NORDIC INNOVATION REPORT 2014:01 // MARCH 2014

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March 2014

Nordic Innovation Publication 2014:01

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ISBN 978-82-8277-056-9 (Print)
ISBN 978-82-8277-055-2 (URL: www.nordicinnovation.org/publications)

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All Nordic Innovation publications can be downloaded free of charge as pdf files from www.nordicinnovation.org/publications

Cover photo: McKenna P - Stock.xchng

Printed on environmentally friendly paper.

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# CONTENT

# EXECUTIVE SUMMARY

Bioeconomy development promotes a more resource-efficient circular economy based increasingly on renewable energy, products and materials produced through sustainable use of ecosystem services from land and water. A greater focus on research and innovation can provide us with new products derived from biomass and new services required for realization of the bioeconomy development. The bioeconomy development helps combat climate change, reduce waste and create new jobs.

The objectives of this study were to identify the innovation-oriented challenges as well as areas with high growth potential within the Nordic bioeconomy. As a starting point, the study also produced important background data concerning the volume and constituents of bioeconomy in Nordic countries.

According to the estimate, the total turnover of the key bioeconomy sectors in Nordic countries is roughly 184 000 M€ including agriculture, fisheries and aquaculture, forestry, food industry, forest industry and bioenergy and biofuels. This is 10 % of the total economy in Nordic countries. The share is highest in Iceland, where the key sectors of bioeconomy stand for 18 % of the total economy, and lowest in Norway with a 6 % share. In all countries, the largest contributors to bioeconomy include forest industry or food industry. This shows the economic importance of intermediate and end product processing in the bio-based value chains.

The largest innovation and growth potential of bioeconomy seems to be in its crosscutting nature. The following interesting crosscutting growth areas of the bioeconomy in the Nordic countries were identified: bio-based chemicals, biomaterials, biofuels and bioenergy, biorefineries, resource-efficiency and industrial symbiosis and services based on ecosystem services or supporting the above mentioned areas of products and creating value without tangible material flows and including design.

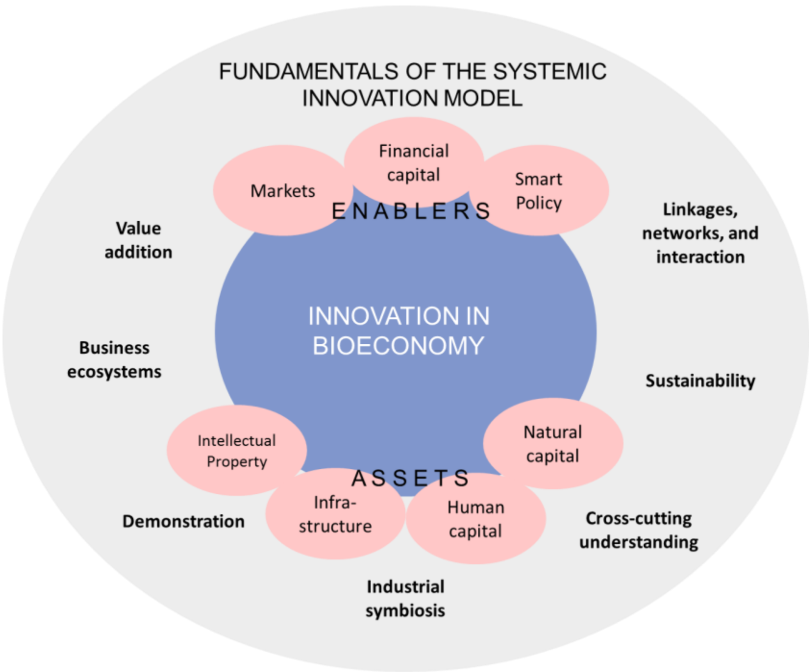
In the business ecosystem analysis concrete business ecosystem illustrations and cases exemplified how bioeconomy innovations have been developed in potential value chains of bioeconomy which cut horizontally through the traditional sectors.  The seven business ecosystems analyzed were 1. Aquatic Biorefinery, 2. Nordic Functional Bio-based Ingredients, 3. Advanced Biomaterials, 4. Biorefinery Concepts, 5. Biocatalysis, 6. Decentralized Bioenergy Systems, and 7. Bioeconomy Related Services. For successful bioeconomy innovations, the business ecosystems are crucial when the novel processes, products, methods, services and systemic solutions developed are taken into use by actors in the concrete value chains and business ecosystems. Key findings from the business ecosystem analysis were the following. First, market access is the key step in successful bioeconomy innovation. It can be concluded from the case studies that it is beneficial to engage end users in target markets as early as possible in the innovation development. Secondly, technology and services of bioeconomy offer global business opportunities and utilization of existing infrastructure on the other hand lowers the commercialization threshold for novel bioeconomy innovations. Importance of complementary actors in the business ecosystems was also emphasized. Ensuring overall sustainability and holistic resource optimization across sectors is instrumental as bioeconomy innovations target resource-efficient use of valuable bioresources. From innovation type perspective it was concluded that nature of the innovation path often combines linear and systemic elements. Matching of best competences is crucial.

Several obstacles of innovation in Nordic bioeconomy were also identified. Lack of capital and funding is a key challenge in the emerging bioeconomy, since the investments have a

long life cycle and are capital intensive and at the same time the emerging bioeconomy sector is not familiar to investors and even to potential customers. Thus also first industrial scale plants are challenging to establish. In addition, unstable operating environment is largely due to the changing regulation related to some of the biggest drivers of bioeconomy such as carbon prices. Also cross-cutting nature of bioeconomy would require if not a breakdown of traditional sector borders, at least a more active communication and cooperation between the sectors. Market access is crucial especially in Nordic countries, since the home markets are relatively small whereas global markets are growing. Lack of actors in ecosystems is also a Nordic challenge; the number of actors and investors is relatively small compared to many other markets such as the US.

In order for the support measures to better tackle the obstacles identified, some areas for further development include networking and developing a common understanding of the roles of different stakeholders, making processes for seeking support and financing easier for SMEs, promoting demand by including criteria for bio-based materials in public procurement as well as promoting cross-sector transfer of existing or new applications for existing processes in already established sectors. In addition, venture capitalists should be included in the networks to ensure they are better able to recognize the potential of commercially viable bioeconomy concepts. Lastly, it can be discussed whether the support provided for R&D and other activities in the innovation process provides the necessary focus to find solutions based on customer needs. More focus may be needed to link the support to finding commercially viable applications with the markets and customers.

Finally, the results of the study were concluded and recommendations made how to better support Nordic bioeconomy innovations. The conclusions and recommendations were given in relation to the systemic model framework for bioeconomy innovation, describing the crucial fundamentals, assets and the enablers required.



# INTRODUCTION

## BIOECONOMY

There is an increasing need for the growth of bioeconomy in EU and globally, since the non-renewable resources are getting scarce and environmental issues are gaining more importance. Nordic countries have a great potential to be a driver of this growth due to their large and sustainably managed biomass resources, as well as world-class competence on bioeconomy.

Bioeconomy development promotes a more resource-efficient circular economy based increasingly on renewable energy, products and materials produced through sustainable use of ecosystem services from land and water. A greater focus on research and innovation can provide us with new products derived from biomass and new services required for realization of the bioeconomy development. The bioeconomy development helps combat climate change, reduce waste and create new jobs.[1]

The definition of bioeconomy by the Nordic Bioeconomy Initiative is used in this study. Briefly, the crucial components regarding bioeconomy are:

- Sustainable production of biomass in order to increase the use of biomass products in a number of 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.

Innovations are important drivers for the growth of bioeconomy. Since bioeconomy encompasses all the sectors related to services and technologies that produce, process or use biological resources, the innovation potential is remarkable.

Product, technology, societal, systemic and operational innovations are needed to take advantage of the opportunities in bioeconomy. The potential for innovation lies, for example, in the development of new types of bio-based products such as biofuels, biomaterials or biochemicals. Also development of process and production technologies, use of side streams and creation of industrial symbiosis to increase resource efficiency are significant when it comes to innovation potential. In addition, also knowledge intensive services and immaterial value-added services can be developed.

These building blocks of bioeconomy are tied together in a variety of different business concepts, business ecosystems and resource flows in Nordic countries and globally. Business ecosystems connect several linear value chains into vibrant and often complex bio-based value networks. In wider value networks the economic and environmental benefits of new bio-based innovations are likely to be realized, as material flows are utilized efficiently into value-added products.

[1] The Nordic Bioeconomy Initiative 2013-2018 http://nkj.nordforsk.org/copy2_of_NBIstrategydocENG.pdf, accessed 20.1.2014.

# TYPES OF INNOVATION AND INNOVATION MODELS

As stated above, many different types of innovation are required in order to take advantage of the opportunities in bioeconomy. These include product, technology and service innovations, as well as societal, systemic, and operational innovations. Innovation itself is defined as something novel, knowledge and ideas, which are applied in commercial markets or in society. To understand the innovations in bioeconomy – whether they are product, technology, services, societal or operational innovations – we need to understand the difference between linear and systemic innovation models.

