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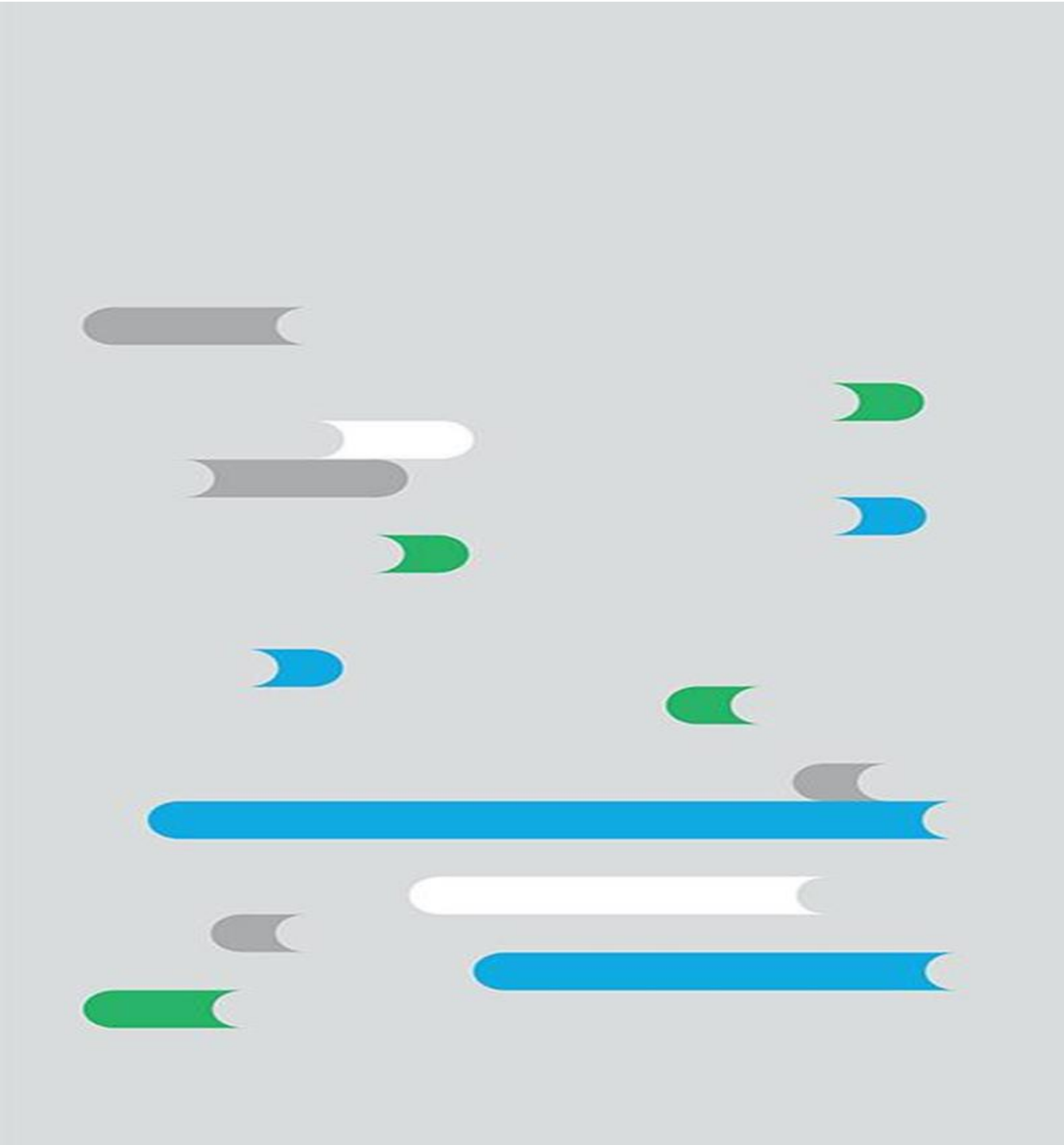
ENERWOODS - wood based energy systems from Nordic and Baltic forests



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Abstract

ENERWOODS results fully confirm that wood and woody biomass is and for long - perhaps very long - will remain the most important component of the renewable energy and resource systems in the Nordic and Baltic regions. Additionally, there is potential for significantly increasing the harvest of low grade wood material to foster an increased biofuel supply in the coming decades. In a longer perspective there is an even larger potential in increasing sustainable forest productivity and forest adaptation capacity to climate change by genetic improvement, non-native tree species, fast growing nurse trees, fertilization as well as afforestation.

We expect that a 50-100% increase of forest productivity at the stand level is possible. This is viewed relative to today's most common forest types and in a sustainable forest management context.

To which extent this potential may become utilized and implemented depend very much on the priorities made by society and decision-makers. Balanced priorities of forest functions and management aims such as nature conservation, biodiversity, recreation, game management, ground water etc. all need to be considered, but we see no problem in combining these aims in good ways in the forest landscapes.

Executive summary

This report is based on a draft executive summary submitted 23. Nov. 2015 to Nordic Energy Research in advance of this final report.

Contents

1. Introduction

(Partly from the research proposal)

The ENERWOODS project included partners from Sweden, Finland, Norway, Latvia, Estonia and Denmark. The results and conclusions are therefore primarily focused on these "ENERWOODS-countries". The project was funded by Nordic Energy Research (NER) as part of the Sustainable Energy Systems 2050 research program that was launched in 2011.

The Nordic countries have adopted an ambitious strategy: fossil independence in the energy sector by 2050! Further, this fossil independence is intended to rest primarily on renewable energy resources. Also, the EU members Finland, Sweden and Denmark have committed themselves to cover 38%, 49% and 30%, respectively, of their total energy use with renewables by 2020 [1].

Forests cover more than 7.5 times the area of agricultural land in the Nordic countries in total [2] and woody biomass and forests must inevitably play a key role in meeting the targets of strategies on energy as well as on sustainable development [1]. In some regions, forest productivity may reach levels that are comparable with those of agriculture or higher [3]. Compared to agricultural residues and annual energy crops, woody biomass from forestry has higher energy density and lower mineral content. These characteristics underscore the low energy use needed for production, harvesting and transport and the low environmental impact of forestry [4, 5, 6].

Forests already contribute significantly to the Nordic energy supply, but have a much larger potential. We expect a 25-80% growth increase at the stand level relative to the current level based on common practise and silvicultural systems within the next tree generation to be within reach. Additionally, such an increase in forest productivity will need proper selection of tree species and silvicultural system [4, 7, 8, 9, 10, 11].

Biomass from well-managed forests fully conforms to the 'Brundtland' sustainability definition, i.e. contributing to social, environmental, and economic well-being for the present as well as future generations [4, 12]

There is an urgent need to develop, improve and optimize a renewable, sustainable and cost-effective woody biomass energy systems [5, 6, 13, 14, 15]. To accomplish this we will base our project on three main **hypotheses**:

1. Woody biomass energy systems can be developed and designed to efficiently support both the 2020 and 2050 energy and climate policy goals without compromising sustainability and environmental benefits of forests.
2. Depending on site, Nordic forest productivity can be increased by up to 80% relative to standard production levels without jeopardizing sustainability.
3. Cost and greenhouse gas mitigation efficiency as well as the degree of utilization of the harvesting and transport fleet can be markedly improved by adapting and matching harvesting systems to resources and feedstocks for final consumer.

1.2 Project objectives

The prime objective of this project is to strengthen the role of Nordic forestry as a significant contributor to the development of competitive, efficient and renewable energy systems. Woody biomass must contribute more to meet fossil energy independence by 2050 as well as the EU 2020 renewable energy goals, while at the same time securing sustainability and the provision of ecosystem services now and in the future. The complete energy chains from resource to energy services have to be considered when designing bioenergy strategies to maximise climate change mitigation and security of energy supply. Robust analyses of energy systems and biological systems are very complex. Here, the goal is to combine such complex analyses to optimise the complete bioenergy chain considering primary energy use and GHG emissions. Furthermore, the aim is to build a strong and interdisciplinary Nordic research network bridging the fields of forestry and bioenergy research as well as industries and suppliers.

Five main **challenges** are linked to meeting the project objectives:

1. A considerable increase in forest productivity by e.g. selection of proper forest management models, species, provenances and clones without compromising ecosystem sustainability and stability.
2. Transportation across long distances and large scale storage of woody biomass in optimized systems linking forestry and end-users.
3. Balancing trade-offs between forest carbon sequestration and fossil fuel displacement by cost- and bioenergy-efficient strategies from a land-use perspective.
4. Balancing integration versus separation of forest functions at appropriate scales in a multifunctional and sustainable forest management context.
5. Efficient implementation of the research findings in the management of forests and the woody biomass energy system.

1.3 Sustainability context of forests and forest management

To fully understand the future potential role for forests and forest management to contribute to mitigation of climate change and as such to a sustainable development of our society it is important to view sustainability in forest management in a relevant context. It is particularly important to understand that the common stand lifecycle is relatively long (50-100 years) compared to most other life cycles we are used to deal with - e.g. the life cycle of farm crops are often less than a year.

From start to end of the ENERWOODS project and covering the whole range of publications including scientific peer reviewed, book and book chapters, reports, forestry journals, mass-media / newspapers, webpages / blog we have informed about these issues. A incomplete list of citations include [16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34].

Supporting sustainable development of society

It is important to initially stress that the approach of ENERWOODS is resting on the Brundtland sustainability declaration of 1987. The focus is on people and on fulfilling the needs of society, people and particularly future generations. In a forest and forest management context these needs include the entire range of ecosystem services - e.g. wood, woody biomass, biodiversity, clean ground water, recreation, landscape aesthetics etc.

The approach of our project is on opportunities for wood supply and has not been on limiting the use of woody products resources within a protection context focusing mainly on biodiversity and nature conservation which has been a commonly seen direction and interpretation of sustainable forest management the past two-three decades.

We do not see high production and utilization of wood as an antagonistic activity towards these other forest functions. Identifying the proper balance on the landscape level between the various ecosystem services is viewed as priorities higher up in the decision and priority-making hierarchy. However, such decisions need to be based as much as possible on a solid base of scientific knowledge. We have by the ENERWOODS project attempted to explore the potentials in forests and forest management to support a sustainable development by particularly increasing forest productivity to increase the harvest of wood and woody biomass to replace

The main challenge addressed by our project is as such our society’s dependence on fossil fuels. As such it has been a premise of our project that it is meaningless to deal with sustainability without taking the great need for renewable resources to replace fossil fuels into account [22, 25, 26, 28, 31, 32, 33, 35]

Forest legislation and forest adaptation to climate change

The "ENERWOODS-countries" covered by this project are Sweden, Finland, Norway, Latvia, Estonia and Denmark and our focus in the project The results and conclusions are therefore primarily focused on these "ENERWOODS-countries" and kept in line with the overall objectives of the SES2050 research program that ENERWOODS was part of.

Consequently, we have used an open mindset to identify and evaluate possible solutions to develop the potentials of forests and forestry much further than today. This means that we have not just considered possible solutions that are available within forest regulations and legislation of all Nordic and Baltic countries - solutions available within one single country is as such considered for the entire region.

