in biomass demand, particularly with respect to woody biomass, while make straw a more attractive alternative, and thereby lead to increases in both straw demand and price.

6.3 National and International

6.3.1 Market for wood chips

The wood chips market in Denmark is mainly local/regional, and wood chips are today only imported to a minor (but growing) extent. Wood chips are however increasingly being traded internationally – mostly on a European level, for example between Denmark and the Baltic States.

Resources

The majority of wood chips in Denmark come from the Danish forests, a substantial part comes from the open landscape, and a small but growing portion comes from import (see table below).

	1.000 ton	TJ
From thinning in forest	520	4,940
Roundwood from forest	200	1,900
Tree tops / branches from deforestation	40	380
From the open landscape (including cities)	400	3,800
Residues from wood-based industries	40	380
Energy willow	10	95
Biomass from gardens and parks	0	0
Total Danish production in 2009	**1,200**	**11,400**
Import*	240	2,280

Table 17: 2009 wood chip production in Denmark (HedeDanmark 2009) *It should be noted that this import figure is lower than that given by the DEA, which for 2008 was over 3,300 TJ.

HedeDanmark has investigated the potential for increased wood chips production in Denmark and have estimated that the production can be almost quadrupled. However, compared to other stakeholders' expectations this estimate is quite optimistic.

As can be seen from the table above, Denmark is currently importing 10-20%[8] of the wood chips consumed. The imported wood chips are primarily for use in bigger plants located close to the sea.

Consumers

The wood chips consumers are mainly heat and power producing plants. As can be seen from the table below, almost the entire consumption goes to energy production.

	1,000 ton	TJ
Decentralised heating plants and CHP plants	770	7,315
Central power plants	350	3,325
Industrial plants	210	1,995
Farms, retail, horticulture	70	665
Total Danish consumption	**1,400**	**13,300**

Table 18: 2009 wood chip consumption in Denmark (HedeDanmark 2009).

Stakeholders

The most important players in the market are:

- Consumers
  - Decentralised heating plants and CHP plants
  - Central power plants
  - Industrial plants
  - Farms, retail, horticulture
- Producers
  - Local forest owners
  - Danish Forest and Nature Agency
- Suppliers and wholesalers
  - HedeDanmark

[8] Depending on whether HedeDanmark or DEA figures for wood chip import are utilised.

- Danish Forestry Extension (Skovdyrkerforeningen)
- Energy Companies

Trade

The majority of wood chips are used in smaller heating and CHP plants. For these smaller plants with a limited consumption, it is cheapest to buy the wood chips locally. Wood chips are purchased either directly through bilateral contracts with local producers or via wholesalers, for instance HedeDanmark, or energy trading companies.

Some of the larger plants with sea access today import wood chips, but the total import is still less than 20% of the total national consumption. Some energy companies have tried to import wood chips for distribution to smaller consumers in Denmark, but until now it has not been profitable to import (by ship) if further distribution by truck to smaller consumers is required. The largest single purchaser/importer is Verdo who utilise the wood chips in Randers Kraftvarmeværk. Verdo currently imports roughly 80,000 tonnes of wood chips and/or unchipped logs on a yearly basis (Verdo 2010). Verdo intends to increase this figure as the Randers CHP plant is planning on utilising an increasingly larger share of biomass and thereby less coal. In addition, Verdo also anticipates that the biomass share will rely more on wood chips, and less on more costly wood pellets.

Today's import is mainly from the Baltic States due to lower production costs and higher quality (the wood chips are produced from bigger trees, resulting in chips with less bark, less ash, lower moisture content and chips are therefore more homogeneous) compared to Danish wood chips. The production costs are lower, but the transportation costs are higher. Therefore import is only profitable for bigger plants placed next to the sea where wood chips can be delivered directly to the plant by ship. The import is also constrained by the number of harbours with sufficient depth. Contracts for imported wood chips are typically for 1 year or 1 season.

Prices

The price of wood chips consists of manufacturing costs, transportation costs and costs of storage. For chips imported from the Baltics, the cost of transportation is generally around 25% of the final product cost, but can vary between 20-35% due to fluctuations in shipping rates (Verdo 2010). This is consistent with a 2003 conducted for the Danish Energy Agency that estimated wood chip shipping prices from the Baltics to Denmark to be roughly 60 DKK/tonne (6.3 DKK/GJ) and unloading costs to be an additional 25 DKK/tonne (2.6 DKK/GJ), giving a total of 85 DKK/tonne (8.9 DKK/GJ) (Boldt, 2009). Given inflation this corresponds very well with roughly 25% of the final wood chip cost. Lastly, the wood chips can either be stored at the producer or at the plant which also influences the price.

The price of wood chips is partly influenced by the oil price, since diesel is used both in cutting, chipping and transportation. However, the diesel cost only amounts to a 3-5% share of the total production which means that the wood chips price is influenced very little by oil prices. Other factors that will affect the price of wood chips are competing sources of demand, foreign exchange rates, and to a lesser extent local labour costs. According to Boldt (2009), the price of wood chips are most closely related to the price for cellulose for use in paper production, as relatively similar low value tree portions are used for both. As a result, if cellulose for paper production increases in price, the price of wood chips is also likely to increase.

Price of Wood Chips	2010 DKK/GJ
Current prices	
Telephone interviews, 2010 (Annex 1)	41,5-47,4 (most pay 47)
Danish Energy Agency (2010)	44.6
Danish District Heating Association (2009)	~42
Prognosis	
Danish Energy Agency 2015	48.3
Danish Energy Agency 2020	50.3
Danish Energy Agency 2025	52.5

Table 19: Current and future forecasted wood chip prices, converted to 2010 DKK via DEA inflation factors DEA (2010), Ea Energy Analyses (2010), Boldt (2009).

6.3.2 Market for wood pellets

Compared to other solid biomasses, wood pellets are a relatively new fuel, in many respects are easier to handle and transport, and have a higher energy density than straw and wood chips. As such, on a regional and international level, biomass trade for use in heat and power generation is largely dominated by wood pellets.

Europe

According to pellets@las (www.pelletsatlas.info), a project funded by the Intelligent Energy EU programme, and aimed at developing and promoting transparency in the European fuel pellet market, Europe produced approximately 8.2 million tonnes of pellets in 2008. These were produced at the roughly 640 wood pellet production facilities in Europe, about half of which have a capacity of less than 30,000 tonnes/year. In 2008 the total utilisation rate for all facilities was roughly 54%. (Sikkema et al, 2009) Meanwhile, total 2008 European wood pellet usage was approximately 9.0 million tonnes (roughly 158 PJ), representing nearly 4% of Europe's 2008 biomass consumption. As such Europe had a net import of roughly one million tonnes of wood pellets.

Consumption type varies from country to country, as some countries use pellets primarily for residential heating (Austria & Germany), others mainly in electricity production (Netherlands), while others such as Sweden and Denmark use if for a variety of purposes (Sikkema et al, 2009). The figure below gives an indication of how wood pellets are utilised and traded in Europe today.

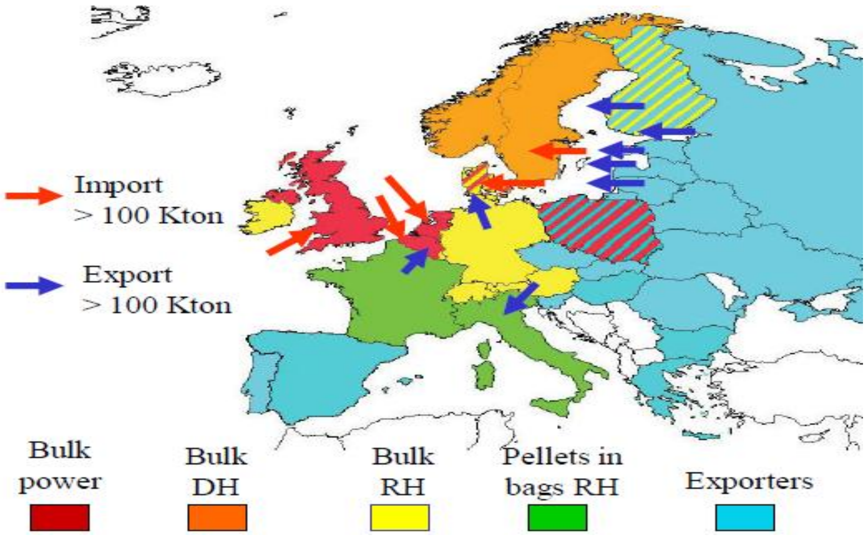


Figure 28: European trade and usage of wood pellets (Sikkema et al, 2009). Bulk power refers to bulk pellets utilised in large scale power plants, Bulk DH for bulk pellets used in district heating, Bulk RH is bulk pellets utilised in small-scale residential heating, and Pellets in bags RH refers to small-scale residential customers whom receive bagged pellets for use in wood pellet stoves.

Based on 2008 figures, the largest pellet consumers are Sweden, Denmark, Holland, Belgium, Germany and Italy, with Holland, Belgium and Denmark being the largest net importers. Meanwhile, large exporters include Russia, Germany and the Baltic States.

Looking more closely at the European states, the figure below displays the country by country production, consumption, import, and export for 32 countries.

