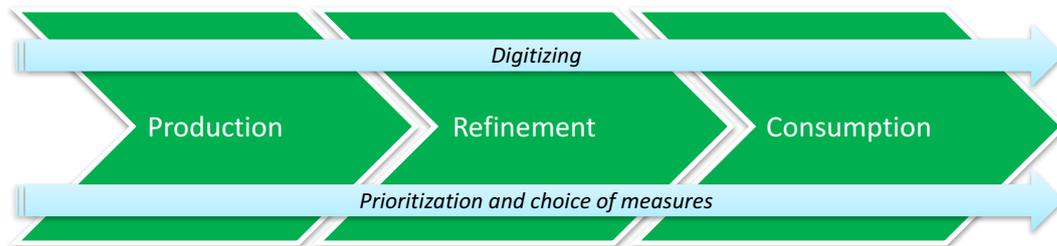


Discontinuities and innovation-oriented challenges in the value chain of bioeconomy



With focus on
the Swedish forest sector

A report for the Swedish Foundation for Strategic Environmental Research

by Anders Esselin, Man & Nature

May 2017

Table of contents

Summary	3
Scope	4
<i>What is bioeconomy?</i>	4
<i>Why bioeconomy?</i>	4
<i>Swedish forestry and forest industry</i>	5
The value chain of bioeconomy	7
<i>Production</i>	8
<i>Refinement</i>	8
<i>Consumption</i>	10
<i>Prioritization and choice of measures</i>	10
<i>Digitization</i>	12
Discontinuities and innovation-oriented challenges	13
<i>Interviews with experts + outcome from workshop</i>	13
<i>Funders of research related to bioeconomy</i>	15
Conclusions & recommendations	19
References	20

Summary

Bioeconomy is an economy that is based on sustainable utilization of renewable resources. It is seen by many as a solution to several staggering threats to our societies. Among other things, a development of the bioeconomy is expected to: mitigate climate change; reduce the use of fossil-based raw materials; promote a more resource-efficient circular economy based on sustainable use of ecosystem services from land and water; improve the economic and environmental sustainability of primary production and processing industries and thereby increase these sectors competitiveness and profitability; and maintain and create economic growth and jobs in rural, sparsely populated, regions.

Sweden with large forest areas, a well-developed forest industry, high competence in bioeconomy, good infrastructure, and with stable politics and policies, is well placed to take the lead in a transition from a fossil-based to a bio-based economy. However, the ability of the forest sector to fulfill all expectations on bioeconomy, without substantial tradeoffs, is a debated issue.

The transition from an economy based on non-renewable materials and fuels to a bio-based economy is perceived by actors in the field to be slow though – frustrating slow. The question is why? One possible explanation is that the link between bio-based products and the market is not always in perfect match. The catch seems to be that the goods and products that are introduced must be smarter, better, cheaper, with better design, compared to those they are intended to replace. And this is not the case today.

To address this challenge, the report suggests four alternatives for a possible Mistra program on bioeconomy:

Alternative 1: A research program focused on the interface between bio-based products, market and policy – how to scale up?

Alternative 2: A research program focused on digitization in all phases, or specific parts, of the value chain of bioeconomy.

Alternative 3: A research program focused on especially promising bio-based products that are close to the market and truly have the potential to meet the high expectations on bioeconomy, e.g. housebuilding/construction in wood and certain new advanced bio-based products.

Alternative 4: More funding to EviEM to do meta-studies on climate mitigation in relation to the forest sector and forest products.

The report is based on interviews with experts (representatives from the forestry and forest industry sector, researchers, and secretaries in research funding organizations), information in reports and on websites, and a survey of funders of research related to bioeconomy.

The bioeconomy consist of food, agriculture, paper and pulp, forestry and wood industry, fisheries and aquaculture, bio-based industries, biochemical and plastics, enzymes and biofuel sectors, recreation and tourism. There are of course important and promising research efforts in all of these sectors, but this report has a focus on the forestry sector.

Scope

What is bioeconomy?

Formas, the Swedish Research Council for Sustainable Development, has defined a bio-based economy (bioeconomy) as an economy based on:

- *"A sustainable production of biomass to enable increased use within a number of different sectors of society. The objective is to reduce climate effects and the use of fossil-based raw materials. An increased added value for biomass materials, concomitant with a reduction in energy consumption and recovery of nutrients and energy as additional end products. The objective is to optimize the value and contribution of ecosystem services to the economy."* (Formas, 2012)

There are many other definitions as well, e.g.:

- The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy (European Commission, 2012).
- The crucial components of the definition of bioeconomy by the Nordic Bioeconomy Initiative are: Sustainable production of biomass to increase the use of biomass products in several different sectors of society; intention to reduce climate impact and usage of fossil-based raw materials; An increased added value for biomass, while energy consumption is reduced, nutrients and energy are utilized as additional products. The aim is to optimize the value of ecosystem services and contribution to the economy (Rönnlund et al, 2014).
- Bioeconomy is economic activity based on biotechnology (Hannertz, 2015).
- To me, bioeconomy is a journey where were fossil raw materials are replaced by bio-based raw materials, which can be fish, algae, waste products, raw materials from forestry and agriculture. (Axegård, personal interview 2017)

Although different actors and governments have slightly different ways of defining bioeconomy, the aim seems to be clear: *to develop an economy that is based on the sustainable utilization of renewable resources* (Nordregio, 2015). Still, the concept can very well be interpret differently depending on what values and attitudes different actors hold (Nordin, personal interview 2017). And Teräs et al (2014) conclude that that the understanding of bioeconomy varies significantly and that the concept of bioeconomy is more familiar among public sector actors and large-scale industries than among smaller companies.

The sectors included also varies depending on context. In the European Commission bioeconomy strategy it is stated that the bioeconomy consist of food, agriculture, paper and pulp, forestry and wood industry, fisheries and aquaculture, bio-based industries, biochemical and plastics, enzymes and biofuel sectors (European Commission, 2012). Other services connected to the ecosystems producing raw materials for the bioeconomy, such as recreation and tourism, could also be included.

Why bioeconomy?

The emerging bioeconomy holds a great potential and is seen by many as a “silver bullet”, able to avert several staggering threats to our societies (Nordregio, 2015). It is even stated that bioeconomy is not a goal rather a means to save the world (Palmer, 2017)! Among other things, a development of the bioeconomy is expected to:

- mitigate climate change;

- reduce the use of fossil-based raw materials;
- promote a more resource-efficient circular economy based on sustainable use of ecosystem services from land and water;
- improve the economic and environmental sustainability of primary production and processing industries and thereby increase these sectors competitiveness and profitability;
- and maintain and create economic growth and jobs in rural, sparsely populated, regions.

