Report: The circular bioeconomy in Scandinavia

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June 15th 2016

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Preface

This report on the circular bioeconomy in Scandinavia is a deliverable of the first work package of the research project “Sustainable path creation for innovative value chains for organic waste products” (SusValueWaste, project number 244249). We gladly acknowledge the Bionær programme under the Research Council of Norway for funding our project.

The report is the result of collaboration between researchers from OREEC, NIFU and CIRCLE. Marianne Reimer took the lead in this collaboration.

This report provides an overview of visions, scenarios and road maps for the circular bioeconomy in Scandinavia and will be an important input into our foresight process.

Oslo, June 2016

Antje Klitkou

Project leader

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Introduction

This report provides an overview of visions, scenarios and road maps for the circular bioeconomy in Scandinavia. The report is a part of the SusValueWaste project, which aims to address the potential for value added, and improved sustainability in the valorisation of organic waste streams, residual feedstock and by-products by analysing value chains inside and across different sectors of the bioeconomy[1]. The project is particularly concerned with the notion of a *circular* bioeconomy, defined as: *"(…) when existing bio-resources are used in an efficient way, which means that organic waste and by-products are treated as a resource for the bioeconomy (…). Especially relevant is value chains crossing existing sectoral borders in the bioeconomy"[2].*

The notion of a *circular bioeconomy* may be seen as what is called a *boundary object* within science and technology studies. This refers to an entity – object, information or term, as in this case – which is interpreted and talked about in different ways and meanings within different communities, retaining nevertheless sufficient identical content to allow communication between these communities and translation between the different uses (Star, 1989)[3]. Other examples of boundary objects are the knowledge-based economy and "the green economy".

In policy-making, the notion of a circular bioeconomy resonates well with the current shift towards Grand Challenge driven research and innovation policy. The 2009 Lund Declaration stressed the urgency of pursuing solutions to problems in diverse fields such as climate change, food security, health, industrial restructuring and energy security. However, Kuhlman and Rip (2016) have emphasized that: "(…) one cannot simple derive what to do by specifying the problem and developing a diagnosis. Grand Challenges are open-ended, and learning about the nature of the challenges and how to address them must be an integral part of any strategic effort[4]". Moreover, such broadening of scope has raised the level of ambition from system improvement towards system transformation (Borras and Edler, 2014[5]). Rather than piecemeal, incremental improvements in existing systems, this implies a transition to fundamentally different systems of production and consumption. Such transitions encompass new technologies and infrastructures, but also require co-evolving shifts in markets, practices, policy and culture.

Guiding visions are a key element for policies that seek to address Grand Challenges through system transformation (Coenen, Hansen and Rekers, 2015)[6]. Since transitions and new technologies are inherently future-oriented, visions and expectations related to such processes have been suggested to be "(…) among the most important objects of enquiry for scholars and analysts of innovation" (Borup et al., 2006[7]).

[1] For more information on the project, see: www.susvaluewaste.no

[2] Definition made in the SusValueWaste project proposal; http://www.susvaluewaste.no/original-proposal/

[3] Star, S. L. (1989). The Structure of 111 «Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving. Distributed Artifidal Intelligence, 2, 37-54.

[4] Kuhlmann, S. & Rip, A. (2016) Grand societal and economic challenges: a challenge for key actors in the Norwegian knowledge and innovation system – Opinion Piece. *Forskningspolitikk* 1/2016.

[5] Borrás, S., & Edler, J. (2014). The governance of change in socio-technical systems: Three pillars for a conceptual framework. *The Governance of Socio-Technical Systems: Explaining Change*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

[6] Coenen, L., Hansen, T., & Rekers, J. V. (2015). Innovation Policy for Grand Challenges. An Economic Geography Perspective. *Geography Compass*, 9(9), 483-496.

[7] Borup, M., Brown, N., Konrad, K., & Van Lente, H. (2006). The sociology of expectations in science and technology. *Technology analysis & strategic management*, 18(3-4), 285-298.

When analysing the guiding visions and pathways to establish a circular bioeconomy in respectively Norway, Denmark and Sweden, the report focuses on four basic questions: What? Why? Who? How?

1) What is the circular bioeconomy?
2) Why is it important?
3) Who drives the transition to a circular bioeconomy?
4) How can it be achieved?

In line with the focus of the SusValueWaste project, this report will focus particularly on analysing the part of the bioeconomy that is concerned with side streams, waste streams and by-products, which should be seen as streams of biomass with great potential to creating new, sustainable value chains that will expand into the bioeconomy.

Through the mapping process of this report, it was clear that the terms *circular economy* and *the bioeconomy* are often found in close relation. Some even argue that the bioeconomy is circular by nature[8]. This will obviously depend on the treatment of the waste streams and organic fractions, by ensuring that the biomass is highly valorised and treated optimally; i.e. not sent to landfill or waste incineration. The findings of this report will be input for a foresight study, where industrial actors and other experts will be gathered to discuss the future of the circular bioeconomy in Norway.

The next section will present our methodological considerations. Then, the *circular economy* in Scandinavia will be analysed in separate chapters on each of the countries: Norway, Denmark and Sweden. Finally, the report summaries the findings and finish with a look at the future of the Scandinavian circular bioeconomy.

[8] e.g. http://biconsortium.eu/news/bioeconomy-circular-nature

Methodological considerations

This analysis builds on the methods of grounded theory (Strauss and Corbin 1998), in an empirical grounded mapping of visions for a circular bioeconomy in Scandinavia. The method structures the analysis in categories generated from the empirical material, by the use of practical techniques for collecting and interpreting data. These categories frame the sampling, combined with the overall theoretical concern in the SusValueWaste project. In this method, collecting and analysing data are parallel processes, where preliminary results give rise to new searches and findings. Such theoretical sampling is a strength in new situational analysis, as in this study of the notion of a circular bioeconomy.

The literature search built the ground by mapping existing visions in the three Scandinavian countries through several steps. All searches were carried out during January-March 2016. A *first* step mapped an introduction to the notion, by the use of an open web-based search for the three national categories of a *circular bioeconomy*. These searches resulted in little information in all three countries, and showed that a *circular bioeconomy* is not an established concept in the Scandinavian countries.

A *second* step applied the broader term of *bioeconomy* as a search category[9], as a theoretical code for a sampling to the study. This part of the mapping focused on visions with *the explicit and the actual use* of the term *bioeconomy*. These literature searches resulted in large amounts of information in all three countries. In contrast to the little findings on the search for a *circular bioeconomy* in the first step, the term *bioeconomy* seems to be well established in the Scandinavian countries. Certainly, all documents were not relevant for our analysis of the notion of a circular bioeconomy in Scandinavia, but needed further consideration. An outline was made for a theoretical sampling by applying several dimensions of a circular bioeconomy as our specific context framing in the SusValueWaste project. One central dimension was *the circularity.* Many findings simply addressed a need for a bioeconomy and focused little on the possible circularity in this economy. These findings showed that the term bioeconomy is also still novel and not a well-established category in the Scandinavian countries. The term has been applied in several strategic documents, but the notion has been little clarified on a broader level in what and how it will bring. Another central dimension was to consider the visions for *value chains of organic waste and by-products*, as the specific context of our research project. These findings helped to structure the identification of the notion of a circular bioeconomy from the general findings on the bioeconomy.

A *third* step in the mapping was aimed at collecting more information on the what's and how's it will bring in these relevant findings, by searching the websites of the various stakeholders speaking for these visions. These were websites of the national governments, regional governments, public agencies, research councils, industrial organisations, key companies, civil society organisations, etc. This step resulted in more data on their visions, e.g. in identifying related strategic documents, states of their visions, and their activities to influence their visions. In this part of the analysis, data was also considered to documents that could be interpreted into or translated to speaking of the *circular bioeconomy*.

Certainly, this methodological strategy has its limitations. The most obvious is the information not included when applying the code of bioeconomy as an outline. On the other hand, it is beyond the limits of this report to analyse all possible visions aimed at related targets within the broader sphere of indirectly related policies, strategies of various industries federations, companies, and civil society organisations. The report focuses on mapping central visions especially addressing the notion of a circular bioeconomy, and does not aim at creating an overview of all possible related strategies indirectly aimed at the notion. By choosing the still unfinished category of circular bioeconomy as the context, this report aims at analysing the status quo

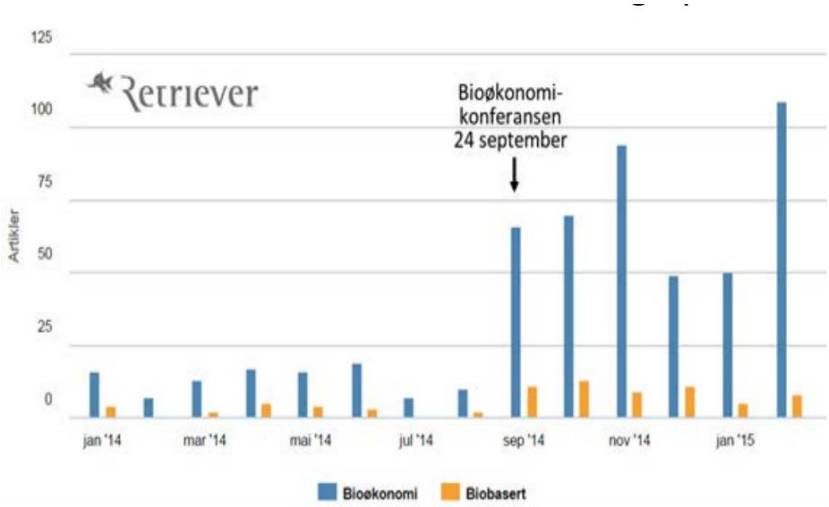
[9] NO: Bioøkonomi, DK: Bioøkonomi, SE: Bioekonomi

of the new and growing notion. The findings from the mapping are summarised in annex 1. This is not an exhaustive list but an intention to provide an overview of the visions for the circular bioeconomy in the three countries.