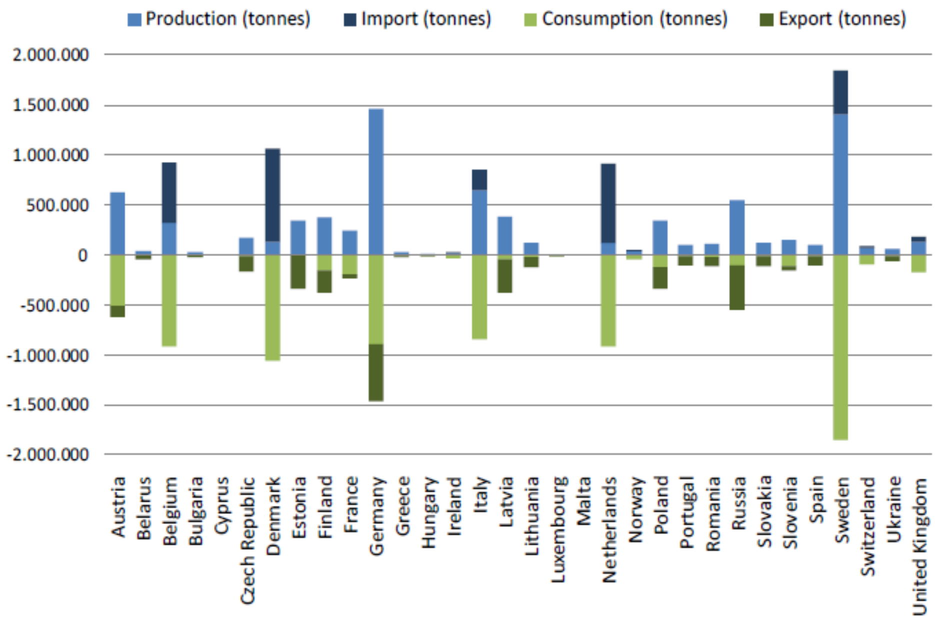


Figure 29: European production, consumption, and import/export of wood pellets (Sikkema et al, 2009)

North Sea Regional Trade

As can be seen from the preceding figure, of the North Sea countries (Germany, Denmark, Sweden, Norway, and the UK), in 2008 only Germany was a net exporter of pellets. This however does not mean that the various countries do not trade with each other.

Germany

In 2008 it was estimated that Germany exported over 560,000 tonnes of industrial pellets, primarily to Scandinavia, Holland, and Belgium, mainly via ship, as large-scale producers generally have access to port facilities located on rivers or by the sea (Hiegl and Janssen, 2009).

Denmark

Focusing in on Denmark, the figure below reveals how the consumption of pellets in Denmark has evolved from 2001 to 2008. Private household use has seen a relatively steady growth, while CHP use really began to take root in 2003 and 2004 when the Avedøre 2 power plant came online and started utilising large amounts of wood pellets. This trend has continued beyond 2008 as other large CHP plants have followed suit (Randersværket and Amagerværket for example), while still others have/are contemplated/ing such a shift (for example Studstrup in Jutland).

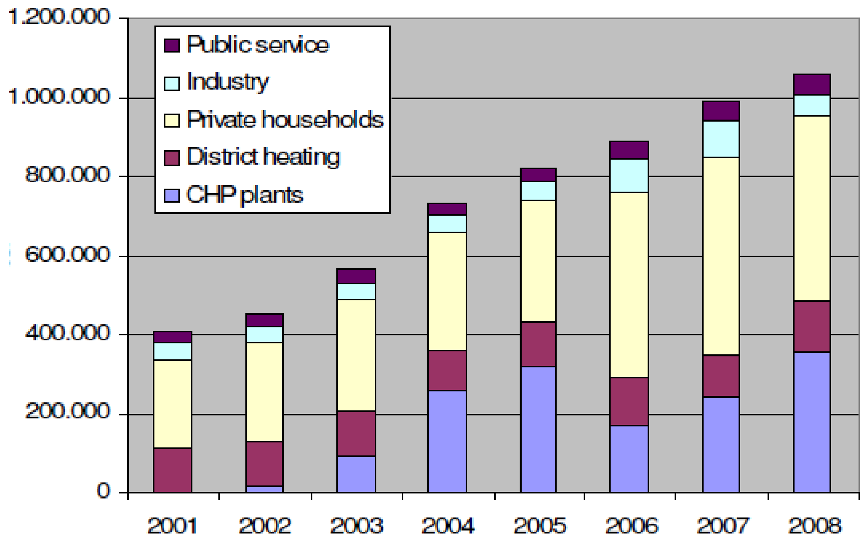


Figure 30: Danish wood pellet consumption (tones) by sector from 2001 – 2008 (Hansen, 2009)

While Danish consumption has increased dramatically, Danish production of pellets has meanwhile fallen, as Danish manufactures face difficulties in acquiring raw material. A prime example is the 180,000 t/y facility in Køge that lies dormant because the nearby wooden floor manufacturer no longer supplies the necessary wood shavings. As a result, the amount of wood pellets that must be imported has grown significantly since 2001, as is displayed in the table on the following page. In addition to the large absolute increase in import (from roughly 200,000 tonnes in 2001 to over 925,000 tonnes in 2008), it is also interesting to note that in 2001 roughly half of the Danish supply was met by imports, whereas in 2008 it was up to 87%, a figure that is even higher today.

	2001		2004		2006		2008	
	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Danish Production	173,073	43%	187,458	26%	137,080	15%	134,280	13%
Import	200,871	50%	470,588	64%	841,132	94%	925,401	87%
Export	0	0%	-795	0%	-17,948	-2%	41,149	4%
Stock increase	27,347	7%	73,883	10%	-64,468	-7%	40,987	-4%
Total	**401,291**		**731,134**		**895,796**		**1,059,843**	

Table 20: Danish Wood Pellet Supply (Hansen, 2009)

With an import of over 900,000 pellets in 2008, roughly half of this came from the Baltic States. Other sources of import include Germany, Sweden, Russia, and North America. (Hansen, 2009)

Sweden

With a 2008 consumption of over 1.85 million tonnes, Sweden is the world's leading consumer of wood pellets (Hansen, 2009b). Despite being one of the world's largest producers, due to its large consumption it is also a significant importer of wood pellets. An overview of the Swedish import, export and total delivery of wood pellets from 1997 till 2008 is displayed in the figure below.

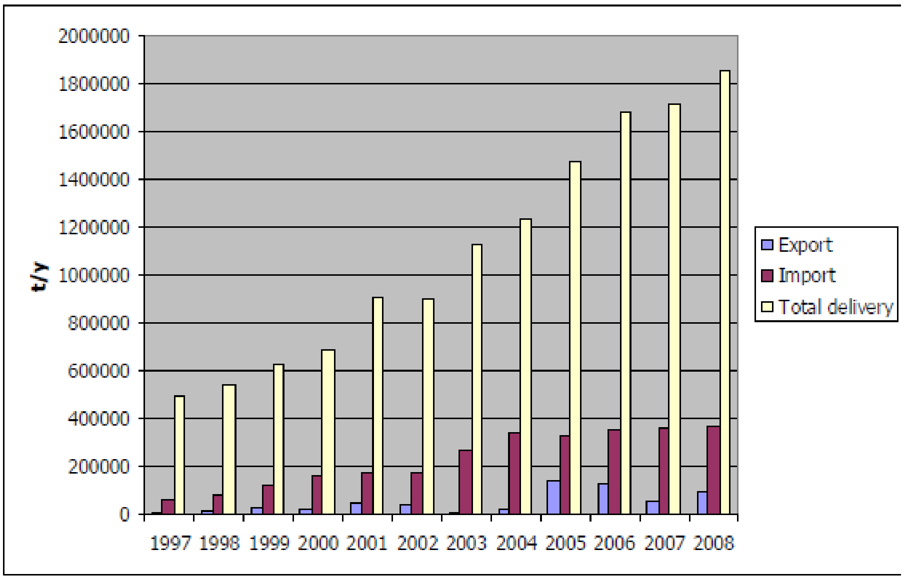


Figure 31: Volume of wood pellets exported, imported, and delivered to the Swedish market. (Hansen, 2009b).

In recent years Sweden imported roughly 300,000 - 400,000 tonnes of pellets from Canada, Poland, Finland and the Baltic countries, while at the same time exporting up to 150,000 to Denmark and the UK. Within Europe these imports and exports were usually carried out by ships capable of carrying 4,000 to 6,000 tonnes, while shipments from North America typically are in the range of 20,000 to 30,000 tonnes (Hansen, 2009b).

Norway

Norway is at present a very minor player in the wood pellet market, however with large tree resources, and the completion of a 450,000 t/y factory in June of 2010, Norway has the potential to become a substantial exporter of wood pellets in the very near future. According to its website (www.biowood.no), the massive pellet factory which is located by the water plans on utilising imported raw materials for the first few years, while moving over to local sources in the long term.

United Kingdom

Like Norway, the UK has been a relatively minor player on the wood pellet market. However, in recent years it has seen a number of new production facilities come online and its production capacity grew from just 25,000 in 2005 to 218,000 in 2008, and it has continued to grow substantially since. Total consumption in 2008 was estimated to be 176,000 tonnes, with 125,000 being produced locally, thus leaving a net import of 51,000 tonnes. Of the pellets exported from the UK in 2008, the majority were shipped to Ireland and Italy. Meanwhile the UK imported pellets from Latvia, France, and while more difficult to confirm, it appears as though pellets were also imported from Germany, Sweden, Finland, Russia, Demark and various Baltic Sates. (Hayes, 2009)

North Sea Regional Trade Summary

While not overwhelming, there is a flow of wood pellet trade between countries in the North Sea Region. In particular, Germany and Sweden export to Denmark, and Sweden exports to the UK. In the future it also appears likely that Norway will begin to export to its neighbouring countries as well.

