

# Geographical employment potentials from bioeconomy

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## Summary

A steadily growing global population means the pressure on Earth's resources is greater than ever before. Rising costs of raw materials and a sustained pressure on the environment and the climate are challenges that point to the need for substantial changes to global consumption and production patterns.

From a Danish perspective, bioeconomy can play a central role in this transition. The reason for this is that bioeconomy fulfils two necessary criteria: It makes good economic sense for society, and it can provide a substantial amount of energy. Given Danish climate goals, energy derived from biomass offers a relatively cost-effective way of solving a problem, while at the same time increasing energy supply security and providing a stabilising complement to wind based electricity production. In addition, Denmark has the potential to produce enough biomass to cover around half of the Danish gross energy consumption in 2050. This is a significant contribution – especially considering that biomass currently contributes less than 10%.

In this analysis we consider the geographical employment potentials from expanding Danish bioeconomy activities, with a focus on a rural perspective.

We find that realising the biomass potential will create 23,700 jobs, of which nearly 80% in rural districts. Depending on the number and size of the required biorefineries, there will either be a large employment effect in a few rural districts, or a small employment effect spread over many rural districts. We refer to as the centralised and decentralised model, respectively, and both models are still on the drawing board.

The agricultural sector in particular will experience positive employment effects, but also the utilities and construction sectors will see larger employment demand. In terms of education levels, we find that a full 12,000 jobs – corresponding to more than half of the jobs created – will go to individuals with a vocational education, and around 6,500 jobs will require at most a *gymnasium* or *erhvervs-gymnasium* background. In other words, it is mainly people with shorter educations in rural areas of Denmark who will benefit from the jobs created.

For many rural *kommuner*, a yearly employment increase of around 1,000 jobs is enough to turn around or at least cancel out the current negative trends in employment. In addition to being economically viable and important for addressing the climate challenge, bioeconomy can thus help support employment in the rural areas in Denmark. Bioeconomy can therefore fulfil a political agenda of a more balanced Denmark, without having to resort to special regional subsidies or transfers.

## Chapter 1

# Bioeconomy potentials

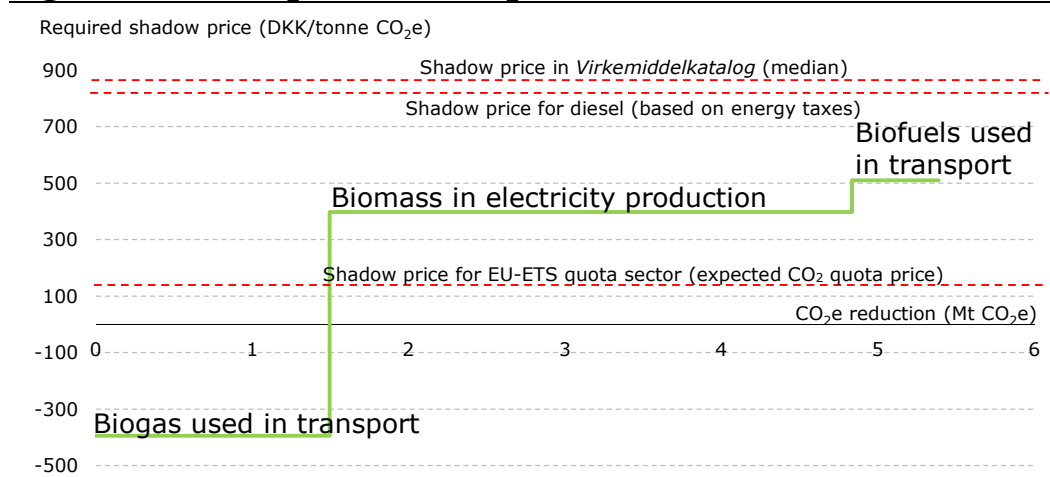
This chapter explains and illustrates how bioeconomy makes good economic sense, and what potential it has as a source of energy in Denmark, followed by a discussion of the value of products derived from biomass.

### 1.1 Bioeconomy makes good economic sense for society

Biomass can provide substantial reductions in CO<sub>2</sub>e emissions, in a way that is cost-effective for society, when used as an energy source. This applies to both transport and power supply, which are the two sectors where bioenergy is expected to play a large role in the future.

The viability of bioenergy can be illustrated with a comparison of required shadow prices between different uses of bioenergy, cf. Figure 1. By 'required shadow prices' we mean the value society must place on reducing emissions of CO<sub>2</sub>e by 1 tonne, for a given use to be profitable for society.

**Figure 1 Shadow prices for bioproducts in 2030**



Note: Shadow costs for CO<sub>2</sub> emissions for biogas and biofuels used in transport are defined as the CO<sub>2</sub> prices that just make each fuel competitive compared to diesel. The CO<sub>2</sub> reduction potentials are based on the assumption that 15% of the car stock runs on biogas or biofuels.

