Final report

1.1 Project details

Project title	IEA Bioenergy Task 43 - internationalt samarbejde om biomasse til energi (2016-2018)
Project identification (program abbrev. and file)	Jr. no. 64015-0632
Name of the programme which has funded the project	EUDP-2015
Project managing company/institution (name and address)	Institut for Geovidenskab og Naturforvaltning (IGN), Det Natur- og Biovidenskabelige Fakultet, Københavns Univer-sitet, Rolighedsvej 23, 1958 Frederiksberg C
Project partners	-
CVR (central business register)	29979812
Date for submission	22 May 2019

1.2 Short description of project objective and results

Dansk
Projektnetværkets formål var at bidrage til at identificere muligheder for øget produktion af klimavenlig og bæredygtig biomasse til energi, biobrændstof og biobaserede produkter. Vi konkluderer at der findes mange muligheder for at øge produktion og mobilisering af bæredygtig biomasse i Danmark og rundt om i verden, men der er ofte nødvendigt at overvinde en kombination af tekniske, økonomiske, sociale og miljømæssige barrierer, som er bestemte af lokale forhold. En væsentlig barriere er manglende tiltro til at biomassen er bæredygtigt produceret. Derfor er det vigtigt med enighed blandt interessenter om hvordan man definerer bæredygtighed, både overordnet og i en given sammenhæng, og beslutter hvilket indikatorer, der skal anvendes, registreres og måles. De valgte indikatorer bør reflektere den reelle påvirkning af parametre, der af parterne anses for at være kritiske. Monitering og krav bør indarbejdes i offentlige eller private reguleringssystemer, med tilstrækkelige kontrolfunktioner and gennemsigtighed til, at de anses og opfattes som værende troværdige. Systemerne bør være adaptive, med indbyggede komponenter, der sikrer en regelmæssig opdatering af mål, indikatorer og deres måling, så systemet hele tiden tilpasses den observerede udvikling. Sådanne systemer er vigtige for opbyggelse af tillid mellem de involverede aktører og offentligheden, selvom diskussionen om bæredygtighed til dels altid vil være værdibaseret.

English
The aim of this project network was to support identification of opportunities for increased production of climate-friendly and sustainable biomass for energy, biofuels and bio-based products. We conclude that there are several opportunities to increase production and mobilization of sustainable biomass in Denmark and around the world, but it is often necessary to overcome a combination of technical, economic, social and environmental barriers, determined by local conditions. A major barrier is lack of confidence that the biomass has been sustainably produced. For this reason, it is important that stakeholders come to an agreement on how sustainability should be defined, overall and in a given context, and decide which indicators to use, record or measure. The chosen indicators should reflect the real impact of parameters considered critical by the parties. Monitoring systems and requirements should be incorporated into public or private regulatory systems, with sufficient con-

trol and transparency for these to be perceived as credible. The systems should be adaptive, with built-in components that ensure regular updating of goals, indicators and their measurement, so that the system continuously adjusts to the observed developments. Such systems are important to build trust between the involved actors and the public, although the discussion on sustainability will, in part, always be value-based.

1.3 Executive summary

We found several opportunities to increase production and mobilization of sustainable biomass in Denmark and around the world, but it is often necessary to overcome a combination of technical, economic, social and environmental barriers, determined by local conditions. Several studies quantify global and regional biomass resources in a larger scale, but often they do not adequately consider the local conditions, and probably tend to overestimate the availability. Often there are no statistics of current uses of for example agricultural residues, or apparently idle lands, but often the lands and resources are to some extent being used by locals or poor people. On-site information is thus crucial when exploring the potentials for production, mobilization and restoration of abandoned or degraded lands. The supply chains are often complicated. It some regions, like the southeastern USA, use is being made of existing infrastructure developed over decades or centuries. New logistic systems are emerging, including so-called biomass hubs, for example in eastern Europe. Bio-hubs are increasingly seen as the key to successful biomass supply chain integration for bioenergy, and perhaps in a longer term, also the larger bioeconomy.