Outside Europe

As was highlighted above, in 2008 there was a net import of roughly one million tonnes of wood pellets, the majority of which came from North America. In 2008 the United States consumed 80% of their 1.8 million tonnes of produced pellets. Canada meanwhile exported nearly 90% of its 1.4 million tonnes, primarily to Europe. The United States utilised roughly 66% of its pellet production capacity in 2008, while Canada used about 81%. In the last 7 years North American production has grown significantly, a trend that has accelerated since 2009 as a number of large new plants intended for export purposes have been built in the United States. (Sikkema et al, 2009). Looking forward, Japan and other Asian countries are also likely to become large importers of North American pellets, a trend that is already being seen with Japan purchasing pellets from Western Canada.

Aspects of the International Wood Pellet Market

Market Players

Generally speaking, there are three types of consumers:

- Large Scale
  - Large heat and power plants, which generally purchase the majority of their pellets via bilateral long term contracts with wood pellet producers.[9]

[9] The exception here is Russian produced pellets, which often go through a wholesaler.

- Medium/Small Scale
    - District heating, industrial boilers, and large residential institutions.
- Residential
    - Often purchase their pellets via a retailer who in many instances has purchased the pellets through a wholesaler. This is the case in Scandinavia where the largest such wholesaler is Neova. In other countries however, the producer also sells directly to the retailer (for example Italy where 50% of pellet produces sell directly to the retailer).

As is the case with large and medium scale consumers, producers generally prefer long-term contracts, particularly plants that are newly established as these contracts likely facilitated the acquisition of financing. As such, the majority of contracts are very long term in nature, and the price is often a reflection of the size and duration of the contract.

- Some of the larger producers to Scandinavia include:
    - Vapo
    - Flex Heat

- Some of the larger European consumers include:
    - Dong Energy
    - E.ON UK
    - Electrabel
    - Electrabel Nederland
    - EoN Benelux BV
    - Essent
    - FORTUM
    - NUON
    - Øresundkraft
    - Vattenfal
    - Verdo

- Meanwhile, some of the larger European wholesalers and retailers include:
    - Flex Heat
    - Neova
    - Nidera

Market Characteristics

While the amount of wood pellets being traded has increased significantly over recent years, the wood pellet market as a whole is still in its infancy. Pellet markets in Central and Northern Europe have matured somewhat, while markets in Eastern Europe are just starting to develop. As a result of it being a relatively new market, there is currently no existing spot trading platform for wood pellets, but there are different price quotations. Major price indices include the Dutch Endex, the Finnish FOEX, and English Argus. The Endex price index will be described in greater detail below.

Endex

Endex is a part of APX-ENDEX, a Dutch Energy exchange for wholesale market participants (www.apxendex.com). It includes producers, distribution companies, financial institutions, industrial end-users, hedge funds, asset managers and brokers. Since November of 2008 Endex has published reference prices for:

- 3 front Month Wood Pellet contracts
- 3 front Quarter Wood Pellet contracts
- 1 front Calendar Year Wood Pellet contracts

According to its website, the goals of establishing this price index are to:

- Enhance price transparency in the bio-energy market
- Standardise market price information
- Further develop the bio-energy market by introducing bio-energy price indices
- Extend the bio-energy product range in the near future.

In arriving at the wood pellet price, Endex has a pricing panel for Industrial Wood Pellets, fixed each Thursday. Prices are compiled by an expert panel (roughly 10 actors), and these panel members represent producers, consumers and traders. The weekly figures are calculated as the sum of all the prices, divided by the number of panel members (with the highest and lowest figures not being included). The figure below displays the index price for one year forward contracts for 2009.

Figure 32: One year forward contract price as per the Endex index (apxendex.com)

To insure uniformity in the pellets being priced, the industrial pellets for which the price index is compiled should have the following characteristics:

- Cost Insurance Freight (CIF) Rotterdam

- Industrial Wood pellets (bulk), Rotterdam
- Diameter: 4<D<10 mm
- Length: < 50 mm
- Raw density > 1.12 kg/dm³
- Moisture: < 10 wt%
- Ash: < 1.5 wt%
- Net Caloric Value: basis 17,0 MJ/kg as received (cp)
- Sulphur: < 0.08 wt%
- Nitrogen: < 0.30 wt%
- Chlorine < 0.03 wt%
- Additives: < 2 wt%
- Fines: <3 wt%

Liquidity of Market

Relative to other commodities there are very few financial transactions that take place involving wood pellets, and as such the market liquidity or 'trading churn rate' for wood pellets is very low. A trading churn rate is simply the amount of times an underlying good is involved in a financial transaction for each time it physically changes hands (ie. Traded volume / Physical volume), and for wood pellets it is close to 1. This is due to the fact that because there has yet to be established a physical market place or clearing house for wood pellets it has only been possible to act through trading companies or by direct contact between supplier and customer. Oil on the other hand has a trading churn rate of 150, which implies that for every time a barrel of oil is physically traded, it has been involved in 150 financial transactions. Other examples (and their churn rates) provided by the international trading company Nidera include Sea Grains (3), FOB NL Wheat (10), CIF NOLA Corn (15), CBOT Corn (20), CBOT Soya (50). Nidera suggests that the liquidity threshold for a commodities market is between at least 10 and 15, and thus the churn rate of just 1 for wood pellets suggest that the market is still quite far from reaching this threshold.

However, there may be a physical clearing house on its way within a relatively short timeframe. At a biomass conference entitled "Biomass Trade and Power" in Rotterdam in March of 2010 the stock exchange APX-Endex and Rotterdam Harbour announced that they were close to concluding an agreement regarding the establishment of a spot trading platform for pellets, similar to that currently found for oil and coal. Amongst other things, this will require the establishment of storage facilities.

Market Prices

Currently the vast majority of wood pellets are produced from wood residues, and input materials typically account for 30-45% of the total wood pellet cost, while production and storage count for 30-50%, and transport and unloading the remainder (Boldt, 2009). These wood residues usually come from wood waste in the form of sawdust, shavings, or sander dust from sawmilling operations, furniture manufacturing, etc.[10] If the demand within these industries is low, then there will be very little wood residue produced, and therefore wood pellet raw material prices will increase. This has been seen on a few occasions over the past few years, for example in Germany and the Baltics in 2008 when the building industry was hard hit and many sawmills sat silent (Bøldt, 2009). It was also seen in North America during the recent American housing crisis which resulted in a reduction in Canadian lumber exports, and thereby a reduction in wood residues from the Canadian saw mills (Bradley, 2010). In the case of Randers kraftvarmeværk the majority of the wood pellets come from the Baltics and Russia where wood pellets are generally produced from wood residues (Verdo, 2010b). These raw materials are then either purchased by a wood pellet manufacturer, or utilised by firms that also have a pellet production facility on site.

Price of Wood Pellets	2010 DKK/GJ
Current prices	
Telephone interviews, 2010 (Annex 1)[11]	80.9
Danish Energy Agency (2010)	67.7
Danish District heating Association (2009)	67 - 69
CIF Rotterdam from Endex (2009)	57 - 61
Prognosis	
Danish Energy Agency 2015	71.3
Danish Energy Agency 2020	74.2
Danish Energy Agency 2025	77.0

Table 21: Current and future forecasted wood pellet prices, converted to 2010 DKK via DEA inflation factors DEA (2010), Ea Energy Analyses (2010), Boldt (2009).

[10] As wood pellet prices have increased, the pulverising of whole trunks for use in wood pellets has also begun to take place. Some dedicated plantations for energy crops (including the production of wood pellets) have also begun to emerge, as is seen with Willmott forests in Australia.

[11] Price paid by 2 small heating units in the 3 municipalities (Annex 1)

7 Case analysis

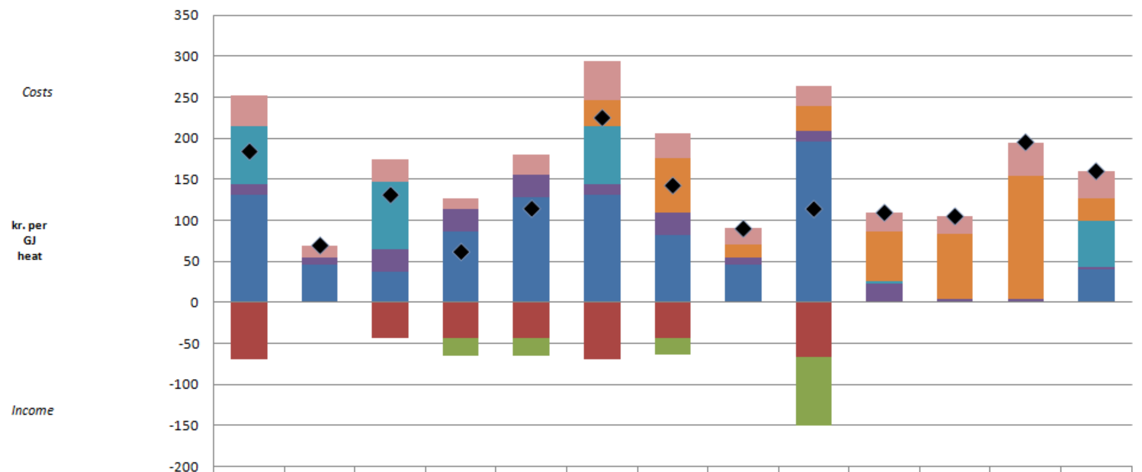
This chapter presents three concrete fuel shift examples and reveals the affects of underlying biomass price assumptions on concrete bioenergy projects.

7.1 Relevant Technological Options

The three selected business case examples involve a fuel shift and as such a brief summary of potential relevant technological options is first presented.