The main legislation issue is about whether forestry only or almost only uses native tree species or if non-native species also are allowed to a significant extent. Denmark is already and due to historical reasons to a large extent using non-native tree species whereas the forest legislations of the other ENERWOODS countries are more restrictive [18, 29].

Restricting forest management to use only native species has implications for both the forest productivity and adaptation capacity of our forests to future climate and other challenges [18, 29, 35]. It is important to understand, that the number of native tree species in Europe and particularly in the Nordic and Baltic region is low compared to other continents. Forestry in the main part of the area is primarily resting on just two tree species - Norway spruce and Scots pine. The spread of risk in our forest management facing climate change is therefore rather restricted if the use of tree species in the future is limited to only - or almost only - native species.

Best use of wood in a climate and economic context

The primary use of wood is timber. This is the most valuable use both in terms of economy and climate mitigation impact. Using wood to replace energy intensive materials like concrete, steel and aluminum for e.g. construction and buildings in the first place and then in a longer time perspective either recycle or burn that wood to replace (substitute) fossil fuels is the most energy and climate effective use of wood [4, 5, 19]. Additionally, wood serves as carbon storage until it is used for energy. Often the primary attention on forests and wood is on its carbon storing function. This is, however, an incomplete focus and approach. The substitution effect may be equally or even more important, but more difficult to calculate because it depends on the specific wood products and what they replace. There is much literature on this topic and a recent study by authors involved in ENERWOODS has recently studied this in detail in a Nordic context [16, 17, 19].

However, only a limited (e.g. 30-40%) amount of the harvested timber will form final products like beams, plywood, flooring, furniture, window frames etc. Large proportions of the raw timber will be transformed to waste or low-grade wood (bark, sawdust, chips, low-grade parts of the timber) during processing and fitting into the final structures and products. Therefore, even with a strong focus at good use of timber in a climate and economic context for multiple wood products - large proportions of the harvested wood will only qualify for being used for energy or alternatively in bio-refineries. However, small-dimension roundwood and some of the wood-processing industry waste wood will qualify for other final products such as fiber or chip boards, paper or cardboard.

2. Materials and methods

(Revised from the research proposal)

The project elaborated on recent work on bioenergy systems [4, 36, 37, 38, 39] in a Nordic/European context and with due attention to the international literature and international scientific networks of the project partners. We employed a dedicated focus on forestry to supply, secure and sustain biomass for renewable energy services.

2.1 Project organization and WPs

The project was organised into four work packages (WP). The systemic challenges were met through a strong focus on the interplay between thematic areas: Production and handling the renewables (WP1, WP2); Climate and cost efficient logistics (WP2, WP3); and woody biomass energy systems (WP3).

Additionally, we allocated significant resources in dissemination activities and interaction with forest managers, owners and industry (WP4). We did also to some extent take part in public debates on the use and potential of woody biomass in energy systems. Further, the ENERWOODS projects aims, results, challenges and perspectives were used in our involvement in teaching and education of the next generations of forest managers and scientists - the latter particularly by involving or seeking collaboration of ENERWOODS in on-going or upcoming PhD-projects.

WP1 - Productive forest management for bioenergy

The objective was to develop silvicultural models with 25-80% increased productivity relative to current levels and develop recommendations on trade-offs between GHG displacement and sequestration. With due attention to Nordic energy and sustainability strategies and to the diversity of conditions in the Nordic countries, we analyse production potentials of existing and future Nordic forests.

The main focus of this WP has been on the potentials for increased forest productivity involved with respect to a number of more general topics with large scale potential impacts:

- Tree species selection - use of native as well as non-native tree species
- Genetic improvement and tree breeding
- Nurse crops - use of fast growing pioneer species to increase productivity in the regeneration phase and early stand development and facilitate establishment of high productive late successional species
- Fertilization of sites where the access to nutrients is severely limiting the tree growth
- Afforestation on farm land.

Additionally, some of the ENERWOODS PhD-projects involved more specialized studies attempting to close some knowledge gaps particularly on the management and potential of poplar and aspen. The PhD-projects have generated some outputs and they contributed well to the overall project activities, but most of them are not yet completed, since PhD projects usually involve four years of duration.

WP2 - Forestry logistics

The WP2 main objective was to develop wood procurement principles and systems optimized towards much higher woody biomass production, long distance transportation and precision supply as well as analyses.

Building on WP1 and other research we aimed at mapping and critically analyse existing forest technologies and logistics in current and future forestry practises evaluating cost saving potentials of precision supply to meet the fluctuating demands for biomass.

WP3 - Strategic analysis of woody biomass energy systems

Main objectives were to identify cost- and energy-efficient woody biomass energy systems with low GHG emissions and to optimize systems from a land-use perspective to maximize society's benefits in terms of energy services per unit of land subject to ecological and economic constraints.

Analyses of trade-offs between carbon displacement and sequestration of the woody biomass supply chain from forest to energy industry were initially placed under WP2 but are more in line with WP3. Finite time optimisation has been applied to analyse the optimal allocation of various forest management systems to maximize society's benefits in terms of GHG-emissions.

Based on WP1, WP2 and existing knowledge analyses of bioenergy chains considering woody biomass use for low carbon transportation, power and heat production were and are conducted.

WP4 - Project administration and dissemination

The objective of WP4 was both to coordinate the project and the WP-cooperation to ensure continued progress, and reporting as well as efficiently disseminate project results and secure end-user involvement. Additionally, WP4 supported the establishment of full practical scale demonstration experiments for high-productive forest types using nurse crops to increase productivity in the regeneration phase and early stand development phase as well s and facilitate low cost establishment of high productive late successional species.

Our project objectives and our dissemination strategies involved two temporal scopes:

1. Short term (2011-2020), with prime focus on increased utilization of wood based bioenergy from today's Nordic forest, building on the current energy infrastructure and use of fossil resources.
2. Long term (2020-2050+), where the consumption of fossil resources is expected to be reduced to a minimum from 2050 and onwards, and where forest productivity gains will begin to show an important increase of the available supplies of wood and woody biomass - provided that the needed changes are implemented soon.

The two temporal scopes greatly overlaps but are listed to clearly show the difference between increasing the utilization of the existing wood and woody biomass resources and the potential in a longer term perspective to increase forest growth and production. The main efforts were dedicated the long term perspective in accordance with SES2050 main target.

3. Results

The project results cover a wide range of outputs and scientific results (Appendix 1).

The dissemination and information outputs include particularly popular articles, letters and notes in national forestry journals, on webpages or in other journals usually informing about the project objectives and main results in a sustainability, forest management and climate change context. Additionally, we have held 19 workshops, seminars or conferences - often including excursions in the field or to wood processing industries or biomass fueled heat and power (CHP) plants.

In total the project has fostered 95 ENERWOODS publications including 20 peer reviewed journal papers. Additionally, 50 publications *related* to ENERWOODS were published of which 16 were peer reviewed journal papers. At the moment four more ENERWOODS peer reviewed journal papers and one related to ENERWOODS have been submitted for publication. More are in the pipeline ("in prep"), but not listed here.

The "pure" ENERWOODS publications are clearly ENERWOODS products and would not have been authored if project hat not existed. The publications *related* to the ENERWOODS have substantial inputs from one or more ENERWOODS participants and are clearly within the ENERWOODS scope. However, most of the ENERWOODS participants were supported more or less by other funding and projects within the project period and it is not possible to draw a strict line between what are and what are not pure ENERWOODS outputs. Besides, ENERWOODS has rested on competences of the participants built in past projects and scientific career as well as on other parallel projects running more or less parallel with ENERWOODS. Besides, ENERWOODS has contributed greatly to the competences of its scientific participants. Therefore, we have chosen this divide between "pure" ENERWOODS publications and publications "related to ENERWOODS.

The main emphasis in this reporting of results is on the general scientific results that are most clearly targeting the overall aim of the SES2050 research program.

The more specific scientific results that all are relevant issues are reported in focused scientific papers [40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51]. The soon expected peer reviewed journal papers to be published include both general and more specific topics [52, 53, 54, 55].

Renewables and wood are already in a leading position in the region

The region (ENERWOODS countries) is already in the frontline of replacing fossil energy with renewables [18, 29]. Currently renewables prove 46% of the total energy consumed, which is far more than the average EU target of 20% by 2020. Biomass and waste are accounting for between 65 and 97% of the renewable energy in Denmark, Finland, Sweden, Estonia and Latvia and forest products are clearly the dominant fraction of the bioenergy supply [18, 29]. Norway is an exception since it is rich in hydropower. To put these figures in perspective the average contribution by wind and sun to the present renewable energy systems are 2.5 and 0.2 %, respectively [34]. Unfortunately, the available statistics do not distinguish between biomass and waste and between biomass originating from forestry, farming and other sources such as peat.

The forests of the ENERWOODS countries cover in total 61 mio. hectares corresponding to 52% of forest cover. Denmark has the lowest cover (14 %) but has adopted an ambitious program to increase this to 20-25%. The annual growth of the forests corresponds to 276 mio. m^3. In average 65% is harvested (179 mio. m^3) [18, 29]. The most profitable use of the harvest is for timber as far as this is possible. However, large proportions of wood waste and low grade materials are only suitable for direct use as energy, pulp wood or fiber boards etc.

Short run potential for increased supply

Very often when potentials for increased forest and forestry contributions to energy systems are evaluated there is focus on how much more of the annual growth that is available for e.g. increased harvest for energy wood. This is the potential for increased utilization of the forest resource. In other words there is usually just focus on how much more low grade material (e.g. small-sized trees, branches, stumps) that is available from forests.

This potential has been evaluated by ENERWOODS as well. An annual harvest of up to 89% of the forest growth is generally considered within the limits of a long term sustainable use [56]. As such there is room for a considerably increased harvest of energy wood in the short run.

The annual supply of woody biomass is estimated by ENERWOODS to be between 230 and 410 TWh for the ENERWOODS countries depending on what levels of legislative and practical restrictions that are implemented in the individual countries [18, 29]. To put it into perspective the present annual supply of biomass and waste [57] in the ENERWOODS countries corresponds to 300 TWh. Again we need to remind that the present use of biomass is not representing woody biomass only, but woody biomass is by far the dominating part of this component. Additionally, it is relevant to highlight that a part of the waste fractions is of woody origin.

Legislative restrictions may include restrictions on the intensity of management - e.g. limiting stump extraction, harvest on steep terrain, in protected areas or limiting the removal of all slash and low grade materials form thinnings and harvests. A considerably intensified harvest of woody biomass as described here will represent an obvious intensification of forest management. Such intensified utilization must be balanced against considerations for soil fertility and soil structure as well as biodiversity.