A major barrier to increased biomass production, mobilization and utilization is a widespread lack of confidence that the biomass is being sustainably produced, harvested and used. For this reason, it is important that stakeholders come to an agreement on how sustainability should be defined, with overall global consensus on the sustainability issues that needs to be addressed, and local specification on what each issue means and how it should be handled in a local context. It is needed to decide, often nationally or locally, which indicators it is most meaningful to use, record and measure. The chosen indicators should reflect the real impact of parameters considered critical by the relevant parties and the public. Monitoring systems and requirements should be incorporated into public or private regulatory systems, with sufficient control and transparency for these to be perceived as credible. The systems should preferably be adaptive, with built-in components that ensure regular updating of goals, indicators and their measurement. The will ensure that the system continuously adjust and develop and thus remain relevant, considering the developments taking place over time and new knowledge that is being generated. Such systems are important to build trust between the involved actors and the public, and realize the potential climate and sustainability benefits from bioenergy, and the bioeconomy. It is also important to recognize, however, that the discussion on sustainability is, in part, based on values and for example the degree of optimism regarding new technological developments in the future. Calculations on the climate benefits of using biomass for energy show less benefits if other renewable alternatives are assumed to become available in the near future. Opposite if it is assumed that renewable alternatives will only realistically become available in the needed scale in a longer term.

1.4 Project objectives

The objective of the project was to identify opportunities for increased biomass production for energy, biofuels and biobased products, as well as investigating the climate benefits and how to ensure, measure and verify that the biomass is sustainably produced, harvested and used.The project was carried out as participation in research activities under the IEA Bioenergy research network "Task 43: Biomass Feedstocks for Energy Markets" during the period 2016-2018. The activity plans were based on those of international Task 43 by the beginning of the triennium. They were organized in a structure with four overall work packages, focusing on the Danish biomass supplies in an international context:

- WP1: Opportunities and challenges associated with biomass production in different regions and landscapes.
- WP2: Quantification of biomass potentials and efficiency of the supply chains.
- WP3.1: Effective governance and certification of the biomass sustainability.

- WP3.2: The climate change mitigation benefits of bioenergy
- WP4: Dissemination of results for a Danish audience.

An overview of course of the project is given in Danish in Appendix A (Bilag A), while an overview of deliveries as well as the originally planned milestones and deliveries is shown in the Gantt-chart in Appendix B (Bilag B). The work under the individual milestones was expanded and developed in the context of the outlined structure, along with the development in the international collaboration. It means at some milestones are not single products, but include several different deliveries. Other milestones and deliverables had to be adjusted, changed or given up for various reasons. Overall, however, the project has resulted in several publications, meetings, networking and collaborations (Bilag A and B) that have also resulted in new activities and continued collaboration after the project ended, e.g. under the umbrella of IEA Bioenergy Task 45 "Climate and Sustainability Effects of Bioenergy within the broader Bioeconomy", or at the national level among different IEA Bioenergy tasks, and researchers and industrial and policy actors within the forestry, agriculture and energy sectors.

1.5 Project results and dissemination of results

1.5.1. Main activities

Main activities in 2016 were a study tour to southeastern United States in April 2016, with Danish participation by Niclas Scott Bentsen (University of Copenhagen), Inge Stupak (University of Copenhagen), Peter Kofod Kristensen (DONG Energy, now Ørsted A/S), Kristine van het Erve Grunnet (Danish Energy) and Lars Martin Jensen (Danish Energy Agency). The theme of the tour was sustainability of biomass production, and the purpose was, among other things, to create a dialogue across the Atlantic to gain a better understanding of the biomass production taking place in the southeastern United States. The trip also resulted in a collaboration on an article on forest biomass and sustainability in the southeastern United States (Dale et al. 2017, with contributions from Inge Stupak and Niclas Scott Bentsen).

Another major activity in 2016 was the IEA Bioenergy inter-Task project "Measuring, governing and gaining support for sustainable bioenergy supply chains". The project addressed three main questions: 1) How to measure and quantify activities aimed at a more sustainable bioenergy practices; 2) How to improve the legitimacy of sustainability governance, including legislation, certification and guidelines; and 3) How to engage a broad group of stakeholders in the context of biomass sustainability governance, to improve legitimate and usefulness of the regulatory systems, thereby building social capital, trust and support among bioenergy stakeholders.