> **Linear innovation** model estimates the development of products, technologies and services from the traditional linear perspective: research leads to more applied research and development activities, which in turn lead to piloting, demonstration and finally commercialization of developed innovations and wider diffusion in society[2]. The traditional linear innovation model usually has one main driving force: technology or market. Thus, the model is often considered to be either technology or market driven.
>
> In technology driven ("technology push") innovation models the starting point is a technological innovation, which is developed further and the best applications are developed and commercialized. In market driven ("market pull") innovation models, on the other hand, the starting point is a market need, for which the best solutions are developed further and commercialized.
>
> The drawback of both approaches is that in the traditional model the view on innovation is often too narrow: research questions can be scoped too narrowly, with no or insufficient interaction to the quickly changing operating environment, as the development progresses. Open innovation and user-driven innovation models have been developed to overcome these shortcomings. These approaches bring more advanced dynamics into innovation: more actors and stakeholders, more iterative approach and more linkages between parallel innovation processes.
>
> In a globalized world traditional (linear) ways of innovation face several challenges: traditional research and development cycle may be too slow to create competitive edge, and financial resources needed for world-class research and innovation may not be available. This has led to a strict focusing of R&D activities to only a limited number of interesting areas in order to keep up with the global innovation race[3].
>
> **Systemic innovation** model takes a broader look on innovation. It targets system-wide innovations, where innovation provides completely new ways of doing things: new value chains, new markets and radically more effective operations. Systemic innovations can link together innovations developed elsewhere, and take these into new markets. In the systemic innovation model, an open innovation cooperation of different actors in the value chains and markets is needed for the development and

[2] Godin and Benoit (2006). The Linear Model of Innovation: The Historical Construction of an Analytical Framework". Science, Technology & Human Values 31: 639–667.

[3] European Commission has launched many innovation policy instruments which target focused and large R&D efforts, like the public private partnerships (PPP) in form of Joint Technology Initiatives (JTI) within Horizon 2020. One of the proposed JTIs focuses on bioeconomy, the Bridge (www.bridge2020.eu). One of the targets of the Nordic Bioeconomy Initiative is also to benefit from advantages of scale through Nordic cooperation.

introduction of the innovations. The advantages of systemic innovation include possibility to create significant value in shorter time frame and reasonable development effort and possibility to utilize potential synergies between different competences, actors and value chains. The potential disadvantage of this approach is that when combining innovations from many actors and sectors into novel value networks, the open innovation model can be challenging to adapt in practice and management of IPR and contractual relationships between various partners can be tedious and even form an obstacle to effective commercialization. Systemic innovations can be supported by transformative innovation policy, which can be applied to support transformative systemic changes like low carbon society or green economy [4]. Systemic innovation model is particularly interesting for bioeconomy, as bioeconomy in essence is a systemic transformation in business and society.

Although the scope of this study is in Nordic countries, it is clear that today innovation is an increasingly global issue. Innovation policy and trends have been highly influenced by globalization and rise of the emerging economies. So called reverse innovation means that nowadays innovations can spread to developed nations from the developing ones, instead of the traditional global dynamics, which goes the other way round[5].

In a globalized world, the best innovation partners are sought for based on world-class competence and physical distance is losing its significance in strategic partnering. On the other hand, when focusing on innovation in the area of bioeconomy, it must be taken into account that bio-based raw materials are a highly local issue, and best competence on understanding the local raw materials and ecosystems is often local. The same applies to markets of bio-based products: some markets are truly global (e.g. high-end bio-based products like pharmaceuticals), and strategic development and business partners are sought on a global basis, while some markets remain highly local (e.g. local bioenergy solutions), where partnering often happens within regional and domestic partners.

## OBJECTIVES AND OUTLINE OF STUDY

The objectives of this study are to ***identify the innovation-oriented challenges*** as well as ***areas with high growth potential*** within the Nordic bioeconomy. As a starting point, the study also produces important background data concerning the ***volume and constituents of bioeconomy in Nordic countries***.

The project provides innovation mapping of Nordic bioeconomy in five Nordic countries which:

- Identifies and describes the innovation potential within Nordic bioeconomy
- Identifies and describes the most important needs in order to strengthen and improve innovation within Nordic bioeconomy
- Identifies and describes the most important innovation supportive measures and activities in Nordic bioeconomy.

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4 Steward, Fred (2012). Transformative innovation policy to meet the challenge of climate change: sociotechnical networks aligned with consumption and end-use as new transition arenas for a low-carbon society or green economy. Technology Analysis & Strategic Management 24. 4 (2012): 331.

5 Govindarajan, Vijay & Trimble, Chris (2012). Reverse Innovation: Create Far From Home, Win Everywhere. Harvard Business Review Press.

The study is based on literature studies and interviews with companies and other stakeholders in Denmark, Finland, Iceland, Norway and Sweden. A list of interviewees and companies and organizations included in the study can be found in Appendix 5.

The current situation of bioeconomy in the Nordic countries is described in Section 3. An estimate of the volume of bioeconomy is given based on statistics from Eurostat and national statistics bureaus, together with analysis of the growth potential from a global perspective and the current bioeconomy strategies of the Nordic countries.

The innovations and constituents in bioeconomy are opened up in section 4, with the help of seven business ecosystems that are of high importance in the emerging Nordic bioeconomy. These business ecosystems are further exemplified with example companies.

Together these make up the descriptions of the volume and constituents of the bioeconomy in the Nordic countries, and describe the areas with high growth potential, which are the two first objectives of the study.

The results from the study related to the third objective, to identify the innovation-oriented challenges, are presented in sections 5 and 6. Presented in section 5 are, the main obstacles and support measures that exist on the path of the innovations. In section 6, conclusions and recommendations are made for development of innovation in bioeconomy in the Nordic countries. These are presented on the basis of the framework developed as a result of the study.

# BIOECONOMY IN THE NORDIC COUNTRIES

The economic and industrial activities that make up the bioeconomy reach across many sectors in the national economies. Agriculture, fisheries, aquaculture, and forestry are a crucial part of bioeconomy. Different industries, including food industry, forest industry, bioenergy, biofuels, chemicals, plastics, textiles and pharmaceutical industries, process bio-based raw materials into products. The technology sector, which manufactures machinery and other technological solutions, is needed in bio-based value chains, together with the biotechnology sector, which produces e.g. enzymes for biomass processing. The construction industry develops the infrastructure and buildings. Waste water treatment and waste treatment is needed for industrial and residential areas. Bioeconomy-related service sector includes recreational activities and tourism which are linked to nature.

There are no published estimates on the current volume of the bioeconomy in the Nordic countries, but the European Commission recently published an approximation of the volume of the European bioeconomy. The emerging bio-based industry estimate, which included bio-based chemicals and plastics, enzymes and biofuel production, accounts for 0.25% of the total economy, while the traditional bioeconomy, which included agriculture, fisheries and aquaculture, forestry, forest industry and food industry, accounts for 9% of the total economy. The emerging bio-based industry is thus still a very small part of the European economy.

## VOLUME OF BIOECONOMY IN THE NORDIC COUNTRIES

The traditional classification of national accounting shows the volume of the sectors, which are relevant for bioeconomy. This is a good starting point for describing the current situation in the countries and specifically, for pointing out the sectors which are emphasized in each country. For some of the sectors, only part of the sector is related to bioeconomy today, while for many sectors the entire sector can be accounted as belonging to the bioeconomy.

Here in the approximation of the volume of the Nordic bioeconomy, only the sectors which can be entirely assumed to belong to the bioeconomy, are included. The following six sectors, which are all based on managing, harvesting and/or processing of bio-based raw materials, are included:

- Agriculture
- Fisheries and Aquaculture
- Forestry
- Food industry
- Forest industry
- Bioenergy and Biofuels.

The assessment was conducted using the NACE[6] codes, as they provide a means for getting a comparable assessment scope across the countries. More detailed description of the assessment scope and the included NACE codes can be found in Appendix 1. The volume of the bioeconomy is measured by turnover and employment. The volume data was collected from publicly available statistics (national statistics bureaus, Eurostat and branch organizations) for year 2011/2012. For the sectors, the data used to determine the turnover, is the production value at basic price.

The Nordic countries included in the study are Finland, Sweden, Norway, Denmark and Iceland. No specific analysis has been done for the Faroe Islands, Greenland and Åland in the scope of this study.