It is difficult to suggest a robust estimate of how much more biomass can be mobilized from the present forest. The high-end estimated supply of 410 TWh woody biomass is certainly high and balancing on the edge of both sustainable forest management and other ecosystem services. That upper limit corresponds to a 35 % increase relative to a 300 TWh present consumption of the total biomass and waste of which woody biomass is the main part. Therefore, this scenario represents a considerably larger than 35 % increase of the present woody biomass supply. A 230 TWh woody biomass supply (under the highest restriction level) is probably somewhat close to today's supply of woody biomass part of the bioenergy system.

Long run potential for increased forest production

A stronger potential involves increasing the growth of our forests. If the forest productivity is increased the forests can provide much higher amounts of wood and wood biomass compared to today's supply with a lesser or even no need to increase the utilization level as described above for the short term potential increase.

Based on the reviews by ENERWOODS we assess that it is possible to increase productivity by 50-100 % at the stand scale (level) by e.g. changing species, genetic improvement, nurse crops and fertilization. These measures can be combined and thereby provide even more powerful solutions.

Additionally, the climate change itself is expected to increase forest productivity by 30% in the region [58, 59, 60]. Therefore, the above mentioned potential at the stand scale is considered a conservative level of the assessment.

The levels of growth increase by the various measures presented below is in the specific situation depending very much on site and the measures chosen as well as on what is replaced. For example, if there is already a genetically improved Sitka spruce stand on a site, then the potential for further increase in productivity is limited whereas if the starting point is a stand of commonly occurring Norway spruce, Scots pine or beech of non-improved genetic material - then the potential of production increase is large. The very high-productive stands of e.g. Sitka spruce are, however, not common in today's Nordic forests whereas non-improved genetic material occupies a very large proportion of the forest areas of our countries. This is also why the growth increase potentials are given at a stand scale because political and/or land owner decisions about how to balance various management objectives needs to be taken before more specific production increase potentials can be calculated.

More tree species

The potential increase by changing to more productive tree species than the commonly used will typically be 25-50 % at the stand scale as stands are regenerated.

A review presented by [61] shows that the most common and important species in the Nordic and Baltic areas are Norway spruce and Scots pine. Other significant native species include birch, aspen and alder particularly in the boreal forests and beech and oak in the temperate forest. Non-native species are only used at a significant share of the forest area in Denmark (app. 50% of the forest land). For the ENERWOODS countries in total the share of non-native species is only around 1 % of the forest area with the most commonly used species being lodgepole pine, Sitka spruce and Siberian larch [61]. Interestingly, Norway spruce is a non-native species in Denmark and the most important of the non-native species there.

Expanding the number of commonly used tree species is also important for increasing the adaptation capacity of our forests to the future challenges of climate change, pests and diseases to avoid large scale disasters with dying or dead forests. More commonly used species in our forests - native as well as non-native - represents, however, at strategy of an increased spread of risk, that seems highly needed when looking at today's situation with forestry and forest industries depending on only two main species.

Nobody knows what specific challenges the future will pose on our forests, their health and thus their productivity. Therefore, this issue about spreading the risk is clearly an issue of the unknown future with all the uncertainties involved.

Genetic improved trees

The potential gain by using genetically improved material typically <u>20-50 % by 2050</u>.

The potential genetic gain fostered by breeding programs depends on the tree species and the intensity of the breeding program - for example whether it is based on seed from seed orchards or selection of clones [62].

Additionally, a breeding program does need time before it can be applied in practice. If resting on seed orchards it will typically need 10-20 years from establishment of the orchards until production of seeds reaches a profitable level, whereas a breeding program based on clonal material can be implemented with shorter notice [62].

For example, the current average genetic gain is 10-15% of Norway spruce based on existing seed orchards compared to unimproved material, whereas by 2050 it is expected to be 20-25 %. However, by using clonal material it is almost immediately possible to gain approximately 25-35% additional growth and by 2050 a 40% gain is attainable [62].

Nurse crops

The additional production the first 15-25 years following regeneration is not well documented in literature. ENERWOODS has provided a new generation of field experiments to provide this knowledge and documentation. In the meantime we have to rest upon initial field studies on indicated average levels of additional production in the range <u>70 - 200 % the first 15-25 years following regeneration</u> - very much depending on species mixtures, site and stocking densities [63].

What the final result will be for the average production over the entire rotation is not known but we expect it to be considerably lower.

Nurse crops are based on the use of pioneer species like poplar, aspen, birch, larch, alder and other species with fast initial growth mixed with often late successional and shade tolerant species (e.g. beech, Norway spruce, silver fir, Douglas fir, grand fir) that usually show a relatively slow growth for 10-20 years until they reach the polestage. Then they are usually very productive until the end of rotation (e.g. 50-100 years).

By utilizing these different growth dynamics it is possible to achieve much higher (e.g. 100 % or more) productivity in the regeneration and early stand phases. The nurse species provide shelter that favor survival of many desired and late successional species in the early regeneration phases, but also require careful management and thinnings in due time to later avoid detrimental competition and thereby damages of the intermixed late successional species.

Fertilization

Fertilization can shorten the rotation age and provide an average annual growth increase of app. 30% - an effect that very much depends on site, species and management in general [29, 64].

Fertilization is a common measure in Swedish and Finnish forestry and has been so since the mid-sixties but declined substantially in both countries to a very low level in the nineties and the first years of the new millennium. Fertilization in Norway, Denmark and Baltic countries has only been conducted on a small scale. However, fertilization has increased again and in 2010 amounted to 80 000 ha fertilized in northern Sweden and 65 000 ha in Finland. For economic reasons, fertilization is usually conducted in mature coniferous forests in operational forestry. The total forest area relevant for fertilization in Sweden is estimated to be 5.5 mio ha i.e. app. 25% of the productive forest area.

Afforestation

A production increase of more than 3 % of the total regional production is expected when the afforestation program is completed.

There is a potential to increase the forest area by 1.6–2 mio. hectares through afforestation of abandoned farmland. This area corresponds to a 3 % increase of the forest area [18, 29]. The farmland that now and in the future may become abandoned and subject to afforestation is expected to have both higher productivity and certainly better accessibility for intensive forest management. This indicates a future productivity that exceeds the average productivity for the regions where the specific areas are located.

Denmark has particularly high potential for afforestation, with a large gap between the current 14% of forest land to the political target of 20–25%.

Logistics

ENERWOODS results and the research elsewhere indicate that modern logistic systems should be based on larger transportation units – on trains and vessels on the long distances and on high-capacity trucks on short distances and on routes where no railway or waterway connection is feasible. Larger transportation units will increase the cost efficiency and reduce the emissions of logistics [65, 66, 67, 68, 69, 70, 71].

4. Perspectives

The IEA/NER report "Nordic Energy Technology Perspectives" [72] projects a 70 % increased consumption of biomass and waste to meet the needs of the ambitious Carbon Neutral Scenario by 2050. Additionally, the report projects a net biomass import to the Nordic region to fulfil this scenario.

We view the 50-100 % increase of forest growth at the stand scale as a conservative estimate of the forest potential to support a sustainable development of our societies towards a carbon neutral future. Additionally, we have the option to mobilize a higher utilization of the biomass from the forests now and in the future, which particularly could be a solution in a transition phase as the measures to increase forest growth are implemented.

Most of these measures - except fertilization and afforestation - depend on each forest stand to reach maturity and thereby the regeneration phase to establish new tree species, new species mixtures, improved genetic material and/or using the nurse crop method.

We therefore view it as a realistic scenario in the long run to fulfil the needs for domestically produced woody biomass in the Nordic region. However, societies need soon to decide to follow this sustainability trajectory of forests and forest management to avoid significant delay in relation to the 2050 goal of reaching carbon neutrality. There is only 35 years left, which roughly corresponds to half a forest stand rotation length in our region, and it is not possible now with great accuracy to state, whether this goal exactly can be met by 2050. Some delay may happen even if a suitable strategy is swiftly implemented; but the goals may also be met sooner than expected.

If the challenges met below are overcome, the strategy may not need significant additional operational investments to facilitate changed practices. Additional investments for training, education, research and development must be expected.

The high-productive forest scenario needed to meet the needs for more wood and woody biomass is expected to have a synergistic interaction with the past and ongoing development of more cost effective regeneration, thinning, harvesting and logistics methods. More productive forests will generally add to the cost effectiveness of interventions in the thinning and harvesting operations as the density of harvested timber and woody biomass will increase per hectare of forest. Besides, the rotation ages may be shortened as well as the first profitable intervention must be expected sooner than in today's forestry, which may improve profitability of investment.

5. Challenges

There are several challenges for a successful implementation of the measures needed to reach the potentials of forests and forest management.

Lack of understanding of sustainable forestry and forest functions in society

It is our sincere impression after having completed the ENERWOODS project that there is a significant lack of understanding in society in general and among decision makers of the dynamics and functions of forests. Consequently, there is also very little understanding of the potentials offered by forests and forest management for increased productivity and contribution to a sustainable development of society towards carbon neutrality.

Another aspect of this is the large historical increase in the forest productivity and standing volumes of wood in our forests the past 150-200 years is a development that is <u>not</u> known by many people. The potential pointed out by the ENERWOODS project to further increase forest productivity can be seen as a continued effort of past forest management efforts. The utilization of this potential is under pressure and the continued increase in productivity may not take place if it is not understood and recognized by society. For example, it is our impression that there is little understanding of the difference between sustainable forest management as it is practiced in the Nordic and Baltic region and then the unsustainable forest management and forest clearing as it is still being practiced in other parts of the World - particularly in the tropics. It seems that it is a common assumption among the public and decision makers that cutting trees in forests are harming the forest ecosystem, carbon storage and productivity as well as the environment in general.

Additionally, it is also our impression that many people do not know why wood and woody biomass is regarded renewable resources. Further, there seems to be a general lack of understanding of why the use of wood and woody biomass is much closer to be carbon neutral resources than fossil fuels and energy intensive materials as long as the use of wood is viewed in a time perspective relevant for a full forest stand rotation.

Another often overlooked fact in public debates is that our forests need to be managed and kept in the regeneration, young and middle aged stand development phases and harvested when they mature if our forests are supposed to maintain their function as an efficient carbon sink source of renewables. Otherwise, they grow into a senescent phase where their productivity drops and their function as a sink and as a source of renewables fades.

High productivity is not against nature conservation and biodiversity on the landscape scale

Stakeholders representing nature and biodiversity interests may often view increased production and harvest of wood and biomass as counterproductive in relation to their interests.

We view this as an oversimplified assumption and that high productive and sustainably managed forests both can support a low carbon society and provide good opportunities to support nature conservation and biodiversity, too.

This will, however, need proper prioritizing at the landscape level of forest functions is implemented to balance the various forest functions and management at the landscape level - but not necessarily at the stand level. Additionally, the contribution of high productive forestry to the habitats in the forest landscape is not zero and intensive forestry may as well provide habitats at the landscape level since it contributes with transition zones and variation in time and space.

To inform about these aspects we had for two of the final ENERWOODS conferences in Nødebo, Denmark, and Stockholm, Sweden, invited representatives from the WWF (WWF-Russia) and the FIBRIA company, Brazil, who both are involved in implementation of the "New Generation Plantations" approach [73, 74, 75]. It is coordinated by the WWF and aims at forest restoration and conservation while recognizing the importance of forest mitigation and adaptation, too.