Source: Copenhagen Economics based on COWI *Alternativ drivmidler* (2013), ENS et al. *Virkemiddelkatalog* (2013) and EA *Energianalyse Elproduktionsomkostninger* (2014)

Biogas as a transport fuel has a negative required shadow price. This means that using biomass to produce biogas for transport is always economically viable to society, as long as we place a positive value on reducing emissions of CO<sub>2</sub>e.

Biofuels have a required shadow price of around 500 kr per CO<sub>2</sub>e. As a comparison, the implicit shadow price for CO<sub>2</sub>e emissions from diesel, based on current energy taxes, is nearly 900 kr. In other words, the way we currently tax CO<sub>2</sub>e emissions from the transport sector suggests a CO<sub>2</sub>e price that is nearly twice as high as what biofuels can offer.<sup>1</sup> For petrol, the shadow price for reducing CO<sub>2</sub>e by a ton, implicit in energy taxes, is around 1,700 kr (not shown in the figure).

Both biogas and biofuels are therefore well below the typical shadow price in the Danish government's "instrument catalogue" for greenhouse gas reductions (Virkemiddelkatalog; 2013), which is close to 900 kr per tonne. This is based on the median of the 53 instruments. Like biogas and biofuels, electric cars are also expected to become socially cost effective. However, electricity will likely not be able to fuel the transport sector in general, as electricity storage for air transport, shipping and international road cargo transport will remain a challenge.

In the power sector, wind will likely remain a cheaper energy source than electricity from biomass. However, the value of wind power will fall as the share of wind in total power production grows. On the one hand, wind power supply cannot be controlled, and on the other hand, a large share of the wind power may be produced at times when electricity has a low value. These two aspects combine to create a need for stabilising the power supply. This is where biomass may play a role, by delivering substantial amounts of power at a shadow cost that is lower than most instruments listed in the *Virkemiddelkatalog*.

Given the Danish targets of a fossil-free power sector in 2035, and a completely fossil-free economy by 2050, there is no doubt that biomass and bioeconomy can play a crucial role in achieving these targets in a cost-effective way. Moreover, over time bioeconomy will be able to deliver higher-value products (pharmaceuticals, etc.) in addition to power and fuels, which will further strengthen profitability.

## 1.2 Large potential for expanding biomass production

The current biomass production in Denmark is around 63 PJ per year, which corresponds to less than 10% of the Danish gross energy consumption, cf. Figure 2. The potential for biomass production in Denmark is four times that, however: around 255 PJ, including renewable waste. If this potential is realised, half of Denmark's gross energy consumption could come from biomass in 2050. In other words, the biomass potential is far from exhausted.

The current biomass production is made up of straw and wood, and some manure (yellow, brown and grey biomass, respectively). Straw and wood are burnt in thermal power plants, while manure is treated to extract biogas, and the degassed manure is returned to farmers. In Energistyrelsen's *Basisfremskrivning* for 2025, the total energy production

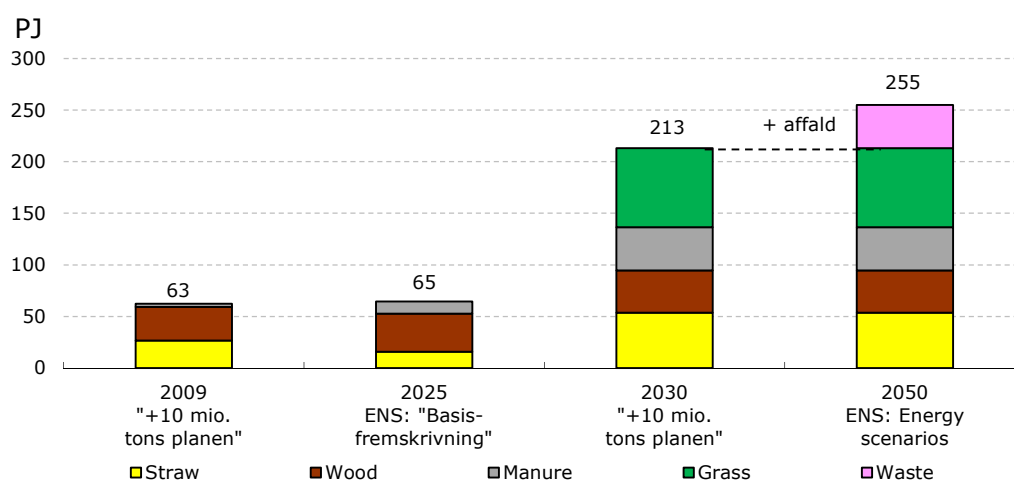
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<sup>1</sup> The implicit shadow price has been calculated in three steps. First, we added the various taxes and duties per GJ energy from diesel (*energiavgift*, *CO<sub>2</sub>-avgift*, *NO<sub>x</sub>-avgift*). We then corrected for the higher efficiency of diesel cars. Finally, we transform energy use in GJ to emissions in CO<sub>2</sub>e. Thus we arrive at the cost per tonne of CO<sub>2</sub>e emissions: the implicit shadow price based on the current tax structure. For more information, see Copenhagen Economics (2013) *Ensartet skat på drivhusgasser*

from biomass is roughly the same as today, but the share from manure is relatively larger, and the share from straw relatively smaller, compared to today.