Circular bioeconomy in Norway

During the last few years, the bioeconomy has gained increased attention in Norway. In November 2014, Innovation Norway and the Research Council of Norway organised a national conference in Oslo with the title "The bioeconomical spring is here"[10]. A subsequent media search performed by Innovation Norway showed that the use of the word bioeconomy in the Norwegian media rapidly increased after this conference (Figure 1)[11].

Figure 1; Media search showing the use of the word bioeconomy in the Norwegian media (Source: Innovation Norway)



Innovation Norway is also pointing at the large sectoral strategies as Hav21[12], Skog22[13] and stakeholder initiatives such as the BioVerdi-report[14] as reasons for this strongly increased attention. The raising awareness of the concept in the Norwegian context is strengthened by the fact that in March 2015, the Norwegian Government decided that a national bioeconomy-strategy would be developed[15]. The Government sees the strategy as an important step to facilitate new and innovative industries that can strengthen green competitiveness and make the Norwegian economy less vulnerable to fluctuations in the petroleum sector.

A dialogue meeting and an open hearing was organised for the bioeconomy strategy in 2015 [16] and the release of the strategy is expected in June 2016. Even though the approach to the bioeconomy is broad in the process, the Government was criticized for defining the bioeconomy too narrow; not including life science and health biotech in their definition[17].

In the following, three different aspects will be presented to give insight about the existing visions, scenarios and road maps for the circular bioeconomy in Norway:

[10] "Den bioøkonomiske våren er her"; http://www.forskningsradet.no/no/Arrangement/Konferanse_om_Biookonomi_Den_biookonomiske_varen_er_her/1253996701571?lang=no
[11] http://www.drømmeløftet.no/wp-content/uploads/2015/05/Biooekonomi-underrapport-Droemmeloeftet-21-mai-final.pdf
[12] http://www.hav21.no/prognett-hav21/Artikkel/Strategien_er_klar/1253981466481/p1253968607691
[13] http://www.innovasjonnorge.no/skog22/
[14] http://www.oslotech.no/oslotechfiles/dokumenter/bioverdi%20rapport%20final160514.pdf
[15] The Ministry of Trade, Industry and Fisheries and the Ministry of Agriculture and Food share the responsibility for the development of the strategy; https://www.regjeringen.no/no/aktuelt/nasjonal-biookonomistrategi/id2402524/
[16] https://www.regjeringen.no/no/aktuelt/regjeringens-biookonomistrategi/id2425964/
[17] http://blogg.uio.no/unidir/ottersen/content/regjeringen-definerer-bioøkonomi-for-snevert

1. Collaborative stakeholder initiatives supporting the bioeconomy

2. The blue bioeconomy

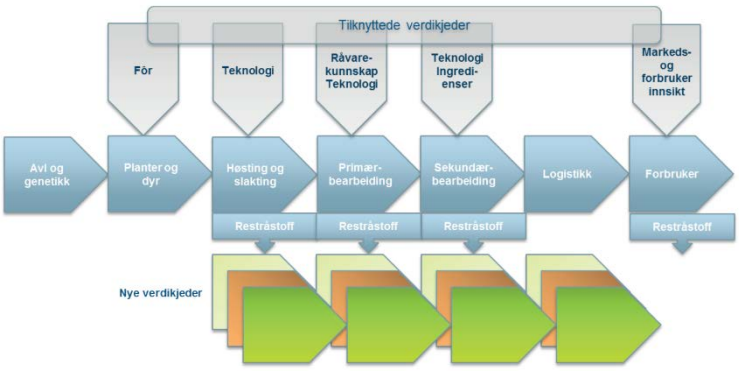
3. Elevating the bioeconomy as a national priority

1. Collaborative stakeholder initiatives supporting the bioeconomy

The main representative organisation for Norwegian employers (NHO) initiated a bioeconomy panel in 2015 to investigate how Norway can become world leading in the bioeconomy[18]. The transferability between the marine and the agricultural sector was one of the starting points for the work. Norwegian companies which had succeeded in making use of by-products from agriculture; the ocean, the fisheries and the forest, were mentioned. It was emphasised how these resources had been regarded previously as waste, now used to produce feed ingredients, food, bio-energy and products for pharmaceutical purposes. This is a direct address to the circular bioeconomy.

The panel was put together by NHO to provide input from the private sector to the development of the national bioeconomy strategy, and they completed a report "Towards the bioeconomy – NHO input for a new international and competitive business" in March 2016[19]. The report highlights four main principles to implement the bioeconomy, and circular economy is one of these. The report states: *"In the bioeconomy it is assumed that resources from one process are used as feedstock in a new, with the aim of complete exploitation of both raw materials and residual resources. This makes up a 'circular economy' where the resources are exploited to the maximum"*[20]. The report also argues that *"This leads to keeping the biological resources in the economy, when the product no longer serves its original purpose (…). In a circular economy, the value chains are more specialised and gives rise to products with increased value. The opportunities in biorefining can contribute to secure full exploitation of the ingredients"* (Figure 2). It is foreseen that the value creation will increase when multiple products are developed from one sort of biomass, and the importance of collaboration and using knowledge and technology across sectors is seen as the only way to succeed.

Figure 2; Complementary value chains and by-products; opportunities for new value chains with large potential for value creation. Source: NHO



According to the report, Norway is already world leading in the marine sector, but still in the starting pit when it comes to developing new products. Furthermore, a vision for the creation of a new, sustainable

[18] https://www.nho.no/Politikk-og-analyse/Forskning-og-innovasjon/Na-trenger-Norge-biookonomi/

[19] https://www.nho.no/Politikk-og-analyse/Forskning-og-innovasjon/verdensledende-pa-biookonomi/?utm_source=newsletter_11.mars.2016&utm_medium=email&utm_campaign=newsletter_all

[20] https://www.nho.no/siteassets/nhos-filer-og-bilder/filer-og-dokumenter/forskning-og-innovasjon/mot-biookonomi.pdf

and high-tech industry based on the natural bio resources is craved for, and as well, a stronger collaboration between *green* and *blue* sectors is needed. The report points to unexploited potential in production of biomass and in exploring the intersections between the aquaculture, agriculture and forestry and the various biotechnologies as nanotechnology and genetic engineering as a way forward. Future opportunities are seen within health and pharma, wood-based construction materials and bioprocessing; as with bio-plastics and bio-energy. The report envisages a scenario for the future Norwegian bioeconomy, which may produce a turnover of nearly 1000 billion NOK in 2050[21]. For this to become a reality, the report sketches four brief scenarios for business development in Norway towards 2050. One of these; a scenario to become leading in bioprocessing of biomass in 2050. Here, the exploitation of side streams in the biomass production is crucially important and in order to succeed, and pilots for biorefining are suggested as the necessary steps forward. Health and biopharma is another scenario, where the biotechnology is seen as the engine in the development of the bioeconomy:

> "To succeed the bioeconomy, all sectors and all parts of the value chains based on biomass are dependent on synergies amongst the various parts and the biotech industry as an arrow head (…) In a high cost country like Norway, it is crucial that we succeed in a thorough value chain approach in order to become competitive on the international level."

In addition to the NHO report, there are two other stakeholder-initiated reports that should be mentioned in this context, as they both address opportunities for future value creation in Norway based on the bioeconomy: *Norway203040* and *BioVerdi*. The report "Norway 203040 – the business opportunity"[22] is referred to as *The climate report of the business sector,* as it was initiated by key players to elevate a business perspective into the public debate on climate- and environment matters[23]. The report highlights the bioeconomy as one amongst five opportunity areas for Norway, with biofuels for transport and bio-products (bio-based chemicals and plastics) as the two key areas that are believed to be ripe for future development and worth to explore. The report looks particularly at these two as key areas where Norway has good preconditions, as competitive companies like Borregaard and FMC Nutrition and Health, who form a strong foundation for further technology development. It is pointed at the importance of developing niche know-how and put it to commercial use; the bioeconomy sector needs predictable regulations for sustainable use of forest and sea biomass[24]. The report states that "Norway would be a natural home for bioeconomy businesses thanks to its rich natural resources and competence in industries related to those resources. In addition, feedstock sources in Norway, such as forests and algae, do not compete with food production"[25].

The second report, BioVerdi, was created in a partnership between 50 actors, representing Norwegian Universities and Research-bodies, science parks, industrial representatives from the bio-sectors and private investors[26]. The report points out four areas with particularly large potential in Norway; health, marine, industrial biotech and agriculture. It also provides specific suggestions on how Norway – with a strong policy and collaboration between the stakeholders and the sectors – can lift the four bio-businesses to becoming the *new oil* to Norway.