(Nordregio, 2015; European Commission, 2012; Rönnlund et al, 2014; Teräs et al, 2014; Eriksson, 2017).

Formas' analysis (2012) shows that Sweden, in comparison with many other countries, has good preconditions given by natural geographic conditions, traditional industry and infrastructure, for being able to convert to a bio-based economy. But a greater focus on cross-industry research and innovation, which can provide us with new products derived from biomass and new services, is required for realization of the bioeconomy development (Rönnlund et al, 2014). And the large-scale impacts of a bioeconomy development still hinge on the upscaling of market development and systemic changes that would need to take place in society (Teräs et al, 2014).

Swedish forestry and forest industry

The Nordic countries with large forest areas, a well-developed forest industry, high competence in bioeconomy, good infrastructure, and with stable politics and policies, are well placed to take the lead in a transition where fossil resources are increasingly being replaced by bio-based materials and fuels (Mistra & Swedish Forest Industries Federation, 2016; Rönnlund et al, 2014; Thor, 2017). In Sweden forests constitutes approximately 70 percent of the total land area, and 80 percent of the forest is cultivated. The yearly harvest is about 70 percent of the yearly growth, which means that the timber stock is growing fast. Every year approximately 75 million tonnes (80–95 million m³) of raw forest biomass is harvested and refined, mainly into sawed wood, pulp, paper and cardboard. The total production value from forestry and forest industry is 250 billion SEK per year, and Sweden is the third largest exporter of forest based products with a yearly contribution to Sweden's net export of 120 billion SEK (125 billion SEK in 2016). The forestry and forest industry sector is thus very important for Sweden's balance of trade, employment and a cornerstone in the Swedish economy (Swedish Forest Industries Federation, 2017).

But the Swedish forest sector is in transition and there are several challenges to cope with. In a report from 2014, Rådström & Thor conclude that the profitability of the Swedish forest industry has been declining for several years and now is reaching levels that are unsustainable. One explanation to falling profitability offered by the authors is changing consumption patterns, where increased consumption of digital information has lowered the demand for printed information and paper. Overcrowding of certain products is another. A third one is that many of the forest industry's products are very sensitive to the overall economy situation in society. And the most important explanation might be that the forest industry has got stuck in "the commodity trap", since the forest industry is a pronounced commodity industry that produces products in large quantities in large capital intensive factories (Rådström & Thor, 2014).

A sign of weakness in the Swedish forest sector, which is perhaps coupled to low profitability, has for many years been a focus on reducing costs and low investments in research and development (R&D) compared to other sectors. A few years ago, the forest industry invested approximately 0,75 percent of the annual turnover in R&D (Rådström & Thor, 2014). Since the report was written the profitability for Swedish forestry and forest industry has improved and the optimism for the future seem to have risen. Among other positive signs there has been large investments in industry facilities (17 billion SEK 2016; 40 billion SEK 2014–2019) and bigger investments in R&D (Thor, 2017; Swedish Forest

Industries Federation, 2017). Today the yearly investment in R&D amounts to approximately 4 billion SEK of which the forest industry invests 2/3 (app. 1 percent of annual turnover) and the Swedish state 1/3. Some Nordic companies (e.g. Stora Enso and Borregaard) has broken this pattern by systematically making substantial investments in R&D over the years (Axegård, personal interview 2017).

Axegård (personal interview 2017) also foresee some future threats to the Swedish forest sector. One is that large, multinational chemical companies move in and become tough competitors to the Swedish forestry industry. A second threat could be if the demand for forest raw material for energy purposes in Europe increase, as this could potentially hinder the development and refinement of forest products in Sweden.

Another development that Nilsson (personal interview 2017) envision is that smaller, agile companies that are fast to adopt transformation and are close to the market, might be the ones that will benefit from the development of new advanced biomaterials and products. Some of these materials and products will be odd and produced in comparatively small volumes, which according to Nilsson doesn't suit the Swedish forest industry of today. Salander-Björklund (personal interview 2017) confirms that it is very costly to go from pilot to full scale production plant, but recognizes the possibilities of smaller production lines for new advanced biomaterials and products parallel to main production lines for pulp. Axegård (personal interview 2017) call for less capital intensive processes: How can we reduce the binding of capital without reducing efficiency?

A primary condition, that is both a challenge and an advantage for the Swedish forest sector, is that forests in Sweden grow slowly. On the negative side, the growth rate for Swedish trees is about five times slower compared to for example trees in Brazil, and plant material refinement therefore takes much more time. On the positive side, the trees in Sweden have fibers that are much stronger than trees elsewhere (Axegård, personal interview 2017).

Climate change can increase the risk of damages on Swedish forests by extreme weather, and outbreaks of insects and fungus that damage forests. Shorter periods of ground frost and more rain can also obstruct and complicate forest management. On the other hand, climate change has already increased the yearly growth period in Sweden by 10–15 days, which means that the Swedish forests grow faster today than they used to do (Skogen, website 20170222).

However, the ability of forestry and forest industry to mitigate climate change is a debated topic (Naudts et al, 2016). And the fulfillment of all the other promises by bioeconomy and at the same time increase long term sustainable use of ecosystem services is debated as well. A central question in the debate is if it is possible to have “more of everything”, i.e. increase the production and harvest of biomass without jeopardizing, the fulfillment of the Swedish environmental quality objectives and the UN 2030 Agenda with its Global Sustainable Development Goals (Skånberg, K., Olsson, O., and Hallding, K., 2016). Today there is no clear consensus among scientists on the issue (68 Finnish researchers, 2017; Swedish Forest Industries Federation, 2017). To prioritize between different ecosystem services in the forests is a political issue.

The value chain of bioeconomy

A value chain is a set of activities that a firm operating in a specific industry performs to deliver a valuable product or service for the market (Wikipedia). As noted earlier, the expectations on the emerging bioeconomy are high, both regarding the needs of the sector (increase competitiveness and profitability), and societal needs (reduce climate effects and the use of fossil-based raw materials, promote circular economy, and create economic growth and jobs in rural regions). Thus, the value chain of bioeconomy can be described as a set of activities that firms operating in the bioeconomy sector performs to deliver a valuable product or service for the market and for the society.

In each part of the value chain of bioeconomy, monetary and non-monetary values are affected. In some cases, there will be synergies between different values – i.e. by using a practice that promotes one value, other values will grow bigger as well. In other cases, there will be conflict between different values – i.e. by using a practice that promotes one value, other values will be reduced. Depending on how the system is defined (international, national, regional, local, organization, etc.) and what policies that are in play and implemented, the focus on which values to be prioritized, or how trade-offs between different values are decided and done, will be different.