Especially with reference to WP1, Uffe Jørgensen from Aarhus University participated in the Task 43 workshop "Landscape management and design for bioenergy and the bioeconomy" and "Mobilization of Forest Biomass to Produce Bioenergy, Biofuels and Bioproducts: Challenges and Opportunities" in Vancouver 21-23 September 2016. In the first workshop he also spoke about "Sustainable intensification of agricultural systems in combination with biorefinery processing can produce more biomass for bioenergy without imposing". Collaboration with Uffe Jørgensen also took place at the national level in the "Bioresource" project, funded by the Danish Research Councils. In this project, PhD students Petros Georgiadis and Anders Tærø Nielsen (business PhD at HedeDanmark) completed their PhD theses entitled, respectively, "Willow and poplar for bioenergy on forms cropland - biomass production, soil carbon, nutrients and water" and "Forest biomass for climate change mitigation". Inge Stupak was co-supervisor of these theses.

With reference to WP2, NSB was invited talk at the IEA Bioenergy ExCo meeting in Rome 16-18 October 2016, with the title: "Grass-based biorefinery systems producing biofuels, biomaterials and feed". As a follow-up on this, NSB participated in a workshop on biomass resource inventories and modeling, on behalf of Task 43, which was organized by The International Renewable Energy Agency (IRENA) and IEA Bioenergy and took place in Berlin on September 28, 2016. The overall purpose of the meeting was to improve and develop projec-

tions and energy scenarios of IRENA and IEA Bioenergy to ensure that they are rely on a solid and validated scientific basis. As an output from the IEA Bioenergy inter-Task project "Mobilizing sustainable bioenergy supply chains" from the period 2013-2015, several reports and articles were furthermore completed with Niclas Scott Bentsen as a lead, and both Niclas and Inge Stupak as contributors, see publication lists (Bilag A and B). In addition, Søren Larsen completed his PhD thesis "Biomass production and its utilization for energy", with Niclas Scott Bentsen as supervisor.

The main activities in 2017 concerned WP3.1 and included continued coordination of activities under the IEA Bioenergy inter-Task project "Measuring, governing and gaining support for sustainable bioenergy supply chains", with Inge Stupak and Tat Smith, University of Toronto as coordinators of one of three work packages. Several Danish and international colleagues contributed as collaborators.

In 2018, this work was presented in the open conference "Governing sustainability of bioenergy, biomaterials and bioproduct supply chains from forest and agricultural landscapes", April 17-19, 2018, University of Copenhagen, organized in collaboration between IEA Bioenergy Task 43, and the Nordic network activities "Effect of bioenergy production from forests and agriculture on ecosystem services in the Nordic and Baltic landscapes" (Nordic Committee on Agricultural and Food Research (NKJ), and SamNordisk Forest Research (SNS)) and CAR-ES III "Center of Advanced Research on Environmental Services from Nordic Forest Ecosystems "(SNS) (WP3.1 and WP4). The organisers were Inge Stupak, Niclas Scott Bentsen and Søren Larsen (Dansk Energi), together with an international scientific committee and practical and IT help from University of Copenhagen. A book of abstracts is available from the conference website (presentations and posters have been available earlier). A synthesis of results from conference was also presented by Inge Stupak at the European Biomass Conference and Exhibitions (EUBCE) in Copenhagen, May 15 2018, and they were presented at an international webinar 13 September, 2018, and at IEA Bioenergy's end-of-triennium conference, "Bioenergy in a Decarbonizing World", 7-9 November, 2018, San Francisco, California, USA.

A special issue is under publication in the international scientific journal "Energy, Sustainability, and Society" (ESSO), with contributions both from the conference and the IEA Bioenergy inter-Task project "Measuring, governing and gaining support for sustainable bioenergy supply chains ". Inge Stupak, Nicholas Clarke (The Norwegian Institute of Bioeconomy Research) and Tat Smith (University of Toronto) are guest editors. From Denmark, Niclas Scott Bentsen and Søren Larsen (Danish Energy) is contributing with papers about sustainability of using straw for bioenergy in Denmark, and experiences from the implementation of the Danish Industrial Agreement on sustainability of wood chips and wood pellets, respectively.