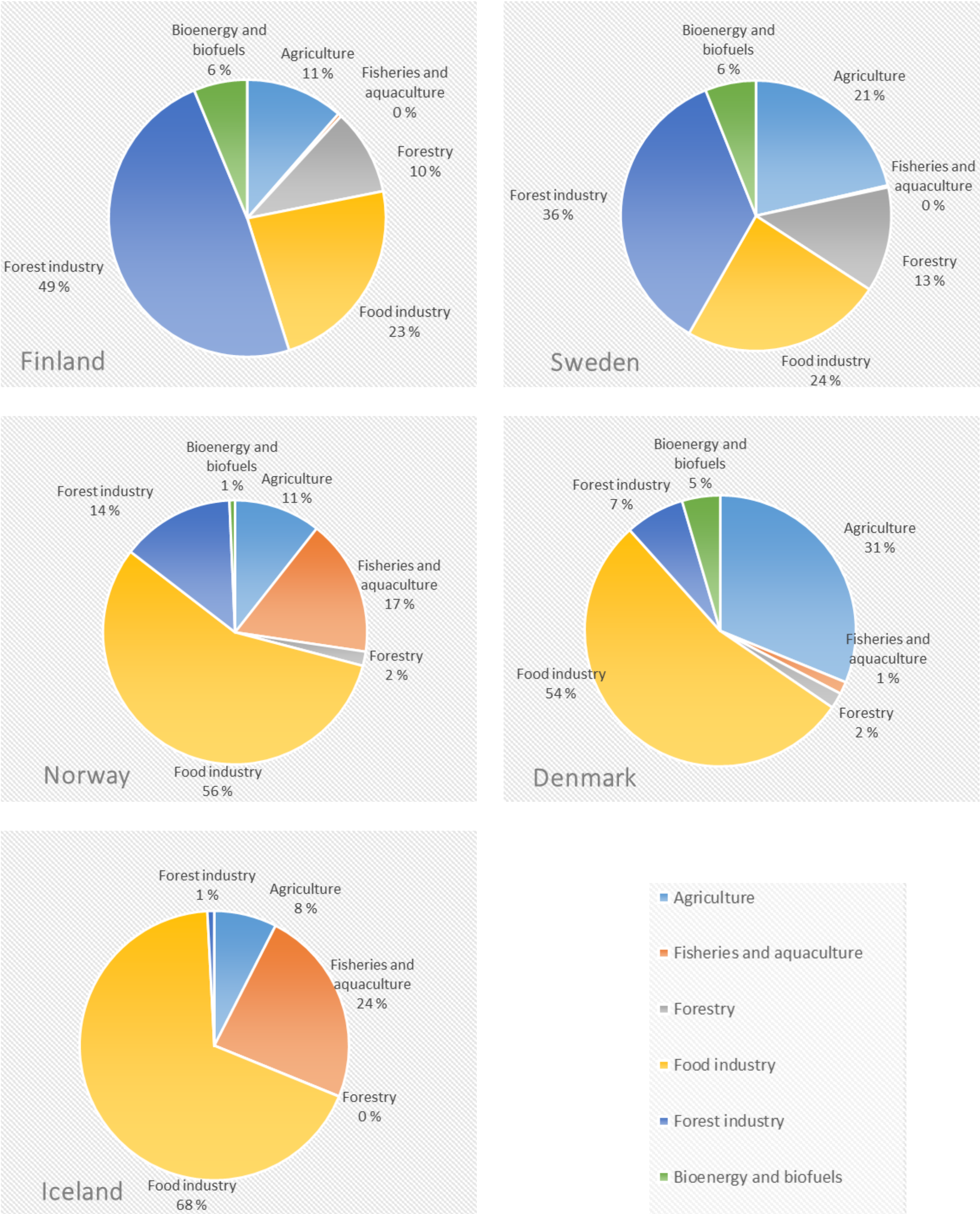
According to the estimate, the total turnover of the key bioeconomy sectors in Nordic countries is roughly 184 000 M€ including agriculture, fisheries and aquaculture, forestry, food industry, forest industry and bioenergy and biofuels. This is 10 % of the total economy in Nordic countries. The share is highest in Iceland, where the key sectors of bioeconomy stand for 18 % of the total economy, and lowest in Norway with a 6 % share. In all countries, the largest contributors to bioeconomy include forest industry or food industry. This shows the economic importance of intermediate and end product processing in the bio-based value chains. The volume of the bioeconomy, as measured by turnover, is presented in detail in Appendix 2.

The share of the different sectors of the bioeconomy are reported in Figure 1 for each country. The situation of the bioeconomy of the EU27 countries are showed in Figure 2. The food industry dominates in Iceland. The food industry is above EU average also in Denmark and Norway. The forest industry is larger than EU average in Finland (49%) and Sweden (36%). Bioenergy and biofuels account for 5-6% in Finland, Sweden and Denmark, while the share is 1% for Norway and 2% for the total EU.

The sectors, which can be related to primary production: agriculture, fishing and forestry, represent around 30-33% of the total of the bioeconomy in Denmark, Norway, Iceland and Sweden, while in Finland this is lower at 21%. The EU average for these sectors is 36%. In Denmark agriculture stands for 80% of the primary production. In Finland, 50% of the primary production is forestry and 50% agriculture. In Sweden 40% is represented by forestry and 60% by agriculture. In Norway 55% of the primary production is represented by the fishing sector and 40% by agriculture.

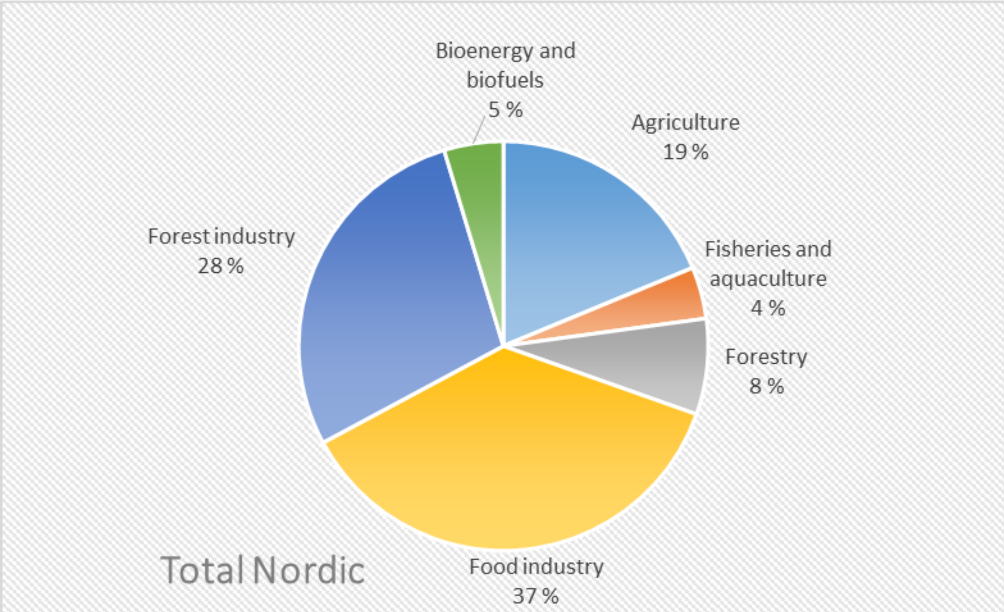
[6] By the European Statistical System EES

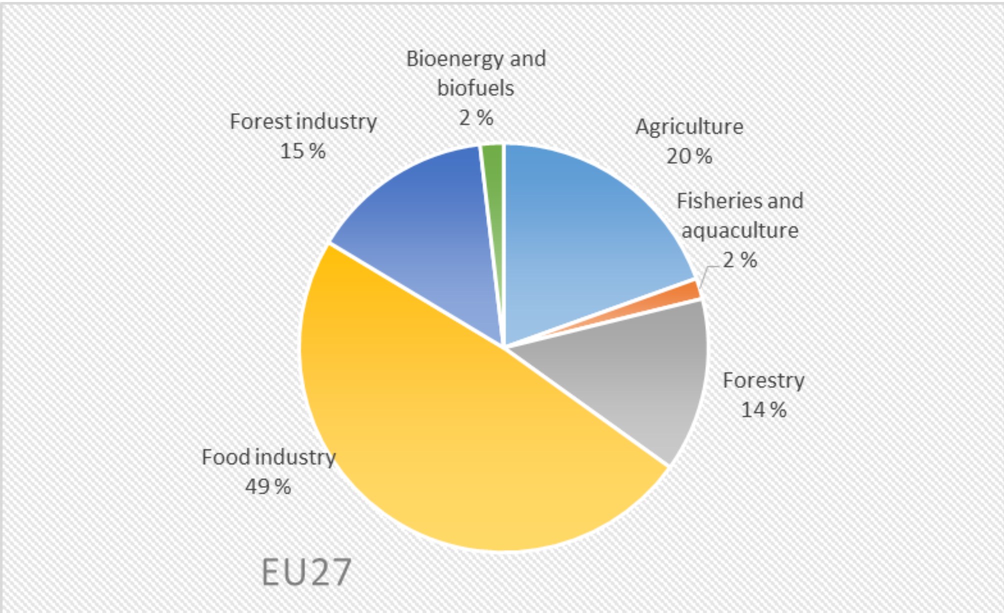
*Figure 1. The share of the sectors included in the bioeconomy of the total bioeconomy sector in the Nordic countries in 2011-2012.*




To achieve a picture of the size of all the Nordic countries together, and how the sectors are represented in the bioeconomy of the Nordic countries, the volumes are added together. This is compared to the EU27 countries in Figure 2. In the Nordic bioeconomy, the bioenergy and biofuels sector has a larger role than in the EU27. This is due to the bioenergy part, as biofuels again are much larger outside the Nordic countries. The forest industry sector and the fisheries and aquaculture sector also have a larger role in the Nordic countries. The sectors: agriculture, food industry and forestry have a smaller role in the Nordic bioeconomy than they do in the bioeconomy of the EU 27.