[21] http://www.dn.no/nyheter/2016/03/11/1326/Jordbruk/1000-milliarder-fra-blgrnne-bedrifter
[22] http://awsassets.wwf.no/downloads/norway203040___report.pdf
[23] The report is a collaboration between: DNV-GL, Hydro, Kongsberggruppen, Posten & Bring, Ruter, SpareBank 1 Forsikring, Statkraft, Statnett, Storebrand, Umoe, WWF, Xyntéo and ZERO.
[24] http://www.mynewsdesk.com/no/storebrand-asa/pressreleases/norge-203040-groenne-muligheter-for-naeringslivet-1237788
[25] http://awsassets.wwf.no/downloads/norway203040___report.pdf
[26] http://www.oslotech.no/bioverdi/

2. The blue bioeconomy

The Ministry of Trade, Industry and Fisheries launched a masterplan for marine research in September 2015[27]. The masterplan is a follow up of the Government's long-term plan for research and higher education[28], which forecasts that public funding for research and development should be increased to the equivalent of one percent of GDP. The four most important actions defined by the masterplan for marine research are: (1) Increased funding for marine research; (2) Facilitate several marine industry clusters; (3) Increased cooperation between research centres in Norway; and (4) Increased internationalisation[29]. The development of the marine sector, referred to as the *Blue bioeconomy*, is seen as important whether it is about modernizing the traditional fishing industry, developing a sustainable aquaculture or to develop entirely new industries based on resources from the sea. Of particular interest is the mentioning of a research initiative to increase the processing of mackerel in Norway, by doing parts of the processing in Norway, instead of exporting round fish like done today. This would increase the sales value and the residual feedstock would give high quality feed ingredients for e.g. the salmon industry. New products and increased value would be made on the basis of the nutritious residual feedstock[30]. This points directly at the circular bioeconomy. The masterplan specifically addresses cross-sectoral and multi-disciplinary research as the way forward. One potential topic is the opportunities between the blue bioeconomy and its development of technology that might be applied across sectors, as the petroleum industry, as well as research within health and nutrition. In a different report, carried out for the Ministry of Trade and Fisheries (July 2015), it is stated that the bioeconomy is growing, and within the marine sector, the potential of better exploitation of residual resources is highlighted as one way to grow[31]. Using marine bioprospecting (exploiting genes, biomolecules and organisms from the marine environment) as a way of adding value to a low value feedstock or by-products is a second way. The reports address framework conditions and opportunities in several sectors, and in the agricultural sector, reuse of residues and by-products from production, mentioning Nortura[32], as an important actor. The industry is exemplified with the advanced biorefinery of Borregaard, and looking at the Bioeconomy in the European context, the transition to an economy with increased reuse of biological resources is highlighted.

These documents both point to the large potential in the *blue bioeconomy*, as the ocean represents massive opportunities. The new research programme HAVBRUK2 hosted a conference in April 2016, with the title "Aquaculture as a driving force for the Norwegian Bioeconomy"[33].

3. Elevating the Bioeconomy as a national priority

Innovation Norway, the Norwegian Government's most important instrument for innovation and development of Norwegian enterprises and industry, has defined the bioeconomy as one amongst six new, large areas of priority to strengthen value creation from Norwegian business. In turn, the business community will gain competitive strengths and take an active part in developing a sustainable and bioeconomic society[34]. Innovation Norway has set an aim to start by mobilising the stakeholders from the

[27] https://www.regjeringen.no/contentassets/3db688adc270495aac99e655c5d28fe1/marin-strategi_webfil.pdf
[28] Meld. St. nr. 7 (2014-2015) Langtidsplan for forsking og høyere utdanning 2015-2024
[29] https://www.regjeringen.no/no/aktuelt/vil-skape-globale-vinnere-av-havets-ressurser/id2437928/
[30] https://www.regjeringen.no/contentassets/3db688adc270495aac99e655c5d28fe1/marin-strategi_webfil.pdf
[31] «Rammebetingelser for bioøkonomi i Norge» http://vista-analyse.no/site/assets/files/6962/2015-07_biookonomi.pdf
[32] In Nortura's meat processing, all parts of the animal is exploited and further valorized; http://www.nortura.no/gir-matglede-rundt-spisebordet/bruker-hele-dyret/
[33] "Havbruk som drivkraft I norsk bioøkonomi"; https://www.havbruk2016.no/
[34] http://www.innovasjonnorge.no/no/energi-og-miljo/biookonomi/#.VswcC9xyP3g

business communities and then turning towards a more market oriented product development and demonstration phase[35].

The report «The Bioeconomy – an important contribution to growth and value creation in the future» was launched as a separate report of Innovation Norway's initiative *Drømmeløftet,* in 2015[36]. The report states that the bioeconomy is *necessary* for a sustainable future, and that the total exploitation of traditional and new feedstock must be secured as one important part of the bioeconomy[37]. This implies measures to (1) reduce loss at all levels of production and (2) integration of various refining processes to enable value creation from all side streams. Borreegaard is mentioned as a great example of an integrated biorefinery; producing more than 50 products from one single feedstock.

The reports highlights four biobased sectors when referring to the status for the Norwegian bioeconomy: (1) Norwegian agriculture; (2) Norwegian seafood; (3) Forestry, and (4) Biobased ingredients – chemicals and energy[38]. These sectors are expected to trigger increased value creation from a broad field of biomass, and it is expected that biotechnology will play a key role in developing environmentally friendly microbial or enzymatic production processes. One important point is that the exploitation of biobased materials will happen partly where the biomass arises; hence, the Norwegian bioeconomy will take on different shapes in different regions. The regional clusters are important, and new regional strategies should be developed based on strengths in order to better collaborate across the country. In this way, they say, the future forestry sector might work closely with fisheries[39].

Amongst the central recommendations from the report, are increased efforts to improving general framework conditions, management plans and licensing regulations in order to facilitate increased exploitation of residual feedstock and new biological resources are mentioned. Innovation Norway suggests that increased production and better exploitation of ingredients for both traditional and new products should be a focus to strengthen Norway's position and growth within the bioeconomy. The report states that the competitive advantages in the Norwegian bioeconomy will be based on cross-sectoral technology transfer.

Several funding agencies offer support programmes in order to further develop and realise the bioeconomy in Norway. Within the Research Council of Norway, a research programme on "Sustainable Innovation in Food and Bio-based Industries", BIONÆR[40] has been established for the period 2012-2022. The programme aims to work user-oriented and in a continuous learning mode in order to solve challenges through financing research and innovation promoting the bioeconomy. The aim is to trigger research and innovation for value creation in Norwegian bio-based sectors, based on four main premises; complete biological circuits, sustainability, value creation and multi-disciplinarity[41]. Further, the visionary framework for BIONÆR is the bioeconomy, or *the biobased society.* The bioeconomy concerns all sustainable production and processing of biological resources for food, health purposes, fibre products, industrial products and energy. One of the key areas of the BIONÆR programme is production, processing and consumption, and the approach is that residual raw materials would be evaluated in line with virgin raw materials; avoid loss

[35] http://www.innovasjonnorge.no/no/Om-Oss/Vi-mener/store-nye-satsninger-2015/#.VswZsdxyP3g
[36] Drømmeløftet and its reports is a constellation of external and internal input that Innovation Norway received through more than 80 meetings with about 3500 participants that were undertaken to discuss the future of Norway in 2015.
[37] http://www.drømmeløftet.no/wp-content/uploads/2015/05/Biooekonomi-underrapport-Droemmeloeftet-21-mai-final.pdf
[38] http://www.drømmeløftet.no/wp-content/uploads/2015/05/Biooekonomi-underrapport-Droemmeloeftet-21-mai-final.pdf
[39] http://innovasjonsbloggen.com/2015/11/09/fremtiden-ligger-i-biookonomien/
[40] http://www.forskningsradet.no/prognett-bionaer/Forside/1253971968584
[41] Bionær Programplan 2012-2012; Bærekraftig verdiskaping I mat- og biobaserte næringer – BIONÆR, Forskningsrådet

and stimulating waste streams to cross one another whenever such can lead to a wider, more sustainable and efficient ways to exploit the bio-resources.

Another relevant programme for the development of the bioeconomy in Norway is the BIOTEK2021 programme. The BIOTEK2021 is the Research Council of Norway's most comprehensive research initiative in the field of biotechnology, running from 2012 through 2021[42]. The bioeconomy is used as a concept to explain the potential for value creation in the field of biotechnology, and is seen as an important part of the bioeconomy as a whole[43]. The research council defines biotechnology as the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services. Biotechnology is not an industry in itself, but rather an enabling technology that holds great potential for enhancing industrial development, innovation and competitiveness. There are many areas of application within the agricultural, aquaculture, health and industrial sectors[44].

In the main strategy for the Research Council of Norway (2015), *sustainability* is the core of the vision for future research and innovation[45]. The bioeconomy is only briefly mentioned, thus emphasised as important in developing sustainable production cycles.

Summing up Norway

The concept Bioeconomy certainly has gained momentum in Norway during the last two years. The conference in 2014 – "The bioeconomical spring is here", implies a revolutionary aspect. The bioeconomy is now being placed on the agendas across sectors, just in line with the concept of "the green shift" which was announced word of the year in 2015[46].

To answer the question of *what,* the circular bioeconomy in Norway is about securing a maximum exploitation of both traditional and new feedstocks. The Borregaard biorefinery is mentioned by several as a key example of this, and the blue bioeconomy is mentioned as a sector of important traditions and potential.

The circular bioeconomy is considered important to Norway because the facilitation of new and innovative industries can strengthen green competitiveness and make the Norwegian economy less vulnerable to fluctuations in the petroleum sector. The discourse is about reducing emissions, the green shift, the new oil and the low-carbon society. The bioeconomy is seen as a key area where Norway has good preconditions, and is already world leading in the marine sector. The bioeconomy is an opportunity for restructuring the economy.

The circular bioeconomy has strong governmental support; there are several funding opportunities for research and innovation in the field. Pointing at examples of Norwegian companies who have succeeded in making use of by-products, Borregaard being a key example.