In relation to climate impacts of using biomass for energy (WP3.2), international articles on carbon debt have been published and Niclas Scott Bentsen and Inge Stupak supervised several master theses on the topic, with Niclas also co-authoring articles in magazines (Bilag A and B). Per E. R. Bjerager (University of Copenhagen) also gave a presentation at the IEA Bioenergy conference International conference on negative CO_2 emissions, 22-24. May 2018, Gothenburg, Sweden, and Niclas Scott Bentsen was involved in the organisation of the workshop "Consequences for climate and bioenergy of land sector carbon accounting under the Paris Agreement", 29-30. August 2018 (IEA Bioenergy Task 38 and 43), Gothenburg, Sweden (see Bilag A and B for details). Finally, he gave a presentation at the Budapest Science Festival, 8 November 2018: "Grass-based biorefinery systems" in a session on bioeconomy clusters and financing.

The project results have thus been widely disseminated. No evaluation have been conducted to assess the direct effects on increased turnover, exports, or employment, or the satisfaction of Danish bioenergy stakeholders with the generated information and networking and meeting activities. The general impression from oral feedback has been positive, but more systematic analysis and assessment would be required to understand how the generated knowledge has been used and how different parts were valued.

1.5.2. Technical results

Biomass potentials and their mobilisation (WP1 and WP2)
Global biomass potential estimates show a very large variation. Some of the most optimistic estimates are created with top-down approaches, where various global models are combined based on a set assumed or, to some extent documented, functional relationships. A comprehensive study was carried out to estimate biomass potentials in Denmark (Gylling et al. 2016 (M5.67, Larsen et al. 2016 (M5.8), Bilag A). It showed that the biomass production in Denmark can be increased by up to additional 10 milion tonnes by 2020.

Questioning top-down approaches and the realisation of theoretical potentials, the IEA Bioenergy inter-Task project "Mobilizing sustainable bioenergy supply chains" took a bottom up approach to estimation of biomass potentials, including identification of barriers to realisation of the biomass potentials for five different generalised supply chains. The project addressed several types of barriers, including technical, economic, institutional, policy, environmental and social barriers (Bentsen et al. 2017 (M5.5), Smith et al. 2017 (M5.4), Bilag A). The project concluded that careful context specific analysis is needed to assess which biomass potentials can be mobilized and which barriers must be addressed and overcome. As a spin-off of that project, a more detailed analysis of straw mobilisation in Denmark and Sweden was carried out (Bentsen et al. 2016 (M5.8), Bentsen et al. 2018 (M7.2), Bilag A). The analyses identified the main drivers behind the much larger mobilisation of straw for energy in Denmark compared to Sweden as 1) the organizational framework, which differs between Denmark and Sweden. Particularly large-scale energy producers have been instrumental in developing the straw-to-energy market, which is why the Danish market is well established and mature, while the Swedish is still developing. In Denmark, the Danish Straw Suppliers Association has also contributed to the establishment of a transparent and well-organized market, 2) policies and applied policy instruments differ between Denmark and Sweden although the overall goals of energy and climate policies are the same. Particularly the technology specific straw mandate in Denmark and the technology neutral green certificate system in Sweden are considered the main reason for the difference in straw use, and 3) in a landscape perspective, the density of straw resources in eastern Denmark is almost double that of Scania in Sweden. Resource density has direct implications for logistics and transportation costs.

Bioenergy and climate change mitigation (WP3.2)
The literature provides diverging estimates of climate change mitigation potentials of biomass used for energy, which challenges knowledge-based policymaking. A meta-analysis of studies estimating so-called carbon payback time (Bentsen 2017 (M12.4, Bilag A)) identified a number of underlying drivers of the diverging estimates presented in the literature. The study analyzed 245 published biomass-for-bioenergy scenarios and found that the main determinant of the reported carbon payback time was the model used to estimate the payback time. Other important factors were the type of biomass resource (e.g. residues or roundwood) used for energy, the type of fossil resource (coal, oil or natural gas) displaced by biomass, the land use history, inter alia factors that can be addressed mainly through management. The study concluded that, at present, the carbon debt concept and its quantification is inadequate as a metric for estimating climate change mitigation potentials and to guide policymaking, but it is a valuable tool to guide management decisions. This is in agreement with the findings from Taeroe et al. (2017) (M11.1, Bilag A).