Forest legislation and certification

Forest legislations and forest certification schemes in most of the Nordic and Baltic countries are very restrictive towards introducing non-native species and perhaps also in some areas improved genetic material. Especially, improved material based on clonal selection is often considered with skepticism due to fear of reducing the genetic variability too much.

Overall, decisions are needed to identify the balances between the important forest management objectives and forest ecosystem services. This leads to needs for decisions about where and how which measures of forest management can be used and how the various objectives of forest management can be pursued.

It is unrealistic to expect that all of the forest area would be subject to fully support the objectives of a carbon neutral future. Many other important management objectives such a nature conservation, biodiversity, recreation, wildlife and game management, ground water etc. are present and needs due attention.

Forest owners and managers need to have confidence in the future markets

The investments in high productive forest types are resting on the decisions of the forest owners and managers. Since forestry has a longer time perspective than most other sectors and industries there is also a need for the professionals to apply long time perspective in their analyses of the returns on the investments.

During the past decades forestry has experienced periods of very low market prices on the forest products. Even if an investment in high productive forest types may not require much higher investments in the regeneration phase forest owners and managers has to consider the risk of very poor markets for wood and woody biomass can happen again.

Climate change is by the Stern-report of 2006 called **"the greatest and widest-ranging market failure ever seen".** This market failure is caused by the fact that the World society and the consumers are not fully paying for the damages we do to the environment and the global climate by our consumption of fossil fuels. The renewables meet this strong competition on price from the fossil based products on the market - and the renewables have great difficulties competing in spite that they offer low-carbon or close to carbon neutral alternatives to the fossil products - but they are not paid for that service.

Forestry and forest industries providing wood based products and thereby renewable resources for society to the markets have for decades existed in an economic environment of very hard competition and sometimes poor demands for their products. That means there is always doubt whether about the profitability of investments in for example forest regeneration beyond the very basic level. Therefore, forestry and forest industry will be looking for firm commitments from society about the real will to meet the 2050 carbon neutral goals in order to provide the investments needed - even that these additional investments may be rather limited.

Other important challenges in practice

Other and more technical challenges include:

- The dense deer and moose populations pose by browsing, fraying (rubbing antlers against small trees) and bark stripping a significant threat of many desired tree species. In many regions these species now need protection by fences or other protection to successfully regenerate and establish the next forest generation. This may be very costly measures and practically unrealistic at large areas.
- Several of the described forest management measures are different from today's common practices which require additional training, revised education as well as continued research and development to support successful implementation of new practices.
- The risk of large scale disturbances of climate changes is a risk that needs due attention on the strategic level. We see for the moment such a large scale forest disturbance caused by insect outbreaks taking place in the north-western North America (Oregon, Washington, British Columbia). In these partly remote areas there is not sufficient forest management, forest industry capacity or infrastructure to cut and utilize all this dead wood. Instead of utilizing the wood and contribute to carbon neutrality the disturbance now fosters a large CO_2 pulse into the atmosphere without replacing fossil fuels or energy intensive materials. In a similar scenario the situation would probably be somewhat different in the Nordic and Baltic regions because of a relatively larger industrial capacity and better infrastructure, but we still need to counteract the risk of having large scale forest disturbances by growing more tree species to spread the risk.

6. Time perspective

Some of the measures suggested by ENERWOODS to increase the forest mitigation and adaptation capacity in the Nordic and Baltic regions can be implemented with short notice (fertilization and afforestation). The most important and powerful measures require, however, introduction of more or new tree species, improved genetic material and/or nurse crops. These measures need to wait until the presents stands mature and reach the harvest and regeneration phase before they can be implemented.

A common rotation length in the region is now typically 70 years - longer under colder climate and shorter under warmer and also very much depending on site conditions and species.

Consequently, a full implementation will take longer than the 70 years. However, the most productive sites are often managed by shorter rotations than 70 years and the majority of forest on the highest productive sites are likely to reach maturity before 2050 and has as such at least been regenerated and offered the chance to be regenerated by high productive species mixtures by then.

7. Nordic perspective

The large forest areas and the well-established forest management, forest industry and infrastructure in the Nordic and Baltic regions make us well prepared along all of the value chains to implement the more intensive management if the forest owners and industries have confidence in the profitability of the investments.

In spite of the formerly described lack of understanding of the potentials of forests and forest management among the public and decision makers it is our impression that this understanding is likely better in our region than in e.g. Europe in general. Forests and forest industries have been and are still important for our societies and as such many people are employed there, which we assume fosters a better than average understanding of these issues compared to Europe in general.

Woody biomass is already the largest contributor to our renewable energy systems so an increase of this component is likely to need relatively smaller additional investments to provide a high impact compared to other alternatives in the renewable energy systems.

It is our impression that there is a wide spread risk in the forestry and forest industry communities of our region that the lack of understanding for forest functions and forest management potentials in Europe in general may pave the road for decisions that may limit the intensity of forest management. Implemented at a European scale this may severely limit the EU and as such also our Nordic and Baltic regions in using the potentials to reach low carbon societies as described and perhaps even threaten the industries and activities as they are taking place today.

Climate change is generally expected to make today's climatic zones shift position in a northeastern direction. What are today's climatic conditions in Denmark and Southern Sweden may become the future climate for the trees we establish now and in the future at large areas in southern and central regions of the lowlands in Norway, Sweden, Finland and the Baltic states. Therefore, our well established Nordic - Baltic collaboration is also well suited to foster exchange of knowledge and experiences within particularly forest management and use of mores tree species than are commonly used today.

The Nordic perspective is therefore to act and speak with one voice to the EU and the rest of World, to highlight the important potentials of forests and forest management to contribute significantly to a sustainable and low carbon development of society. There are ongoing efforts to foster large scale forest landscape restoration on the wide spread degraded lands created by unsustainable landuse. These efforts are taking place under the "Bonn Challenge" and "New York Declaration" and have a growing attention on forest adaptation and mitigation of climate change [35, 76, 77]

A strong Nordic strategy on a similar effort within ongoing forest management and forest industry has the potential of showing global leadership on strengthening today's most important component - globally as well as regional - within the renewable resource and energy systems.

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Appendix 1
- technical summary of ressources, staff, collaboration and outputs

1. Project budget and accounts

Total project budget:	*Total amount in NOK* 18.603.085 (not including the budget of the Baltic partners)			
Financing from Nordic Energy Research:	*Total amount in NOK and Share of total project budget (%)* 14.000.001, 75% NER financing (not including the budget of the Baltic partners)			
Has the project received financing from other sources? If yes, please specify:				Yes X No ☐
Name of institution/company		*Indicate whether public or private*	*Country*	*Total amount in NOK*
Univ. Of Copenhagen (KU) – internal finance		Public	Denmark	1.665.436
Naturstyrelsen		Public	Denmark	315.790
Skogforsk – internal finance		Public	Sweden	843.000
Skogssällskapet		Private	Sweden	125.000
Energimyndigheten		Public	Sweden	25.000
METLA/LUKE Linnaeus Univ.(LNU) – internal finance Swedish Univ. of Agric. (SLU) – internal finance Swedish Fortifications Agency Univ. of Eastern Finland (UEF) – internal finance Finnish Environment Inst. (SYKE)–internal finance Norwegian For. Landsc. Inst. (NFLI/NIBIO) – (internal finance)		Public Public Public Public Public Public Public	Finland Sweden Sweden Sweden Finland Finland Norway	246.331 400.000 350.648 177.000 30.000 30.000 394.880 Total: 4.603.085

2. Project organisation

Total number of participants:	*Total number (39) of which women (10)* *Bernt Håvard Øyen, NFLI/NIBIO, Norway, is no longer at our list since he resigned earlier in 2012.* *Søren Schmidt Thomsen (Danish District Heating) has replaced Henrik Andersen (Danish District Heating) in the Advisory Board. Søren Schmidt Thomsen left Danish District Heating in April 2014.*
Project steering	*Please list name, title, institution, country* 1. Associate Professor, Lars Rytter, Skogforsk, Sweden

group:	2. Scientist, Head of Section, Bruce Talbot, Norwegian Forest and Landscape Institute (NFLI/NIBIO) 3. Senior Researcher, Perttu Anttila, METLA/LUKE, Finland 4. Professor, Leif Gustavsson, Linnaeus University (LNU), Sweden 5. Professor, Magnus Löf, Swedish Univ. of Agric. Sciences (SLU) 6. Senior Researcher, Antti Kilpeläinen, Finnish Environment Institute (SYKE), Finland 7. Academy Professor, Seppo Kellomäki, University of Eastern Finland (UEF) 8. Professor Peeter Muiste, Estonian Univ. of Life Sciences (EULS) 9. Senior Researcher, Dagnija Lazdina, Latvia State Forest Research Inst. (SILAVA) 10. Project Owner, Head of Dept., Vivian Kvist Johannsen, University of Copenhagen (KU), Denmark 11. Project Secretary, Associate Professor, Inge Stupak, KU 12. Project Manager, Professor, Palle Madsen, KU *Total number (12) of which women (3)*
PhD candidates:	*Please list name, title, institution, country* 1. Ph.D. Student, now PhD, Researcher, Johanna Routa, METLA/LUKE, Finland 2. Ph.D. Student, Rebecka Mc Carthy, Skogforsk (enrolled at SLU), Sweden – begins her Ph.D. study by 5. March 2012. 3. Ph.D. Student, Civil Engineer Sylvia Haus, LNU, Sweden - began her Ph.D. study by 20. February 2012. 4. Ph.D. Student, Anders Tærø Nielsen, HedeDanmark (enrolled at KU), Denmark – began his Ph.D. study by 1. May, 2012. 5. Ph.D. Student, Petros Georgiadis, KU, Denmark – began his Ph.D. study by 15. September, 2012. 6. Ph.D Student, Marek Irdla, Estonian University of Life Sciences – began his Ph.D study by September, 2012 7. Ph.D Student, Johannes Windisch, METLA/LUKE, Finland – began his Ph.D. study by 1. April. 2009 8. Ph.D Student Arta Bardule, Silava, Latvia – began Ph.D studies by September 2011 (Latvia Universitu faculty of chemistry - supported just by data from ENERWOODS) 9. Ph.d student Santa Kaleja, Silava, Latvia – began Ph.D studies by September, 2011. (Latvia Agriculture University Forest faculty - supported just by data from ENERWOODS) Most of the students are co-funded from other sources including own finance from the universities. Most of the students have not yet defended their theses. A PhD-project usually takes more than the four years that is standard duration because they often add leaves for specific work tasks or for maternal leaves. Besides, several of the students started several month later than the start of the ENERWOODS project. *Total number (9) of which women (5)*
Post-docs:	*Please list name, title, institution, country* 1. Assistent Professor (Post Doc), Niclas Scott Bentsen, KU ENERWOODS supports one Post Doc position. In the Project Contract it is stated that the project supports two. In the 2012 Status report it was described how Inge Stupak changed her position to become permanent staff instead of Post Doc. The finance from other sources in Norway to support the Post Doc position of Helmer Belbo did not come through as expected – so we are down to one Post Doc position. Instead we have more Phd. Students involved and supported by ENERWOODS than stated in the Project Contract. *Total number (1) of which women (0)*