The below analysis is based on general technology data from the technology catalogue of the Danish Energy Agency from 2005 and the project Heat Plan for Greater Copenhagen. Assumptions on fuel price, CO_2 price and power price are based on the assumptions of the Danish Energy Agency. Prices for 2015 are used. It is assumed that power production can be sold at the average Nord Pool price in 2015. For biogas a production cost of 100 DKK/GJ for delivery at the CHP plant has been assumed, which includes capital and operation and maintenance costs. In addition, the same costs as a new natural gas CHP has been presumed. Lastly, the current electricity subsidy of 0.745 DKK for biogas has been assumed.

The figure below summarises the economic analysis of costs for the heating companies including taxes.



kr./GJ	Existing natural gas CHP	Existing wood chips boiler	Existing coal CHP (Randers)	Existing wood chips CHP (Randers)	Existing wood pellets CHP (Randers)	New natural gas CHP	New wood chips CHP	New wood chips boiler	New biogas CHP	New geo-thermal plant	New solar heating	New solar heating with seasonal storage	Heat pumps (electricity)
Costs distribution loss	39	15	28	13	24	47	30	19	24	23	22	41	34
Capital costs	0	0	0	0	0	32	67	16	31	61	79	150	27
CO2-og energy taxes, CO2 quota	70	0	83	0	0	70	0	0	0	3	0	0	57
Operation and maintenance	12	9	27	27	27	12	27	9	13	23	4	4	2
Electricity subsidies	0	0	0	-21	-21	0	-21	0	-84	0	0	0	0
Electricity sales	-69	0	-44	-44	-44	-69	-43	0	-66	0	0	0	0
Fuel	132	46	38	87	128	132	83	46	196	0	0	0	40
♦ Total heat cost	184	70	131	62	114	225	143	90	114	110	105	195	160

*Figure 33: The figure summarises the economic analysis of costs for the heating companies including taxes. The figure shows heat production costs in DKK/GJ at the consumer. The total heat production cost (sum of income and costs) is marked with a **black dot**.*

Costs for heat losses in the district heating network are included (21% of the heat produced) but investment costs for the district heating network are not included. Establishment of the district heating network is thus regarded as sunk costs. The figure shows heat production costs in DKK/GJ at the consumer. Capital costs are distributed over the lifetime of the technical installations and an interest rate of 6% has been used.

From the figure it can be seen that existing biomass CHP and biomass boilers as well as new biomass boilers have low heat production costs compared to other technologies. The main reason for this is that biomass has no taxes and CO_2 costs. Furthermore, wood chips are relatively cheap as a fuel. The town of Randers and most of the district heating areas in Djursland use biomass technologies and therefore have low heat production costs compared to other district heating areas. Due to CO_2 quotas and energy taxes, coal has higher costs, which is one reason why Randers Kraftvarmeværk has shifted from coal to biomass. Natural gas fired plants have high costs compared to biomass and coal and therefore there can be potential savings in shifting to other technologies. However, the plants are politically obliged to use CHP technology and not heat-only boilers if they want to change to biomass. From the figure it can also be seen that biomass CHP has fairly high heat production costs because of the high investment and O&M costs. Other renewable energy technologies, biogas, geothermal and solar heating could also be interesting. However, there is still a high uncertainty about the geothermal potential and investment costs, while solar heating can only be used as a supplement if it is not combined with a seasonal storage at a higher cost.

7.2 Biogas for CHP

Local slurry and energy crop potential

Today the use of slurry and energy crops in the 3 municipalities is minimal, however the primary energy potential from slurry and energy crops for production of biogas is considerable. As displayed in the table below, the primary total energy potential from slurry and energy crops (maize) is 995, 813, and 1,114 TJ/year respectively in Norddjurs, Syddjurs and Randers. The feasibility and sustainability of these potentials is however open to discussion (see Ea Energy Analyses, 2010).

Municipality	Biogas potential from slurry (TJ)	Biogas potential from maize (TJ)	Total biogas potential (TJ)	Natural gas for CHP (TJ)
Norddjurs	286	709	995	0
Syddjurs	252	561	813	0
Randers	300	844	1.144	334*
Total	**838**	**2144**	**2953**	**377**

*Table 22: Total primary energy potential from biogas production based on slurry and maize and the use of natural gas for CHP in the municipalities of Norddjurs, Syddjurs and Randers (Ea Energy Analyses, 2010). *The natural gas consumption at Randers Renseanlæg has not been included as it does not produce any heat according to available data.*

Compared to the total primary energy use of 20.8 PJ in the 3 municipalities, biogas has the potential to play a significant role in the energy supply.

Displacement of existing district heating plants with biogas

The most straightforward way to use slurry and energy crops for biogas production is in a combined heat and power plant. In the municipality of Randers there is a potential for substituting natural gas with biogas in the existing CHP plants, whereas biogas CHP will substitute straw or wood chip fired boilers in Norddjurs and Syddjurs.

According to the Danish Energy Agency and the Danish transmission system operator Energinet.dk (2010), biogas has the highest socio-economic value and furthermore contributes to security of supply, when it displaces existing natural gas fired CHP. Furthermore biogas can potentially replace natural gas fired CHP with only minor additional costs in comparison to erecting an entire new biogas CHP plant.

In addition to using biogas for local CHP, it can also be upgraded (by removing CO_2) and transported in the natural gas grid i.e. to a distant CHP plant, or for use in transportation thereby replacing liquid fuels. Currently there are however substantial costs associated with upgrading biogas.

In the municipalities of Norddjurs and Syddjurs there are not any natural gas fired CHP plants. A potential new biogas CHP would then have to displace an existing biomass plant.

Locally in Norddjurs and Syddjurs 10 out of the 20 biomass based plants plan to keep firing with either wood chips or straw. The main reason for this is the relatively low biomass fuel prices in the two municipalities (Ea Energy Analyses, 2010). From a climate mitigation point of view this would also be the most desirable option.

A special case is the Grenå CHP plant which today uses coal and straw for heat and electricity production. Establishment of a biogas plant there has the potential for reducing CO_2 emissions.

The Grenå case is quite complex as a significant part of the heat produced has been delivered to the local industry as steam. Some of the industry has closed down and establishment of a new CHP plant will therefore have to be seen as a part of an overall heat plan for the town, including estimation of the future heat demand as well as production from the local waste CHP plant.

Displacement of natural gas fired CHP in Randers

The situation in Norddjurs and Syddjurs is quite different from the one in Randers, where there are 6 natural gas fired power plants and only 2 biomass fired plants. As shown in the table above, the use of natural gas for CHP in Randers is 334 TJ, while the biogas potential is estimated to 1,144 TJ. Thus, the biogas could potentially displace the total consumption of natural gas in the municipality.

Time frame

The natural gas fired plants were all built in the early 1990's (Ea Energy Analyses, 2010). Given a technical lifetime of 20-25 years, they will presumably have to be replaced within the next 10 years. If the natural gas fired plants are to be displaced with new biogas CHP, it is recommended that the initial planning should start within a couple of years due to the fact that biogas projects require several approvals by the authorities in compliance with the Planning Act, the Environment Protection Act, the Nature Protection Act, etc.

Effect on fuel consumption and GHG emissions

If the 6 natural gas fired CHP plants were each to be replaced with a new biogas CHP it would result in an increased biogas consumption of 331 TJ and a decreased natural gas consumption of approximately 334 TJ. The fuel consumption will decrease due to the fact that a new biogas CHP produces more heat with less fuel input, but with a lesser electricity production. The overall efficiency would remain the same.

Displacing the consumption of natural gas at the 6 plants would result in a reduced CO_2 emission of approximately 19,000 tons.[12]

Replacing biogas fired district heating plants with biogas CHP has no effect on the local CO_2 emissions. However, the production of electricity replaces the marginal electricity production in the electricity system and will reduce the CO_2 footprint of the electricity system. In this case, however, biogas should be compared to CHP based on straw or wood chips.

Economy

When switching from natural gas CHP to biogas the economy looks very good assuming that existing plants are already paid off. For a new biogas fired CHP plant the heat cost might be reduced with 35-45% compared to today's costs based on an existing natural gas fired CHP and reduced with 50-60% compared to erecting a new natural gas fired CHP plant. The total heat production cost (sum of income and costs) from a new biogas CHP is approximately 100-120 DKK/GJ_{heat}. In comparison the total heat production cost from a new natural gas CHP is 200-250 DKK/GJ_{heat} and ca. 180 DKK/GJ from an existing natural gas fired CHP.

Supposing biogas will displace existing straw or wood fired heat only boilers, it might result in a 40-70% higher heat production cost, based on total heat production costs of 70 DKK/GJ_{heat} for an existing straw or wood chip fired boiler.

Based on the assumed costs it is therefore economic to displace the existing natural gas CHP in Randers with new biogas CHP if the existing plants are paid off. Furthermore, establishment of new biogas CHP is cheaper than erecting new natural gas fired CHP. On the other hand, it does not seem economic

[12] Given a CO_2 content of 56.77 kg/GJ natural gas (Danish Energy Agency, 2009). Not including GHG emissions (methane) from biogas plants and reduced emissions (methane and laughing gas) from slurry management etc.

to displace the existing straw and wood chips fired boilers with new biogas CHP in Norddjurs and Syddjurs. Put another way, in the short term there is a market potential for new biogas CHP in Randers, while the potential in Norddjurs and Syddjurs seems limited. In the longer term however, it could become attractive to displace the straw and wood chip fired boilers with new biogas CHP, particularly if the fuel prices for straw and wood chips rise.

Assuming a 30% to 50% higher biogas production cost for delivery at the CHP plant for instance due to e.g. higher capital costs for a smaller plant (economy of scale) and/or a substantial jump in operation and maintenance costs, the total heat production cost of a new biogas CHP would increase to approximately 180-230 DKK/ GJ_{heat}. This would bring the production cost into a range similar to that from natural gas, and therefore make it less attractive to displace straw and wood chip fired boilers with biogas.