Taeroe et al. (2017) set out to answer the question if unmanaged or managed forest is most beneficial to climate, and found that it depends on the time perspective, the fossil fuel reference and several very uncertain factors, for which we do not have much available knowledge. Such factors include the degree to which harvested wood is used for longer lived products or energy, and especially, to extent to which wood products replace more fossil fuel intensive products. Such information must be further clarified before payback times can be made useful for making policy decisions. A study by Larsen et al. (2017) (M12.3, Bilag A) furthermore quantified the climate benefits of shifting from fossil fuels to a diversity of biomass fuels from Danish agriculture and forestry. Across three scenarios, the study found a

potential reduction in Danish GHG emissions between 6 and 10 million tonnes CO_2eq annually from 2020.

Biomass sustainability (WP3.1)

When seeking to realize the climate change mitigation benefits of bioenergy, it is necessary that the biomass is sustainably sourced and produced, without unacceptable consequences to environmental or social values in Denmark or elsewhere.

A comprehensive literature review and sustainability analysis of straw used for heat and electricity production in Denmark (Bentsen et al., 2019 (Y4)) demonstrated the risk of burden shifting when transitioning the energy production from fossil to biomass based energy. The study showed that using straw for energy can benefit in terms of reduced GHG emissions, reduced fossil fuel use, increased income generation for a rural population, and increased diversity of the energy supply. On the other hand, there is a risk of increased particle emissions, increased land use intensity, and impacts on biodiversity. These risks can and must be addressed in planning and deploying biomass for energy.

Danish and international reviews have identified the potential sustainability risks of forest biomass harvesting (Stupak and Raulund-Rasmussen et al., 2016 (Y3)). Comprehensive field research has been conducted in other Nordic countries and North America, while such research is lacking in Denmark. Guidelines for sustainable forest biomass harvesting in Denmark was published in 1985. These have not been updated since, and currently, the sustainability of forest biomass produced and used for energy in Denmark is governed by the Industrial Agreement on wood chip and wood pellets sustainability, which is well under implementation (Larsen et al. 2019 (Y5)). In the near future, it is recommendable to revisit the agreement, its effectiveness in protection of any undesirable impacts.

More generally, innovation policies for renewable energy are desirable for a transition to a movement towards more sustainable societies, namely reduction of greenhouse gas emissions (Stupak et al. 2019, M9.8). At the same time it is crucial that other sustainability goals are duly regarded. Sustainability governance can be seen as a means to resolve alternative perspectives on what goals and practices can be regarded as sustainable. To be successful, it is critical that the governance measures hold a high level of legitimacy. Theory on legitimacy suggests that this can be achieved through 1) actors' participation and involvement in the governance system (input legitimacy), 2) ensuring success of the governance system in what it attempts to achieve (output legitimacy) and 3) administrative and economic efficiency in implementation and enforcement (throughput legitimacy). In spite of the efforts made to create effective, efficient legitimate systems, these are often subject to criticism.

In order to avoid such criticism, it is important to conduct careful analysis as basis for identifying the best combination of renewable and bioenergy policies policies, with regard to their effectiveness, efficiency, political and social feasibility, as well as balancing these with any undesirable economic, environmental and social impacts (Stupak et al., 2019, M9.8). Sustainability governance to protect against undesirable impacts tends to emerge with various time lags compared to developments evoked by renewable and bioenergy policies, depending on the mechanisms in place to identify them. Such time lags may be critical to the realization of the opportunities offered by bioenergy, if public support for bioenergy policies vanishes when concerns are not addressed.

Careful analysis and assessment is needed to identify the most effective, efficient and legitimate sustainability governance design (Stupak et al. 2019, M9.8). This requires tailoring to the owner types and structures and culture in each region or country, when putting in place a mix of mandatory and voluntary, incentivising or command and control approaches, prescriptive or less prescriptive requirements, and management unit level or risk-based approaches to verification. Any verification systems will rely on formalized or informal assessment of risk. In order to increase transparency, we suggest movement towards formalization of risk assessment elements.

Considering the complexity of all interactions, high levels of uncertainty, and the speed with which conditions can change in unpredictable ways, due to introduced policies or other dynamics in society, it is important to continuously monitor and assess the renewable energy policies and sustainability governance against agreed criteria and establish platforms for stakeholder communication and exchange of experiences (Stupak et al. 2019, M9.8). These tools should be embedded in adaptive governance frameworks, where policies as well as the criteria against which they are assessed are continuously revised according to observed impacts, developments and changes in values. This also includes adjustment of financial incentives when necessary, or discontinuation of these, when they are no longer needed.