Other project participants:	*Please list name, title, institution, country* *(This list includes all staff members - not only scientific staff - that have been paid salary from the project - from a few hours to several month)* 1. Senior Researcher, Andis Lazdins, SILAVA, Latvia 2. Senior researcher, Mudrite Daugaviete, SILAVA, Latvia 3. Researcher, Allar Padari, EULS, Estonia 4. Professor, Antti Asikainen, METLA/LUKE, Finland 5. Professor, Eero Kubin, METLA/LUKE, Finland 6. Researcher, Mikko Nivala, METLA/LUKE 7. Researcher, Miina Jahkonen, METLA/LUKE, Finland 8. Senior researcher, Juha Laitila, METLA/LUKE, Finland 9. Secretary, Leena Karvinen, METLA/LUKE, Finland 10. Senior Researcher, Lars-Göran Stener, Skogforsk, Sweden 11. Secretary, Lynn Karlsson, Skogforsk, Sweden 12. Laboratory assistant, Vera Rytter, Skogforsk, Sweden 13. Associate Professor, Johan Bergh, SLU, Sweden 14. Associate Professor, Per Magnus Ekö, SLU, Sweden 15. Professor, Roger Sathre, LNU, Sweden 16. Senior researcher, Kjell Andreassen, NFLI/NIBIO, Norway 17. Researcher, Helmer Belbo, NFLI/NIBIO, Norway 18. Engineer Hans Nyeggen, NFLI/NIBIO, Norway 19. Engineer Wibecke Nordstrøm, NFLI/NIBIO, Norway 20. Adviser Jan Ole Skage, NFLI/NIBIO, Norway 21. Senior Adviser Stein Tomter, NFLI/NIBIO, Norway 22. Lead Engineer Stig Støtvig, NFLI/NIBIO, Norway 23. Researcher, Anne Holma (SYKE, Finland) 24. Researcher, Tiia Grönholm (SYKE, Finland) 25. Senior Reseatorrcher, Morten Ingerslev, KU, Denmark 26. Webpage and budget manager, Karin Kristensen, KU, Denmark 27. Senior Researcher, Thomas Nord-Larsen, KU, Denmark 28. Conference organizer, Britt Majgaard, KU, Denmark 29. Senior Researcher, Ulrik Braüner Nielsen, KU, Denmark 30. Senior Consultant, Simon Skov, KU, Denmark 31. Senior Consultant, Kjell Suadicani, KU, Denmark 32. Senior Researcher, Lars Vesterdal, KU, Denmark *Total number (32) of which women (10)*

Have potential users been involved in the project? If yes, please specify:		Yes X No ☐
Name of institution/company	*Country*	*Role in project (e.g. steering group member, financier, expert)*
EFINORD – North European Regional Office, European Forest Institute, Head of Office Mika Mustonen, mika.mustonen@efi.int	Nordic	Advisory board member. Mika Mustonen left EFINORD by 1. Jan. 2015
Metsähallitus, Development Manager Tore Högnäs, tore.hognas@metsahallitus.fi	Finland	Advisory board member, participated in ENERWOODS Thematic Day
Skåneskogens Utvecklings AB, Director Esben Møller Madsen, emm@skaneskogen.se	Sweden	Advisory board member and hosting fertilization experiment in poplar conducted by Anders Tærø Nielsen, KU, and Inge Stupak, KU and participated in ENERWOODS Thematic Days, Final Conference as well as authoring and co-authoring ENERWOODS publications.
Holmen Skog, FoU-Chef Erik Normark, erik.normark@holmenskog.com	Sweden	Advisory board member, participated in ENERWOODS Thematic Day and Final Conference
Göteborgs energi, Jägmästare Karl	Sweden	Advisory board member, participated in

Sandstedt, karl.sandstedt@goteborgenergi.se		ENERWOODS Thematic Days
Borregaard, Vice President Business Development Gisle L. Johansen, gisle.l.johansen@borregaard.com	Norway	Advisory board member. Facilitated Borregaards presentation at the Final Conference.
HedeDanmark, Director Michael Glud, mgl@hededanmark.dk	Denmark	Advisory board member, participated in ENERWOODS Thematic Days and serves as industry partner host and co-advisor for Ph.D. student Anders Tærø Nielsen. Facilitated HedeDanmarks presentations at Final Conference and Final Thematic Day in Denmark.
Danish District Heating Association, Chief Advisor, Søren Schmidt Thomsen, sst@danskfjernvarme.dk	Denmark	Advisory board member, participated in ENERWOODS Thematic Days
DONG Energy, Purchase Manager of Biomass, Tonny Sørensen, tonso@dongenergy.dk	Denmark	Advisory board member
Stora Enso Ltd.	Finland	Provided data and for paper WP2-D4
Fortum Ltd.	Finland	Provided data and for paper WP2-D4
Keravan Energia Oy	Finland	Excursion host at the roadshow on 19 June
13 forest districts and administrations Denmark, Sweden, Latvia and Finland	Denmark Sweden Latvia Finland	Hosting demonstration and other field experiments

3. Project progress

a) Summary of the past year

Please describe the most interesting and innovative developments in your project in the last 12 months (max 800 signs). See final report, above.

b) Work progress

Has the project progress generally been according to plans?	Yes X No ☐
Short report regarding progress and main findings according to work packages /milestones (max 800 signs): Covered by final report above.	

b) Time schedule and possible deviations

Has the project progress been according to time schedules?	Yes X No ☐
Have there been major deviations?	Yes ☐ No X
Covered by final report above	

4. Networks, co-operations, seminars and mobility

a) Co-operation/networks

Has the project co-operated with other projects/networks? (e.g. joint application for EU projects etc.) If yes, please specify: *Comment: The project partners are in their on-going research and development involved in numerous networks and projects – national, Nordic, EU and international - and more or less related to the goals and topics of ENERWOODS. Here we list selected networks which are highly ENERWOODS related by e.g. co-funding Ph.D. students or by including several ENERWOODS participants. Only ENERWOODS participants including Advisory Board members of the networks are listed in this table.*		Yes X	No ☐
Nordic X EU ☐ International ☐ Nordic Forest Research Co-operation Committee (SNS)	*Name of network/project* OSCAR – Operation Systems - Centre of Advanced Research	*Coordinator/ Key Participant(s)* Dagnija Lazdina and Andis Lazdins, SILAVA Peeter Muiste, EULS Antti Asikainen, Perttu Anttila and Johanna Routa, METLA/LUKE Bruce Talbo, NFLI/NIBIO Kjell Suadicani, KU	*Main benefits/ results* Additional demonstration field trials. Update on latest findings and news within forest operations and logistics (WP2)
Nordic ☐ EU ☐ International X	*Name of network/project* National Poplar Commission of Sweden, which is member org. of the FAO - International Poplar Commission	*Coordinator/ Key Participant(s)* Lars Rytter, Skogforsk Dagnija Lazdina, Silava	*Main benefits/ results* International update on latest findings and news within silviculture of poplar

Nordic ☐ EU X International ☐	*Name of network/project* EU COST Action FP0902 “Development and Harmonization of new operational research and assessment procedures for sustainable forest biomass supply	*Coordinator/ Key Participant(s)* Antti Asikainen, Perttu Anttila and Johanna Routa, METLA/LUKE Dagnija Lazdina and Andis Lazdins, SILAVA Bruce Talbot, NFLI/NIBIO Kjell Suadicani, KU Peeter Muiste and Allar Padari, EULS	*Main benefits/ results* Update on latest findings and news within forest operational research at the EU level
Nordic ☐ EU ☐ International X	*Name of network/project* Cenbio Bioenergy Innovation Centre	Bruce Talbot and Helmer Belbo, NFLI/NIBIO	Update on latest findings and news within develpment of sustainable and costeffective bioenergy systems including both biomass and waste products.
Nordic X EU ☐ International ☐ Danish Research Council funded project	*Name of network/project* **Bioresource** project: Environmental consequences of intensive biomass production	*Coordinator/ Key participant(s)* Inge Stupak and Petros Georgiadis, KU	*Main benefits/ results* Collaboration between Danish parti-cipants of the cooperation project and the two Ph.D. students on poplar fertilization experiments – the other being Anders Tærø Nielsen (WP1)
Nordic X EU ☐ International ☐ Danish Industry Ph.D. project funded by HedeDanmark	*Name of network/project* Modeling growth and productivity of poplar in relation to site and fertilization treatments	*Coordinator/ Key Participant(s)* Inge Stupak and Anders Tærø Nielsen, KU Michael Glud, HedeDanmark	*Main benefits/ results* Collaboration between Danish participants of the cooperation project and the two Ph.D. students on poplar fertilization exp. – the other being Petros Georgiadis (WP1)
Nordic X EU ☐ International ☐ Swedish Energy Agency funded projects	*Name of network/project* Research and development of forest management methods to sustainably produce biomass	*Coordinator/ Key Participant(s)* Lars Rytter, Lars-Göran Stener, Rebecka McCarthy, Skogforsk	*Main benefits/ results* The Swedish Energy Agency supports the research projects that are part of or closely related to ENERWOODS. The Agency does also facilitate networkning and collaboration between research and practise.