If Denmark decides on a full-scale expansion of bioeconomy, things will look radically different. A transition to the *+10 mio. tons planen* scenario with the largest biomass production would mean a doubling of straw use, a 15-fold increase in biomass production from manure, and a substantial production of green biomass (e.g., grass and beets) that does not exist today. In addition, biomass will not mainly be burnt for power production, but used in biorefinery processes, primarily for production of biofuels.

**Figur 2 Future biomass potential in Denmark**



Note: For 2050, only Danish produced biomass is included

Source: Copenhagen Economics based on *+10 mio. tons planen* (2012); ENS *Basisfremskrivning* (2014); ENS Energy scenarios (2014)

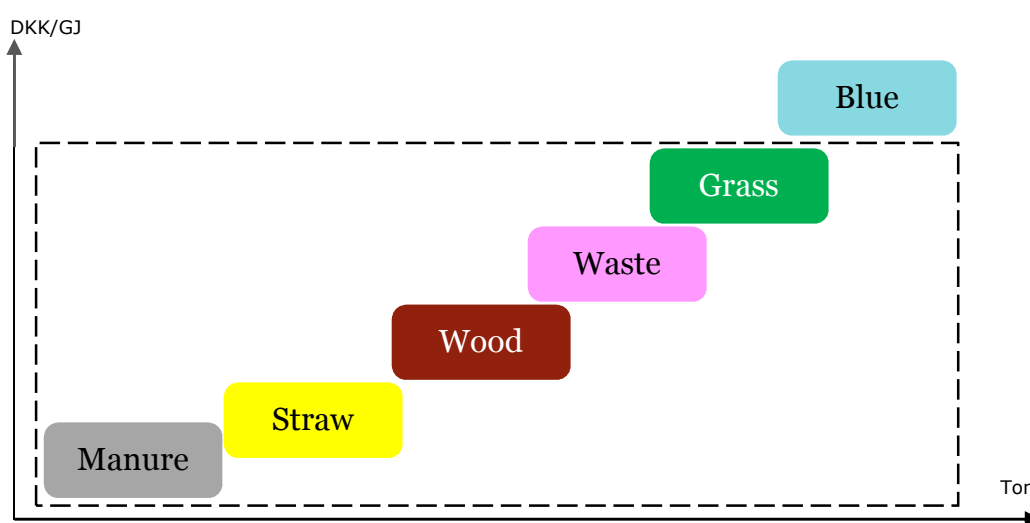
*Energistyrelsens* energy scenarios for Danish produced biomass in 2050 are based on the same numbers used in the *+10 mio. tons planen*. The only difference is that *Energistyrelsen* also include renewable waste in their numbers for biomass potential. Whether this potential can be realised already in 2030 rather than 2050 depends on how quickly a number of technological challenges can be overcome, which in turn depends on the introduction of the right policy conditions for bioeconomy.<sup>2</sup> The paper *+10 mio. tons planen* is a plan for biomass in 2020, but due to the right policy conditions not being in place yet, our assessment is that this potential can only be realised in 2030.

Manure, straw and waste are currently used in biorefinery processes, and are close to market maturity, cf. Figure 3. The technologies for harvest and processing of green biomass are still not fully developed, and as such they have higher production costs. Blue biomass (algae) has a potential to play an important role in the future, but available tech-

<sup>2</sup> Copenhagen Economics have published several studies analysing the importance of policy conditions for bioeconomy development. See, e.g., *Ensatet skat på drivhusgasser* (2013), *Den biobaserede økonomi: Danske styrkepositioner og potentialer* (2013) and *Efficient strategy to support renewable energy* (2013)

nologies for energy production from blue biomass are still in their infancy, and demanding in terms of area requirements. The employment effects from bioeconomy presented in the next chapter are therefore only based on the lower part of the biomass supply curve, abstracting from blue biomass. On the other hand, we do assume, in line with the *+10 mio. tons planen*, that the necessary technological innovation for harvesting and processing green biomass has taken place.