The value chain of bioeconomy is previously described by Formas (2012), and the Swedish Forest Industries Federation (2017). With the purpose of identifying discontinuities and innovation-oriented challenges in the value chain of bioeconomy this report re-use the structure proposed by Formas, with some modifications. The value chain of bioeconomy is thus described as roughly composed by three successive parts:

- Production
- Refinement
- Consumption

There are also some functions that are non-specific to the different parts of this value chain, but have the potential to influence the development of values, i.e.:

- Prioritization and choice of measures
- Digitizing

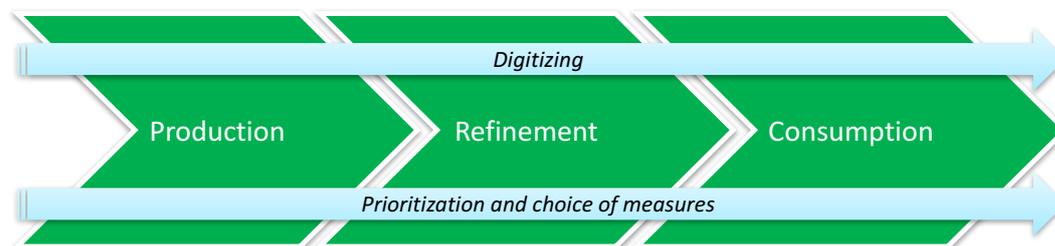


Figure: The value chain of bioeconomy

Production

Raw materials for a bioeconomy are produced from land and water-based ecosystems through different forms of husbandry. Putting the forest sector in focus, this part of the value chain concerns forest management practices, including the development and refinement of plant material, planting, production, management, harvest, enrichment, transport, etc. It is of utter importance to have detailed knowledge about the raw material and the ecosystem where it grows. Different climates, fertility, competition, management, genetics, tree ages and damage pressure give a great variety of properties of the Swedish forestry – between and within objects, but also in the tree trunk, bark, branches, barrels and stumps of individual trees (Swedish Forest Industries Federation, 2017).

A challenge in achieving a growing bioeconomy and reduced use of fossil based raw materials is how to increase production volumes and improve the quality of the raw materials. This applies to both animal and vegetable raw materials and presumes that social, economic and ecological consequences are taken into consideration (Formas, 2012).

The total annual production in the Swedish forest can increase by 30 million cubic meters with the right measures, including more intensive forest cultivation, hybrid aspen cultivation on farmland, and aquaculture. Already today, the harvest of biomass could increase significantly by using residues like branches and peaks (Mistra & Swedish Forest Industries Federation, 2016).

Refinement

The aim of the refining phase of bioeconomy is to increase the value of harvested biomass. The path to the end products is currently short for many agricultural products, but forestry raw materials often require more downstream refining and processing. The challenges are to achieve smarter products and more efficient processing, while at the same time reducing the negative impact on the environment (Formas, 2012).

The limits of the potential seem only to be restricted by peoples' imaginations. In a scenario analysis from 2016 (Skånberg, K., Olsson, O., and Hallding, K., 2016) the importance of forest raw material as building materials is expected to grow, especially in industrial wood house construction. Bio raw materials are also expected to increase in importance in the fuel, chemical, textiles and material composite sectors. Rönnlund et al (2014) identified the following interesting crosscutting growth areas of the bioeconomy in the Nordic countries: bio-based chemicals, biomaterials, biofuels and bioenergy, bio-refineries, resource-efficiency and industrial symbiosis and services based on ecosystem services or supporting the mentioned areas of products and creating value without tangible material flows and including design.

Bio-refineries, which can be major industrial complexes or micro-plants, will probably play a key role in the development of bioeconomy (Skånberg, K., Olsson, O., and Hallding, K., 2016; Mistra & Swedish Forest Industries Federation, 2016). In these bio-refineries the products are not dependent on whether the raw material comes from forestry, agriculture or aquaculture – it is the molecules in the biomass that are interesting. Another advantage is that the vision of future bio-refineries reminds of today's pulp mills and consequently easy to recognize for today's forest industry and machine suppliers. This implies that bio-refineries can act as bridges into the bioeconomy (Mistra & Swedish Forest Industries Federation, 2016).

Traditional products

Traditional forest industry products like sawed wood, pulp, paper, card board, packaging and hygiene products are today the economically most important products for the industry, and they will be an important base for the forest industry also in a 30-years perspective. Within packaging and hygiene, for example, there are excellent possibilities for Sweden to develop smart and easy-to-use products that suit an aging population (Mistra & Swedish Forest Industries Federation, 2016; Swedish Forest Industries Federation, 2017).

Buildings and construction

A great potential for bio-based systems is available in house building/construction. Building with wood instead of concrete, reduces carbon dioxide emissions by two thirds compared with concrete. Today, only about 10% of the houses in Sweden are built in wood. A technical development issue is to reduce material thickness. Other areas for technical development are to combine wood with other materials, ability to build higher houses with more floors, and modular construction which can increase the degree of prefabrication for faster establishment (Mistra & Swedish Forest Industries Federation, 2016).

Textiles

Demand for textiles increases while cotton farming poses considerable strains on ecosystems. This is one of the reasons that the production of wood fiber textiles has gained a boost. Pulp for production of textiles is already a commercial reality today, and Södra and Domsjö have production lines for textile pulp. The pulp is exported to textile factories in Asia, where the fibers are dissolved and spun to viscose from the thin threads. An important area of knowledge is reactive cellulosic fibers, that is, plant-based cellulosic fibers that easily convert into, for example, regenerated fibers for the manufacture of textiles.

New advanced bio-based products

New consumer needs and brand new products are pictured as a great opportunity for the forestry industry. This applies, for example, to already established areas such as hygiene products, textile products and house production, but above all, this is probably true in entirely new areas, outside the traditional forest industry. These can be bio-based composites, plastics, chemicals, drugs and much more (Rådström & Thor, 2014). Nanocellulose for example, which is extracted from wood fiber, has several attractive properties and is thus an exciting area for development (Dahlberg, 2014; Rådström & Thor, 2014). The challenges are to strengthen the R&D environment, to attract venture capital and to create cross-border cooperation between traditional industries, such as forest, chemical, textile and automobile.