To answer the question of *how*; bridging the blue bioeconomy in extended cross-sectoral collaboration is highlighted as a key. A second aspect is the notion of the exploitation of the biomass; it will happen partly where the biomass arises. Hence, as argued by Innovation Norway, the Norwegian bioeconomy will take on different shapes in the different regions. Regional clusters are important, and new regional strategies

[42] http://www.forskningsradet.no/prognett-biotek2021/Forside/1253970728155

[43] Se Biotekstrategi 2011; Nasjonal strategi for bioteknologi – For framtidas verdiskaping, helse og miljø, Kunnskapsdepartementet

[44] http://www.forskningsradet.no/prognett-biotek2021/Programme_description/1253970728220

[45] http://www.forskningsradet.no/no/Nyheter/Ny_hovedstrategi_er_klar/1254008654156

[46] «Det grønne skiftet»; http://www.sprakradet.no/Vi-og-vart/hva-skjer/Aktuelt/2015/arets-ord-det-gronne-skiftet/

should be developed based on strengths in order to better collaborate across the country, as well as across sectors. The importance of predictable long-term regulations is also addressed. Strengthening the work on framework conditions, management plans and licensing regulations are needed in order to facilitate increased exploitation of residual feedstock and new biological resources.

It seems important to several stakeholders to describe the bioeconomy as a realistic industrial *alternative* to the petroleum industry, and a wide group of actors want to be included in this rising field with the potential of becoming the “new oil” in Norway.

Circular bioeconomy in Denmark

In 2011, Denmark launched a new governmental energy strategy including the long-term goal of becoming completely independent of fossil fuels (coal, oil and gas) by 2050[47]. In this strategy, the primary focus for biomass was in relation to its potential to become feedstock for bioenergy production. Since then, different stakeholders in Denmark have put a strong emphasis on developing a sustainable bioeconomy that can secure long-term economic growth and position the country as a leader in providing sustainable solutions in the global bioeconomy. As expressed by the Danish Bioeconomy Panel, the vision for Denmark is to become "a growth hub for sustainable bioeconomy"[48].

The plans and strategies launched by the Danish government and its advisory body, the National Bioeconomy Panel, are designed as growth strategies, which could contribute to increasing economic growth, employment and exports of Danish solutions. Furthermore, they seek to create new business opportunities and strengthen the competitiveness and innovativeness of the Danish enterprises, and place them as leaders in the global market for bio-based products and solutions. Additionally, there is also a range of industry-driven initiatives focusing on the development of the biorefinery sector and aiming as well at securing Danish global leading position in the field.

Denmark does not have a dedicated bioeconomy strategy. The development of the Danish bioeconomy is addressed in several sectorial strategic documents that are part of the bioeconomy[49]. In this way, the concrete focus areas and proposed initiatives are directly addressing the different sectors belonging to the bioeconomy. Some of the more traditional bioeconomy sectors in Denmark (e.g. agriculture) are described as highly productive and efficient in the way they extract value from biomass[50]. Thus, the current focus in Denmark is on increasing efficiency and profitability in the sustainable bioeconomy by increasing the utilization of by-products for high value purposes. Different published reports and analyses explain that using the organic waste and by-products in cascading biorefineries holds a major untapped potential for developing Denmark's sustainable bioeconomy[51,52].

The evolution of Denmark towards the development of a sustainable bioeconomy will be explained through three major phases that have been defined by the authors of this report:

1. The first steps

2. Bioeconomy as a source of economic growth

3. The National Bioeconomy Panel

Following, the three phases are shortly described:

1. The first steps

The current analyses identified that the term *bioeconomy* started to attract attention in Denmark in the period 2011-2012. This is based on the fact the term started to appear in the literature and media in that period. This was marked by two important events: a) Establishment of the Biorefining Alliance in 2011 and

[47] Danish Government (2011): Energy Strategy 2050.
[48] The term circular economy in not used in the Danish context; sustainable bioeconomy is the one used.
[49] The Danish Government (2013): Denmark at Work. Plan for Growth for Water, Bio & Environmental solutions.
[49] The Danish Government (2013): Denmark at Work. Plan for Growth for Food Industry.
[50] Nordregio (2014): Bioeconomy in the Nordic region: Regional case studies.
[51] Institut for Fødevare- og Ressourceøkonomi KU (2016): Organisk affald – Fra husholdninger og servicesektoren samt effekter af nuværende anvendelse.
[52] Ellen MacArthur Foundation (2015): Delivering the Circular Bioeconomy. A toolkit for policymakers.

b) Bioeconomy in action: Conference and The Copenhagen Declaration during the Danish Presidency of the Council of the European Union in 2012.

The Biorefining Alliance is an association established in December 2011 by four major industry stakeholders in the bioeconomy in Denmark: DONG Energy, Novozymes, Haldor Topsøe and Danish agriculture & Food Council. The association has a range of highly ambitious objectives, which also reflect their vision for Denmark in the bioeconomy[53], including:

- to create growth and jobs in Denmark by contributing to the development of new biorefining technologies;
- develop Denmark into a centre for development and demonstration of new technologies for agriculture, biorefining, as well as production and utilization of new materials;
- provide support for Danish companies to become preferred partners for other companies and research institutes within biorefining;
- to represent Danish political interests within biorefining in Denmark, Europe and globally in cooperation with other organisations.

The first published strategy of the Biorefining Alliance identifies waste management as a position of strength for Denmark in the global bioeconomy[54]. The document mentions that Denmark has built up significant expertise in the area of biological processing of both sorted-at-source and unsorted waste, which provides substantial potential for marketing Danish process technology, consultancy and enzymes.

The conference *Bioeconomy in action* was organized in Copenhagen during 26-28 of March 2012 by the Danish Presidency of the European Union (January-June 2012) and the Danish Council for Strategic Research. The event was organized to discuss the then newly launched European Bioeconomy strategy[55] and how to be more operational in the bioeconomy by moving from concepts to actual implementation scenarios. The three-days conference resulted in the development of *The Copenhagen Declaration for a Bioeconomy in Action* providing key findings and recommendations presented and debated with ministers, high level governmental officials, research councils, industry, stakeholder organisations, NGOs, and scientists that attended the conference[56]. The declaration emphasizes the importance of the residues and waste in a sustainable bioeconomy:

> *"The perceived conflict between food and non-food production from arable land could be overcome by using agricultural crop and forestry residues and bio-degradable waste as well as selecting feedstock such as algae and other under-exploited resources from aquatic and marine environments, and by using existing and new knowledge and technologies to increase biomass yield"[57].*

Even though the conference and the Copenhagen declaration had a European focus, and the resulted recommendations fed-in the actions and plans at European level, they helped to put the sustainable bioeconomy and the focus on waste and side streams on the agenda of the Danish national, regional and local authorities and policy makers. This is proved by the strong focus on bioeconomy in the different strategic documents and analyses published afterwards.

[53] BioRefining Alliance (2011): Vedtægter for BioRefining Alliance.
[54] Biorefining Alliance (2012): Denmark in a Global Bio-based Society – do we want to be customers or producers?
[55] European Commission (2012): Innovating for sustainable growth. A bioeconomy for Europe. Launched on the 13th of February 2012.
[56] The Danish Council for Strategic Research (2012): The Copenhagen Declaration for a Bioeconomy in Action.
[57] The Danish Council for Strategic Research (2012): The Copenhagen Declaration for a Bioeconomy in Action, p.3.

2. Bioeconomy as a source of economic growth

The Danish Government has launched in 2013 a series of national growth plans grouped under the title *Denmark at work*. The growth plans describe initiatives and focus areas within different sectors of the Danish economy that can generate economic growth and jobs in the country, and can generate competitiveness for Danish enterprises in the global market.

Denmark does not have a dedicated national strategy for bioeconomy, but the commitment of the Danish government to the sustainable bioeconomy is defined in the *Plan for growth for Water, Bio and Environmental solutions*[58]. Furthermore, the sustainable bioeconomy is also mentioned as important in the *Plan for Growth for the Food Industry*[59].

The objective of the Plan for growth for Water, Bio and Environmental solutions is to strengthen Danish and European markets within these sectors. The strategy intends to support new business opportunities and facilitate product and technology development within enterprises. The strategy mentions the strong position that Denmark possesses within industrial biotechnology and the great potential in relation to the production of biobased materials. It also defines a strategic focus for strengthening the potential for future market pull for biobased solutions to generate growth and jobs. Overall, the goal is to support Danish enterprises in claiming a greater share of the growing international market within the areas in which Denmark possess strengths and competitiveness, and hence make a positive contribution to growth and job creation. Furthermore, the initiatives described in the plan intend to secure that Denmark is at the leading edge of research, technology and know-how by supporting the testing and market maturation of biobased products.

3. National Bioeconomy Panel

A direct result of the Plan for Growth for Water, Bio and Environmental solutions was the establishment of the National Bioeconomy Panel in 2013. The Panel consists of 27 members representing the Danish industry and industry associations, academia, NGOs and regional authorities. The Panel has a cross-ministerial secretariat and is chaired by the Danish AgriFish Agency (Ministry of Environment and Food of Denmark)[60].

Its mission is to identify the possibilities for concrete business and research initiatives that can transform Denmark into a *growth hub for sustainable bioeconomy*, this being their vision. The focus is on developing new bio-based value chains and increasing the efficiency and productivity of existing ones.

The Panel functions as an advisory body for the Danish government and its tasks include:

- Advise on the types of biomass and value chains Denmark should focus on in order to create growth and build competitive advantage at international level;
- Advise on the types of technologies and market-based initiatives Denmark should focus on in the coming years;
- Indicate how framework conditions and regulations can be improved to allow the development of new value chains;
- Support knowledge sharing and coordination with the EU.

The sustainable bioeconomy is firstly defined in the statement of the National Bioeconomy Panel as "(…) an economy in which the basic building blocks used for production of energy, chemicals and materials

[58] The Danish Government (2013): Denmark at Work. Plan for Growth for Water, Bio & Environmental solutions.
[59] Regeringen (2013): Danmark i arbejder. Vækstplan for fødevarer.
[60] http://agrifish.dk/about-us/the-danish-bioeconomy-panel/

originate from renewable biological resources, including plants and animal waste. Products encompass, for instance, foodstuffs (and foodstuff ingredients), animal feed (and feed ingredients), biobased products (biomass-based chemicals, biomaterials, etc.) and bioenergy"[61].