Nordic ☐ EU X International ☐	*Name of network/project* EU COST Action FP1206 EuMIXFOR	*Coordinator/ Key Participant(s)* Magnus Löf, SLU Palle Madsen, KU Dagnija Lazdina, Silava	*Main benefits/ results* EuMIXFOR aims at creating a European research network on mixed forests, which can contribute to the increase of knowledge of adaptive forestry, the sustainability of management and the conservation and improvement of mixed forests
Nordic ☐ EU X International ☐	*Name of network/project* EU COST Action FP1301 EuroCOPPICE	*Coordinator/ Key Participant(s)* Kjell Suadicani, KU Magnus Löf, SLU Dagnija Lazdina, Silava	*Main benefits/ results* The COST Action to bring together European scientists, experts and young scholars to exchange knowledge about coppice forestry and to start developing innovative management and utilization concepts/techniques
Nordic ☐ EU X International ☐	*Name of network/project* METY-project ("A tool for estimating environmental and economic impacts of forest energy biomass production –METY"), (proj. A32172, European Regional Development Fund)	Coordinator/ Key Participant(s) Antti Kilpeläinen SYKE UEF METLA/LUKE	*Main benefits/ results* Developing methodologies for assessing environmental and economic impacts of energy biomass production and its utilization in substituting fossil energy
Nordic x EU ☐ International ☐	*Name of network/project* ADAPT-project ("Adaptation of forest management to climate change: uncertainties, impacts, and risks to forests and forestry in Finland (proj. 14907, Academy of Finland)	Coordinator/ Key Participant(s) Antti Kilpeläinen, UEF FMI (Finnish Meteorological Institute)	*Main benefits/ results* Assessing the net climate impacts of forest bioenergy
Nordic x EU ☐ International ☐	*Name of network/project* SUBI-project (Sustainable bioenergy, climate change, and health (proj. 931081 UEF strategic funding)	Coordinator/ Key Participant(s) Antti Kilpeläinen, UEF	*Main benefits/ results* Integration of sustainable bioenergy production and utilization, climate change and human health issues
Nordic x EU ☐ International ☐	*Name of network/project* Nordic Forest Research Co-operation Committee (SNS)	Coordinator/ Key Participant(s) Perttu Anttila, Mikko Nivala, METLA/LUKE	*Main benefits/ results* Update on latest findings and news within forest operations and logistics (WP2)

Nordic International X	*Name of network/project* Intelligent Energy for Europe Programme of the European Commission project "Short Rotation Woody Crops (SRC) plantations for local supply chains and heat use Project No: IEE/13/574"	Coordinator/ Key Participant(s) Dagnija Lazdina, Silava	*Main benefits/ results* Support and speed-up the development of local supply chains of Short Rotation Woody Crops (SRC) by implementing various capacity building measures and regional mobilization actions for the key actors in local supply chains.
Nordic x EU ☐ International ☒	*Name of network/project* IEA Bioenergy Task 43 'Biomass feedstocks for Energy Markets'	Coordinator/ Key Participant(s) Göran Berdnes C. Tat Smith **Inge Stupak**	Main benefits/ results Research collaboration on sustainability of forest biomass supply chains

b) Conferences

Has the project organised PhD courses/summer schools/conferences/workshops? If yes, please specify: **In total:** **19 conferences, workshops, seminars, or courses.**		Yes ☐		No ☐
Type of event	*Title of event*	*Date(s), host institution, country*	*Number of partici-pants*	*Main benefits/ results:*
Workshop/forest excursion	Thematic Day, Denmark: High-productive forestry for a sustainable future	19. June, 2012, KU in cooperation with Prosilva Denmark	102	Dissemination and input from end-users in relation to ENERWOODS objectives, challenges, and content
Workshop/forest excursion	Thematic Day, Sweden: Forest bioenergy and bioenergy systems	28. August, 2012. Skogforsk and SLU, Sweden	42	Dissemination and input from end-users in relation to ENERWOODS objectives, challenges, and content
Workshop/forest excursion	Thematic Day, Finland: Boosting the resource base and supply of forest energy	4. September, 2012. METLA/LUKE, Finland	30	Dissemination and input from end-users in relation to ENERWOODS objectives, challenges, and content
Scientific seminar S11	Research Seminar on Precision Supply of Forest Biomass for Energy	3. September, 2012, METLA/LUKE, Finland	20	The purpose was creating an up-to-date overview of the cost saving potential of precision supply of woody biomass in relation to latest developments in biomass energy systems to meet the power and heat generation fluctuations at biomass plants. The seminar was very useful in that respect

PhD-course	Forest Restoration in Theory and in Practise, 3 ECTS	10-14 Dec. 2012, SLU, Höör, Skåne, Sweden	17 students	The purpose was to provide a deeper knowledge of different restoration approaches and what factors are determining the success. Additionally, it provides insight into research opportunities in disturbed forest ecosystem and to explore the challenges of restoration in light of carbon offset proposals
Scientific seminar S12	Intelligent use of biomass	29. April, 2013, KU, Frederiksberg, Denmark	20	Discuss and put the use of woody biomass in perspective of forest contributions to a sustainable development of societies. The complexity of the LCA and strategic analyses will be demonstrated and the critical selection of the pre-assumptions that such analyses rest on will be highlighted.
3rd Project Management Meeting incl. Roadshow	Silviculture as a tool to reduce GHG emissions and increase CO_2 removals in forests in long term perspective	25. June 2013, SILAVA, held at Ministry of Agriculture, Riga	25	Presentations and exchanges of Latvian perspectives on forests and woodbased energy systems in relation to ENERWOODS objectives, challenges, and content
PhD-course	Management of forest ecosystems for bioenergy, with implications for climate change mitigation (4 ECTS)	2-6 Sept. 2013, UEF, Joensuu, Finland	18	To provide PhD students the basic and up-to-date knowledge on carbon cycling mechanisms in (boreal) managed terrestrial ecosystems and how energy biomass is produced in a sustainable way to substitute fossil fuels and to reduce CO_2 emissions in energy production, with potentials to mitigate climate change in forest management.
Thematic Day for end-users	Poplar – a nurse as well as a high-productive tree species	17. Sept. 2013, KU, SLU, Advisory board member and international colleagues Rudkøbing and Lohals, Langeland, Denmark	25	Update participants on scientifically based knowledge on the use of poplar and other pioneer species as nurse crops to increase forest productivity and support the main species in the regeneration phase.
Course organized by Skogforsk for the Swedish Forest Agency	High-productive broadleaves and conifer species	Ekebo, Scania, Sweden, 3. June 2014	20	Update participants on scientifically based knowledge on the use of high-productive species of broadleaves (particularly poplar and aspen) as well as conifers
Excursion/seminar for end-users:	Broadleaves for the future (Lövskog för framtiden)	17. June, 2014, SLU Snogeholm	150	20 short presentations to provide updated knowledge and recommendations on broadleaf silviculture focussing at the links to issues of mixed forests, nature conservation and bioenergy
5th Project	Bio-fuelled	19. June, 2014,	25	ENERWOODS presentations at

Management Meeting incl. Roadshow for endusers	combined power and district heating and Non-native species in Finnish forestry	METLA/LUKE, Vantaa, Finland		METLA/LUKE followed by a visit at Keravan Energia Oy and a field trip to experimental forest
Workshop/forest excursion	Thematic Day, Norway: Intensive silvicultural approach elevates the forest productivity (Aktiv skogskjøtsel øker biomasseproduksjo n)	26. August 2014, NFLI/NIBIO, Ås, Norge	35	ENERWOODS presentations at METLA/LUKE as well as presentations by representative from industry followed by a field trip to field study at Skiptvet including the productivity of mixed birch and spruce stands
Seminar/forest excursion	ENERWOODS Final Thematic day - Latvia: Adaptation and mitigation: Strategies for management of forest ecosystems	23-24. April 2015 Latvian State Forest Research Institute, Silava	40	Improvement of tree growth (breeding, soil preparation, fertilization), bioenergy production and natural disturbances (including the effect on forest carbon balance Proeceedings available online http://www.silava.lv/userfiles/file/Pasakumi/2015_04_Adapt_konf_Book_of_Abstracts.pdf
Seminar/forest excursion	ENERWOODS Final Thematic day - Finland	4. May 2015, Natural Resources Institute Finland (METLA/LUKE), Oulu, Finland	23	Involvement and discussions of ENERWOODS results and perspective with forest managers and researchers with focus at the northern boreal forests
Conference / excursion	ENERWOODS Final Thematic day - Denmark: Joint conference - IEA Bioenergy Task 38 Climate Change Effects of Biomass and Bioenergy Systems Conference and ENERWOODS Conference 27th May, 2015, Växjö Wood based energy systems from Nordic and Baltic Forests - A Nordic Research project	26-27. May 2015, Växjö, Sweden	20-40	Involvement and discussion between Life Cycle Analyses, biomass and forest resarchers as well as managers and decision-makers within biomass and forest industry
Seminar/International conference	ENERWOODS Final Thematic day - Denmark: Skovenes dobbeltrolle: Tilpasning til og modvirkning af klimaforandringer	25. Aug. 2015 Skovskolen, IGN, Københavns Univ., Nødebo	60	Organized in collaboration with Pro Silva Danmark. Involvement and discussions of ENERWOODS results and perspective with forest managers, certification organisation, industry, nature protection NGOs and researchers - including invited

				speakers from Brasil, Russia and British Columbia
International conference	ENERWOODS Final International Conference: Wood based energy systems from Nordic and Baltic Forests - how to increase forest productivity and adaptation in tandem with more efficient use of the wood	27. Aug. 2015 The Royal Swedish Academy of Agriculture and Forestry, Stockholm	40	Involvement and discussions of ENERWOODS results and perspective with forest managers, industry, agencies, nature protection NGOs and researchers - including invited speakers from Brasil, Russia and British Columbia
Seminar/forest excursion	ENERWOODS Final Thematic day - Norway: Økt biomasse-produksjon som klimatiltak – muligheter og utfordringer på Vestlandet	23. Sept. 2015 Stend videregående skole v. Bergen, Norge	25	Involvement and discussions of ENERWOODS results and perspective with forest managers, industry, and researchers

c) Mobility

Has there been international exchange and mobility in the project? If yes, please specify:		Yes X		No ☐
Name, role in project *(PhD student, post.doc. etc.)*	*Home institution, country*	*Host institution, country*	*Period*	*Main benefits/ results:*
PhD student Rebecka Mc Carthy	SLU and Skogforsk	USDA, Forest Service, Southern Research Station at the Center for Bottomland Hardwoods Research in Stoneville, Mississippi, USA (Dr. Emile Gardiner)	8 Sept. 2014 - 8. Dec. 2014	Study of root and shoot development of poplars under different water regimes – scientific publication and dissertation in prep.

Master theses:

- **Urbas, A.** 2014. Cost analysis of utilization of wood chippers – a case study. EULS. Data has contributed to WP2.
- **Asmussen, R.V.** 2015. Potentials for increasing biomass production in the regeneration phase of beech by use of nurse crops. Can we increase biomass production without reducing the long-term

potential for high quality timber production? MSc. Thesis. Department of Geosciences and Natural Ressource Management, University of Copenhagen. 109 pp

5. Results

a) PhD degrees

Has the project produced PhD degrees? If yes, please specify:			Yes X	No ☐
Name, gender, nationality	*Home institution, country*	*Title of thesis*	*Date*	
Johannes Windisch, male, German	METLA/LUKE	Process redesign in development of forest biomass supply for energy	27. Feb. 2015	

b) Academic publications

Has the project produced academic publications? If yes, please, specify number of publications. *Please list them here or attach a list of publications as a separate document*	Yes X	No ☐

Number of publications

ENERWOODS participants are **highlighted.** Total number of publications does not include "publications related to the ENERWOODS project"**.** The "submitted" and "in prep" publications do not include all of what is in the pipeline of the project.

Total number of publications

Published including "in press", "early view" and "accepted"**:**

95 ENERWOODS publications including 20 peer reviewed journal papers.

Additionally, 50 publications were published and related to ENERWOODS of which 16 were peer reviewed journal papers.

At the moment **four ENERWOODS publications and one related to ENERWOODS** have been submitted for publication.

More are in the pipeline ("in prep"), but not listed here.