*Figure 2. The share of the sectors included in the bioeconomy, of the total bioeconomy sector, in the Nordic countries added together, and in the EU27 countries added together, in 2011-2012.*




## VOLUME OF THE ADDITIONAL SECTORS RELEVANT FOR THE BIOECONOMY

As mentioned above, in certain sectors only part of the sector can be considered relevant for bioeconomy. This applies to sectors such as building and construction, where bio-based raw materials like wood are used together with other building materials. These sectors provide additional potential for bioeconomy, and therefore their volume was assessed separately in this study. These sectors included chemicals and plastic industry, the enzymes industry sector, *building and construction industry sector*, the *pharmaceutical industry sector*, the *technologies sector*, the *textile industry sector*, the *services sector*, the *wastewater treatment sector* and the *waste treatment sector*. The sectors and their general relevance for bioeconomy is briefly described below, followed by sectorial current volumes.

In the analysis sub-sectors which are known not to be bioeconomy relevant where subtracted from the sectorial volumes. Otherwise the analysis was carried out as described in earlier chapter. A more detailed description of the assessment scope and the specific subsectors that have been included, together with their NACE codes, can be found in Appendix 1.

**Chemicals and plastics industry**

According to the EU approximation[7], the bio-based chemicals and plastics sector corresponds to about 7% of the total chemicals and plastics industry sector in the European Union.

In the chemical and plastics industry bio-based chemicals and plastics are gaining market, such as platform chemicals that substitute petroleum-based bulk chemicals, and the further refined products from these such as bio-based adhesives, paints and varnishes, fertilizers, and bio-based polymers that can replace plastics or be used in composites. Catalysts are also increasingly important for efficient utilization of biomass as a raw material and for lowering production temperatures, and thus lowering energy requirements for processing. Catalysts can be bio-based, like enzymes, or originate from fossil or mineral raw materials.

**Building and construction industry**

In the building and construction industry sector bio-based materials are used together with other materials in construction of buildings. The biomaterials used in the construction of buildings are for example wood products, construction boards, bio-based insulation materials, bio-based adhesives, paints and varnishes and various composite materials. Certain bio-based side streams from other industries are also used in construction of roads and landscaping.

**Pharmaceutical industry**

Similar to the bio-based platform chemicals, which can replace petroleum-based bulk chemicals in the chemicals and plastics industry, bio-based compounds can be used and also replace petroleum-based compounds in the pharmaceutical industry. Examples of bio-based compounds in the pharmaceutical industry are surfactant bulk chemicals.

**Technologies sector**

Technology solutions are required for management of biomass production, handling of biomass streams and manufacturing of bio-based products. Equipment for management of biomass production and handling of biomass streams is required in agriculture, fisheries and aquaculture and forestry. Biomass processing technology equipment is needed in bioenergy,

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[7] EU MEMO/12/97 http://europa.eu/rapid/press-release_MEMO-12-97_en.htm?locale=en,

food and forest industries. Examples of biomass processing equipment are boilers, drying, heating and cooling equipment, measurement equipment and separation equipment.

### Textile industry

The textile industry is partly bio-based, but also synthetic materials are used in textile manufacturing. Bio-based raw materials of the textile industry include materials from agriculture like wool, flax and hemp. Also cellulose-based materials originating from the pulp and fiber industry are used, like viscose.

### Services sector

Services like recreational activity services, accommodation and food services are partly related to ecotourism, which is part of the bioeconomy, benefiting from synergistic use of the rich natural environment, forests and aquatic ecosystems. However, partly these services are related to other tourism and leisure activities which cannot be associated with bioeconomy.

### Wastewater treatment and waste treatment

Wastewater treatment and waste treatment are connected to bioeconomy through recycling and utilization of the bio-based materials in the wastewater and waste streams. The recovered bio-based material can be utilized for heat and electricity production, for transportation fuels production or in chemicals and materials production.

### Sectorial volumes

The sectorial volumes are summarized in Table 1. The technologies sector, which includes technologies relevant for food industry and forest industry, and the emerging bioeconomy sectors: the bioenergy, biochemical, biomaterials and bio ingredients, has the largest share in Finland and Denmark, representing 3% of the total economy. EU average is at 2%. In Sweden the share of the technology sector is 2% and in Norway 1%. Building and construction industry has the same share in Norway, Sweden and Finland with shares of around 7%, and somewhat lower in Denmark (5%).

In addition to food, forest and energy industry, chemicals and plastics industry is the industry where current bioindustrial development is mainly taking place. Chemicals and plastics industry represents about 7% of the total in all the Nordic countries, except Iceland. The EU average is larger at 12%.

*Table 1. Volumes of additional sectors relevant for bioeconomy in the Nordic countries in 2011/2012.*

| Sector | Finland | Sweden | Norway | Denmark | Iceland |
|---|---|---|---|---|---|
| **Building and construction** | 24 154 | 48888 | 39111 | 22698 | 1 |
| **Textile industry** | 947 | 1188 | 884 | 1199 | |
| **Chemical and plastics industry** | 8 334 | 12546 | 8519 | 6657 | 1 |
| **Pharmaceutical industry** | 1 403.5 | 5500 | 880.0 | 8 583.9 | 0 |
| **Technologies** | 9 209 | 11189 | 6421 | 13180 | 414 |
| **Services (accomodation and food services)** | 5390.2 | 10919 | 7124 | 5803.9 | 480 |
| **Water treatment and supply** | 861 | 477 | 54 | 778 | 4 |
| **Waste treatment** | 1 506 | 4373 | 2626 | 2050 | 35 |

## THE ROLE OF THE NORDIC BIOECONOMY COMPARED TO ALL EU MEMBER COUNTRIES

The share of the Nordic bioeconomy sectors of the whole EU is shown in Table 2. The Nordic bioeconomy represents 10% of the total EU bioeconomy whereas the share of the Nordic total economy is 9% of the total EU economy. Thus the Nordic share of EU bioeconomy is in line with overall Nordic share of the EU economy. However, sector wise there are differences. The sectors that have a lower Nordic share than the Nordic share of the total EU bioeconomy are highlighted with red. The sectors that have a higher Nordic share than the Nordic share of the total EU bioeconomy, are highlighted with green.

In the forestry sector, the Nordic countries have a smaller share of the entire EU forestry sector than the Nordic share of the total EU bioeconomy. However, on the other hand in the forest industry sector, the role of the Nordic countries is large. The Nordic countries have the largest share of the sector in Bioenergy and Biofuels, where the Nordic countries stand for 24% of the total sector. The other important sector is the fisheries and aquaculture sector, which stands for 23% of EU's total fisheries and aquaculture.

The share of additional sectors relevant for bioeconomy in the Nordic countries compared to the whole EU is shown in Table 3. The chemicals and plastics industry, the pharmaceutical industry and the water treatment and supply sectors are below the average of Nordic share of the total economy.

*Table 2. The table shows the volume of the bioeconomy sectors in the Nordic countries per the volume of the bioeconomy sectors in the EU 27 countries in year 2011. The sectors that have a lower share of EU 27 than the share of the total bioeconomy of EU 27 are highlighted with red and the sectors that have a higher share than the total bioeconomy has, are highlighted with green.*

| **Sectors** | **Nordic turnover/ EU 27 turnover** |
|---|---|
| Agriculture | 9 % |
| Fisheries and aquaculture | 23 % |
| Forestry | 5 % |
| Food industry | 7 % |
| Forest industry | 18 % |
| Bioenergy and Biofuels | 24 % |
| *Total bioeconomy* | 10 % |

*Table 3. The table shows the additional sectors of importance for bioeconomy in the Nordic countries, and their share of the corresponding sectors of the total EU-27 in year 2011. The sectors that have a lower share than the share of the total economy are highlighted with red and the sectors that have a higher share than the total economy has, are highlighted with green.*

| **Sectors** | **Nordic turnover/ EU 27 turnover** |
|---|---|
| Building and construction | 9 % |
| Textile industry | 2 % |
| Chemical and plastics industry | 5 % |
| Pharmaceutical industry | 8 % |
| Technologies | 10 % |
| Services (accomodation and food services) | 6 % |
| Water treatment and supply | 4 % |
| Waste treatment | 8 % |
| Total economy | 9 % |

# GROWTH POTENTIAL OF BIOECONOMY

The growth potential of bioeconomy is building on the existing bioeconomy sectors described in the previous chapter. European bioeconomy market is estimated to be 2 trillion Euro, employing around 21.5 million people, which gives a strong existing market to expand and develop further[8]. Growth potential builds also on sustainable management and availability of primary biomass and various side streams. The present biomass supply in EU is estimated at 314 MtOE and the biomass potential[9] is between 375 to 429 MtOE depending on the sustainability criteria applied[10]. The farming and fishery waste was 39 Mt in 2010 creating significant side stream potential for biorefineries.[11]

Abundant feedstock provides excellent possibility for bioeconomy-related new business and growth. Under-utilized biomass fractions and side streams can be refined into value added products or used as energy to replace fossil fuels. Currently existing strong industrial infrastructure in biomass processing sectors is an excellent starting point for industrial renewal and novel production platforms. Technology and service providers and R&D actors are required for this development, and growth of these sectors is also important constituent of the overall growth potential.