The Panel has identified that Denmark can further build its sustainable bioeconomy by using biomass from agriculture, forestry and fisheries, as well as a variety of waste streams from the food industry, shops and restaurants and private households[62]. The different types of available biomass have been categorized as follows:

- Blue biomass: discards and side-streams from the fish industry; macro algae;
- Green biomass: grass, clover and other plants or plant parts; alternative protein crops;
- Yellow biomass: straw and other by-products containing cellulose;
- Brown biomass: secondary quality wood;

By-products and waste: by-products from the meat industry; by-products from the dairy industry; unsorted household waste.

The inclusion of a focus on utilization of, and value extraction from, by-products and waste is part of the definition of a circular bioeconomy. Without actually using the term *circular* (the used terms is *sustainable*), Denmark aims to develop such a bioeconomy.

The Panel has mapped the new value chains that can generate more value in the Danish sustainable bioeconomy for all of these types of biomass. Table 1 presents the new value chains suggested for by-products and waste streams.

Table 1. New value chains in the Danish bioeconomy based on organic waste feedstock as suggested by the National Bioeconomy Panel

Feedstock	Existing use	New value chain
By-products and waste from meat production	Meat and bone meal, animal feed	Upgrading of meat protein
By-products and waste from dairy industry	Some of the whey is used today	Whey protein used for various food products
Unsorted household waste	Incineration	Biogas and new materials from household refuse: through the 'REnescience' process, a bio-liquid is made, which may be used for microbial production of materials or biogas

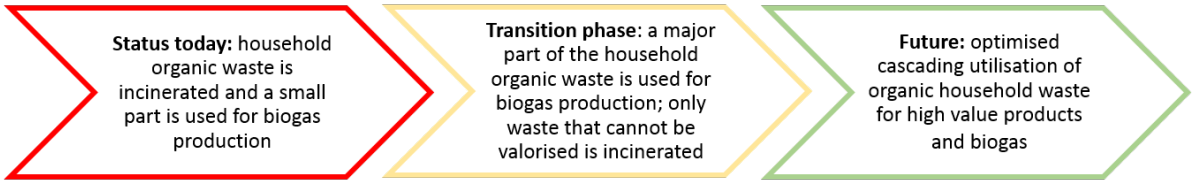
The Panel has a strong focus on increasing the value extraction from by-products and has published a set of recommendations on how can Denmark enable the available by-products and waste streams as feedstock in the sustainable bioeconomy[63].

In this regard, their long-term vision for Denmark is to transition from the current waste management practice today where the majority of waste is incinerated with energy recovery, towards a phase where the major part of the organic waste is used for biogas production. The ambition is to reach a phase where organic waste in used as feedstock in cascading biorefineries for the production of high value products and

[61] The National Bioeconomy Panel (2014): Denmark as a growth hub for a sustainable bioeconomy, p1.
[62] The National Bioeconomy Panel (2014): Denmark as a growth hub for a sustainable bioeconomy
[63] Det Nationale Bioøkonomipanel (2016): Organisk affald – vejen mod en bedre udnyttelse af vores ressourcer

biogas, as illustrated in Figure 3. It is worth also mentioning here that the Danish Government has set as a goal, in its waste-related strategy[64], to reach 50 pct. recycling of household organic waste by 2022 (from 22 pct. in 2011) and 60 pct. recycling of organic waste from the service sector by 2018 (17 pct. in 2011).

Figure 3. Envisioned evolution of management of organic household waste (Source: The National Bioeconomy Panel; figure redesigned and translated from Danish)



The Panel's recommendations to the Danish Government for an improved utilisation of the organic waste, include[65]:

- Long-term framework for planning and investments within the waste sector, which can support the uptake of resource efficient technologies;
- Revision of existing regulation, to secure access to organic waste as feedstock. Re-organisation of the waste sector;
- Monitoring of the municipalities' efforts to secure that municipal organic waste is used for higher value purposes (not incineration).
- Clear objectives for optimal utilisation of organic waste in accordance with the EU Circular Economy package.
- Adaptation of the incineration capacity to the current and future demand.

Summing up Denmark

A major part of the analysed Danish documents show a common rationale for the bioeconomy: the vision of a Denmark as a global leader and the objectives of jobs and growth creation. The circular bioeconomy is a sustainable bioeconomy; an economy in which the basic building blocks used for production of energy, chemicals and materials originate from renewable biological resources, including plants and animal waste.

This is important in Denmark in order to become completely independent of fossil fuels, and even more important: to create employment and export of Danish solutions.

Amongst the driving actors are some of the more traditional sectors in Denmark, as the agricultural sector, which is described as highly productive and efficient in extracting value from biomass. Nevertheless, the Biorefining Alliance seems to have a central role with the important part of developing strategies and recommendations on how to improve and suggest the steps on how to get there. A long-term framework for planning and investments is on top of the list, as well is revising existing regulations, particularly focused on the waste management sector.

There is a common agreement that cascading biorefineries are key towards the development of a well-functioning and competitive sustainable bioeconomy where by-products and waste streams are used, along with other renewable biomass types, as feedstock for the production of high value bio-based products.

[64] The Danish Government (2013): Denmark without waste
[65] Det Nationale Bioøkonomipanel (2016): Organisk affald – vejen mod en bedre udnyttelse af vores ressourcer

It is clear that the sustainable bioeconomy is a major priority for the public as well as private stakeholders communities and they have united forces to realize the yet untapped potential in using by-products and waste streams as raw materials.

Circular bioeconomy in Sweden

In Sweden, a national research and innovation strategy for a bio-based economy was launched in 2012. This strategy started a number of processes. Importantly, it was developed in dialogue with industrial actors, public agencies and academia. Their work gave rise to the grand innovation programme "BioInnovation", with the overall aim of transforming Sweden to a bioeconomy in 2050. Other research programmes have also been aimed at a circular bioeconomy, although at a smaller scale, and geographically and industrially defined. The forest industry has been central in several of these programmes, and the Forest Industries Federation has played a critical role in developing many of these programmes. This industry federation launched their visions for a wood-based bioeconomy already in the beginning of 2000s. Lately, other industrial federations have ascribed the forest as the cornerstone in the Swedish bioeconomy, and several cross-sectoral efforts have been made. However, there are still no governmental strategies or any ongoing processes aimed towards raising the notion of a circular bioeconomy at the governmental level in Sweden.

These main findings are here treated in three separate sections:

1. National research and innovation strategies

2. Forest – the cornerstone

3. Limited governmental strategies

1. National research and innovation strategies

A national research and innovation strategy was launched in February 2012 aimed at generating a bio-based economy and sustainable development[66]. The research council Formas assigned the strategy in consultation with the innovation agency Vinnova and the Swedish Energy Agency. The strategy calls attention at the role of knowledge-based innovation to accomplish a transition to a bio-based economy:

> *"Converting to a bio-based economy means a transition from an economy that to a large extent is based on fossil-derived raw materials to a more resource-efficient economy based on renewable raw materials produced by the sustainable use of ecosystem services from land and water. (…) To achieve efficient utilization of renewable biomass in the process of converting raw materials into finished product, including efficient use of by-products and waste products, requires knowledge-based innovation[67]".*

The strategy identifies four major challenges that form the basis of the strategy, and outlines detailed strategies along each of these: I) replacement of fossil-based raw materials with bio-based raw materials, II) smarter products and smarter use of raw materials, III) change in consumption habits and attitudes, and IV) prioritisation and choice of measures. The strategy is both extensive and detailed in scope, identifying many solutions to the four challenges. Critics often disapprove such broad strategies for spreading out targets and fragmenting accountability. However, the need for transboundary activities have been given emphasis to by the Swedish innovation agency Vinnova, in their attempts to implement the research strategy. Most importantly, the strategic innovation programme BioInnovation[68] was launched in 2015. This new research programme aspires at stimulating innovation of new biobased materials, products, and services. The overall vision is: "*(…) to transform Sweden to a bioeconomy in 2050*". The objective is to create

[66] See: http://www.formas.se/PageFiles/5074/Strategy_Biobased_Ekonomy_hela.pdf
[67] Swedish Research and Innovation Strategy for a Bio-based Economy, p. 13
[68] BioInnovation, see http://www.vinnova.se/sv/Var-verksamhet/Gransoverskridande-samverkan/Samverkansprogram/Strategiska-innovationsomraden/Strategiska-innovationsprogram/bioinnovation/

the best conditions for increased valorisation and competitiveness in the Swedish bio-based industry, through creating transboundary collaboration across sectors in forestry, chemical, and textile industry, with the vision of a biobased economy in 2050. The programme is a participatory stakeholder-based initiative consisting of over 60 partners representing companies, industrial actors, public agencies, universities and research institutes. The Swedish Forest Industries Federation coordinates the programme.

The brand new national strategic innovation programme Re:source[69] from 2016 has also an orientation towards a circular bioeconomy. The programme aims at increasing economic growth and sustainability in waste management. The target is development of innovations that can contribute to resource efficiency within industry and society as a whole, create new business possibilities and competitiveness to meet global challenges. The overall vision is: "*(…) to become world leader in minimizing and profiting of waste*". This partnership consisted of 80 partners already when the programme was launched. These are actors mainly from the recycling and waste industry, being: material producers, manufacturing industry, research institutes, municipalities and regions. The Swedish Energy Agency runs the programme, and the SP Technical Research Institute of Sweden coordinates it. These two actors have played a major role in developing the programme. Their idea spins out of their strategic network called Waste Refinery[70] established in 2007. In the end of 2015, the government decided to support the programme financially with allocating 20 million SEK per year in the period from 2016-2019. The funds are granted by Vinnova. Formas, the Swedish Energy Agency, and the enrolled companies also support the programme.