Biofuels and bioenergy

The practice of using forest raw materials and other renewable materials for fuel and energy production has a long history. Today, residues from forestry and forest industries, as well as farming, are used to produce both heat and electricity in the industries as well as in power plants. The last decades, a lot of effort has also been invested in research and development of alternative and/or more advanced biofuels like bio-ethanol, raw bio-diesel and di-methyl-ether (DME). But still, these new bio-based fuels haven't been able to outcompete fossil fuels.

Consumption

As stated above, the forestry and forest industry sector is very important for Sweden's balance of trade and employment, and thus constitute a cornerstone in the Swedish economy. This implies that there is a national and global consumer demand for bio-based products from the Swedish forest sector. However, the ambition and expectations coupled to a developed bioeconomy is high. An example of this is that the Swedish Forest Industries Federation has formulated a vision that says that production (measured as value added) in the Swedish forest industry cluster will double by 2035. Half of this growth shall come from new products (Swedish Forest Industries Federation, 2012). And it's obvious that the transition from an economy based on non-renewable materials and fuels to a bioeconomy, based on renewable material and fuels, takes time and is perceived as slow. This fact seems not only frustrating for the sectors engaged in bio-based production, but also to politicians, agencies and the public.

A bio-based economy cannot be achieved until the materials and products developed are sold on the market. The big profits of the future are expected to be in the new forest products, but the link between the industry and the market is not always in perfect match. The catch is that the goods and products that are introduced must be as good as, or more attractive than, those they are intended to replace. An additional challenge is that the public's role must develop to create a favorable playing field for bioeconomy products and solutions. Teräs et al (2014) call for facilitation of markets, infrastructure and action by consumers.

Prioritization and choice of measures

Environmental consequences

A key challenge in the development of bioeconomy is how to increase production, refinement and consumption of bio-based materials and products without compromising, rather contributing to, Sweden's 16 environmental quality objectives and the United Nations 17 sustainable development goals (Skånberg et al, 2016; Formas, 2012). Increased use of one ecosystem service often has consequences for other ecosystem services and conflicts of objectives can arise. This must always be taken into consideration when managing an ecosystem and drawing on different ecosystem services (Formas, 2012). The emerging bioeconomy should also encompass and contribute to a circular economy with efficient use of bi-products and waste products, recycling of raw materials, nutrients and energy, and soil amendment. The pressing question is how to find solutions all along the value chain of bioeconomy that both increase the commercial and environmental benefits, and if this is even possible?

Socio-economic consequences

Increased productivity and the production of new types of biomass can impact other users of land, forests and water. This includes reindeer herding, recreation, berry and mushroom-picking, hunting and fishing. The development of a bio-based economy creates preconditions for new industries and other commercial companies within the bioeconomy value chains. This has consequences, for example, on infrastructure, transport, urban and rural development, education and employment (Formas 2012).

Policy instruments

There are some significant barriers that hinders the development of the bioeconomy. One of those is lack of market pull. A series of new bio-based products cannot at present compete with equivalent

existing products made from fossil material. Another barrier is that transition from the research stage to the first pilot and demonstration projects, and not least from pilot and demonstration projects to full-scale industrial production, is difficult for new bioeconomic value chains (The National Bioeconomy Panel, 2012).

If the bioeconomy is to gain more momentum, sufficient incentives must be provided for the actors involved in the development and implementation of bio-based technologies and services. This requires development of policy measures that are both cost-effective and effective dynamically. Such policy measures can be found at international, national as well as regional and local level.

In 2012, the European Commission adopted the strategy “Innovating for Sustainable Growth: A Bioeconomy for Europe”. The Bioeconomy Strategy and action plan focuses on three key aspects: developing new technologies and processes for the bioeconomy; developing markets and competitiveness in bioeconomy sectors; and pushing policymakers and stakeholders to work more closely together (European Commission, 2012). The EU strategy is to be updated 2017.

Several other international governmental agencies have also developed strategies for a bio-based and fossil fuel independent economy (see overview of political bioeconomy strategies around the world: BioSTEP, website). As an example, OECD, Organisation for Economic Co-operation and Development, launched a Green Growth Strategy in 2011 (OECD, 2011). Several governments in countries around the World has also outlined steps that agencies shall take to drive the bioeconomy, e.g.:

- USA: “The National Bioeconomy Blueprint” (the White house President Barack Obama, 2012).
- Ireland: “Developing the Green Economy in Ireland” (Department of Enterprise, Trade and Employment, 2009)
- Germany: “National Research Strategy BioEconomy 2030: Our Route towards a biobased economy” (Federal Ministry of Education and Research, 2011)
- Denmark: “Agreement on Green Growth” (Ministry of the Environment, 2009). The coordination of bioeconomy related issues I Denmark is discussed between the five ministries present in the National Bioeconomy Panel.
- Finland: “Sustainable growth from bioeconomy – The Finnish Bioeconomy Strategy (Ministry of Agriculture and Forestry, 2014)
- Norway: “Kjaente ressurser – uante muligheter. Regjeringens bioøkonomistrategi (Norwegian Government, 2016)

In 2011, the Swedish Government commissioned Formas, in consultation with Sweden’s Innovation Agency and the Swedish Energy Agency, to prepare a national strategy for the generation of a bio-based economy and sustainable development. The strategy, “Swedish Research and Innovation Strategy for a Bio-based Economy”, was published in 2012 (Formas, 2012). The Swedish Government and Parliament dictates legislation and governance etc. for promoting the transition to a bio-based economy. There are also several national initiatives for a transition to a bio-based economy but Sweden still lack an overarching national strategy. Initiatives, examples:

- The Government’s strategic collaboration programs, the collaboration program for circular and bio-based economy (Regeringen, website 170509)
- The national forest program (Regeringen, website 170509–2)
- ForMAX – a portal to future forest industry (MAX IV Laboratory, website 170509)

The regions and municipalities in Sweden are also a driving force, as they often develop regional research and innovation strategies jointly with commercial enterprise to utilize collective resources more efficiently (Formas, 2012).

Digitization

The Swedish forestry and forest industry is characterized by rather complex logistics regarding the supply of raw materials. This situation is caused by divergent flow of raw material from the forests, large variation in the raw materials attributes and qualities, seasonal variations in volumes and attributes, and long supply chains (Rådström & Thor, 2014). Digitization has brought some negative effects on the sector, e.g. the demand for paper is reduced as more and more people consume digital and less printed information. But new possibilities have also emerged as digitization can improve processes, create conditions for new bio-based products and services, and increase efficiency in large systems as well as in small details. Digitization can be used to find bottlenecks and optimize the process flow to produce smarter, cheaper and more cost effective. Digitization also offers better possibilities to link different parts of the value chain of bioeconomy, from production to consumption (Formas, 2012; Swedish Forest Industries Federation, 2017).