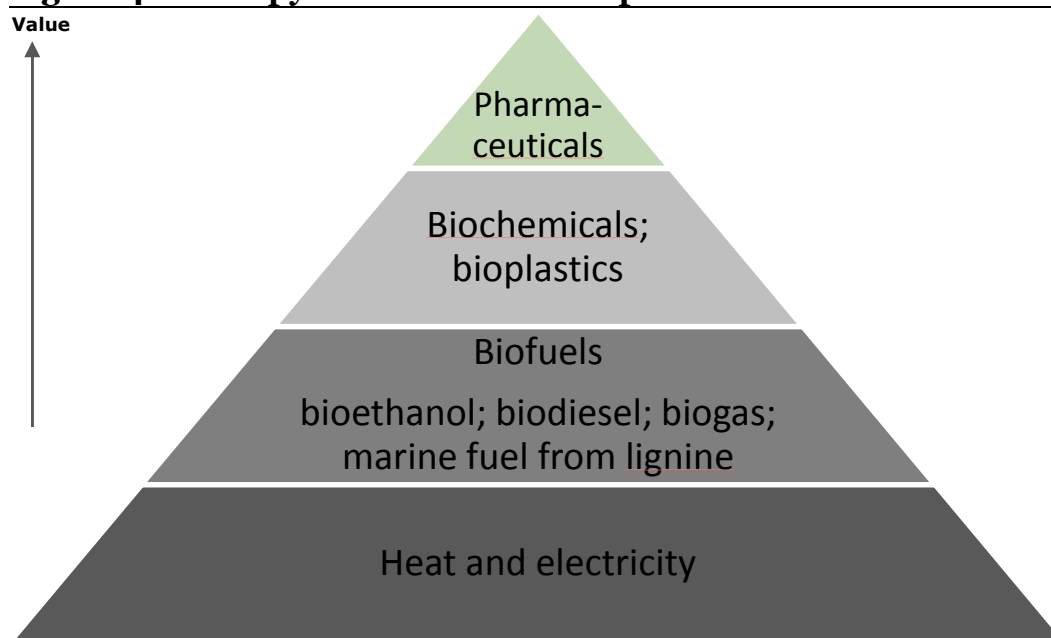
**Figure 3 Supply curve for biomass**



Source: Copenhagen Economics

### 1.3 Value differences across bioeconomy products

Just as production costs per energy unit vary across energy carriers, there are also large differences in the values of final products, cf. Figure 4. Low-value products are related to burning biomass for electricity and heat production, while highly refined pharmaceuticals are at the other end of the value spectrum. There are also large variations in market maturity, indicated by the areas of the pyramid segments in the figure: Biomass used for electricity and heat production is fully market mature, while higher-value technologies are still at various intermediate levels of market maturity.

**Figure 4 Value pyramid for biomass products**

Note: Market maturity is indicated by the size of each section

Source: Copenhagen Economics

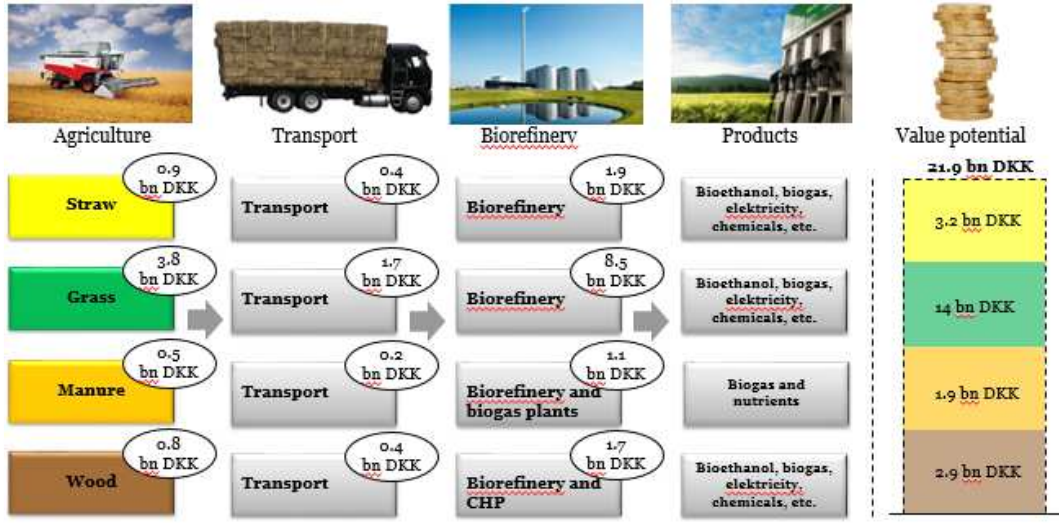
Denmark is at the research frontier of a range of technologies that can convert biomass to high-value products. This includes technologies based on bio-enzymes and microorganisms. There is a distinct possibility of employment effects related to high-value bioeconomy products, but there is substantial uncertainty about how this sector will develop, and in addition, these effects are not likely to materialise in the immediate future. High-value bioeconomy jobs will primarily be industrial jobs in urban areas, and are therefore unlikely to play a major role for rural regions.