The Biorefinery of the Future[71] is a similar partnership, although at a smaller scale and geographically located to the region of Örnsköldsvik and Umeå. This project platform involves companies, public agencies and universities in this region. Their goal is to be a creative hub in a world-leading cluster for developing biorefinery processes. They will run processes and projects that focus on addressing the present energy and climate challenges by using raw materials from forests and energy crops into green products, chemicals and material. Their vision is well anchored in a circular bioeconomy: "*For the Biorefinery of the Future, environmental and climate friendliness is not just a goal – it is a working method. Our focus on sustainable development lays the foundation for long term regional and national growth*". The program is rooted in the research agenda on "Biorefineries for a green Sweden"[72].

> *"The conversion to a fossil-free society can only take place if existing process industries adapt to a biorefinery concept through (…) utilisation of available bio-based resources – from forest to agriculture and future marine sources – is the focal point when tomorrow's chemicals, materials and energy are being produced. To succeed in this regard, there is a considerable need for developing new technology platforms and integrating them with each other and existing processes, as well as adapting innovation processes, defining new supply chains, securing the supply of competencies."*[73]

Paper Province[74] is another partnership based cluster. It is a vital wood-based research and innovation initiative located in the region of Värmland. Their vision is to create products and energy from the forest, as an alternative to fossil materials. The cluster was founded as early as in 1999 by seven companies in the pulp and paper industry and consists now of over 200 members. Hence, the cluster has a distinct accumulated expertise in the forest industry. In 2013, the cluster received ten years support from

[69] http://resource-sip.se/
[70] http://wasterefinery.se/
[71] See: http://www.vinnova.se/sv/Resultat/Starka-forsknings-och-innovationsmiljoer/Framtidens-Bioraffinaderi/
[72] See: http://www.vinnova.se/sv/Var-verksamhet/Gransoverskridande-samverkan/Samverkansprogram/Strategiska-innovationsomraden/Strategiska-innovationsagendor/Forteckning-agendor-2013/Bioraffinaderier-for-ett-gront-Sverige-/
[73] http://www.nra-sweden.se/gron-agenda-agenda-bioraffinaderier
[74] See: http://paperprovince.com/

VINNVÄXT Vinnova programme to promote sustainable development in the growing field of a regional forest based bio-economy.

2. Forest – the cornerstone

As already pointed at, the forest industry stands out as a central industrial sector in the research and innovation strategies for a circular bio-economy in Sweden. Forest industry is a generic term for all industry with timber as a raw material, which includes many various actors. Nonetheless, the Swedish Forest Industries Federation is representing many of these, in being the industrial and employers' organisation for all pulp, paper mills, and woodworking industries in the nation. This federation has an orientation towards a circular bioeconomy in their overall vision:

> *«The forest industry – the driver for a sustainable bioeconomy»*[75].

Their main objective is to emphasise the need for making use of the resources of sawn timber, pulpwood, and forest fuel, as streams from a sustainable forestry. Their argument is in the unique renewable raw material of timber. The biogenic carbon dioxide from burning of trees and wood-based products is part of the natural carbon cycle, in contrast to the fossil-based carbon dioxide from oil and coal which adds new volumes of carbon dioxide and contributes to climate change. This bio-based production cycle creates sustainable growth through investments in research and innovation, skills, a resource efficient industry, and sustainable consumption[76]. Importantly, their vision also emphasises the value creation in generating of more jobs in a rising forestry industry and in indirectly related industries in engineering, transport, IT, and various parts of the service sector[77].

Their orientation towards a sustainable bioeconomy can be traced back to strategies launched in the beginning of 2000s, in a myriad of documents, see annex 1. Early documents called for a sustainable production, e.g. "Forest industries sustainable goals" in 2008[78]. Various related agendas have been discussed in strategies for a paper based industry, forest fibre industry, biofuel[79], etc. Their yearly publication "Living Forests" [80] has discussed the issue each year from 2011 to 2015. The federation has also accomplished a governmental position by inviting ministers to several seminars raising policy issues for a circular economy[81]. An important fact is the many strong companies in the pulp and paper industry, which have been under a strong pressure for a need for change.

The forest industry can replace products based on fossil materials, which people need in their everyday life. These products are not purely new and spectacular, but hold also traditional products, in combinations with new or existing functions, as timber for green buildings[82] and packaging. The federation highlights the need for seeing packaging in a lifecycle analysis of the product as a whole as packaging contributes to reduce food waste along the value chain. Packaging also meets an increased demand from growth in internet shopping[83]. The importance of renewable energy and transport are already pointed at here. The future need for textiles expects to grow, and many Swedish companies are developing new techniques for

[75] Living Forests 2015
[76] E.g. see: *The forest industry – the driver for a sustainable bioeconomy*
[77] E.g. see: New Visions – a story about opportunities; The forest industry – the driver for a sustainable bioeconomy
[78] Forest industries sustainable goals 2008
[79] E.g. The Swedish Forest Industries Manifesto 2008; Unfold the future. The Forest Fibre Industry 2011; Biofuel from forest 2014
[80] See: Living Forests 2011-2015
[81] E.g. "Vilken roll spelar skogsindustrin för en hållbar utveckling" 2011; "En hållbar bioekonomi krever økad tillväkt" 2011
[82] According to research referred in the "Swedish Forest Industry Report" 2012, p. 13.
[83] E.g. Paper Wins! 2010

production of viscose fabricate[84]. As well, lignin and green chemicals are expected further research and development of new products and markets[85]. BioInnovation is an area for investigating such potentials in collaborations and in cross-sectoral projects, with e.g. the textile industry and the automobile industry. Biorefinery of the Future and Paper Province are others. The Federation of Swedish Farmers has also emphasised the forestry in their green growth vision, enabling profitability, growth and quality of life[86]. Hence, the cornerstone of forestry has moved away from the traditional industrial boundaries of the forest industry in Sweden.

3. Limited governmental strategies

At the governmental level, on the other hand, there are still no governmental strategies or any ongoing processes towards raising the notion of a circular bioeconomy. Recently, a policy goal was launched, heading for the circularity of the bio-based economy. The governmental programmes for forestry and biodiversity and ecosystem services are also shedding governmental goals for a circular bioeconomy.

A bio-based economy was as one of the policy goals presented by the Prime minister in the Statement of Government Policy to the Swedish parliament in September 2015[87]. In his speech, the Prime minister highlighted climate, environment, and energy as three important policy areas, and declared how the Government will speed up the work against the global challenges. He presented a long list of policy goals, e.g.: halving the global greenhouse gas emissions, reduced dependence on fossil fuels through investment in green transport and renewable energy, a toxin free environment, investments for renewable energy, environment and climate technology investments and biological diversity. Amongst these, a goal for a circular bio-based economy was stated:

> *"The foundation will be laid for a circular, bio-based economy that contributes to the achievement of the environmental objectives. What is waste today will become a resource, inspiring new business opportunities".*

This policy goal addresses the circularity of the bioeconomy and calls attention to it as a source to economic growth. Several of the other policy goals also address the creation of business opportunities, jobs, and economic development, e.g. in how governmental investments may create impetus for technological and economic development in maritime wind power, the national forestry programme and the forests green gold, environment and climate technology investment to strengthen innovative capacity in companies, etc. It is also worth mentioning that several of these other policy goals are indirectly relevant for a circular bioeconomy, e.g. investment in green transport and infrastructure for biogas, intensified protection and raised bars to biological diversity, and natural habitats.

In this regard, many governmental strategies could be relevant. The ongoing National Forestry Programme stands out as particularly relevant here since this programme has an overall vision of a circular bioeconomy:

> *" Forests – our green gold – can contribute to workplaces and sustainable growth all over the country and to the development of a growing bioeconomy"[88].*

84 E.g. see central actors of Smart Textiles and Swedish Industrial Design Foundation
85 E.g. see the Industrial and Chemical Employers Association
86 Towards a biobased economy 2015
87 See: http://www.government.se/articles/2015/10/statement-of-government-policy-as-it-pertains-to-the-areas-of-responsibility-of-the-ministry-of-the-environment-and-energy/
88 See: http://www.regeringen.se/regeringens-politik/ett-nationellt-skogsprogram-for-sverige/

The government started working on the programme in September 2015. The Ministry of Enterprise and Innovation leads the work through workgroups, regional dialogue, and a council. These workgroups have discussed various value chains in the forest industry: (1) forests as a resource, (2) production and sustainable growth, (3) creation of biobased products, smart transport, and export, and (4) international questions. The work is rooted in previous governmental programmes for strengthening the biodiversity[89] and the strategy for research and innovation[90].

These governmental programmes for strengthening the biodiversity have also addressed the circularity in biological production processes. In particular, the strategy for biodiversity and ecological system services from 2014 which presents long-term goals for protection of land and sea, endangered plant and animal species, and natural and cultural environment considerations. This programme gives emphasis to the value of ecosystem services and biodiversity and how to integrate political and economic strategies. It calls attention at a need for increased cooperation with industry and spots many new business opportunities in sectors as agriculture, forestry, pharmaceutical industry, fisheries and tourism. Yet, these opportunities have been little further developed at the level of national governmental programmes.