The Swedish forest sector is quite well positioned regarding digitization and digital infrastructure. Techniques in industrial digitization include: Internet of things (sensors and actuators that connects the entire plant including business systems), information storage, cloud computing, mobility (access to data everywhere), and control of steering (Mistra & Swedish Forest Industries Federation, 2016). Already, digitization has led to streamlining in harvesting, enrichment and transportation regarding economy, environment and social considerations. Better planning, clearer business deals and developed measurement and calculation techniques in harvesting machines provide increased precision in forest production management. Information on product characteristics and traceability is retained throughout the production chain and information systems, making it possible to link measurement results from industrial customers' systems with data on growth and harvest from the forest. Work productivity for forestry machines has increased, while both fuel consumption and tracing ground contact has been significantly reduced (Swedish Forest Industries Federation, 2017).

Every year, Tieto publish a report, the IT barometer, that examines the Swedish forest sector's attitudes towards digitization (Tieto, website 160321; Skogssverige, website 170422). Some findings from 2016 were:

- Forest companies are investing heavily in IT investments, but 55% believe that they do not get adequate profitability.
- Views on the role of IT among the companies in the forest industry is increasingly moving from business support to commercial.
- The use of cloud services increases.
- Strong mobility trend continues.
- Small companies have a more positive attitude to IT collaboration with other companies.
- Only four out of ten companies have formulated a strategy for digitization.

Discontinuities and innovation-oriented challenges

After two initial chapters of overview it is time to take on the central question of this report: *Where in the value chain of bioeconomy would it be wise for a funder of research, who want to make a difference, to invest money today?* As you might know by now, bioeconomy is a very wide and all-encompassing concept. Almost any sector and all activities that in some way deal with renewable materials and fuels, fit in and the value chains are both long and complex. In addition, as the topic bioeconomy is high (not to say hot) on the political agenda there are numerous ongoing research efforts.

To approach this central question, I have interviewed experts in the field (representatives from the forestry and forest industry sector, researchers, and secretaries in research funding organizations), read a report from a workshop on the subject at Mistra (Mistra & Swedish Forest Industries Federation, 2016) and scanned funders of research related to bioeconomy. What I've been looking for is discontinuities and innovation-oriented challenges in the value chain of bioeconomy – i.e. knowledge gaps that need to be researched to facilitate the fulfillment of the high expectations on bioeconomy.

Of course, the research needs concerning bioeconomy are much more elaborated in Formas' Strategy for a Bio-based Economy (Formas, 2012), the Swedish Forest Industries Federation's Research agenda (Swedish Forest Industries Federation, 2017), and Skogforsk's R&D strategy 2017–2020 (Skogforsk, 2016).

Interviews with experts + outcome from workshop

If it was your choice, where in the value chain of bioeconomy would you invest 100 money on research (currency and number of zeros behind 100 unspecified)?

Production

- Genetics
- Plant breeding and genetic modification of various species of trees
- Development of new types of cellulose
- Development of forestry harvesting technology
- Development of new, or modification of existing, forestry machinery
- Climate research
- All aspects of forestry
- How can you transfer knowledge from traditional and modern plant breeding to forestry and forest managers? For example, it could be very important in terms of damages caused by root rot and moose.
- Efficiency
- Transport
- Efficient and holistic resource supply of forest raw materials

Refinement

- How can the polymers in wood be separated with cheaper techniques?
- Development of new materials and products
- Development of new materials and products
- Development of new materials, fuels, packaging, and hygiene products

- Basic research on new materials – how they are structured and how they function
- Small scale bio-refineries
- House building/construction with wood
- Develop building-/construction systems with increased use of wood
- Houses – accelerated wood value
- New materials – experiments and up-scaling

Consumption

- How can we increase house building/construction of wood? Why is the market's transition so slow?
- How can we speed up commercialization of new materials and products?
- How can we upscale and commercialize bio-based products?
- Development of the entire value chain of bioeconomy – from production to consumption
- Pilot projects researching points of contact between the forest sectors products and the consumers
- How can we bring the knowledge generated by research to consumers in a way that leads to changed behavior, i.e. that the consumers start buying and using bio-based products instead of fossil-based products?
- What needs to be done in terms of upscaling and efficiency, so bio-based products become commercially competitive?
- Policy and instruments that allow the bio-economy to grow. Bio-based materials and fuels are too expensive today compared to fossil-based products and fuels. It takes more than just streamlined processes to make bio-based products more efficient and competitive. It requires policies, laws, procurement rules, instruments, standards, communication and a change of attitudes! We need more research on the effects of different instruments and behavior of different actors.

Prioritization and choice of measures

- What systemic changes are needed for Sweden to be able to participate in the race of bioeconomy? Although there are technical challenges to deal with, it is primarily challenges in political governance and policy that puts kicks in the wheel. If you do not understand them, the vision of the bioeconomy will not become reality.
- Policy is an effective method of conversion. Sweden is a small country, and the forest industry is export dependent and therefore we must research and affect international policy.
- One could also research risks associated with a conversion into bioeconomics.
- It is difficult to define the concept of bioeconomy, and the term is used differently by different actors depending on what values they hold. It would be interesting with research on how different groups understand and define the concept.
- It's all about policy. Without control means, substitution of fossil materials and fuels will not work.
- Control means for a developed bioeconomy.

Digitization

- Research on digitization in the forest sector to produce smarter, cheaper and more cost-effective materials and products, e.g. traceability, systematic overview regarding climate and environmental issues, more effective use of land (remote sensing), well-balanced decisions on fertilization etc.

- What we need to keep in mind is that we are already very advanced when it comes to digitization in the Swedish forest sector. If you do not have a very good idea of what a research effort on digitization is about, it only risks repeating what we already do.
- Digitization for decision support, mapping of trees and forests, data from forest machines when harvesting forests, etc.
- Digitization! Let's say that we have identified trees that are non-susceptible to root rot, then we could have geo-positioning and take care of them in a special way, for example, save these plants when clearing. Big data on individual tree's positions, groundwater streams, etc -> more precise management programs. This is visionary but not impossible.

Funders of research related to bioeconomy

A survey of funders of research related to bioeconomy reveals that there are many actors which are engaged in all sorts of crosscutting collaborations, in many countries, that provide funding for thousands of research projects, and that it is almost impossible to frame “research related to bioeconomy”. Thus, without an ambition to present a complete list of funders and what kind of research they fund – here is a quick list of examples, with a focus on Swedish funders.