For all types of biomass, the bioeconomy value chain consists in three main parts: agriculture, transport and biorefineries (including distribution), cf. Figure 5. If the scenario with the largest biomass production in *+10 mio. tons planen* becomes reality, this will give a total increase in bioeconomy production value added of 21.9 bn kr per year.<sup>3</sup> By far the largest contribution to this figure comes from green biomass, which is expected to represent the largest share of biomass, compared to no green biomass production today.

It is this additional value added of 21.9 bn kr per year that will be converted to employment effects in the next chapter.

<sup>3</sup> Gylling et al. (2012) *+10 mio. tons planen*

**Figure 5: Yearly additional production value from biomass sources in 2030**



Source: Copenhagen Economics based on +10 mio. tons planen (2012), interview med Maabjerg Energy Concept (MEC) and own calculations

## Chapter 1

# Geographical employment effects

This chapter explains and illustrates the geographical bioeconomy employment effects. We distribute these employment effects across rural and urban areas, across sectors of the economy, and across employment types and levels. Finally we address the importance of bioeconomy job creation for certain rural districts, all of which are experiencing a continuous fall in the number of local employment opportunities.

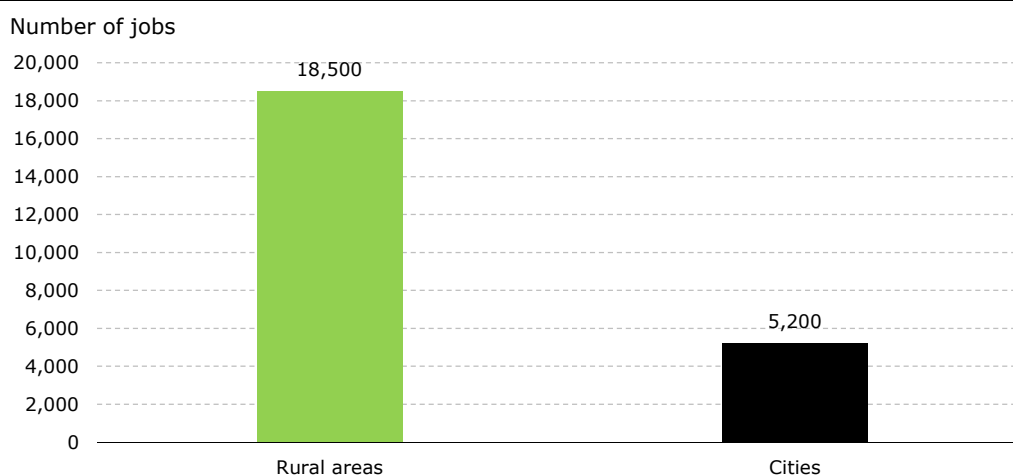
## 2.1 Bioeconomy creates 23,700 jobs – 80% in the countryside

Converting the production value added of 21.9 bn kr to employment effects gives a total long-term employment creation of 23,700 full-time jobs. Of these, 18,500, or 78%, are linked to rural areas. The remaining jobs are linked to cities, primarily greater Copenhagen. The details of our methodology is explained in Appendix A.

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**Figure 6: Total rural/urban employment effect**

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Source: Copenhagen Economics based on + 10 mio. tons planen (2012), MEC statusrapport (2013) and interviews with MEC

A detailed geographical distribution of these 23,700 additional jobs requires a knowledge of where future integrated biorefineries and biogas plants will be located. The employment effect will typically be largest in *kommuner* where the refineries are located, but especially neighbouring *kommuner* and other nearby areas may also benefit from, e.g., production and transport activities.

The biorefinery locations used in our analysis are based on qualified guesses, reflecting what would make most sense with respect to straw deliveries.<sup>4</sup> The distribution of the 18,500 rural jobs is then calculated based on weights for each *kommune*, with higher

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<sup>4</sup> This is based on, e.g., interviews with *Danske Halmleverandører* for an expert opinion