Rich natural environments in the Nordic countries, forests and aquatic ecosystems offer also significant growth potential for recreational services like ecotourism. As population increases globally and environmental problems occur and ecosystems are deteriorated, the pure nature of the Nordic countries even increases its attractiveness.

Especially when utilizing side stream feedstock new cross-sectorial value chains need to be developed in order to tap the growth potential. Raw material sourcing, new processing concepts and tailoring of products for various end uses needs to be developed in a holistic manner. A new concrete business model seen in these new crosscutting innovations of the emerging bioeconomy is large companies joining together and forming joint ventures. In joint ventures the competences from the two companies can be joined, and the existing knowledge can be added together quickly to benefit from the growth potential of bioeconomy. Examples of these include enzyme companies and food manufacturers, chemical companies and biorefining technology companies, bulk chemicals producers and fine chemicals or material producers, and, pulp and paper companies and energy companies.

### Bio-based chemicals

Current global bio-based chemical and polymer production is estimated to be around 50 million tonnes, whereas global petrochemical chemical and polymer production is estimated at around 330 million tonnes[12]. The theoretical market potential is 100 % substitution of petrochemical chemicals and polymers by bio-based products, which corresponds to 280 million

[8] Bio-Based economy, website, accessible at: http://www.bioeconomy.net (referred on 21.1.2014)

[9] including waste, agricultural residues, rotational crops, perennial crops, landscape care wood, round wood production, additional harvestable round wood, primary, secondary and tertiary forest residues

[10] BE Sustainable, Sustainable biomass supply in EU, accessible at: http://www.besustainablemagazine.com/cms2/?p=26, (referred on 21.1.2014)

[11] Eurostat, Generation of waste, website, accessible at: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes (referred on 21.1.2014)

[12] excluding biofuels and including non-food starch derivatives, cellulose derivatives, oleochemicals and fermentation products such as ethanol, amino acids and citric acid, Source IEA, Bioenergy Task 42 Biorefinery, accessible at: http://www.biorefinery.nl/fileadmin/biorefinery/docs/Brochure_Totaal_definitief_HR_opt.pdf (accessed 23.1.2014)

tonnes. It is estimated[13], that in favorable market conditions, renewable bulk chemicals could reach 113 million tonnes by 2050, representing 38 % of all organic chemical production. Under more conservative market conditions, the market could still be significant 26 million tonnes, representing 17,5 % of organic chemical production. In Europe, the current market size for bio-based chemicals and bioplastics is estimated to be 50 billion €[14]. The global estimation for bio-based chemicals and polymers in 2015 is 90 billion €[15].

In the Nordic countries the bio-based chemical production could benefit from utilizing the side streams of agriculture, fisheries and aquaculture, forestry, and the food and forest industries as raw material. Currently bio-based chemical production in the Nordic countries is focusing on tall-oil and other wood derived chemicals, and the enzyme and ingredient industry using agricultural feedstock is also in focus. Growth could be achieved by building on these existing assets or by investments on novel bio-based chemicals production.

**Biomaterials**

The biocomposite (including wood-plastic composites, WPC, and natural fiber composites, NFC) production in European Union was 0,4 million tonnes in 2012 which corresponds to 10-15 % of the total European composite market. According to nova-Institute, WPC volumes have risen strongly and Europe has reached a mature WPC market. In addition to biocomposites, advanced biomaterials like nano and micro cellulose are potential. These products have not yet reached wide commercialization.

In the Nordic countries wood-plastic composites and natural fiber composites are already manufactured, and although the market is rather mature, growth potential still exists to some extent through novel applications. In addition to that, small companies and extensive development efforts are focused on advanced biomaterials. Commercialization of advanced applications like micro and nano cellulose could lead to significant growth opportunities for the Nordic countries, with their strong forest industry sector.

**Biorefineries**

During 2012 global biofuel capacity was 100 Mt 2012 and biochemical capacity 50 Mt[16]. 1415 installed biorefineries were scattered across United States, Brazil and Europe, one third on each. According to PikeResearch's forecast, nearly 1800 new biorefineries will be commissioned during this decade. More than half of them will use non-food feedstock. Biorefineries will attract 132 billion € investments between 2012 and 2022, reaching 240 million tonnes per year of installed capacity. The global market for advanced biorefineries is less than 5 % of the conventional biorefinery market, but almost all global investments are focused on advanced biorefineries. [17,18]

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[13] The BREW Project, accessible at: http://brew.geo.uu.nl/BREW_Final_Report_September_2006.pdf (accessed at 27.2.2014)

[14] IEA 2010

[15] FPAC 2011

[16] NNFCC 2010

[17] Business Wire, Global Investment in New Biorefinery Infrastructure will Total $170 Billion through 2022, accessible http://www.businesswire.com/news/home/20120926005205/en/Global-Investment-Biorefinery-Infrastructure-Total-170-Billion, (referred 21.1.2014)

[18] Green Car Congress, Pike Research forecasts surge in investment and growth in advanced biorefineries through 2022, accessible http://www.greencarcongress.com/2012/09/pike-biorefs-20120922.html (referred 21.1.2014)

In the Nordic countries biorefineries have significant growth potential, especially in connection to the strong current industrial infrastructure, and the forest and food industries. Pulp and paper mills can be converted into biorefineries with a more diversified production portfolio and also food production facilities can diversify their portfolios through production of biofuels, bioenergy and biomaterials from process side streams.

**Funding instruments for innovation in bioeconomy**

The growth and innovation potential can indirectly be estimated also based on funding instruments that invest on areas growing rapidly. For example NER300 is a financing instrument managed jointly by the European Commission, European Investment Bank and Member states[19]. NER300 offers finance for installations of innovative renewable energy technology and CCS in the EU. During the first call awards of the fund in 2012, 4 of 8 NER300 project funds in biomass-based energy and biofuels were granted either to Nordic projects or for a Nordic company[20]. Horizon 2020 is EU's largest research and innovation program with nearly 80 billion € of funding available over the next 7 years[21]. The budget related to bioeconomy, food security, sustainable agriculture, forestry and marine research is 3.85 billion €, which is 5 % of the total funding[22]. The investment is significantly higher compared to the investments on bioeconomy in the previous R&D framework program of European commission, the framework program 7.

**Nordic education and R&D community**

Education and research is highly supported in the Nordic countries. Financing for R&D is high per GDP. In Finland the state R&D financing is focused on industrial production and technology, energy and agriculture. In Denmark industrial production and technology receives the largest share. This sector is highly prioritized in Norway as well, along with agriculture. The R&D development in Iceland is focused on agriculture and in Sweden on energy and transport and communication. [23]

The support for education can also be seen in the high level of education. The percentage of the population that have completed tertiary education is above the EU average of 22% in all the Nordic countries.[24] The highest percentage of tertiary education can be found in Finland and Norway (30%), tightly followed by Iceland, Sweden and Denmark.  PhD graduates were around 750 per 1 million inhabitants in both Sweden and Finland, and about 500 to 550 per 1 million in Denmark and Norway. In Iceland the corresponding number is 200 PhD graduates per million inhabitants.

Universities perform research in tight connection with private companies, and a substantial part of the research is funded by companies. Commercialization of the extensive R&D efforts of the Nordic countries in bioeconomy can lead into significant growth opportunities.

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[19] NER300, accessible at: http://www.ner300.com/ (accessed 24.1.2014)

[20] NER300 first awards 2012, accessible at: http://ec.europa.eu/clima/news/docs/c_2012_9432_en.pdf (accessed 24.1.2014)

[21] European Commission, Horizon2020, accessible at: http://ec.europa.eu/programmes/horizon2020/ (accessed 24.1.2014)

[22] Horizon 2020 Projects, accessible at: http://horizon2020projects.com/societal-challenges/bioeconomy/ (accessed 24.1.2014)

[23] Nordic Statistical Yearbook 2013

[24] Nordic Statistical Yearbook 2013

## EU AND NORDIC BIOECONOMY STRATEGIES

Most Nordic countries have existing bioeconomy strategies. However, some of the strategies are more research, development, and innovation (RDI) oriented (Norway and Sweden), and some take a more policy level view on the issue (Denmark and Finland). The focus on RDI is reasonable as knowledge, research, and innovation have been crucial, and still are, for the development and full exploitation of the opportunities of the bioeconomy. However, increasing understanding of the potential and opportunities puts further focus on the operating environment, including a wide variety of policy measures, to make sure, for example, that the promising results of RDI will realize in new value-added products and services and environmental benefits. Thus strategic insight on both levels is needed (Figure 3).

**Policy Level Strategies**

Identify the supporting environment including a wide variety of policy measures to make sure, for example, that the promising results of RDI will realize in new value-added products and services and environmental benefits.

**Research Strategies**

Identify the most potential areas on RDI so that investments can be focused on those areas, building on the existing RDI strengths and foreseen drivers which support future development.

*Figure 3. Both policy level and research strategies are likely to be needed to support the growth and development of bioeconomy in the Nordic countries.*

In the following, the main EU policies on bioeconomy and the main strategies of the Nordic countries on bioeconomy are presented briefly. Only the most important bioeconomy focused strategies are included although both on the EU level and in all the Nordic countries several other strategies related to, for example, agriculture and forestry, energy and climate, environment, and natural resources can be relevant regarding bioeconomy.