Number of publications in:

International journals - peer review (referee system)

Published**: 20**

Submitted**: 4**

1. **Routa, J., Asikainen, A.**, Björheden, R., Laitila, J. and Röser, D. 2012. Forest energy procurement- state of the art in Finland and Sweden. Wiley Interdisciplinary Reviews: WIREs Energy and Environment 2012. doi: 10.1002/wene.24.
2. **Routa, J., Kellomäki, S.,** Strandman, H.**, Bergh, J.,** Pulkkinen, P., Peltola, H. 2012. The timber and energy biomass potential of intensively managed cloned Norway spruce stands. GCB Bioenergy 5: 43-52.
3. Øyen, B.-H., Nilsen, P., Bøhler, F. & **Andreassen, K.** 2012. Predicting individual tree and stand diameter increment responses of Norway spruce (*Picea abies* (L.) Karst.) after mountain forest selective cutting. *Forestry Studies/Metsanduslikud Uurimused* 55: 33–45.
4. **Mc Carthy, R., Ekö, P.-M. & Rytter, L.** 2014. Reliability of stump sprouting as a regeneration method forpoplars: clonal behaviour in survival, sprout straightness and growth. *Silva Fennica* 48(3), http://dx.doi.org/10.14214/sf.1126.
5. **Nielsen, U.B., Madsen, P.,** Hansen, J.K.**, Nord-Larsen, T., Nielsen, A.T.** 2014. Production potential of 36 poplar clones grown at medium length rotation in Denmark. Biomass and Bioenergy 64, 99-109.
6. Hedwall, P.-O., Gong, P., **Ingerslev, M**., **Bergh, J**. 2014. Fertilization in northern forests – biological, economic and environmental constraints and possibilities. Scandinavian Journal of Forest Research, 29: 301-311.
7. **Haus, S., Gustavsson, L., Sathre, R.** 2014. Climate Mitigation Comparison of Woody Biomass Systems with the Inclusion of Land-use in the Reference Fossil System. Biomass and Bioenergy. 65. 136-144.
8. **Löf, M.,** Bolte, A., Jacobs, D. & Jensen, A. 2014. Nurse trees as a forest restoration tool for mixed plantations: Effects on competing vegetation and performance in target tree species. Restoration Ecology 22:758-765
9. **Gustavsson, L., Haus, S.,** Ortiz, C.A., **Sathre, R.**, Truong, N.L. 2015. Climate effects of bioenergy from forest residues in comparison to fossil energy. Applied Energy. 138. 36-50.
10. **Mc Carthy, R., Rytter, L.** 2015. Productivity and thinning effects in hybrid aspen root sucker stands. Forest Ecology and Management 354: 215-223.
11. **Rytter, L., Andreassen, K., Bergh, J., Ekö, P.-M.,** Grönholm, T., **Kilpeläinen, A., Lazdina, D., Muiste, P., Nord-Larsen, T.** 2015. Availability of biomass for energy purposes in Nordic and Baltic countries – land areas and biomass amounts. **Accepted** for publication in **Baltic Forestry 21 (2).**
12. **Kilpeläinen, A.,** Torssonen, P., Strandman, H., **Kellomäki, S., Asikainen, A**. and Peltola, H. 2015. Net climate impacts of forest biomass production and utilization in managed boreal forests. Global Change Biology Bioenergy**. Early View.**
13. Torssonen, P, **Kilpeläinen, A**., Strandman, H., **Kellomäki, S**., Jylhä, K., **Asikainen, A**. and Peltola, H. 2015. Effects of climate change and management on net climate impacts of production and utilization of energy biomass in Norway spruce with stable age-class distribution. Global Change Biology Bioenergy. **Early View.**
14. **Windisch, J.**, Väätäinen, K., **Anttila, P.**, **Nivala, M.**, **Laitila, J.**, **Asikainen, A.** & Sikanen, L. 2015. Discrete-event simulation of an information-based raw material allocation process for increasing the efficiency of an energy wood supply chain. Applied Energy 149: 315-325**.**
15. **Nivala, M.**, **Anttila, P.** & **Laitila, J.** 2015. A GIS-based comparison of alternatives for long-distance transportation of energy wood from young inland forests to the coast of Finland. International Journal of Forest Engineering. **Accepted .**
16. **Belbo, H. & Talbot, B**. 2014. Systems analysis of ten supply chains for whole tree chips. Forests 5(9): 2084-2105.
17. **Stupak I,** Joudrey J, Smith CT, Pelkmans L, Chum H, Cowie A, Englund O, Goh CS, Junginger M. 2015. A global survey of stakeholder views and experiences for systems needed to effectively and efficiently govern sustainability of bioenergy. WIREs Energy & Environment 2015. doi: 10.1002/wene.166. **in press.**
18. **Taeroe A, Nord-Larsen T, Stupak I**, Raulund-Rasmussen K (2015). Allometric Biomass, Biomass Expansion Factor and Wood Density Models for the OP42 Hybrid Poplar in Southern Scandinavia. Bioenergy Research, 8:1332–1343. DOI 10.1007/s12155-015-9592-3.
19. Pyörälä, P., Peltola, H., Strandman, **H., Kilpeläinen, A., Asikainen,** A, Jylhä, K. **and Kellomäki, S**. 2014. Effects of management on economic profitability of forest biomass production and carbon neutrality of bioenergy use in Norway spruce stands under the changing climate. Bioenergy Research 7:279-294.
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126. **D. Lazdina**, A. Bardulis, A. Bardule, **A. Lazdins**, M. Zeps, A. Jansons The first three-year development of ALASIA poplar clones AF2, AF6, AF7, AF8 in biomass short rotation coppice experimental cultures in Latvia / // Agronomy Research. - No.12(2) (2014), p.543-552.
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136. Jansons, A., Zurkova, S., **Lazdina, D.**, Zeps, M. (2014). Productivity of poplar hybrid (Populus balsamifera x P. laurifolia) in Latvia / // Agronomy Research. - No.12(2), p.469-478.
137. **Lazdina, D.**, Liepins, K., **Bardule, A.,** Liepins, J., Bardulis, A. (2013). Wood ash and wastewater sludge recycling success in fast-growing deciduous tree birch and alder plantations / // Agronomy Research. - No.11(2) (2013), p.347-356.
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139. **Rytter, L.,** Persson, P.-O., Johansson, T., Hjelm, B. 2015. Checklista inför etablering av hybridasp- eller poppelodling. Skogforsk, Webbartikel nr 822015, Uppsala, 2 p.

c) Other publications / information activities

Which channels have been used for information activities?	Daily press ☐	Popular scientific magazines/ newsletters ☐
	WEB ☐	Social media ☐

Please specify (channel e.g. name of newspaper, name of web-site, author/person interviewed, date etc.)

Other publications

Published**: 10**

140. **Anttila, P**. 2013. ENERWOODS – pohjoismaisella yhteistyöoä tehoa puubiomassan kasvatukseen ja hankintaan. METLA/LUKE Newsletter
141. **Routa. J., Anttila, P.** & Lindroos, M. Enerwoods - energising the cultivation and procurement of woody biomass through Nordic cooperation. METLA/LUKE bulletin 22.10.2012. Available at: http://www.METLA/LUKE.fi/uutiskirje/bulletin/2012-03/.
142. **Felby, C., Madsen, P., Bentsen, N.S., Graudal, L.** 2013. Bioenergianalyser er faret vild I skoven. Ingeniøren, Kronik 3. October 2013.
143. **Madsen, E.M & Hilbert, P**. 2013. Sund skov kan sagtens være højproduktiv. Kronik i Weekendavisen 22. February 2013.
144. Rothenburg, M. (interview m. Poul Norup og **Palle Madsen**) 2003. Danmark er allerede for varmt til rødgran. Politiken, 27. Jan. 2013.
145. **Madsen, P.** 2013. What shall we do with our forests: Recognize high productivity as a sustainablility criterion. NBForest Blog 12. April 2013. http://www.nbforest.info/blog/what-shall-we-do-our-forests-recognize-high-productivity-sustainability-criterion
146. **Madsen, E.M. & Madsen, P.** 2013. Urørt skov er ikke den eneste vej. Indlæg i Altinget 9. september 2013.
147. Roga A. (interwiew with Dagnija Lazdina) Jauna lauksaimniecības prakse?, Baltijas koks, 2015 septembris http://www.silava.lv/userfiles/file/Aktualitates/2015_09_17_BK_1.pdf ¨
148. Hannerz, M., **Rytter, L., Madsen, P., Anttila, P.** 2015. Skogen visar vägen till et förnybart Norden. http://www.skogforsk.se/kunskap/kunskapsbanken/2015/skogen-visar-vagen-till-ett-fornybart-norden
149. Segerstedt, R. 2015. Forskare: Skogen kan ge mer energi. Skogsland 35, 21. Aug. 2015, 5.

Presentations: 52

NB! This list of presentation does not include the presentations of events organized by ENERWOODS (e.g. ENERWOODS Thematic Days) or our teaching of BSc and MSc levels at the universities

12. March 2012: **Vivian Kvist Johannsen** represents ENERWOODS and gives an expert comment (oral presentation) at Seminar "Opportunities for enhanced Nordic cooperation in the field of solid biomass for energy purposes" organized by Pöyro and Nordic Council of Ministers, Oslo

20-21 March 2012: **Inge Stupak and Palle Madsen** presented ENERWOODS (oral presetation) and participate in the conference: **Sustainable Production and Use of Biomass for Bioenergy in the Baltic Seas Region, Nordic Council of Ministers, Copenhagen**

2. July 2012: **Palle Madsen** presents ENERWOODS) at the 5th meeting for the Heads of National Forest Research Institutes (in Europe) at a seminar at KU, Forest & Landscape, Copenhagen

3. July 2012: **Palle Madsen** presents ENERWOODS (oral presentation) at the Nordic Forest Research Co-operation Committee (SNS) 40 years jubilee conference, Faculty of Life Sciences, Copenhagen

15. August 2012: **Leif Gustavsson** presents "Bioenergy and greenhouse gas mitigation". A challenging future for the Boreal forests – Can all demands be met? A travelling workshop in northern Sweden, 12-19 August.