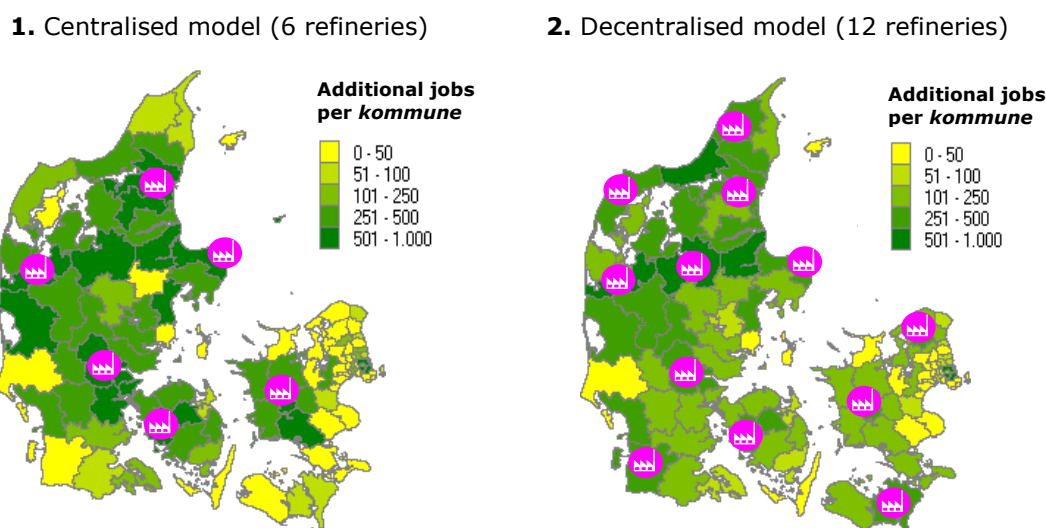
weights for *kommuner* with a biorefinery, or with firms active within the bioeconomy sector. In Appendix B we list the names of local bioeconomy firms included in the analysis. The distribution of the 5,200 city-based jobs, we have used weights based on the current number of jobs in each *kommune*.

In addition to location, the number and size of biorefineries matters for the employment distribution. We have considered two models for the geographical bioeconomy employment effects: A centralised and a decentralised model, cf. Figure 7.

In the centralised model, we assume six large integrated biorefineries will process all the Danish biomass production. The associated employment effects will be nearly 1,000 jobs in *kommuner* where the refineries are located, or that border a refinery *kommune*. This includes a range of *kommuner*, e.g., Holstebro, Norddjurs and Aalborg. In this model, each refinery is assumed to have roughly twice the capacity of what Maabjerg Energy Concept is expected to have.

In the decentralised model we assume 12 biorefineries to process all biomass in Denmark. This model distributes the same employment over more rural districts and accommodates local biogas plants to a larger extent. Few *kommuner* experience employment effects in the range 500–1,000 full-time jobs in this scenario, but on the other hand there will be at least 50–250 new jobs in more or less all Danish *kommuner*.

**Figure 7: Geographical employment effects (two scenarios)**



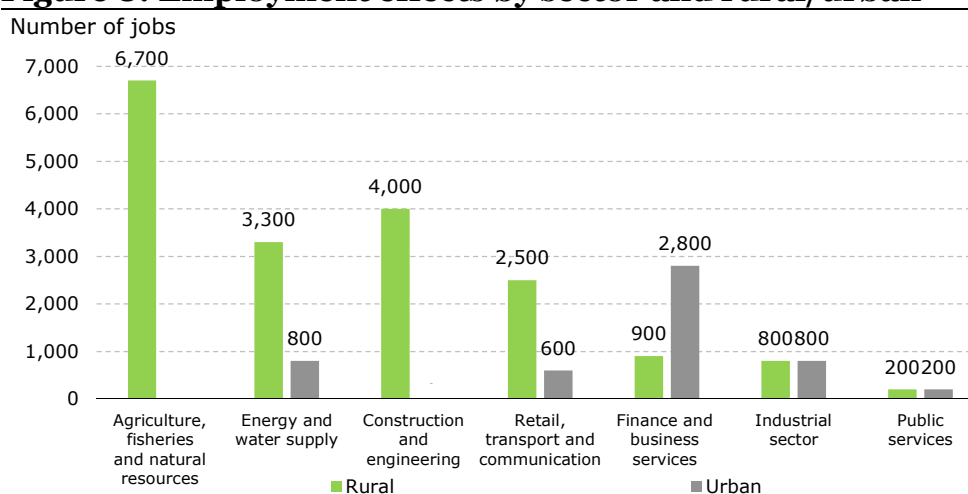
Note: The locations of refineries are hypothetical, but make sense in relation to straw deliveries. The distribution of the 18,500 jobs in rural areas is found using weights that benefit each *kommune* if it either has a biorefinery, if it borders a *kommune* with a biorefinery, or has firms active within the bioeconomy sector. The distribution of the 5,200 city-based jobs is calculated using weights based on the size of the labour force in each *kommune*. More details are available in Appendix A.

Source: Copenhagen Economics based on interviews with *Danske Halmleverandører* and own calculations

## 2.2 Benefits to agriculture and to the vocationally trained

Distributed across employment sectors, agriculture is expected to be the main winner, with in total 6,700 jobs, corresponding to 28% of the full effect of 23,700, cf. Figure 8. Other sectors that represent a large share of the employment effect are energy and water supply, and construction and engineering, with 4,100 and 4,000 full-time jobs, respectively.