Summing up Sweden

The mapping of the circular bioeconomy in Sweden showed a research and innovation-based notion, in the many existing programmes supporting activity related to new bio-based products and services, waste management, biorefinery and other products and energy from forests. Importantly, these research and innovation programmes have been developed in dialogue with various stakeholders. Industrial actors and federations have been active, but also academic interests have been influential. Several of these programmes originate out of the national research and innovation strategy for a bio-based economy, when the research council, the innovation agency, and the energy authorities invited in actors to develop a strategy in dialogue with industrial actors, public agencies, and academia. However, most of these initiatives also have much earlier roots, in previous industrial visions and long-standing networks and clusters.

Above all, the forest-based industry and its industry federation stand out as a driver with long and strong traditions in the Swedish industrial bioeconomy. Notably, this federation has called the forest as “the green gold”, because of its potential to develop and offer workplaces and sustainable growth all over the country. The renewable material of timber has been emphasised, as a raw material to efficient utilisation of the renewable biomass into finished products, including efficient use of by-products and waste products. This call for knowledge-based innovation, and research and innovation strategies are important to achieve the circular bioeconomy in Sweden. The Bioinnovation programme is one great example of cross-sectoral collaboration in this regard.

In Sweden, the circular bioeconomy has been regarded important because it contributes both to achieving environmental objectives and to inspire new business opportunities. Yet, direct governmental strategies are still limited, in comparison to the other two Scandinavian countries.

89 http://www.regeringen.se/rapporter/2014/04/m2014.06/;Prop 2013/14:141 En svensk strategi för biologisk mångfald och ekosystemtjänster

90 Rapport från Forskningsrådet Formas: Forsknings- och innovationsstrategi för en biobaserad samhällsekonomi

Circular bioeconomy across the Scandinavian countries

There are numerous initiatives and visions in all three Scandinavian countries for how to develop the bioeconomy. This report has focused particularly on the part of the bioeconomy that is concerned with side streams, waste streams and by-products, which should be seen as streams of biomass with great potential to creating new, sustainable value chains that will expand into the bioeconomy. There is still a large potential in exploitation of biomass in more specialised value circles. To accomplish this circularity in the bioeconomy, several findings in this report highlight the necessity of cross-sectoral collaboration, both on the local, regional and international levels.

As the analysis has given some answers to the questions what, why, who and how, it is obvious that the circular bioeconomy is a matter of great importance to all three Scandinavian countries, but the matter is approached quite differently amongst the three.

- In Norway, it is emphasised that one will need to collaborate more across sectors in order to reach the full potential of the circular bioeconomy. The bioeconomy is recently put on the agenda on the governmental level and several stakeholder initiatives seek to contribute to the shaping of it, where particularly the marine sector and best practice of biorefinery from forest biomass are important for the circular bioeconomy.
- In Denmark, the approach is very much oriented around business and export opportunities, and recent initiatives have been particularly focused on the waste management sector. Biorefineries and the agricultural sector are highlighted, and for both these countries the bioeconomy represent a path on the way to becoming fossil-free.
- In Sweden, the notion of research and innovation to accomplish a transition to a bio-based economy is strong. Several programmes have been developed in the aftermath of the national research and innovation strategy. Several of these are participatory stakeholder-based initiatives. Industrial actors, but also public agencies and academia have been actively involved. The forest industry has been an important sector with long roots in the Swedish economy, and one sees large potential in building further on this.

All three countries have ambitions to become world leading in different aspects of the bioeconomy, notably in the marine sector, biorefineries, and forests. As well, it is referred to exchange of knowledge and international collaboration as important on the path to the new bioeconomy in Scandinavia. The three countries share linguistic and cultural similarities, which would be a good starting point for such. As a slight wider geography, we find the Nordics, with formal political megastructures, such as the Nordic Council of Ministers (NCM); established to ensure the shared interests of the Nordic countries. Hence, when looking at the circular bioeconomy across Scandinavia, one should have a glance at the NCM.

NCM has a dedicated focus for the development of a *"(…) cross-sectorial and systematic approach, with a basis in circular economy"* in the Nordic region, called the Nordic Bioeconomy[91]. An analysis commissioned by the NCM in 2014[92] supported the development of a list of policy recommendations for national and regional levels to develop the bioeconomy in the Nordic region, also included in a Policy Brief[93]. Amongst the recommendations, the creation of a common understanding of the concept bioeconomy is highlighted as it has "(…) an impact on ambitions, visions, tools and learning between countries and regions". Financial incentives, stimulation of the demand for bio-based products and promotion of export might all be carried out in strong co-operation between the countries. Further knowledge sharing between the local sectors and actors, through regional clusters or quadruple helix models is advised, and further cooperation can be

[91] http://www.norden.org/en/theme/nordic-bioeconomy
[92] NordRegio (2014): Bioeconomy in the Nordic region: Regional case studies
[93] NordRegio (2015): Bioeconomy – the Growth Engine of the Nordic Regions? Policy Brief 2015:5

encouraged through co-financing of development projects[94]. These recommendations are very much in line with the findings from the national analysis. This is interesting as it highlights the importance of the joint understanding of the term *bioeconomy*; a novel term that needs to be further discussed. In turn, through becoming more aware about the opportunities in the bioeconomy, it will become more likely that one can see and understand how to achieve sustainability in new, fine-tuned value chains. In this regard, the ongoing bio-economic strategy in Norway will be interesting, and the strategic BioInnovation programme in Sweden, contributing to bring actors together and develop common understanding.

As actual value-chains based on bio resources gradually will start to mature, networking and partnerships will ultimately not be delimited by national boundaries. In a report from 2014, Nordic Innovation estimated that the total turnover of the key bioeconomy sectors in the Nordic countries is roughly EUR 184.000 mil[95]. The report adds that there is remarkable innovation and growth potential in the Nordic bioeconomy, identifying six crosscutting growth areas, repeatedly mentioning *bio-based side streams* as a particular focus.[96] This specific mentioning is highly interesting in the context of the circular bioeconomy.

Under the NCM Icelandic presidency in 2014, the development of a three-year program called *NordBio* was initiated with an overall objective to assist the Nordic countries to lead the way to a stronger bioeconomy[97]. The establishment of the Nordic Bioeconomy Panel[98] is a direct outcome of this initiative. The Panel was set up based on the joint interest from the Nordic countries to develop a cross-border bioeconomy strategy. The first meeting in the Panel was held on March 7, 2016 and consisted of representatives of official agencies, research bodies, private companies and civil society from the Nordic countries. The panel is seen as an important step in the vision to becoming "a world leading region in the field of bioeconomy"[99]. The panel is also expected to stimulate innovation and to contribute to a sustainable transformation towards the bioeconomy in the Nordic countries. Furthermore, the panel will explore and expose the potential of the Nordics to take a global lead in the field[100]. This harmonises well with the visions of the three countries.

In a report launched by the NCM in February 2016, a group of researchers from the Nordic countries made a mapping of the biorefineries and business models available in the region[101]. The report describes a set of business needs and opportunities for further developing the Nordic Bioeconomy. The analysis identified the need for *"a strong co-Nordic biorefining innovation center, which actively supports biorefining industries and registration, funding, marketing, scale-up and regulatory framework, both within the region and globally"*. The report also states that the Nordic biorefining sector still has to gain market experience and build several large-scale biorefinery operations running for proof-of-concept. In that regard, governmental co-investments and initiatives are needed to attract and minimize the risk of private investors required for these new technologies and applications. In Sweden, the Biorefinery of the Future is an example of a partnership based research programme in the Northern region of Sweden, and the Borregaard plant in Norway is a great example of proof-of-concept.

To approach a Nordic bioeconomy, The *Nordic Bioeconomy Programme* will be funding activities that generate new knowledge on how to promote and advance the transition to a bioeconomy-based society in

[94] NordRegio (2015): Bioeconomy – the Growth Engine of the Nordic Regions? Policy Brief 2015:5
[95] Nordic Innovation (2014): Creating value from bioresources. Innovation in Nordic Bioeconomy
[96] Bio-based side streams are mentioned in the following areas; bio-based chemicals; biomaterials; biofuel and bioenergy; biorefineries; resource-efficiency and industrial symbiosis. Services based on ecosystem services or supporting the above mentioned is the sixth area.
[97] http://nordbio.org/
[98] http://www.norden.org/en/theme/nordic-bioeconomy/nordic-bioeconomy-panel/about-the-nordic-bioeconomy-panel/
[99]http://www.norden.org/en/nordic-council-of-ministers/the-nordic-council-of-ministers/the-secretary-general/the-secretary-generals-blog/the-way-forward-is-sustainable-bioeconomy
[100] http://www.norden.org/en/theme/nordic-bioeconomy/nordic-bioeconomy-panel/about-the-nordic-bioeconomy-panel/
[101] NCM (2016): Development of the Nordic Bioeconomy. NCM reporting: Test centers for green energy solutions - Biorefining and business needs

the Nordic countries[102]. This will be done by integrating research, innovation and entrepreneurship in the private and public sectors. The aim is to fund three Nordic Centres of Excellence in the bioeconomy for a five-year period starting with 2017. This offers great opportunities to take some important steps towards answering the question of *how to get there.*

The development of a shared vision for the bioeconomy in the Nordic countries is still in an incipient phase, but the ambitions are high and the focus on sustainability and the circular aspect is explicit. One of the questions remaining for the Scandinavian bioeconomy is how it should be further approached to reach the visions of becoming world leading; through national efforts or through a common or coordinated Nordic approach.