Potential barriers and enablers

Even though the heat production costs of a new biogas CHP seems economical compared with both new and existing natural gas fired CHP, biogas plants face a number of significant challenges, which could explain its limited penetration (Ea Energy Analyses, 2010). For example, there are issues with the lack of industrial waste, sufficient organic material to “boost” the gas output, limited energy crop production today to supplement or replace the industrial waste, limited flexibility due to modest biogas storage possibilities, a biological limit to how fast the biogas production can be regulated, and high transportation costs. Additionally, in terms of the planning and establishment of biogas plants, the authorisation process is often complex and time-consuming, and due to the financial crisis it can be difficult to acquire financing. Another important economic aspect is the uncertainty of the electricity subsidy over the long term.

Potential enablers for some of these issues are for instance long-term stability in the incentive framework, loans guaranteed by the municipalities, perhaps with partial re-guarantees from the State, and standard contracts for sale of heat produced via biogas.

7.3 International biomass for CHP

Randers kraftvarmeværk

The second concrete fuel shift to be analysed is that of increased international biomass usage at Randers kraftvarmeværk. First put into operation in 1982, the Randers kraftvarmeværk is located on the River Guden in Randers, Denmark’s 6th largest city with a population of roughly 60,000. Since its inception Randers kraftvarmeværk has produced the majority of the central heating in the area, as the local heating stations have only been called on to produce additional heat in short periods during the winters. A heat accumulator was added to the plant in 1991, which for example allows heat produced during the night to be utilised during the morning (Verdo, 2010a).

Technical aspects

The plant is equipped with two Ålborg boilers with a common steam turbine system. The steam data are 110 Bar and 520°C. The plant can supply 50 MW of electricity and up to 116 MJ/s of heat. The total efficiency of the plant is approximately 85%. Under full load conditions the plant is capable of burning 1200 tons of wood chips and roughly 500 tons of alternative biomass per day, or 600 tons of coal. The wood chips are transported to the grate via a shaft, and the alternative biomass is typically blown in (depending on the type of biomass). There are many options for adjusting the air intake and this is one of the reasons that the plant can fire so many different fuels, and up to 100% biomass.

Fuel usage

The plant has traditionally relied on coal as its main fuel input, with nearly 100% coming from coal as recently as 2002. However, recent modifications have increased the flexibility of the plant, allowing it to utilise a growing proportion of biomass. This is reflected in the plant's 2008 annual green audit, which reveals that the percentage of fuel input met by coal has decreased from 83.0% in 2004, to 59.6% in 2008. Biomass inputs have increased from 16.5% to 40.0% during the same years, and were over 66,000 tons in 2008 (Energi Randers Produktion, 2009). Today the plant is capable of utilising 85-90% biomass, and the transformation to a power plant capable of firing 100% biomass is expected to be completed by 2011 (Miljømagasinet, 2009).

The current biomass utilisation is comprised of roughly 60% wood chips, and 40% from wood pellets and alternative biomass, including: olive stones, shea nuts, sunflower hulls and wood residues. These alternative biomass forms typically come from Denmark, the Baltic States, and Southern Europe (Verdo, 2010b).

In the future it is anticipated that wood chips will count for 60-80% of the biomass usage, with wood pellets and alternative biomass sources accounting for the remaining 20-40%. Verdo anticipates that the wood pellet portion will become less significant as it is not foreseen to be economically competitive with wood chips and/or the alternative biomass sources (Verdo, 2010b).

Reasons for fuel shift and fuel selection

The Randers kraftvarmeværk is an interesting case to look at because it exemplifies the role of Danish heat and electricity taxes, exemptions, and subsidies in determining fuel choice decisions. If we take the above technical aspects of the Randers kraftvarmeværk into consideration, and apply the relevant Danish heat and electricity taxes, exemptions, and subsidies to the Danish Energy Agency's forecasted future prices for fuel and CO_2 quotas, it is possible to see the forecasted fuel costs facing operators of the Randers kraftvarmeværk. These costs, in 2008 DKK/GJ are presented in the figure below.[13]

[13] Calculations in the figure are based on an electrical efficiency of 27% and a heat efficiency of 59%. Coal and natural gas taxes are 72.1 and 66.1 DKK/GJ respectively. Utilising the V formula and a 59% heat efficiency, this corresponds to a fuel tax of 34.0 and 31.2 DKK/GJ respectively for coal and natural gas. CO_2 quota prices are based on DEA forecasts, and CO_2

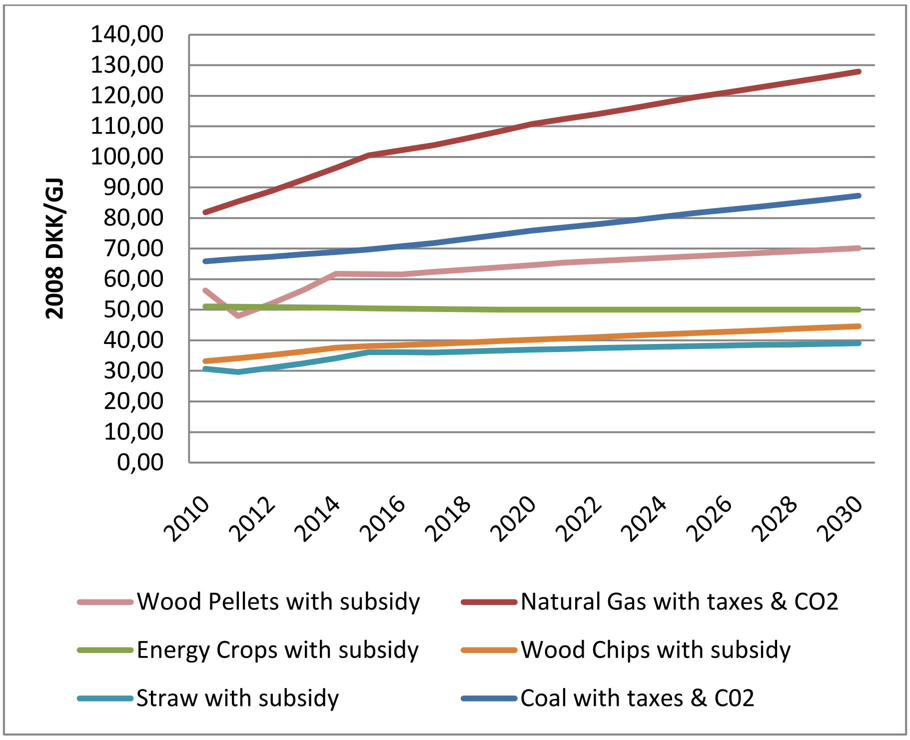


Figure 34: Danish Energy Agency (DEA) forecasted fuel prices for combined heat and power production, at the plant gate, exclusive VAT at Randers kraftvarmeværk, including subsidies and energy taxes in 2008 DKK/GJ. (DEA, 2010)

In looking at the figure it quickly becomes apparent why a shift from away from fossil fuels is attractive for the Randers CHP plant, as all forms of biomass are cheaper than coal now, and are anticipated to continue to be so in the future. A combination of a decrease in biomass subsidies, CO_2 prices, and the price of fossil fuels would have to take place before it would be more cost-effective for Randers kraftvarmeværk to utilise fossil fuels as opposed to biomass. Or seen from the biomass side, the price of biomass would have to increase substantially before heating companies would turn to fossil based fuels. Given that the Danish government is committed to reducing CO_2 emissions, if the biomass and fossil fuels did begin to converge, it is quite likely that new taxes would be implemented to make fossil fuel utilisation in the heating sector less attractive.

The figure also demonstrates why it is advantageous for the plant to increasingly utilise more wood chips, and less wood pellets. Although wood chips do have some disadvantages relative to wood pellets in large CHP plants (such as increased ash and slag), for Randers kraftvarmeværk these are lessened by the type of technologies in place, and therefore wood chips are a more cost-effective fuel choice under current market and regulatory conditions. It is also

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contents of 95 and 57 kg/GJ for coal and natural gas. With an electrical efficiency of 27%, electricity subsidies for biomass of 41.7 DKK/GJ correspond to a subsidy of 11.4 DKK/GJ. Sulphur and NO_x taxes are not included. For further details on underlying figures please see Ea Energy Analyses (2010).

worth noting that due to its location by the water, the Randers kraftvarmeværk is able to purchase wood chips at a lower cost than DEA figure utilised in the figure.

Versatility

In addition to benefiting from its access to sea delivers, the Randers kraftvarmeværk also benefits from boilers that are quite versatile with respect to the input materials. In addition to being able to burn wood pellets and wood chips, the ability to utilise numerous forms of alternative biomass, such as olive stones, shea nuts, sunflower hulls, etc., allows Verdo to scour the international market for suitable biomass at competitive prices. This also acts a potential buffer against unexpected price shocks, as the plant can relatively easily shift over to another input fuel.

Alternative price scenario

This report has highlighted the potential growth in demand for woody biomass (particularly in the EU) that is likely to take place in upcoming years. If this demand results in a higher price for wood chips than otherwise anticipated by the DEA, then energy crops might become a more cost effective option for CHP plants such as Randers kraftvarmeværk. According to Verdo, the Randers plant would happily utilise local energy crops if they became price competitive with imported wood chip prices (Verdo, 2010b). All other things being equal, if wood chip prices are roughly 20% higher than DEA forecasts in 2020, and/or 10% higher by 2030, then locally produced energy crops could be a viable option for CHP plants such as Randers.