**Figure 8: Employment effects by sector and rural/urban**



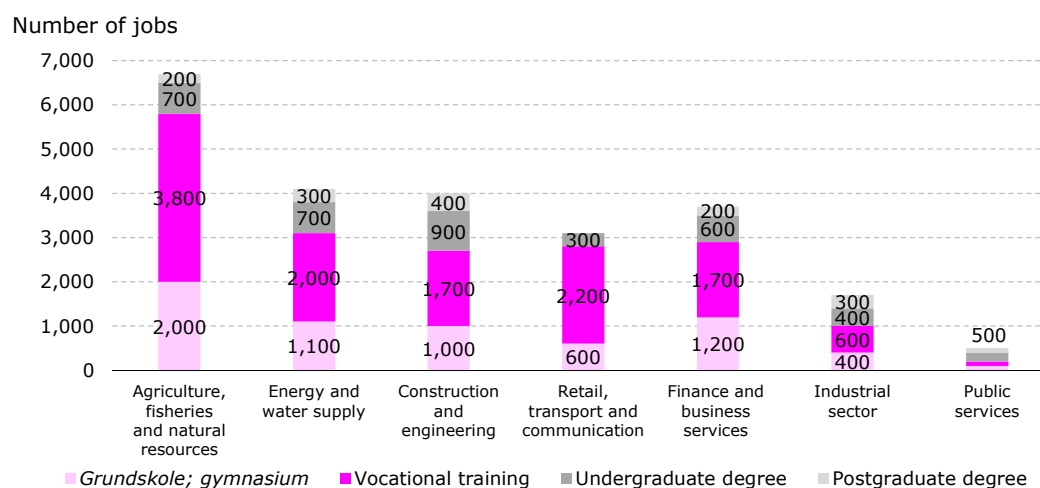
Note: The sectoral distribution and the rural/urban split is based on expected employment effects from Maabjerg Energy Concept

Source: Copenhagen Economics based on MEC *Statusrapport* (2013) and interviews with MEC

Employment in energy and water supply is mainly linked to the day-to-day running of refineries, while employment in construction and engineering is related to day-to-day maintenance of the refinery, as well as continuous construction work in connection with the building of the required refineries. As for agriculture, most of the employment effect in these two sectors will benefit the geographical areas close to the refineries, which is also the reason that nearly 80% of the total employment effect happens in rural districts. The employment effect in cities is mainly due to effects in finance and business services.

Based on the sectoral distribution, the employment effects from bioeconomy will primarily benefit individuals with vocational and other short employments. A distribution of the 23,700 full-time jobs across required education levels shows that most of the jobs will require a vocational education, cf. Figure 9. There are also jobs to be had for individuals with a lower level, such as *grundskole* or *gymnasium*; roughly 6,500 of the jobs are expected to be at these levels.

**Figure 9: Employment effects by education levels**



Note: The distribution of employment across education levels is based on the current national distribution of employment levels across sectors (Danmarks Statistik serie KRHFU2). This approach was chosen based on consultations with MEC

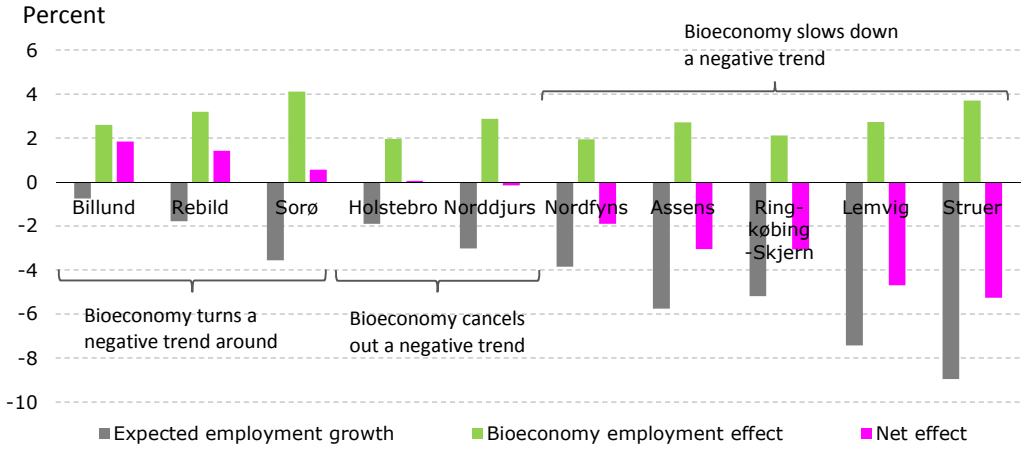
Source: Copenhagen Economics based on Danmarks Statistik and interviews with MEC

### 2.3 Bioeconomy can reverse a negative local employment trend

Over the past 10 years, there has been a noticeable decrease in employment in less densely populated areas. The number of jobs in manufacturing, for example, has fallen by 25-30% all over Denmark, except the Greater Copenhagen area, where the fall has only been 8%. At the same time, service jobs, which are much more likely to be found in the larger cities, have become more common. These trends combine to increase the risk for a sustained loss in rural jobs in Denmark.