Special concerns arise for international supply chains. In this case, the private bioenergy and certification sector plays a distinct role in the development and implementation of sustainability governance systems, while governments are important for providing the overall sustainability frameworks (Stupak et al. 2019, M9.8). Special attention is required to mitigate the democratic deficiency of such policies in third countries, especially when the voice of less powerful local actors is not heard among more well-organized, powerful or charismatic international profit optimizing and non-profit organizations.

Since bioenergy is not an island, it is also important that governance systems and associated monitoring systems and assessment methodologies include the larger sectors to which bioenergy development is linked, for example agriculture, forestry, waste handling, nature conservation (Stupak et al. 2019, M9.8). As a basis sustainability governance innovation to address these issues, the potentials of a diverse range of emerging landscape and regional approaches to governance can be explored, and consistent information about biomass flows from production in the field to end-of-life should be collected. Such flow mapping should include both traditional and novel bioeconomy products, as well as bioenergy, re-use and recycling. The information is critical to comprehensively assess climate impacts of bioenergy in the context of the larger sectors.

Considering challenges with creating trust in sustainability of bioenergy, which are due to misunderstandings and misapprehension, or biased and unreliable information, rather than legitimate concerns, it is suggested that carefully designed, and impartially implemented and enforced bioenergy policies combined with carefully designed sustainability governance systems are a necessary basis ensuring sustainability of bioenergy practices, as well as building trust in these practices Stupak et al. 2019, M9.8).

1.5.3. Commercial results and expectations

The project has not to our knowledge resulted directly in increased turnover, exports, or employment. It is assumed and expected, however, that the generation and exchange of knowledge and information has had impacts and will continue to have this in the coming period.

1.6 Utilization of project results

Project participants, Inge Stupak and Niclas Scott Bentsen, are build their continued work built on the results from this project. There are several examples of continued collaborations, with one being an input to a side event at the Sustainable Forestry Initiative's (SFI) annual conference, 21-25 October 2019, Richmond, Virginia, the USA. The side event is funded by the American Forest Foundation, Enviva, and the Sustainable Biomass Program (SBP), and focuses on "Risk-Based Approaches to Identifying and Managing Sustainability Risks in Sensitive Forests in the US". The input will address Danish and European requirements to sustainable forest biomass. Another example is an application for funding submitted to Nordic Forestry Research (SNS) and the Forest Bioeconomy Research Network (FBN), for a study tour on sustainable forest biomass practices in the three Baltic states, under the title "Advancing the dialogue on pathways towards sustainable development for forest landscapes: research, monitoring and governance". It includes partners from Europe and North America, with a planned focus on field research on sustainability of forest biomass harvesting practices, and modelling of impacts on forest carbon. The latter is planned to be addressed through a course in modelling of forest carbon, to be held after the tour. Furthermore, the generated

knowledge and collaboration will also in the future provide a basis for international and national research applications, policy advice, and collaboration on teaching and research with the private sectors. For example, guest lectures from the private sector are being included in courses, and the participants teaching at the University of Copenhagen is research-based, including the research outcome from this project (Bilag A and B). It is expected that there will be an indirect contribution to realizing Danish energy policy objectives, but the contribution has not been assessed, and even less, quantified. There are no plans to use any of the project results commercially, or take out any patents. The results are freely available in open source publications.

1.7 Project conclusion and perspective

Based on the available information, we judge that there are considerable potentials to increase the biomass production in Denmark, as well as imports, if there is political will. However, it will also be critical to closely follow and monitor the situation and a number of critical potential impacts, to be able to adjust incentive structures, governance and regulations to avoid undesirable economic, social or environmental impacts, if they occur. Agreed governance and regulatory systems should be in place to ensure public support and a stable investment environment to realise the climate and other benefits that can potentially come from bioenergy production. Practices and regulations need to be regularly adjusted according to monitoring results, and new research knowledge.

It is furthermore important incentives, governance and regulations specific to bioenergy are coordinated and integrated with incentives, governance and regulations for the larger sectors, including agriculture, energy and forestry. In a future bioeconomy, the same requirements can beneficially apply to all bio-based sectors and biomass end-uses.

Appendices

Bilag A - Rapport for hele projektperioden 2016-2018
Bilag B - Gantt diagram, EUDP projektet IEA Bioenergy Task 43 2016-2018