7.4 Local biomass

Local biomass yield and today's use

To increase the consumption of local biomass in the region, straw is the most obvious choice. There is a surplus of local straw, which is not the case for local wood chips in the 3 municipalities. In addition, before it has been tested in a small scale pilot project, it is not currently recommended to start growing energy crops on a larger scale.

Today the total straw production in the 3 municipalities amounts to a total of 340,000 tonnes/year, or 4,960 TJ/year. Of this 1,380 TJ is used for energy production, some is used for agricultural purposes, and some will never be collectable (Ea Energy Analyses, 2010). It is assessed that another 2,000 TJ/year could be available for additional energy production.

Approximately half of the straw used in energy production in the three municipalities today is used for CHP production at Grenaa CHP plant. The rest is used in 7 smaller district heating plants and in small scale straw boilers.

Means to increase biomass usage

To increase the usage of local biomass, 2 different approaches can be considered: To focus on erecting several small biomass CHP and to start planning for the replacement of Grenaa power plant, when the technical lifetime has come to an end (most likely 10 or so years from now).

Whether the focus is on building a new CHP plant replacing Grenaa or building new small CHP, technologies enabling 100% biomass firing can be chosen.

7.4.1 Erecting small district heating plants

New bio CHP replacing natural gas CHP

Today there are 6 natural gas fired CHP plants in the municipality of Randers. All 6 existing natural gas fired plants are from the early nineties, and therefore are likely soon ready for replacement. They could be replaced with biomass fired CHP units.

Effect on fuel consumption

If the 6 natural gas fired CHP plants were replaced with wood chips fired CHP units it would result in an increased wood chips consumption of 150-200 TJ/y and a decreased natural gas consumption of 250-300 TJ/y. The fuel consumption will decrease due to lower electrical efficiency and thereby lower power production from wood chips fired CHP units compared to natural gas fired CHP units. That is to say the efficiency of a new wood chip fired CHP plant has a higher overall efficiency, and produces more heat with less fuel input, but at the same time produces less electricity.

Economy

When switching from natural gas to biomass the economy looks fine, even if the existing natural gas fired plant is already paid off. For a new wood chips fired CHP the heat cost might be reduced with 20-25% compared to today's costs based on the existing natural gas fired CHP and reduced with 35% compared to erecting a new natural gas fired CHP. The total heat production cost (sum of income and costs) from a new wood chips CHP is around 150 DKK/GJ_{heat}.[14] In comparison the total heat production cost from a new natural gas CHP is 200-250 DKK/GJ_{heat}. Still other technologies such as biogas CHP or solar heating will result in an even lower heat production cost (Ea Energy Analyses, 2010).

New straw DH plants in new DH area

To establish new straw fired district heating units in new district heating areas is more costly, since both the new district heating grid and the new heat unit has to be depreciated. To be profitable the district heating area should not be too small. Today there are CHP / district heating in many of the towns in the 3 municipalities, but there might still be towns where district heating with a straw fired heating unit could be interesting. It could be considered to investigate if there are areas where new district heating grids and new straw fired heating units could be established.

[14] Given the rather small nature of these CHP plants, these general cost figures may prove to be too low, and therefore more detailed investigations on a plant to plant basis would be required.

7.4.2 Replacement of Grenaa power plant

Grenaa CHP plant today

Today Grenaa CHP plant utilises around 50% straw and 50% coal. To increase the biomass share beyond 60% is problematic when the biomass is straw and the boiler is a CFB (circulating fluid bed) boiler. Straw has corrosive characteristics, causing problems in the boiler, but the co-combustion with coal reduces/balances these negative effects. To increase the share of straw in the boiler as it is might not be possible without compromising the remaining lifetime of the power plant.

The power plant is from 1991, and can therefore be assumed to have a remaining lifetime of about 10 years. Switching to 100% straw in this power plant will probably require substantial investments (if at all technical possible), which cannot be expected to be paid back within the remaining lifetime.

Replacement of Grenaa CHP plant

When the technical lifetime of Grenaa power plant comes to an end, a new medium-to-big straw fired power plant could replace it. The present power plant is oversized compared to the present (reduced) demand for process steam in the nearby industry. A new plant will therefore probably have to be smaller than the Grenaa power plant.

Size of a new plant

The average district heat production (net) was 484 TJ/year from 2004-2008, and quite stable. The process steam production on the other hand changed quite a bit around 2006. In 2004-2005 the average process steam production was 1,626 TJ/year, which was reduced to an average of 323 TJ/year in 2007-2008 (DONG, 2009).

Danish Biofuel Holding plan to build a bio ethanol plant in Grenaa. This plant will use 1,000 TJ of process steam a year (Niras, 2009). At first this will be delivered from Grenaa CHP plant, and in the future probably from the replacement of Grenaa CHP plant.

A new plant should therefore be dimensioned to produce around 1,300-1,350 TJ steam/year and 550 TJ district heating/year, unless the prerequisites chang in the meantime. This means a CHP with a capacity of 100-200 $MW_{thermal}$ and a yearly fuel consumption of 2,000-3,000 TJ depending on the distribution of the heat/steam demand load over the year and number of hours with full load heat/steam production. This would result in an increased straw consumption of 1,300-2,300 TJ, which is in accordance with the 2,000 TJ of straw available for additional energy production.

Technology

If a new plant should be based 100% on bio fuel, a grate fired (GF) boiler is at present the most obvious choice. Today grate fired boilers up to the size of 150 $MW_{thermal}$ can be erected. 10 years from now it will likely also possible to build such units larger.

In a GF boiler there are better possibilities for changing fuel if there is a lack of straw resources and for instance wood chips are available. These years many new biomass CHP technologies are developing and are being tested, and it might be that another technology is more advantageous in 5-10 years when the new plant is to be planned.

Economy

At present the investment costs for a GF boiler in that size range can be estimated to around 600-1,200 MDKK (DEA and Energinet.dk, 2010). There are not many references, which makes the estimate uncertain.

Relative to other fuels, the price of straw is expected to have a lower rate of increase in upcoming years (DEA, 2010b).

Time frame

If a new straw fired CHP should be ready for commissioning when the technical lifetime for Grenaa will comes to an end, assuming around 2021, then planning should start 3-4 years in advance to decide the size, technology and authority matters.

8 Opportunities and barriers facing biomass markets

This chapter will summarise the possible opportunities and barriers for developing markets for biomass resources found in the present report.

Trade of biomass is like all other goods highly dependent on supply and demand. Political climate and energy goals constitute the major demand side drivers. With high European targets for the share of renewable resources in the energy production the demand for biomass is expected to increase dramatically towards 2020. However, the distribution of biomass fired production plants is not keeping pace with this target, which indicates that there are different barriers to be overcome before the utilisation of the various resources is optimal. Particularly local resources such as biogas and energy crops, and to a certain extent straw, face challenges related to economy and technology.

To meet this increasing demand, particularly for woody biomass, there will be pressure on the global forest resources to produce the needed biomass. On one hand these new market possibilities are expected to create new jobs in the forest and agriculture industries. On the other hand concerns about sustainability, land use, and competition with food production become increasingly important issues. As the pressure on woody biomass increases, it is expected to eventually spread out to other forms of biomass.

8.1 Opportunities and barriers locally and nationally

Biogas, straw and to certain extend wood chips from forestry and energy crops are traded on a local or national level.

Biogas

As was described in the biogas case in chapter 7, at first glance the heat production costs for new biogas fired CHP plants seem to be economical compared to natural gas fired CHP. However, biogas has never really experienced a major breakthrough in Denmark, despite the fact that such a large unused resource potential has been identified.

Barriers

Lack of industrial waste and sufficient organic material is one problem. This problem could be met by the production of energy crops to replace the industrial waste. However, the production of energy crops in Denmark is currently very limited and there are currently no immediate prospects of a major introduction of energy crops. Furthermore, the possibilities to store biogas are limited, there is a biological limit to how fast the biogas production can be regulated, and the transport costs are high.

Other types of barriers with respect to developing local markets for biogas production are that the planning and authorisation processes are time-consuming and often also complex. Biogas plants are often unpopular amongst neighbours and previously it has been difficult to achieve the needed political support from the municipality to select locations for new biogas plants. Finally, investments in biogas plants have been impeded by uncertainties related to long term subsidies.

Enablers

To overcome the aforementioned barriers related to biogas and to take advantage of opportunities of producing heat at a competitive price, a number of economical enablers could be considered. Some barriers are already partly addressed by the new political goals and incentives such as the Danish National Governments “Grøn Vækst” plan that sets out new targets for erecting new biogas plants and improving the economic incentives. This is expected to result in a higher willingness in the municipalities to point out locations for biogas plants and to encourage investments.

Furthermore, investment loans guaranteed by the municipalities could provide lower risk for the investors and thus lead to the erection of more biogas plants, and thereby increase the demand for manure.

Straw

Straw is traded on a local and national level and to a minor extent also between countries. The use of straw for heat and CHP production is mainly a Danish phenomenon, but trade with the surrounding countries can occur. Straw is a cheap resource compared with wood chips and wood pellets and there seems to be substantial unused resources available.

Barriers

In spite of its low prices and local availability, recent trends and expectations show a decrease in the demand of straw for CHP production, at least in the short term. The decreasing demand is caused by competition with wood resources, as wood chips and wood pellets are easier to handle and causes less technical problems than straw. However, there seems to be a large potential for replacing coal with straw at Grenaa Kraftvarmeværk.