The Swedish Research Council Formas

In 2007 Formas and Sweden’s Innovation Agency were commissioned by the Swedish Government to jointly develop a research strategy for the environmental technology area. Based on this research strategy Formas then introduced an Environmental Technology Program for the period 2007–2012. This program comprised four calls in collaboration with Vinnova and the Swedish Energy Agency, all with co-financing from the commercial sector. Over the period 2010–2014 Formas also participated in Ecolnnovera, an ERA-Net (EU collaboration) for environmental technologies and environmental innovations. In this collaboration 25 organizations, research funding bodies and research administrators from 20 EU countries participated. Formas participated in the two calls launched by Ecolnnovera. Another program with a major environmental technology content was the program that was run in collaboration with the Swedish construction industry's innovations centre, BIC. Formas and BIC jointly announced a large number of both national and international calls. A number of the strong research environments that have received funding from Formas in recent years have also had an environmental technology focus. In total 160 projects have received funding 2008–2017 within these various programs and collaborations. The projects can be sorted under six categories: Natural Resources in the Circulation Cycle, Biological Resources, Energy, New and Advanced Materials, and Sustainable Building and Planning – Technologies and Processes, Environmental protection technology.

In addition, Formas finance the research program Forest raw materials and biomass. So far, there has been four calls within this program:

- First call: Research for further processing. Most projects involved new bio-based products and materials (e.g. chemicals, biofuels, textiles, plastics, building materials) and various types of biomass process technology (e.g. enzyme, microwave and drying technology). A few also involved value chains and cost-effectiveness (from raw materials, via bio-refinery to the market).
- Second call: Research for primary production, focused on how biomass can be produced in an efficient and sustainable manner. For example, processing and selection of woods (e.g. fast growing ash, or pine with special wood properties), new or improved forest management methods (e.g. linked to thinning or moose protection), and questions about conservation and balances between different ecosystem services. Some projects treated the

production of other types of biomass than from the forest, for example, the cultivation of microalgae or energy crops.

- Third call: Research syntheses about sustainability aspects within different systems for production and use of forest raw materials and biomass.
- Forth call: Research for the transition to a bio-based economy (within sustainable production and smarter use and processing of biomass, but also within the development of consumption patterns, economic business models and governance).

Formas also collaborates within the environmental technology area by having the task of providing state funding for research in collaboration with other various research organizations. Such financing for example is allocated to the Swedish Environmental Research Institute, IVL, and the Swedish Institute of Agricultural and Environmental Engineering, JTI. (Formas, 2016)

Vinnova – Sweden’s Innovation Agency

Vinnova assist the Swedish government’s strategic collaboration program for circular and bio-based economy. Today there are two strategic innovation programs within this collaboration: Bioinnovation and RE:source. Projects within BioInnovation shall be innovative, smaller research and innovation projects that address a radical and innovative issue. Innovations made within the framework of RE: source shall contribute to sustainable material supply, sustainable energy systems and more efficient use of resources in society and industry.

Examples of other research initiatives relevant to bioeconomy funded by Vinnova:

- The Paper Province 2.0
- Agenda Bioraffinaderi
- Digitization of Swedish industry
- Test beds for environmental technology
- Test beds for innovations for a sustainable society
- Vinnväxt
- Produktion 2030
- Skogsdataalabbet@SLU

Swedish Energy Agency

Research funded by the Swedish Energy Agency shall have the potential to create a revolutionary change to significantly improve the ability to cope with a transition to a long-term sustainable energy system. Finances research for new and renewable energy technologies, smart grids, and vehicles and transport fuels of the future. The Agency supports commercialization and growth of energy related cleantech.

Swedish Foundation for Strategic Research

The Swedish Foundation for Strategic Research funds problem or application-driven research projects within the area of Biological production systems. Biological production systems are envisaged to be instrumental in the future transition to a sustainable bio-based economy. Essential to this transition is the development of industrial processes that are fed with renewable raw materials, and where the outputs are products with a high content of cutting-edge knowledge, and hence with a high added commercial value.

Knut and Alice Wallenberg Foundation

Knut and Alice Wallenberg foundation support basic research projects with relevance for bioeconomy. Some examples:

- Wallenberg wood science center
- The use of nano cellulose in biomedical applications
- ShapeSystems – Systems Biology of Plant Cell Shape
- Studying regulation paths in eukaryotes, developing effective cell factories for sustainable production of biofuels and chemicals, and developing metabolic models for eukaryote cells to understand metabolism and complex diseases.
- Power Papers
- Spruce Genome Project

Additional Swedish funding agencies of special relevance for forest related projects

- The Swedish Government: Finance a feasibility study on Formax, a collaboration between industry and academia that will generate forest-based products that fit into a bio-based economy.
- Swedish Environmental Protection Agency: Provides grants to support environmental action.
- Royal Swedish Academy of Agriculture and Forestry (KSLA): Manages a number of foundations that promotes scientific research and development in the green sector. Funding to support or finance syntheses and analyses through research, investigation, promotion, information, etc., and/or fellowships/scholarships.
- Anna och Nils Håkanssons stiftelse: Promotes scientific education and research in order to promote the country's forestry. In the first place, the forestry in Norrland
- Bo Rydins stiftelse: Supports qualified research projects, but also provides travel grants to graduate students who wish to take part in scientific conferences
- Brattåsstiftelsen för skogsvetenskaplig forskning: Promotes and supports scientific research on forestry, primarily outside the actual large forestry.
- Carl TryggersStiftelse för Vetenskaplig Forskning: Supports research in natural sciences- including forest and agricultural science and technology that can be expected to contribute to business development in Sweden.
- Kempestiftelserna: Funding focus primarily on education and research. Only applications from institutions and individuals in Norrbotten, Västerbotten and Västernorrland.
- Norrskogs Forskningsstiftelse (NFS): Promotes research mainly in northern Sweden on; forest management, forestry operating system, wood mechanical processing in sawmills, and forest raw materials to fuels.
- Skogssällskapet: Research, knowledge development, communication and dissemination of knowledge about forest management and nature conservation. Finances first and foremost applied research and knowledge development, to clearly see the benefits of the projects that will receive funding.
- Stiftelsen Nils och Dorthi Troëdssons forskningsfond: Supports mainly research in the forestry industry and the exploitation and processing of Swedish forest products. The Foundation mainly support larger projects.
- Södra Skogsägarnas stiftelse för forskning, utveckling och utbildning: Promotes research and education at university level or equivalent, of relevance for forestry and/or forest industry, carried out in southern Sweden.
- Ångpanneföreningens forskningsstiftelse (ÅForsk): Promotes research primarily on: Energy, environment, safety, materials engineering, forest industry processes and products.