3. October 2012: ENERWOODS – pohjoismaisella yhteistyöllä tehoa puubiomassan kasvatukseen ja hankintaan. 'Kansainvälinen metsäntutkimus' newsletter. Available at: http://www.METLA/LUKE.fi/uutiskirje/kv/2012-03/uutissivu-3.html
22. October 2012: ENERWOODS – energising the cultivation and procurement of woody biomass through Nordic cooperation. METLA/LUKE Bulletin. Available at: http://www.METLA/LUKE.fi/uutiskirje/bulletin/2012-03/news3.html"
24-26. October 2012: ENERWOODS participation (Norway, Finland, Estonia, Denmark) in "The Nordic Baltic Conference on Forest Operations – OSCAR" organized by our Latvian participants **Dagnija Lazdina and Andis Lazdins. Palle Madsen** presented ENERWOODS by an oral presentation
6-7. March 2013: **Leif Gustavsson** presents "ENERWOODS – Wood based Energy Systems from Nordic Forest". Programkonferens Hållbarhet, SLU Uppsala.
21. May 2013: **Leif Gustavsson** presents "What is most efficient: to make heat and electricity or biofuels for transportation from forest biomass?" Nordic Baltic Bioenergy, Oslo
23. May 2013: **Palle Madsen, Anders Tærø Nielsen and Esben Møller Madsen** present from ENERWOODS poplar as a nursetree species and an important species for high-productive forestry. SKOVEN 45 (8/2013), 314-315.
29. May 2013: **Palle Madsen** presents "Sustainability of intensive forest management and wood production". Joensuu Forestry Networking Week 2013 organized by METLA/LUKE.
2. June 2013: **Sylvia Haus** presents "Greenhouse Gas Emission Comparison of Wood Biomass Systems with the inclusion of Land-use in the Reference Fossil System". European Biomass Conferencen & Exhibition 2013, Copenhagen
10-12. June 2013: **Dagnija Lazdiņa** presents: Experience of forest, re-cultivated areas and short rotation plantation fertilization in Latvia. International Baltic Sea Region Scientific Conference Interdisciplinary Research for Higher Socioeconomic Value of Forests, June 10–12, Riga. Silava & Latvijas Valsts Mezi, Latvia
18. June 2013: **Leif Gustavsson** presents "Bioenergy, greenhouse gases and climate change" at 4th AEBIOM Bioenergy Conference, Brussels
19. June 2013: **Magnus Löf** presents "ENERWOODS – ett nordiskt project om skog och energy" at SLU seminar for forest owners and managers (80-90 participants) at Tylösands Strandhotel, Halland, Sweden
21. August 2013: **Leif Gustavsson** presents "How to get the most out of forest biomass?. 4th Generation District Heating – Second Conference, Combined heat and power plants – now and in the future. Aalborg University, Copenhagen Campus
23. August 2013: **Palle Madsen** presents "Kulturintensitet og kulturmodeller: Erfaringer fra naturnær skovdrift og øget biomasseproduktion". NordGen Forest Thematic Day "Kulturkvalitet og øget træproduktion", Sabro v. Århus
2-6. September 2013: **Leif Gustavsson** presents "Use of forest bioenergy – a solution to mitigate climate change?" Management of forest ecosystems for bioenergy, with implication for climate change mitigation, Finland.
1. Sept. 2013: **Johannes Windisch** et al. present "Precision supply of forest biomass to combined heat and power and bio-oil plants. Bioenergy Exhibition and Conference, Jyväskylä
19. Sept.; 30th Sept. 9th Oct. 2013: **Johannes Windisch** presents "Management science meets reality: Process management and simulation for forest biomass supply". Freising (Germany) Professorship Symposium; FORMEC conference, Stralsund
30. Sept. 2013: **Mikko Nivala** et al. present "A GIS-based comparison of alternatives for long-distance transportation of energy wood from young forests in Finland. FORMEC conference, Stralsund
03. October 2013: **Leif Gustavsson** presents "Skogsskötsel I framtiden" KSLA - Skogsskötselkommittén, Workshop, 3. October, Tagels gård, Sweden

23-26. Oct. 2013: **Kjell Andreassen** and Bernt-Håvard Øyen present "Growth, yield and biomass production in afforestation tree species in Northern Norway". Conference Afforestation to protect soils, rehabilitate derelict land and sequester carbon, Iceland 23-26. October, 2013. Organizer Icelandic Forest Research and Nordic Council of Ministers.

11-12. November 2013: **Lars Rytter** presents "ENERWOODS – a joint Nordic project to promote a sustainable development of our societies by wood based energy systems". Conference organized by Future Forests and EFI: Climate change and forestry in northern Europe, Uppsala

12. November 2013: **Sylvia Haus and Leif Gustavsson** present "Climate Mitigation Woody Biomass Systems". Conference organized by Future Forests and EFI: Climate change and forestry in northern Europe, Uppsala

12. November 2013: **Sylvia Haus and Leif Gustavsson** present "Climate Mitigation Woody Biomass Systems". Conference organized by Future Forests and EFI: Climate change and forestry in northern Europe, Uppsala 13. November 2013: Leif Gustavsson and Sylvia Haus present "Ger bioenergi och träbyggande klimatfördelar?" Skogen – Nyckeln till ett framgångsrikt klimat och energiarbete. Nolia city conference, Piteå

23. July 2014: **Mc Carthy, R.** Productivity and thinning effects of hybrid aspen (Populus tremula x P. tremuloides) root sucker stands. International Poplar Symposium VI, IUFRO, Vancouver, BC, Canada

10. November 2014: **Mc Carthy, R.** Productivity and thinning effects of hybrid aspen (Populus tremula x P. tremuloides) root sucker stands in Sweden – including general management to prevent damage from game populations. Iowa State University, Natural Resource Ecology and Management Department, Ames, Iowa.

23. March 2014: **Rytter, L.** Vad ska jag välja för trädslag vid ett förändrat klimat. Seminar Framtidens skogsbrukande arranged by Hushållningssällskapet Skogsförvaltning Syd, Bjärsjölagårds Slott, Skåne, Sweden

8. May 2014: **Rytter, L.** Lövskogsproduktion. Seminar arranged by Uppvidinge Community and Södra, Åseda Småland, Sweden

9. September 2014: **Rytter, L., Mc Carthy, R. & Stener, L.-G.** Rotskottuppslag i hybridasp – tillväxt och skötselmöjligheter. Poplar Day of Sweden arranged by the National Poplar Commission of Sweden, SLU, Uppsala, Sweden,.

8. May 2014. **Rytter, L.** Land areas and biomass production for current and future use in the Nordic and Baltic countries. Mini Symposium arranged by Lund University, Lund, Sweden

23-26. September 2014. **Belbo, H. & Talbot, B.** Systems comparison of 10 supply chains for whole tree chips. 5th World Forest Engineering Conference, Gerardmer France.

23-26. September 2014. **Irdla, M., Padari, A., Muiste, P.** The transport of wood chips in Estonian conditions – a case study. 5th World Forest Engineering Conference, Gerardmer France.

20-27. September 2014. **Gustavsson, L., Haus, S.,** Ortiz, C.A., **Sathre, R.**, Truong, N.L. Climate effects of bioenergy from forest residues in comparison to fossil energy. The 9th Conference on Sustainable Development of Energy, Water an Environment Systems – SDEWES 2014, Venice-Istanbul

6. October 2014. **Gustavsson, L.** Net greenhouse gas analysis of forest-based material and energy systems. XXIV IUFRO World Congress 2014, Salt Lake City, USA

15. October 2014. **Stupak, I.**, Raulund-Rasmussen, K., **Nielsen, A.T.**, Mustapha, W.F., Seitsonen, A., **Bentsen, N.S., Johannsen, V.K.** 2014. Drivers of very intensive biomass harvesting in Denmark and implications for carbon balances. Intersections Seminar at the University of Toronto, 15 October.

20-22. October 2014. **Nielsen, A.T.**, Mustapha, W.F., Raulund-Rasmussen, K., Seitsonen, A., **Stupak, I.** 2014. Climate change mitigation benefits of intensively managed and untouched forest. Presentation at the CAR-ES workshop. METLA/LUKE, Vantaa, Finland

5. November 2014. **Haus, S.** 2014. Time dynamic and radiative forcing of using forest bioenergy to mitigate climate change. PhD Course: Life Cycle Assessment with Focus on Bioenergy

19. November 2014. **Stupak, I.**, Smith, T., **Bentsen, N.S.** 2014. Bæredygtig skovdrift og bæredygtighedskriterier for forskellige biomassetyper – hvor langt er vi? [Sustainable forest management and sustainability criteria for different types of biomass – how far are we?]. Presentation at thematic meeting, The Danish Energy Agency, Copenhagen, Denmark.

26. November 2014. **Bentsen, N.S.** Carbon debt (kulstofgæld) – hvad er det og hvordan reduceres det? (Carbon debt – what is it and how to reduce it? Bæredygtige biobrændsler. Konference, Dansk Energi. 6-11. October 2014. Stanturf, J.A., **Madsen, P**., Park, Y.-D., Blay, D., Engel, V.L., **Löf, M**., Gardiner, E.S. 2014. Restoration strategies, methods, and operations. In Parotta al. (Eds.) book of abstracs. XXIV IUFRO World Congress, 6-11 October, Salt Lake City, USA 6-11. October 2014. Stanturf, J.A**., Madsen, P**., Dumroese, R.K., Palik, B., **Löf, M.** 2014. Novel and neo-native, native and exotic, restoration and intervention, oh my! In Parotta al. (Eds.) book of abstracs. XXIV IUFRO World Congress, 6-11 October, Salt Lake City, USA 6-11. October 2014. **Madsen, P.**, Madsen, T.L., Madsen, E.M., **Nielsen, A.T**., Stanturf, J. Pioneer species uses as nurse crops – a powerful silviculturalmethod in forest restoration and forest adaptation. XXIV IUFRO World Congress, 6-11 October, Salt Lake City, USA 14-16. October 2014. **Löf, M**., Claesson, G., Jacobs, F.D. 2014. From conifers to native broadleaves. In Jacobs et al. (Eds.) book of abstracs. 2nd Restoring Forests Congress, 14-16 October 2014 in West Lafayette, Indiana USA (invited oral presentation). 15-16. April 2015. **Lazdina**, D. Potential of Short rotation forest and short rotation coppice as additional resource for biomass production in Latvia, Latvia State Forest Research Institute (Latvia) Nordic Baltic Bioenergy Conference, Riga, Latvia 16-17. April 2015. **Lazdina,** D. Trees as recultivation or fitopurification instrument and usage of municipal residues (wastewater sludge and wood ash) for rehabilitation of tree stands" Green bridge forum. http://www.greenbridgeforum.com/en/conference/programme/ 27-29 May 2015. **Löf, M.** 2015. Nurse trees as a forest restoration tool for mixed plantations. COST and IUFRO workshop on silviculture of mixed forests. Arezzo, Italy 15-16 Sept. 2015. **Löf, M.** 2015. Establishment of mixed species stands. SNS conference on Wise Use of Improved Forest Reproductive Material, Riga, Latvia 2-4. September 2015. **Irdla, M., Padari, A. and Muiste, P.** The comminution cost of wood raw material for fuel in Estonian conditions - a case study. Bioenergy Conference, Jyväskylä, Finland 4-6. November 2015. **Irdla, M., Padari, A. and Muiste, P.** The alternatives of transport of wood chips in Estonian conditions - a case study. International Scientific Conference, Riga, Latvia

d) Patents

Has the project applied for any patents? If yes, please specify:			Yes ☐ No X
Type of patent (brief description)	*To which patent office? (E.g. USPTO or EPO or other)*	*Application date*	*Name of applicant and association to the project*

12. Any other business/comments

13. Signatures
(original signed paper copy only required for final report)

Project owner	Project manager
Place, date:	Place, date:
Frederiksberg, 10th December 2015	Vejle, 10th December 2015

Project owner Vivian Kvist Johannsen

Project manager Palle Madsen