Enablers

In the long term, as the global pressure on wood resources increase, the demand for straw is likely to increase again. In Grenaa in particular, it could be relevant to gather the relevant local actors for a discussion of the possibilities to utilise a much larger amount of straw to replace the current coal fired CHP production. Alternative uses of straw, for example in 2nd generation bioethanol production could also ensure an increasing demand curve for straw.[15]

Energy crops

Wood chips from energy crops only exist to a minor extent in Denmark today.

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[15] It should be noted that as of yet, the technology for 2nd generation bioethanol has not yet proved to be commercially viable, however a lot of R & D and investments are being made in this field. With increasing pressure on biomass resources it could also be questioned whether bioethanol production provides the best utilisation of a future scarce resource, as the level of energy utilisation of straw is higher in a CHP plant.

Barriers

Investments in energy crop plantations such as willow or poplar have thus far been hampered by high costs for planting and harvesting equipment. Willow chips, for example, have therefore had trouble competing with both the price and quality of forest wood chips. In addition it should be noted that there are certain sustainability issues associated with the establishment of energy crop plantations, particularly related to land use priorities. Replacing existing grain fields in Denmark may lead to displacement of land for food production or natural reserves other places in the world.

Enablers

As a consequence of the increasing biomass demand, the market for energy crops for CHP production is expected to expand. Technology development is also expected to improve in time so that the expenses for planting and harvesting machinery will decrease and the prices of the product thus become more competitive. A potential enabler is the support of energy crop pilot programs, so solutions to many of the above issues can be identified and developed.

8.2 Opportunities and barriers internationally

International trade with biomass is primarily related to wood pellets, and to a lesser (but growing) extent, wood chips.

Wood pellets and wood chips

Barriers

A potential barrier for further expansion of the international market for biomass could be the lack of standardisation related to the quality of biomass resources.

For producers, import from other countries can make it difficult to control the quality of the product that will be delivered. Biomass definitions vary from country to country, as do standards related to quality.

For wood pellets examples of quality standards are seen through the newly started price quotations, for example the Dutch price quotation system Endex. Through a pricing panel consisting of producers, consumers and traders reference prices for wood pellets are published. To ensure uniformity in the pellets being priced the pellets for which the price index is complied shall fulfil a predefined set of characteristics, including for example diameter, length, density, ash and chemical contents. This system, however, does not include all wood pellet producers and there is no such system for other internationally traded biomasses such as wood chips.

Another barrier can be public apprehension towards import of biomass as opposed to using local/national resources. This can be due to a desire to utilise local resources, as well as due to concerns regarding the sustainability of imported biomass. Biomass from outside the EU can be difficult to control, especially if the wood is imported from developing countries.

Enablers

Development of EU wide biomass standards related to both biomass quality and certification of sustainability are essential to promoting the growth in biomass trade.   Such standards and criteria will go a long way to addressing the above concerns raised by both energy producers and consumers.

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The Municipality of Norddjurs (1/3)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality bor-ders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expecta-tions regarding replacement**	**Plans for future fuel types**
Grenå Kraft-varmeværk	Coal, oil, straw, additional bio fuels	1,222,643 GJ/year (64,760 tonnes/year in total (in 2008)). Coal 642,325 GJ/year (25,693 ton-nes/year). Oil 20,966 GJ/year (491 tonnes/year). Straw 553,494 GJ/year (38,172 tonnes/year). Additional bio fuels: 5,858 GJ/year (404 tonnes/year).	Unknown	Unknown	Unknown	Unknown	Unknown	The plant was built in 1991.	Unknown
Grenå For-brænding-sanlæg	Waste	231,000 GJ/year (22,000 tonnes/year)	Reno Djurs I/S	50 %	Reno Djurs I/S is charged 16.2 DKK/GJ (170 DKK/tonne waste deliv-ered)	The town of Grenå (30 % of the district heating in the town)	Inside the supply area it is possible to connect a few new consumers to the grid.	The incineration plant was built in 1981. In 2000 the service life of the plant was length-ened. A replacement or a renewal has to take place in 2015.	The waste delivery agreement with Reno Djurs I/S runs until 2015. It has been discussed whether or not the waste will be delivered to the incin-eration plant in the future. If not, a new fuel type must be chosen, e.g. wood chips or straw.
Voldby Fjern-varmeværk	Wood chips	11,810 GJ/year (1,181 tonnes/year (in 2009))	HedeDanmark A/S (from the area of Eastern Jutland)	Unknown	47 DKK/GJ	The town of Voldby (approx 120 consumers)	Inside the town it is possible to connect a few new con-sumers to the grid. Outside the town there are no im-mediate expansion possibili-ties.	The plant was built in 2002. It will probably be re-placed around 2022.	Uncertain

The Municipality of Norddjurs (2/3)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality borders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expectations regarding replacement**	**Plans for future fuel types**
Gjerrild Fjernvarmeværk	Wood chips	21,330 GJ/year (2,133 tonnes/year (in 2009))	HedeDanmark A/S (from the area of Eastern Jutland)	Unknown	47 DKK/GJ	The town of Gjerrild (approx 160 consumers)	Inside the town it is possible to connect a few new consumers to the grid. Outside the town there are no immediate expansion possibilities.	The plant was built around 1997. It will probably be replaced around 2017.	Uncertain
Trustrup-Lyngby Varmeværk a.m.b.a.	Wood chips	45,000 GJ/year (4,500 tonnes/year)	Local suppliers (from the area of Djursland)	Unknown	43 DKK/GJ	The towns of Trustrup and Lyngby (475 consumers in total – corresponding to around 85-88 % of the households in the area)	There are no immediate expansion possibilities outside the supply area, since the nearby towns are too small to make it profitable. Inside the supply area they are constantly working on getting more consumers connected to the grid.	The plant was built in 1997. The boiler will probably be replaced around 2015-17.	Still wood chips
Ørum Fjernvarmeværk	Wood chips	24,960 GJ/year (2,496 tonnes/year (in 2009))	HedeDanmark A/S (from the area of Eastern Jutland)	Unknown	47 DKK/GJ	The town of Ørum (approx 190 consumers)	Inside the town it is possible to connect a few new consumers to the grid. Outside the town there are no immediate expansion possibilities.	The plant was built in 1994. A replacement of the boiler is planned for 2013-14.	Still wood chips
Stenvad Fjernvarmeværk	Wood chips	11,150 GJ/year (1,115 tonnes/year (in 2009))	HedeDanmark A/S (from the area of Eastern Jutland)	Unknown	47 DKK/GJ	The town of Stenvad (approx 100 consumers)	Inside the town it is possible to connect a few new consumers to the grid. Outside the town there are no immediate expansion possibilities.	The plant was built around 1997. It will probably be replaced around 2017.	Uncertain
Ørsted Fjernvarmeværk	Straw (oil as backup)	72,500 GJ/year (5,000 tonnes/year)	Mainly local suppliers (from the municipality of Norddjurs)	Around 6 %	34.5 DKK/GJ (500 DKK /tonne)	The town of Ørsted (650 consumers)	There are no immediate expansion possibilities as there are no nearby towns.	The plant was built in 1988. The boiler was replaced in 2007.	Uncertain

The Municipality of Norddjurs (3/3)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality borders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expectations regarding replacement**	**Plans for future fuel types**
Allingåbro Varmeværk a.m.b.a.	Wood chips	60,000 – 70,000 GJ/year (6,000-7,000 tonnes/year)	Local suppliers (from inside and outside the municipality borders)	Unknown	41.5 DKK/GJ	The town of Allingåbro (625 consumers)	Inside the town it is possible to connect a few new consumers to the grid. Outside the town there are no immediate expansion possibilities.	The plant was originally built in 1962, but was last replaced in 2002. It will not be replaced in a while.	Probably still wood chips
Vivild Fjernvarmeværk	Wood chips	60,000 GJ/year (6,000 tonnes/year)	Local suppliers	Unknown	45 DKK/GJ	The towns of Vivild and Nørager (510 consumers in total)	Inside the towns it is possible to connect more consumers to the grid.	The plant was originally built in 1962. The entire plant was replaced in 2009, while the reserve plant was replaced in 2007.	Uncertain
Glesborg Fjernvarmeværk	Wood chips	21,480 GJ/year (2,148 tonnes/year)	HedeDanmark A/S (from the area of Eastern Jutland)	Unknown	47 DKK/GJ	The town of Glesborg (approx 160 consumers)	Inside the town it is possible to connect a few new consumers to the grid. Outside the town there are no immediate expansion possibilities.	The plant was built in 1994. A replacement of the boiler is planned for 2014.	Still wood chips
Auning Varmeværk	Straw	116,000 GJ/year (8,000 tonnes/year)	Local suppliers (mainly from Djursland)	50 %	35,9 DKK/GJ (520 DDK/tonne)	The town of Auning (1,000 consumers)	Inside the town it is possible to connect a few new consumers to the grid. Outside the town there are no immediate expansion possibilities.	The plant was built in 1992. In 2000 an extra boiler was installed. A replacement will have to take place before 2015-16.	Still straw