Nordforsk

NordForsk is an organization under the Nordic Council of Ministers that provides funding for and facilitates Nordic cooperation on research and research infrastructure. The organization finance the Nordic Bioeconomy Programme, with the overall aim is to produce new knowledge on how to foster and advance the transition to a bioeconomy-based society in the Nordic countries by integrating research, innovation and entrepreneurship in the private and public sectors. The point of departure for this program is water.

The research Council of Norway

BIONÆR/BIONAER is a research program on Sustainable Innovation in Food and Bio-based Industries. The program will work user-oriented and in a continuous learning mode to solve challenges through financing research and innovation promoting the bioeconomy.

European Commission and European Research Council

The European Commission works on ensuring a coherent approach to the bioeconomy through different programs and instruments including the Common Agricultural Policy, the Common Fisheries Policy, Horizon 2020, European environmental initiatives, the Blue Growth initiative for the marine sector and the European Innovation Partnership on Sustainable Agriculture. The European Research Council (ERC) complements other funding activities in Europe such as those of the national research funding agencies, and is a flagship component of Horizon 2020, the European Union's Research Framework Programme for 2014 to 2020.

Horizon 2020 provides significant funding opportunities for Swedish research and innovation actors as well as opportunities for participation in European cooperation projects for technology development and solutions to societal challenges (Publector, 2016).

In 2014, ERC establishing the Bio-based Industries Joint Undertaking (BBI JU) a new Public-Private Partnership between the EU and the Bio-based Industries Consortium. Operating under Horizon 2020, it is driven by the Vision and Strategic Innovation and Research Agenda (SIRA) developed by the industry. The objective of the BBI Joint Undertaking is to implement a program of research and innovation activities in Europe that will assess the availability of renewable biological resources and the development of new bio-refining technologies to sustainably transform these resources into bio-based products, materials and fuels.

In a draft not yet adopted or endorsed by the European Commission (9. Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy), proposed focus areas of research include:

- Digitizing and transforming European industry and services
- Circular Bioeconomy Thematic Investment Platform (risk-sharing financial instrument)
- Bio-based products and services

In addition, the Societal Challenge 5 Work Programme for 2018–2020 focuses on moving to a greener, more resource efficient and climate-resilient economy in sync with the natural environment, demonstrating a strong commitment to supporting the UN's Sustainable Development Goals (SDGs) and the targets of the COP21 Paris Agreement.

According to one assessor, bioeconomy is about to be downsized in Horizon 2020, while more focus is put on sustainable development, rural development and circular economy.

Conclusions & recommendations

The expectations on the emerging bioeconomy is high, not only among commercial actors in sectors operating in the bioeconomy, but also among politicians, agency officials and the public. A development of the bioeconomy is, among other things, expected to: mitigate climate change; reduce the use of fossil-based raw materials; promote a more resource-efficient circular economy based on sustainable use of ecosystem services from land and water; improve the economic and environmental sustainability of primary production and processing industries and thereby increase these sectors competitiveness and profitability; and maintain and create economic growth and jobs in rural, sparsely populated, regions.

But the transition towards a bio-based economy is perceived by many to be slow – frustrating slow. The question is why? One possible explanation is that the link between bio-based materials, products and fuels and the market is not in perfect match. The catch seems to be that the goods and products that are introduced must be as good as, or more attractive than, those they are intended to replace.

To improve this situation research is needed in all parts of the value chain of bioeconomy. This was confirmed by the experts interviewed. When asked to make suggestions for a future research program they came up with ideas on pertinent and critical research issues all along the value chain. Since it is probably not possible to achieve all the high hopes on bioeconomy at the same time, a funder of a new research effort in bioeconomy carefully needs to consider how to prioritize, i.e. which of the stated aims of bioeconomy that should be primarily addressed.

Traditionally, most of the money in R&D of the Swedish forest sector have been invested in issues related to forestry, i.e. in the Production phase in the value chain of bioeconomy and in issues related to Prioritization and choice of measures. Today, several Swedish research funding bodies instead focus their investments further downstream the value chain in the Refinement phase of the value chain – i.e. in research and development of bio-based materials, products and fuels. At the European level, Horizon 2020 provides significant funding opportunities for Swedish research and innovation actors, but according to one assessor the trend is that bioeconomy is being downsized in Horizon 2020, while more focus is put on matters like sustainable development, rural development and circular economy.

Based on this understanding, and returning to the challenge that to spark the bioeconomy bio-based goods and products must be smarter, better, cheaper, with better design etc., than those they are intended to replace, I propose four alternatives (not in priority order) for a possible Mistra program on bioeconomy:

Alternative 1: A research program focused on the interface between bio-based products, market and policy – how to scale up?

Alternative 2: A research program focused on digitization in all phases, or specific parts, of the value chain of bioeconomy.

Alternative 3: A research program focused on especially promising bio-based products that are close to the market and truly have the potential to meet the high expectations on bioeconomy, e.g. housebuilding/construction in wood and certain new advanced bio-based products.

Alternative 4: More funding to EviEM to do meta-studies on climate mitigation in relation to the forest sector and forest products.

References

68 Finnish researchers (2017). Public statement

<http://www.bios.fi/publicstatement/publicstatement240317.pdf>

BioSTEP, website (170509). Overview of political bioeconomy strategies

<http://www.bio-step.eu/background/bioeconomy-strategies.html>

Dahlberg, Carina (2014). *Swedish forest can be converted into new environmentally friendly super material*. Knut and Alice Wallenberg foundation

<http://kaw.wallenberg.org/en/research/swedish-forest-can-be-converted-new-environmentally-friendly-super-material>

Department of Enterprise, Trade and Employment (2009). *Developing the Green Economy in Ireland*

<https://www.djei.ie/en/Publications/Publication-files/Developing-the-Green-Economy-in-Ireland-01-12-09.pdf>

Eriksson, Linda (2017). *Skogsbruk behövs för att lösa klimatproblemen*. SvD Debatt 1 mars 2017

<https://www.svd.se/skogsbruk-behovs-for-att-losa-klimatproblemen/om/debatt>

European commission (2012). *Innovating for Sustainable Growth – A Bioeconomy for Europe*

http://ec.europa.eu/research/bioeconomy/pdf/bioeconomycommunicationstrategy_b5_brochure_web.pdf

Federal Ministry of Education and Research (2011). *National Research Strategy BioEconomy 2030: Our Route towards a biobased economy*

https://www.bmbf.de/pub/National_Research_Strategy_BioEconomy_2030.pdf

Formas (2012). *Swedish Research and Innovation. Strategy for a Bio-based Economy*