### EUROPEAN UNION[25]

To ensure smart green growth, the European Commission introduced the concept of **knowledge-based bioeconomy** during the UK Presidency of the EU in 2005. It was considered as one of the important means to support growth and employment in the EU and to tackle climate change. In addition, the cross-cutting nature of bioeconomy enables addressing complex and inter-connected challenges. In 2005 knowledge-based bioeconomy in EU was estimated to be worth more than EUR 1.5 trillion per year[26]. In 2009, the bioeconomy market was estimated to be worth over EUR 2 trillion, providing 20 million jobs and accounting for 9% of total employment in the Union[27].

To further support the transition towards an optimal use of renewable resources and to maintain Europe's competitiveness, further measures and actions have been taken. In February

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[25] http://europa.eu/rapid/press-release_MEMO-12-97_en.htm?locale=en , http://ec.europa.eu/research/bioeconomy/policy/strategy_en.htm

[26] http://ec.europa.eu/research/conferences/2005/kbb/pdf/kbbe_conferencereport.pdf

[27] http://ec.europa.eu/research/bioeconomy/policy/bioeconomy_en.htm

2012, the European Commission adopted a strategy and action plan for a sustainable bioeconomy in Europe, called **"Innovating for Sustainable Growth: a Bioeconomy for Europe"**[1]**.** The strategy addresses comprehensively the ecological, environmental, energy, food supply and natural resource challenges of bioeconomy. The strategy consists of three key pillars, which are 1) investing in research, innovation and skills, 2) developing markets and competitiveness in bioeconomy sectors, and 3) pushing policymakers and stakeholders to work more closely together.

As a cross-cutting area, bioeconomy is influenced by policy measures on several policy areas such as environment, energy, and agriculture. Examples include the Renewable Energy Directive which sets targets for renewable energy and thus, especially when supported by the national policies, promotes the use of biofuels in transportation. To ensure the sustainability of these biofuels, EU has launched sustainability criteria.

Bioeconomy is strongly emphasized in the **EU Research and Innovation Programme Horizon 2020** which is the biggest EU Research and Innovation programme ever with some EUR 79 billion of funding available over 7 years (2014 to 2020). Bioeconomy is well covered by the theme “Food security, sustainable agriculture, marine and maritime research, and the bioeconomy". Furthermore, bioeconomy themes will also be partially supported under the themes "Climate action, resource efficiency and raw materials", "Secure, clean and efficient energy" and "Health, demographic changes and wellbeing". In addition, bioeconomy related research is supported by a Public-Private Partnership (PPP) on Bioeconomy between the European Commission and the Bio-based Industries for the support of industrial research and innovation, and having its own research agenda[28].

## DENMARK[29] [30]

The Government policy on **Green growth** from October 2011 sees Denmark as a green knowledge and production society where the needed sustainable biomass do not conflict with food production but will reduce our dependence on imported feed and energy resources. The focus is on energy, food, climate and resources.

Especially the **energy agreement** from March 2012 has meant a lot for the prospects of green growth. The agreement includes over 35 % target for renewable energy by 2020 and is an important milestone on the way to converting Denmark's energy supply for renewable energy in 2050. The agreement includes a wide range of energy policy initiatives. Before the end of 2018 further initiatives shall be discussed for the period after 2020. The actions of the agreement include efforts to increase funds for research, development and demonstration (Green Growth-programs), and initiatives concerning how to finance the new initiatives of the green energy agreement.[31]

**Biorefining Alliance**, which was established by the government, came out with a green strategy in June 2012[32]. It recommends that bioeconomy be made a new priority area for

[1] http://europa.eu/rapid/press-release_MEMO-12-97_en.htm?locale=en , http://ec.europa.eu/research/bioeconomy/policy/strategy_en.htm

[28] http://biconsortium.eu/sites/default/files/downloads/BIC_SIRA_web.pdf

[29] http://www.norden.org/en/analys-norden/tema/does-sustainability-pay/danish-investment-in-green-growth

[30] http://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=705&menu=975

[31] http://www.kebmin.dk/sites/kebmin.dk/files/klima-energi-bygningspolitik/dansk-klima-energi-bygningspolitik/energiaftale/Faktaark%201%20-%20energiaftalen%20kort%20fortalt%20final.pdf

[32] http://biorefiningalliance.com/uploads/Strategi_UK_online.pdf

Denmark and that a political action plan to be adopted on the basis of 19 recommendations in the areas of markets, bio-resources, demonstration and R&D.

In March 2013 came the government **Growth Plan**. The growth plan aims at strengthening and developing the Danish and European markets for resource-efficient solutions in water, bio and environmental solutions. It should provide new business opportunities by strengthening companies' product and technology development and supporting targeted initiatives in the form of research, demonstration, test and international marketing. The plan seeks to strengthen the basis for Danish companies and get more involved in the growing international market and thus contribute positively to growth and new jobs. A lot of the initiatives of the Growth Plan need new laws and regulations, additional funding etc.

In November 2013 a **National Bioeconomy Panel** was established with participants from the business sectors such as the Danish Agriculture and Food Agency, the research sector, and companies. The panel's main task is to provide input for concrete action to promote bioeconomy.

### FINLAND[33]

The **Finnish Strategy on Bioeconomy** aims at promoting bioeconomy-based business, and improving Finland's competiveness and welfare simultaneously with decreasing climate change impact and improving resource-efficiency. The target is to increase the value of bioeconomy in Finland to 100 billion euros by 2025 and to create 100 000 new jobs. The priority areas of the strategy are to create a favorable operating environment for bioeconomy, to support the creation of new business in bioeconomy, to develop and ensure bioeconomy skills, and to ensure the ability to use renewable resources sustainably. The strategy is currently being finalized and is likely to be published during early 2014.

The strategy has been developed and will be developed by several ministries, and other stakeholders. Bioeconomy is already high on the agendas and strategies of many research organizations (such as Metla, MTT, and VTT), research funders (such as Tekes and Sitra), and several regional actors.

Bioeconomy strategy has a lot of linkages and synergies to other national strategies on agriculture and forestry, energy and climate as well as natural resources, among others. Thus, these policies have a remarkable impact on the development of bioeconomy in Finland, as in any other Nordic country as well. In addition, bioeconomy is one of the themes of the **Innovative Cities Programme**, which aims at benefiting from the strengths of the different regions in Finland.

Finland has also six **Strategic Centers for science, technology and innovation in Finland (SHOK)**, all having their research strategies. One of these six Strategic Centers, the **Finnish Bioeconomy Cluster (FIBIC)**, is strongly focused on bioeconomy related research and innovation, although other SHOKs are supporting the area as well. The aim of FIBIC is to create an innovative development environment within the bio-based economy, with its re-

[33] http://www.biotalous.fi/biotalouden-askelmerkit , http://www.maaseutu.fi/attachments/new-folder_25/2013/lietelanta_tuottamaan_ja_kosteikkoja_kylille_pieksamaki_10.4.2013_ja_rantasalmi_11.4.2013/eip-seminaari_hameenlinna_5.11.2013/6L7XxJ8dv/Biotalousstrategia_lyhyesti_05112013.pdf

search and innovation programs. With interaction between end-users, companies and researchers, opportunities are sought through open innovation and new ways of networking, aiming at close, long-term cooperation and leveraging competences and resources.[34]

## Iceland

The main strategy connected to bioeconomy in Iceland is the Iceland 2020 strategy[35]. The other development directing is the Law on public procurement (84/2007) and the Agreement on eco-friendly public procurement[36].

**The Iceland 2020 strategy** targets eco-innovation as the main growth sector in the next decade, and aims to double growth in turnover between 2011 and 2015.[37] Green public procurement also enjoys high priority.

**The law on public procurement (84/2007) and agreement on eco-friendly public procurement.** Green procurement is gaining a strong foothold in Iceland. The law on public procurement (84/2007) contains references to green procurement or eco-friendly procurement. The law stipulates that public procurement may favor products/services that are eco-friendly and/or promote environmental awareness. In March 2009 the minister of finance and the minister of environment signed an agreement on eco-friendly public procurement. The agreement will be used as policy guidance for all public procurement in Iceland.

## Norway

**BIONÆR[38]** is Norway's research program on **Sustainable Innovation in Food and Bio-based Industries**. The duration of the program is 2012-2021 and the overall budget was approximately NOK 200 million for the year 2013. The BIONÆR program promotes research that increases the level, profitability and sustainability of production in the value chains for agriculture, forestry and nature-based industries, and for seafood from the time raw materials are taken out of the sea until they reach the consumer.

The primary objective of the BIONÆR program is to promote research and innovation that enhances value creation in Norway's bio-based industries. The secondary and strategic action points of the program are to:

1. Strengthen and develop
    a. Knowledge and expertise in selected areas to promote sustainable bio-based industry in Norway, and
    b. Research-based innovation in bio-based companies and bioresource management.
2. Implement innovative work forms that involve players in the research community, trade and industry, the public administration and special interest organizations.
3. Use coordination and dissemination activities to enhance the benefits of knowledge and expertise gained by the industry and public administration.