The Municipality of Syddjurs (1/3)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality borders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expectations regarding replacement**	**Plans for future fuel types**
Ebeltoft Fjernvarmeværk a.m.b.a.	Wood chips	180,000 – 120,000 GJ/year (18,000-20,000 tonnes/year)	HedeDanmark A/S (mainly from the area of Djursland)	Unknown	47.4 DKK/GJ (Approx 9 million DKK/year)	The town of Ebeltoft (approx 2,000 consumers)	There are always expansion possibilities, but no immediate plans.	The plant was built in 1963. Parts of the plant are being replaced in 2014.	Still wood chips
Balle-Hoed-Glatved Fjernvarmeværk	Wood chips, landfill gas from a nearby landfill	Wood chips: 9,250 GJ/year (925 tonnes/year (in 2009)). Landfill gas: 11,999 GJ/year (521,702 m^3/year (in 2009))	HedeDanmark A/S and Glatved Losseplads (from the area of Eastern Jutland)	Unknown	Wood chips: 47 DKK/GJ. The landfill gas is free (only investment costs regarding the pump)	The towns of Balle, Hoed and Glatved (150 consumers in total)	Inside the towns it is possible to connect a few new consumers to the grid. Outside the towns there are no immediate expansion possibilities.	The plant was built in 1998. It is uncertain when it will be replaced.	Uncertain
Nimtofte Fjernvarmeværk (Brdr. Thorsen Varmeværk I/S)	Straw	50,750 GJ/year (3,500 tonnes/year) increasing to 72,500 GJ/year (5,000 tonnes/year)	Nimtofte Maskinstation (owned by Brdr. Thorsen)	0 %	31-34.5 DKK/GJ (450-500 DKK/tonne)	The towns of Nimtofte and Ramten, and Lybker Golf Resort (approximately 400 consumers increasing to approximately 700 consumers in total)	Currently, they are expanding the grid (increasing the number of consumers from approximately 400 to approximately 700 in total)	The plant was built in 2007. It is uncertain when it will be replaced.	Uncertain
Rønde Fjernvarmeværk	Straw	92,800 GJ/year (6,400 tonnes/year (in 2009))	Local suppliers	Maybe 10 %	Varies from month to month, e.g. 40 DKK/GJ (580 DKK/tonne)	The towns of Rønde and Ugelbølle (1,200 consumers in total)	An expansion including Ubbebølle has just been accomplished (increasing the number of consumers from 869 to 1,200 and rising to approximately 1,400 in total).	The plant was built in 1987. It is uncertain when it is being replaced.	Still straw

The Municipality of Syddjurs (2/3)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality borders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expectations regarding replacement**	**Plans for future fuel types**
Thorsager Fjernvarmeværk a.m.b.a.	Straw	36,250 GJ/year (2,500 tonnes/year)	Local suppliers	Around 10-20 %	37.9 DKK/GJ (550 DKK/tonne)	The town of Thorsager (386 consumers)	Outside the supply area there are no immediate expansion possibilities. Inside the supply area, all oil consumers have been connected to the grid. They are continuously working to connect consumers within the supply area.	The plant was built in 1989. The boiler was replaced in 2007.	Uncertain
Ryomgaard Fjernvarmeværk a.m.b.a.	Straw	72,500 GJ/year (5,000 tonnes/year)	Local suppliers (from the municipalities of Syddjurs and Norddjurs)	Around 50 % from the municipality of Norddjurs	37.9 DKK/GJ (550 DKK/tonne)	The town of Ryomgaard (approx 600 consumers)	They are working on including 250 potential consumers in the town.	The plant was built in 1989. It is expected to be replaced in 2013.	Still straw
Mesballe Varmeværk	Wood pellets	4,794 GJ/year (282 tonnes/year (in 2009))	Greenii A/S	Almost all of it	80.9 DKK/GJ (1,375 DKK/tonne)	The town of Mesballe (approx 35 consumers)	Inside the towns it is possible to connect a few new consumers to the grid. Outside the towns there are no immediate expansion possibilities.	The plant was built in 1998. It is uncertain when it is being replaced.	Uncertain
Pindstrup Varmeværk a.m.b.a.	Surplus heat from Novopan and oil	Surplus heat: 32,400 GJ/year (9,000 MWh/year). Oil: Approx 330,000 liters/year.	Surplus heat: Novopan. Oil: Q8.		Surplus heat: 43.1 DKK/GJ (155 DKK/MWh). Oil: 5-7 DKK/liter.	The town of Pindstrup	Inside the towns it is possible to connect a few new consumers to the grid. Outside the towns there are no immediate expansion possibilities.	The plant was built as an oil-fired plant in 1965. In the 1970s they began to buy surplus heat from Novopan. A replacement is planned for 2010.	Still surplus head, but a change of fuel to wood chips instead of oil is planned.

The Municipality of Syddjurs (3/3)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality borders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expectations regarding replacement**	**Plans for future fuel types**
Rosmus Varmeværk	Wood pellets	5,270 GJ/year (310 tonnes/year (in 2009))	Greenii A/S	Almost all of it	80.9 DKK/GJ (1,375 DKK/tonne)	The town of Rosmus and Rosmos School (approx 35-36 consumers)	Inside the towns it is possible to connect a few new consumers to the grid. Outside the towns there are no immediate expansion possibilities.	The plant was built in 1997. It is uncertain when it is being replaced.	Uncertain
Tirstrup Varmeværk	Wood chips	17,640 GJ/year (1,764 tonnes/year (in 2009))	HedeDanmark A/S (from the area of Eastern Jutland)	Unknown	47 DKK/GJ	The town of Tirstrup (approx 130 consumers)	Inside the towns it is possible to connect a few new consumers to the grid. Outside the towns there are no immediate expansion possibilities.	The plant was built in 1999. It is uncertain when it is being replaced.	Uncertain
Kolind Halmvarmeværk	Straw	Around 58,000 GJ/year (4,000 tonnes/year)	A local agricultural contractor and local suppliers	Unknown	41.4 DKK/GJ (600 DKK/tonne)	The town of Kolind (well over 400 consumers)	Currently they are connecting more consumers to the grid. When the expansion is completed there will be approximately 500 consumers in total.	The oil-fired plant was built in 1964. The straw-fired plant was built in 1989 and is being replaced with a new straw-fired plant in 2010.	Still straw

The Municipality of Randers (1/2)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality borders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expectations regarding replacement**	**Plans for future fuel types**
Langå Varmeværk a.m.b.a.	Natural gas	Unknown	HMN Naturgas I/S and DONG Energy	Unknown	Unknown	The town of Langå (approx 900 consumers)	There are no immediate expansion possibilities, but it depends on the development.	Langå heating plant was built in 1960. Langå combined heat and power plant was built in 1991. It is uncertain when it will be replaced.	Possibly, solar heat will completely or partially replace natural gas
Værum-Ørum Kraftvarmeværk a.m.b.a.	Natural gas	Unknown	Unknown	Unknown	Unknown	The towns of Værum, Jebjerg and Væth (the number of consumers unknown)	Inside the towns it is possible to connect potential consumers to the grid.	Unknown	Uncertain
Mejlby Fjernvarmecentral	Natural gas	23,926 GJ/year (604,198 m^3/year)	HMN Naturgas I/S	Unknown	46.2 DKK/GJ (1.83 DKK/m^3 (exclusive of transmission, storage, distribution and taxes))	The town of Mejlby (approx 192 consumers)	The expansion possibilities are dependent on the local development regarding partitioning.	The plant was built in the 1990s. They currently have a service agreement including a main service in 2011.	Uncertain
Mellerup Kraftvarmeværk a.m.b.a.	Natural gas	31,680 GJ/year (800,000 m^3/year)	HMN Naturgas I/S	Unknown	Unknown	The town of Mellerup (177 consumers)	Inside the town it is possible to connect approximately 40 households to the grid.	The plant was built in 1993. It is uncertain when it will be replaced. In 2012 the debt will be settled making new investments possible.	A change of fuel to wood pellets is considered.

The Municipality of Randers (2/2)									
Plant	**Fuel type**	**Amount of fuel**	**Suppliers**	**Percentage of the fuel coming from outside the municipality borders**	**Fuel price**	**District heating area**	**Immediate expansion possibilities**	**The age of the plant + expectations regarding replacement**	**Plans for future fuel types**
Uggelhuse-Langkastrup Kraftvarmeværk a.m.b.a.	Natural gas	Around 35,640 GJ/year (900,000 m^3/year)	HMN Naturgas I/S	Unknown	Almost 4 million DKK/year ~ 112 DKK/GJ (all included)	The towns of Uggelhuse and Langkastrup (approx 195 consumers)	It is possible to include approximately 50 consumers by forced connection. Because of the high prices on the heat they are losing consumers.	The plant was built around 1995. The motors were replaced in 2007.	They have tried a change of fuel (dead stock) but taxes have made it impossible.
Havndal Fjernvarmeværk a.m.b.a	Straw	33,350 GJ/year (2,300 tonnes/year)	Local suppliers	0 %	31.7 DKK/GJ (460 DKK/tonne)	The town of Havndal (357 consumers)	All parts of the town are connected to the grid. Outside the town there are no immediate expansion possibilities.	The plant was built in 1993. The boiler was replaced in 2008. A replacement is not expected before 2028.	Uncertain
Gjerlev Varmeværk a.m.b.a.	Straw	Around 29,000 GJ/year (2,000 tonnes/year)	Local suppliers	0 %	30.3 DKK/GJ (440 DKK/tonne)	The town of Gjerlev (230 consumers)	Inside the town it is possible to connect approximately 70 households to the grid. Additionally, a pipeline of 5-6 km could be laid including yet another village. However, it requires that an extra boiler is installed.	The plant was built in 1990. A replacement is expected around 2020.	Still biomass
Gassum-Hvidsten Kraftvarmeværk a.m.b.a.	Natural gas	Around 47,520 GJ/year (Around 1,200,000 m3/year)	HMN Naturgas I/S	Unknown	Around 4 million DKK/year ~ 84 DKK/GJ (all included)	The towns of Gassum and Hvidsten (197 consumers)	It is possible to include approximately 30 consumers by forced connection. Because of the high prices on heat they are losing consumers.	The plant was built around 1994. The motors will be replaced before 2014-15.	If it were made possible by the politicians, they would like to make a change of fuel to biogas.