<http://www.formas.se/Documents/Strategy%20-%20Biobased%20Economy.pdf>

Formas (2016): *Research projects 2008–2017. Environmental Technology Research Funded by Swedish Research Council Formas*

http://www.formas.se/Documents/FOR15-0100%20Environmental%20Technology_WEB.pdf

MAX IV Laboratory (website 170509). ForMAX – a portal to future forest industry

<https://www.maxiv.lu.se/news/formax/>

Hannerz, blogpost 150813. *Innovation and Chemical Industries in Sweden*

<https://bioekonomi.wordpress.com/2015/08/13/ny-wikipediadefinition-av-bioekonomi-pa-svenska/>

Ministry of Agriculture and Forestry (2014). *Sustainable growth from bioeconomy – The Finnish Bioeconomy Strategy*

http://biotalous.fi/wp-content/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf

Ministry of the Environment (2009). *Agreement on Green Growth*

http://eng.mst.dk/media/mst/69152/Danish%20Agreement%20on%20Green%20Growth_300909.pdf

Mistra & the Swedish Forest Industries Federation (2016). *Svensk bioekonomi för global samhällsnytta och stärkt svensk konkurrenskraft. Bioekonomi + Digitalisering – En workshop för framtida forskningsprogram.*

Naudts et al (2016). *Europe's forest management did not mitigate climate warming.* Science
<http://science.sciencemag.org/content/351/6273/597>

Nordregio (2015). *Bioeconomy – the Growth Engine of Nordic Regions?* Nordregio Policy Brief 2015:5
<http://www.nordregio.se/en/Publications/Publications-2015/Bioeconomy---the-growth-engine-for-Nordic-regions/>

Norwegian government (2016). *Kjaente ressurser – uante muligheter.* Regjeringens bioøkonomistrategi
https://www.regjeringen.no/contentassets/32160cf211df4d3c8f3ab794f885d5be/nfd_bioekonomi_strategi_uu.pdf

OECD (2011). *Towards Green Growth*
<http://www.oecd.org/greengrowth/towards-green-growth-9789264111318-en.htm>

Palmer, Carl Henrik (red.) (2017). *Bioekonomi – lösningens för svensk försörjningstrygghet.* KSLA Nytt & Noterat, nr 1 207.
http://www.ksla.se/wp-content/uploads/2017/04/KSLA-Nytt_1-2017.pdf

Publector (2016). *Lägesrapport Horizon 2020*
http://www.publector.org/Arsbok_2016/1_Lagesrapport_Horisont_2020

Regeringen (website 170509). *Regeringens strategiska samverkansprogram:*
<http://www.regeringen.se/regeringens-politik/regeringens-strategiska-samverkansprogram/>

Regeringen (website 170509–2). *Ett nationellt skogsprogram för Sverige.*
<http://www.regeringen.se/regeringens-politik/ett-nationellt-skogsprogram-for-sverige/>

Rådström Lennart & Thor, Magnus (2014). *Skogsnärings värdekedjor – Definition, dagsläge och angelägna utvecklingsområden.* KSLAs tidskrift nr 1 2014
http://www.ksla.se/wp-content/uploads/2014/04/KSLAT-1-2014_Skogsnaringens-vardekedjor.pdf

Rönnlund et al (2014): *Creating value from bioresources. Innovation in Nordic bioeconomy.* Nordic Innovation report 2014:01.
http://www.nordicinnovation.org/Global/Publications/Reports/2014/2014_01%20Innovation%20in%20Nordic%20Bioeconomy_final.pdf

Skogen, website 170222. *Klimatförändring får fart på svenska skogen*
<http://www.skogen.se/nyheter/klimatforandring-far-fart-pa-svenska-skogen>

Skogen, website 170427. *Snart byggs vartannat flerbostadshus i trä*
<http://www.skogen.se/nyheter/snart-byggs-vartannat-flerbostadshus-i-tra>

Skogforsk (2016). *Tillämpad forskning och innovation för framtidens skogsbruk.* FoU-strategi 2017–2020
<http://www.mynewsdesk.com/se/skogforsk/documents/skogforsks-foi-strategi-2017-2020-61126>

Skogssverige, website 170422. *Den svenska skogsindustrin ökar digitaliseringstakten – men många företag saknar tydlig strategi*
http://www.skogssverige.se/node/53501?utm_campaign=unspecified&utm_content=unspecified&utm_medium=email&utm_source=apsis-anp-3

Skånberg, K., Olsson, O., and Hallding, K. (2016): Den svenska bioekonomin: definitioner, nulägesanalys och möjliga framtider. Stockholm Environment Institute, Project Report 2016-02
<https://www.sei-international.org/mediamanager/documents/Publications/SEI-2016-ProjectReport-DenSvenskaBioekonomin.pdf>

Teräs et al (2014). *Bioeconomy in the Nordic region: Regional case studies*. Nordregio Working Paper 2014:4
<http://www.nordregio.se/en/Publications/Publications-2014/Bioeconomy-in-the-Nordic-region-Regional-case-studies/>

The National Bioeconomy Panel (2012). Denmark as growth hub for a sustainable bioeconomy
http://naturerhverv.dk/fileadmin/user_upload/NaturErhverv/Filer/Indsatsomraader/Bioekonomi/Denmark_as_growth_hub_for_a_sustainable_bioeconomy_statement_by_the_Danish_Bioeconomy_Panel.pdf

the White house, President Barack Obama (2012). National Bioeconomy Blueprint
<https://obamawhitehouse.archives.gov/blog/2012/04/26/national-bioeconomy-blueprint-released>

Tieto, website 160321. *Ny studie avslöjar: Innovation och affärsutveckling alltmer på skogsbranschens agenda*
<https://www.tieto.se/nyheter/ny-studie-avslojar-innovation-och-affarsutveckling-alltmer-pa-skogsbranschens-agenda>

Personal interviews with experts, 2017:

Axegård, Peter, RISE – Research Institutes of Sweden
Elvnert, Johan, Forest-based Sector Technology Platform (FTP)
Fahleson, Jan, Swedish Foundation for Strategic Research
Gatenholm, Paul, Chalmers university of technology
Holmgren, Anders, Vinnova
Lehorst, Camilla, Government offices of Sweden
Nilsson, Sten, Forest Sector Insights
Nordin, Annika, Swedish university of agricultural sciences
Petterson, Torgny, the Swedish Forest Industries Federation
Salander-Björklund, Elisabeth, Bergviks skog
Svensson, Jan, The Swedish Research Council Formas
Thor, Magnus, the Forestry Research Institute of Sweden