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[34] http://fibic.fi/

[35] http://eng.forsaetisraduneyti.is/media/2020/iceland2020.pdf

[36] http://www.nordregio.se/en/Metameny/Nordregio-News/Green-Economy-in-Policy-and-Practice/Can-Iceland-become-a-green-land/

[37] http://www.oecd.org/iceland/sti-outlook-2012-iceland.pdf

[38] http://www.forskningsradet.no/prognett-bionaer/Programme_description/1253971968649

4. Participate in international cooperation in order to strengthen knowledge-building and innovation in priority areas.

Under the BIONÆR program, there are four cross-cutting perspectives which apply to all activities: achieving complete biological *closed-loop systems*; incorporating the environmental, social and economic aspects of *sustainability* across the board; maintaining consistent focus on market orientation and *value creation* in the Norwegian bio-based industries; promoting *interdisciplinarity* to ensure the societal relevance of knowledge-building under the program. And for food production in particular: ensuring *food security* and *safe and healthy food*.

The scope of the BIONÆR program does not cover the entire bioeconomy. Norway also has other programs and funding instruments at the Research Council which provides funding for research activities addressing the bioeconomy.

### Sweden

The **Swedish Research and Innovation Strategy for a Bio-based Economy** was published in March 2012. Driving forces for the strategy were the need to reduce the dependency on fossil-based raw materials and the emission of carbon dioxide and other greenhouse gases.

The strategy includes four major research and development needs. These are:

1) The replacement of fossil-based raw materials with bio-based raw materials,
2) Smarter products and smarter use of raw materials,
3) Change in consumption habits and attitudes, and
4) Prioritization and choice of measures.

In addition to these measures, the strategy emphasizes that to convert to a bio-based economy, research and development must be complemented by innovation-fostering initiatives and measures that specifically address bioeconomy challenges. Widespread, cross-sectorial collaboration among different actors is considered a prerequisite to deal with the complex issues and demands for solutions needed for a bio-based economy.

Based on the analysis conducted for the strategy, the existing collaboration between Formas (the Swedish Research Council), VINNOVA (Sweden’s Innovation Agency) and the Swedish Energy Agency is considered sufficient but further development of divisions of roles and responsibilities is needed. Additionally, Formas will establish a User Forum comprising of representatives of users (agencies, companies, members of the community) and other national and international stakeholders.

## SUMMARY

According to the estimate, the total turnover of the key bioeconomy sectors in Nordic countries is roughly 184 000 M€ including agriculture, fisheries and aquaculture, forestry, food industry, forest industry and bioenergy and biofuels. This is 10 % of the total economy in Nordic countries. The share is highest in Iceland, where the key sectors of bioeconomy stand for 18 % of the total economy, and lowest in Norway with a 6 % share. In all countries, the largest contributors to bioeconomy include forest industry or food industry.

There is remarkable innovation and growth potential in the Nordic bioeconomy. This is due to, at least, the extensive bio-based resources as well as strong refining and technology industries and competent and well-educated workforce. As highlighted in the previous chapters the largest innovation and growth potential of bioeconomy seems to be in its crosscutting nature. New innovation and growth is likely to occur where companies, industries, sciences, resource flows, and actors interact and crosscut, thus opening up new opportunities to use raw materials and competences in creative ways. The following interesting crosscutting growth areas of the bioeconomy in the Nordic countries can be identified:

- **Bio-based chemicals** where different bio-based raw materials and side streams are processed to high value added and sustainable products for consumers and a variety of industries.
- **Biomaterials** where different bio-based raw materials and side streams are processed to high value added and sustainable products for consumers and a variety of industries including building and construction.
- **Biofuels and bioenergy** where bio-based raw materials and side streams can be effectively used to provide renewable energy sources for heating, cooling, electricity, as well as land, air, and marine transportation.
- **Biorefineries** producing all of the above from bio-based raw materials, side streams and waste in highly optimized and resource-efficient processes as a part of local and global value chains and business ecosystems.
- **Resource-efficiency and industrial symbiosis** where bio-based processes, product portfolios, and use of the raw materials are well optimized, and resource flows, side streams and waste are used innovatively and in a cascading manner.
- **Services** based on ecosystem services or supporting the above mentioned areas of products and creating value without tangible material flows and including design.

In Denmark, there are three strategic policy level plans related to bioeconomy, but none of them named specifically as a bioeconomy strategy: energy agreement including several aspects supporting bioeconomy, green strategy focusing on bioresources, biorefining, biofuels and bioproducts and green growth plan focusing on resource-efficient solutions in water, bio and environmental solutions.

In Finland, a specific bioeconomy strategy gives concrete turnover and employment targets for bioeconomy, and, in addition to pointing out sustainability, resource-efficiency, and business development as important drivers for the strategy, points out the strategic actions. These include: create a favorable operating environment for bioeconomy, support the creation of new business in bioeconomy, develop and ensure bioeconomy skills, and ensure the ability to use renewable resources sustainably.

In Norway, BIONÆR program brings together the bioeconomy-related issues targeting to promote research and innovation and to support production in the value chains for agriculture, forestry and nature-based industries and seafood. The four cross-cutting perspectives are closed-loop systems, sustainability, interdisciplinarity and food security and safe and healthy food.

In Sweden, the Research and Innovation Strategy mention four major research and development needs. These are replacement of fossil raw materials with bio-based raw materials, smarter products and smarter use of raw materials, change in consumption habits and attitudes and prioritization and choice of measures.

Although the scope of the existing strategies of the Nordic countries is different, the most important building blocks of them are similar:

- **Most important drivers for the growth and development of bioeconomy** in all the strategies include reducing greenhouse gas emissions and climate change thus pointing out the global responsibility that the Nordic countries are willing to take and

the opportunities they see in this development. Other drivers include less discussed and more sensitive drivers such as food security and self-sufficiency regarding energy. Final targets of the strategies in all Nordic countries are measured in economic growth, jobs, increased well-being, and sustainability.
- On the general level, **the strengths that the strategies build on are similar**. These include the supply of raw materials in the form of biomass from agriculture, forestry, and aquaculture, many of the necessary technologies, and core competencies in agriculture, food, fisheries, technology, logistics, IT, services, research, development and consultancy.
- All the strategies **recognize the importance of competence and innovation** on this field. This being one of the strengths of all the Nordic countries is a natural building block for all the strategies.

A lot of focus on strategies for the past years has been on bioenergy and biofuels in all Nordic countries, and there are a lot of success stories on the area. Both have been benefiting from the regulatory pull, are partly controversial and future development is currently actively discussed.

Although more advanced products and services such as bio-based chemicals and biomaterials are now included into the research strategies, there is less concrete examples on them in the policy level strategies. This might be due to the lack of understanding on their concrete potential and ways to promote them. In addition, the development of services is less-known than that of products and technologies in both policy level and research strategies.

Thus in the future at least the following aspects would benefit from having more strategic insight and weight on the strategies:

- Promotion of the development and growth of advanced value-added bio-based chemicals and biomaterials with resource-efficient processes.
- Exploitation of the full potential of services based on bio-based value chains.
- Systemic view on the innovation and growth in bioeconomy including all the aspects described elsewhere in this report.

# INNOVATION IN BUSINESS ECOSYSTEMS OF THE NORDIC BIOECONOMY

In the previous chapter the Nordic bioeconomy was described through sectorial volume analysis, growth potential analysis and analysis of the bioeconomy strategies. With these approaches the operating environment for the Nordic bioeconomy innovations was described. In order to better understand innovation in the Nordic bioeconomy, it is important to analyze the innovation paths from idea into implementation more specifically.

Bioeconomy includes products and services of very different character, and from several different industrial sectors. The common basis for all these is that the bio-based resources should be sustainably managed and utilized. Holistic approach to sustainable resource utilization means that the resources used in the value chains of bioeconomy often originate from several different industrial sectors. This means that the value chains of bioeconomy are often horizontal in relation to the industry sectors, and value added is therefore dispersed across several sectors. Looking at business ecosystems is a way to follow these value chains and paths of the associated bioeconomy innovations.

**The business ecosystems** point out the relevant sectors, associated actors and their interaction as well as key raw materials, products, services, and material flows within the studied bioeconomy value chains. Raw material producers, production as well as waste handling facilities, retailers and consumers are all typical actors of the business ecosystems. In addition, regional and local policy makers, research institutes and educators, as well as governmental and other funders, might have a role in the business ecosystems impacting the actors and material flows between them. Transportation providers and facility equipment suppliers support the whole business ecosystem.

In line with the important sectors of the Nordic bioeconomy described in the earlier chapter, the areas with global and Nordic growth potential and certain pre-defined criteria seven business ecosystems were chosen as examples of important bioeconomy-related business ecosystems in the Nordic countries**. The selection criteria** for the business ecosystems were that the business ecosystem should be relevant for 3-5 Nordic countries, it should include a new or emerging value chain with growth potential, and it should represent high value addition or other beneficial economic impacts for the Nordic countries (such as reduced imports of fossil products). Other selection criteria were that the ecosystem should have social and environmental benefits and it should be relevant for both SMEs and large companies. Together, the ecosystems should provide a comprehensive view on the different areas of bioeconomy and they should involve different innovation models.