An expansion of bioeconomy can help support employment in the rural areas of Denmark, in a way that makes good economic sense for society. The employment effects from bioeconomy is enough to turn a negative trend in the number of jobs to an overall positive development in several *kommuner*, cf. Figure 10. In other *kommuner*, it can help cancel out a negative trend, while most *kommuner* will experience a marked slowdown in the negative trend.

**Figure 10: Fall in employment vs. bioeconomy effect**



Note: Illustrated are the ten *kommuner* with relatively highest bioeconomy employment effects in the centralised model. These are mostly smaller *kommuner* close to a biorefinery. The expected employment growth refers to a six-year period (2014-2020)

Source: Copenhagen Economics based on Danmarks Statistik and own calculations

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## Appendix A

# Calculation methodology for employment effects

The employment effect calculations rely on three main sources: the so-called *+10 mio. tons planen* (Gylling et al, 2012), Maabjerg Energy Concept Statusrapport (2013) og *Danmarks Statistik's* databank.

**The total employment effect** is taken from the *+10 mio. tons planen*, which lays out in detail which changes to agricultural activities are needed to achieve an increase in production of 10 million tonnes of biomass. This plan, combined with an input-output analysis, gives a number of jobs that will be needed to be consistent with the ambition to increase biomass production by 10 million tonnes. It should be noted, that the job creation figures do not account for the fact that other jobs elsewhere may disappear, as a result of this job creation. Given the current pressures on rural areas (job destruction and migration to cities), we argue that a gross figure for job creation is most relevant for assessing rural job creation potentials. In addition to the total employment effect from the *+10 mio. tons planen*, we have added an annual contribution from the construction phase of 1,250 jobs.

**The employment distribution across sectors** is taken from the MEC *Statusrapport* 2013. In contrast to the *+10 mio. tons planen*, the *Statusrapport* is based on activities in an actual biorefinery, and the numbers therein should therefore correspond better to the actual sectoral distribution than the numbers in the *+10 mio. tons planen*.

**The employment distribution across geographical areas is calculated** based on the sectoral distribution. After interviewing Maabjerg Energy Concept, we have distributed the jobs created in each sector across rural and urban jobs. For example, all jobs in agriculture are assumed to be rural. National job numbers are then distributed across all *kommuner* based on their current size (measured as number of jobs). Rural jobs are distributed across *kommuner* based on the number of local businesses in bioeconomy, as well as our assumptions about where biorefineries will be located in the future. An overview of local bioeconomy businesses is available in Appendix B.

**The employment distribution across education levels** has been calculated based on the current national distribution of employment levels across sectors (Danmarks Statistik, series KRHFU2). We used the employment distribution across sectors calculated above, and distributed further by employment levels, using this data from Danmarks Statistik.

## Appendix B

## Overview over bioeconomy businesses

**Table B.1 Overview over bioeconomy businesses**

ABB	Komteks anlæg
Agro Business Park	Kongskilde (part of the DLG group)
AgroTech	Krüger
AL-2 Teknik	L-Rahbek
Babock & Vilcox Vølund	Lundsby
BB Hydraulic	Lynex
Bema	Maabjerg Energy Concept
Bigadan	Niras
BWSC	NNePharmaplan
Champion Danmark	Nordic Engineering
Chr. Hansen	Nordic Seed
Cimbira	Novozymes
Combigas	On/Off Management
Compleks Innovation	Parkland Maskinfabrik
Cormall	Passat Energi
Cowi	Picca Automatization
Danisco/Dupont	PlanAction
Dansk Rustfri Kolding	Planenergi
DFL Trifolium	POMI
DM&E	Q-interline
DONG Energy	Qubiqa
Doppstadt Danmark	Rambøll
Fagerberg	Renew Energy
GasCon	RETEC
Grontmij	Sejet Planteforædling
Guldhammer engineering	Siemens
Håldor Topsøe	Solum anlæg
Haarslev Industri	Stjernholm A/S
JF-Stoll	Univalve
JH Stål	Weiss
KD Maskinfabrik	Xergi

Source: Copenhagen Economics (2013) *Den biobaserede økonomi: Danske styrkepositioner og potentialer*