[102] https://www.nordforsk.org/en/programmes-and-projects/programmes/copy_of_nordic-bioeconomy-programme

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Annex - Mapping

NORWAY		
Strategies and documents	**Responsible**	**Year**
Report from Expert Committee on green competitiveness	Idar Kreutzer and Connie Heedegaard, with mandate from the Government. Initiated to create a foundation for an overall strategy for how to achieve competitiveness success with a green restructuring in Norway	Oct 2016 (in process)
Road map for the circular economy in Norway	Avfall Norge, Mandate from Norwegian Environment Agency	June 2016
Bioeconomy strategy	Ministry of Trade, Industry and Fisheries & the Ministry of Agriculture and Food	2016 (in process)
"Sett pris på miljøet"	Report from "Green Tax Commission", appointed by the Government	Dec 2015 (open hearing in process)
Drømmeløftet; "The bioeconomy – an important contribution to growth and value creation in the future"	Innovation Norway	2015
Conditions for the bio-economy in Norway	Report by Vista Analyse, assigned by the Ministry of Trade and Fisheries	2015
Research for innovation and sustainability – strategy for the Research council of Norway	The Research Council of Norway	2015-2020
Masterplan for Marine Research	Ministry of Trade, Industry and Fisheries	2015
SKOG22	Report initiated from the Ministry of Agriculture. Carried out by 17 key stakeholders, representing the forest-based value chain	2015
National cross-sectoral biogas strategy	Ministry of Climate and Environment	2014
MILJØ21	Research strategy developed by the Norwegian Research Council in collaboration with other stakeholders	2014
Energi21	National strategy developed by the Energi21 group, mandate from Ministry of Petroleum and Energy	2014
«From waste to resource» Waste management strategy	Ministry of Environment	2013
HAV21	Research strategy, developed on the initiative by the Ministry of Fisheries and Coastal affairs	2012
National strategy for biotechnology	Ministry of Education and Research	2011-2020
Knowledge for climate	Research strategy developed by the forum KLIMA21 with mandate from the Government	2010
Strategy for marin bioprospectring	Ministry of Fisheries	2009
Strategy for an environmental and sustainable marine sector	Ministry of Fisheries and Coastal affairs	2009
Stakeholder initiatives		
Bioeconomy Panel	NHO established a panel to follow and deliver input to the process of developing the national bioeconomy strategy.	2015
Towards the bioeconomy – NHO input for a new international and competitive business"	Report from NHOs bioeconomy panel. The report presents various scenarios for Norway 2050	2016

Norway203040 – The business opportunity	Report. Initiated by key players to elevate a business perspective into the public debate on climate- and environment matters. Parties: DNV GL, Hydro, KONGSBERG, Posten & Bring, Ruter AS, SpareBank 1 Forsikring, Statkraft, Statnett, Storebrand and Umoe, as well as supporting partners WWF-Norway, Xyntéo and ZERO.	2015
Comprehensive conditions for waste treatment	Report/A set of projects established by Avfall Norge. One of these called "Scenarier for avfallsmengder og behandlingskapasitet i Norge fram mot 2030»	2015
This is how Norway can make a difference	Report. Launched by Norwegian climate foundation	2015
BioVerdi	Report. Created in partnership between 50 stakeholders across the industry, academia, knowledge hubs, investors and organisations; initiative by Oslotech AS.	2014
RUBIN	Foundation. Closed in 2012. Aim was to contribute to a total exploitation of fish and increased value creation of bio-feedstock in Norway	1992-2012

DENMARK		
Strategies and documents	**Responsible**	**Year**
Biorefining Alliance – Local solutions to Global needs	Association. Initiated by industry representatives: DONG Energy, Novozymes, Haldor Topsøe and the Danish Agriculture and Food Council	2011
Denmark in a Global Bio-based Society – do we want to be customers or producers?	Strategy. Biorefining Alliance	2012
The potential of the bioeconomy and the value for the different sectors	Analysis. Developed by Copenhagen Economics	2012
+19 mill. tonnes plan. Possibilities for an increase Danish production of sustainable biomass for biorefineries	Analysis. Developed by Copenhagen University, Dep. for Food and Resource Economics	2012
Green Transition – the road to new jobs and a better climate	Report. Developed by the 3F (Fagligt Fælles Forbund)'s Green Think-Thank. The report includes recommendations that can generate jobs within the Danish bioeconomy	2015
The potent for green jobs in Denmark	Report. Arbejderbevægelsens Erhvervsråd	2015
The start of the Danish Bioeconomy	Status report from the first Danish integrated biorefinery, Maabjerg Energy Concept	2015
Nature and Agriculture Commission	The commission issued a set of recommendations on how to increase the innovation, productivity, investments and exports in agriculture. One of them: conscious focus on utilizing biomass for energy and other bio-based products.	2013
Denmark without waste. Recycle more, incinerate less	Strategy issued by the Danish Ministry of Environment and Food. The focus is on reduction of incineration of waste and increase of recycling.	2013
Growth and development in the entire Denmark	Growth strategy by the (latest) Danish Government. Includes an analysis of the opportunities to support the production and use of advanced biofuels	2015
VILLUM Center for Science of Sustainable Fuels and Chemicals	Technical University of Denmark in cooperation with Southern Denmark University and Stanford University (basis research to develop alternative chemicals and fuels to replace those from fossil sources)	2016-2023

Stakeholder initiatives		
Green Roadmap 2030 – Scenarios and instruments for the transition of the transport sector and its energy consumption	Developed by Ea Energianalyse. Focus on shifting to alternative fuels in the Danish transport sector, where utilization of bio-based fuels is a major focus	2015
Novozymes Innovation Campus	Novozymes plans to build its biggest global biotech innovation campus in Denmark by 2018. This will host 800 research and development employees.	2018
Biocluster	Biocluster initiative is organized as a pilot project and focuses on business opportunities and innovation in the conversion to bioeconomy. Consortium that includes Central Denmark Region, Aarhus University, Danish Agriculture and Food Council, Viborg Municipality, VIBORGegnens Erhvervsråd and Agro Business Park	2013-2015
Carlsberg Circular Community	An innovation partnership with key partners to rethink the design and production of packaging materials to eliminate waste and optimize materials for high quality. In 2015, Carlsberg presented a prototype of a biodegradable beer bottle (Green Fibre Bottle)	2015

SWEDEN		
Strategies and documents	**Responsible**	**Year**
National Forestry Programme	Government, Minister of Rural Affairs	Ongoing
RE:Source	Strategic Innovation Programme by Swedish Energy Agency, VINNOVA and Formas, led by SP Technical Research Institute in collaboration with Chalmers Industrial Technology, IVL Swedish Environmental Research Institute, Swerea, Chalmers, Luleå University of Technology and Inno Group	2016
BioInnovation – Strategic Innovation Programme	Participatory stakeholder based, coordinated by Swedish Forest Industries Federation. Financed by Research Council Formas, innovation agency VINNOVA, and Swedish Energy Agency	2015
Roadmap for Biological Diversity and ecosystemservices	Goverment	2014
Biorefineries for a green Sweden – a Strategic Research and Innovation Agenda for developing a cross-industrial biorefinery concept	VINNOVA, Lund University, SP Technical Research Institute of Swede, in collaboration with academic, industrial, and public actors	2013
Swedish Strategy for biological diversity and ecosystemservices	Govermnental proposition, Minister of Climate and the Environment	2013
Swedish Research and Innovation Strategy for a Bio-based Economy	Research Council Formas, VINNOVA, and Swedish Energy Agency	2012
Stakeholder initiatives		
Biorefinery of the Future	SP Processum, cluster of companies in biorefinery processes, public functions, and universities in the Örnsköldsvik and Umeå region	2008
Paper Province	Cluster in region of Värmland	1999
Living Forests	Swedish Forest Industries Federation	2011-2015

Biofuel from forest	Swedish Forest Industries Federation	2014
National strategic research agenda for the forest-based industry in Sweden	Research agenda jointly prepared by forest industry, scientific community and public research financiers, and coordinated by NRA Sweden (the Swedish National Support Group) under the leadership of the NRA Council. A large number of people and organisations submitted expert contributions by participating in workshops, reference groups and surveys.	2013
The Forest Industry – the Driver for a Sustainable Bioeconomy	Swedish Forest Industries Federation	2012
Unfold the future. The Forest Fibre Industry – 2050 Roadmap to a low-carbon bio-economy	Swedish Forest Industries Federation	2011
Paper wins!	Swedish Forest Industries Federation	2010
The Swedish Forest Industries Federations Manifesto	Swedish Forest Industries Federation	2008
New Vision – a Story about Opportunities	Swedish Forest Industries Federation	2007
Time to take the fossil free future for real!	The Federation of Swedish Farmers	2015
How we reach a biobased economy – an input from the Federation of Swedish Farmers	The Federation of Swedish Farmers	2015
Farmbased small scaled bioenergy and biomassproduction – an agenda for the need for research and innovation	The Federation of Swedish Farmers, SP Technical Research Institute, Hushållningssälskapet	2014
A biobased economy for sustainable development	AgroVäst, AgrÖst, Formas, Hushållningssällskapet, Hästnäringens Nationella Stiftelse, Jordbruksverket, JTI – Institutet för jordbruks- och miljöteknik, the Federation of Swedish Farmers, Livsmedelsföretagen, Livsmedelsverket, Mistra, Naturvetarna, SkogForsk, Swedish Forest Industries Federations, Skogssällskapet AB, SP Trätek, Statens Veterinärmedicinska Anstalt, Stiftelsen Hästforskning, Stiftelsen Lantbruksforskning, Svenska FSC, Sveriges Lantbruksuniversitet, Vinnova, World Wildlife foundation WWF	2011
Long-term goals for biological waste treatment in Waste Refinery – communication and priorities	Waste Refinery	2016
Smart Textiles – for a better world through textile innovation	Smart Textiles	2016
Design is an obvious driving force for sustainable development	Swedish Industrial Design Foundation	2016
There are no differences between industrial development and climate change – only possibilities	Industrial and Chemical Employers Association	2016