Based on these criteria, the chosen business ecosystems in this study were: **1. *Aquatic Biorefinery, 2. Nordic Functional Bio-based Ingredients, 3. Advanced Biomaterials, 4. Biorefinery Concepts, 5. Biocatalysis, 6. Decentralized Bioenergy Systems, and 7. Bioeconomy Related Services***.

The seven business ecosystems are exemplified with **forerunner company case studies**. The forerunner companies are examples of companies, operating within the business ecosystems described here, which have managed in innovation, i.e. in taking a novel bioeconomy-related idea or knowledge into implementation. The information for the forerunner case studies was gathered through interviews with key persons in the companies. For each forerunner company, the business ecosystem and the innovation development of the company are described and analyzed. The business ecosystem is described from the viewpoint of the type of company. For manufacturing companies, raw materials, processes, products and co-operation partners are in focus. For other actors, such as development organizations, clusters and service providers, the main activities of the companies are described together with a description to which parts of the value chain they are connected.

The innovation development in the company is described depending on type of the forerunner case through the development path of an important innovation, the general innovation management in the company, the success factors for innovations and/or the growth potential seen for innovations. Interviews also brought up views on obstacles and important support measures of innovation in bioeconomy. These are included in the respective sections of the report, obstacles and support measures.

The forerunners have been chosen so that they evenly cover the Nordic countries, the described business ecosystems and different innovation types. Both large and small companies, as well as newcomers and established companies, have been included in the study. As a consequence the forerunners may not be specifically forerunners in every aspect, rather than provide an insight to the actors, activities and important issues on innovation within the business ecosystem. In addition, some case examples are given based on literature studies.

# AQUATIC BIOREFINERY

## ACTORS AND LINKS IN THE BUSINESS ECOSYSTEM

Aquatic Biorefinery business ecosystem is based on aquaculture and includes marine, freshwater and dry land fisheries and the algae industry. In addition to producing goods for the food industry, the aquaculture can provide raw materials to other industries. The availability of the aquatic raw material is a strength in the Nordic countries, specifically Norway and Iceland. For many value chains in aquatic biorefinery it is essential that the raw material and the production facilities are situated nearby, as the raw material needs to be fresh when processed.

In aquatic biorefineries the aquatic biomass is refined efficiently into multiple products for a variety of industries and end uses. For example in addition to producing goods for the food and feed industry from the aquatic biomass, fish waste can be used in biodiesel production and omega oils and algae can be used in dietary supplements, to name a few examples. The numerous possibilities to connect other industries to the fisheries and algae industry, which are in the core of the aquatic biorefineries business ecosystem, are shown in Figure 4.

Possibilities for synergies between fish farming, algae production, food production and energy, biofuel and chemicals and nutrients production are numerous. Nutrient recycling can be supported, for example, by using the residues and organic waste flows from aquaculture as a raw material at biogas plants and then further refining the reject waters of the biogas plant into fertilizers for agriculture. In addition to the nutrient recycling, also energy is generated in the biogas plant and can be used as heat and electricity or as a transportation fuel if the biogas is upgraded.

Fish farms can benefit from close proximity of greenhouses by utilizing their excess heat and from algae industry by utilizing the oxygen provided by growing algae. A full industrial symbiosis can be generated around aquaculture ecosystems, where nutrients are recycled, energy produced from residues and all raw materials being utilized to their full potential.

One important aspect to consider in aquatic biorefineries is the linkage with sustainable management of the aquatic resources. Sustainable management aims at keeping the vitality of the aquatic ecosystems in the long run and minimization of any adverse effects the aquatic biorefineries may have on these ecosystems. Vital aquatic ecosystems are basis for future business potential on this area, but also for other synergistic uses such as natural excursions, ecotourism and of course for valuable ecosystem services that the aquatic ecosystems provide.

The companies within the fisheries and aquaculture sector tend to be small. Financing is often a bottleneck and co-operation is necessary to be able to finance development and new investments. The companies chosen to exemplify the possibilities in the aquatic biorefineries business ecosystem were **Sybimar Oy** (Finland) and the **Icelandic Ocean Cluster** (Iceland). Sybimar was included as an innovative SME on a business which combines many different concepts within the bioeconomy, having aquatic biorefinery as a core of the concept. The Icelandic Ocean Cluster was included as a service company which connects missing links into the aquatic biorefineries business ecosystem, which in this case are funding organizations and companies of small and large size.

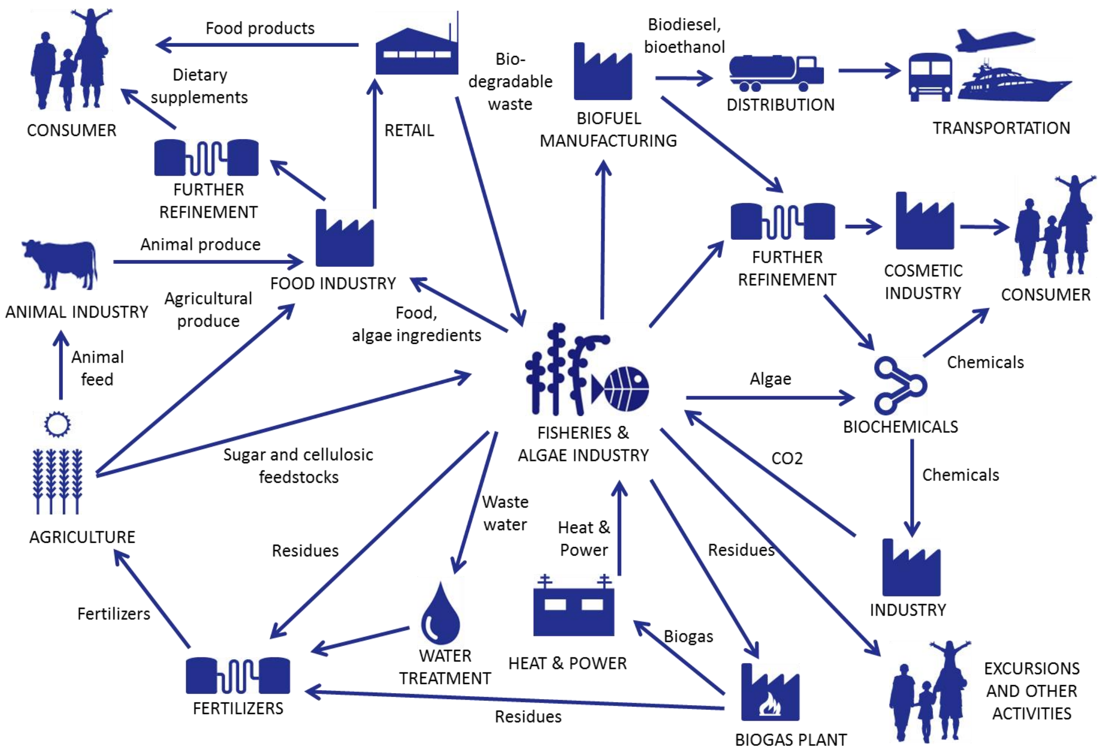


*Figure 4. The Aquatic biorefinery business ecosystem.*

## Relevance for the Nordic Bioeconomy

The aquatic biorefineries business ecosystem is relevant especially for Norway and Iceland based on the large volume of the fisheries and aquaculture sector in these countries. The bioeconomy strategies of these countries also focus on fisheries and aquaculture. All Nordic countries however have marine and freshwater resources, aquaculture and fisheries and for example the amount of fish waste generated is recognized on the EU level.

The ecosystem also includes emerging value chains with growth potential, such as use of valuable components of fish and crustacean in dietary supplements and development of dry land fishery concepts. The ecosystem supports achieving high value addition from the aquatic resources and other beneficial economic impacts for the Nordic countries such as increased export of value added products and/or reduced import of fossil products. Fish landings are decreasing and therefore value added products related to the fish and other ocean products are growing in importance. The export value of Icelandic cod, has for example managed to double in 20 years, due to increased raw material utilization, product diversification and innovation, although cod landings have decreased by more than the double[39]

The ecosystem has also social and environmental benefits, as it increases local and rural employment, increases material efficiency and decreases waste generation. The ecosystem currently consists mainly of SMEs, but there is a business possibility also for larger companies which can combine the activity of smaller players.

[39] http://www.sjavarklasinn.is/wp-content/uploads/2012/08/OceanClusterAnalysisApril2013.pdf

## Forerunner case Sybimar

### Business ecosystem

Sybimar is a Finnish SME producing fish at its dry land fish farms, which are based on circulating water technology. In addition to fish Sybimar produces biofuels from fish waste and food industry by-products and offers related process equipment. Fish farming is synergistically connected with biogas production and greenhouse farming. The associated modular concepts for fish farming, greenhouse farming and bioenergy production from food production side streams have been developed by Sybimar and are sold as technological solutions to other companies as well. Sybimar's presence in the aquatic biorefinery ecosystem is presented in Figure 5.

Sybimar covers the raw material production partly (fish farms) and the entire production of multiple products, as well as the required waste treatment and part of the required electricity and heat production, and is thus not very dependent on other actors in the value chain. Cooperation is extensive with research partners, raw material suppliers and end product buyers. The activities are also reciprocal as services are exchanged in both directions.

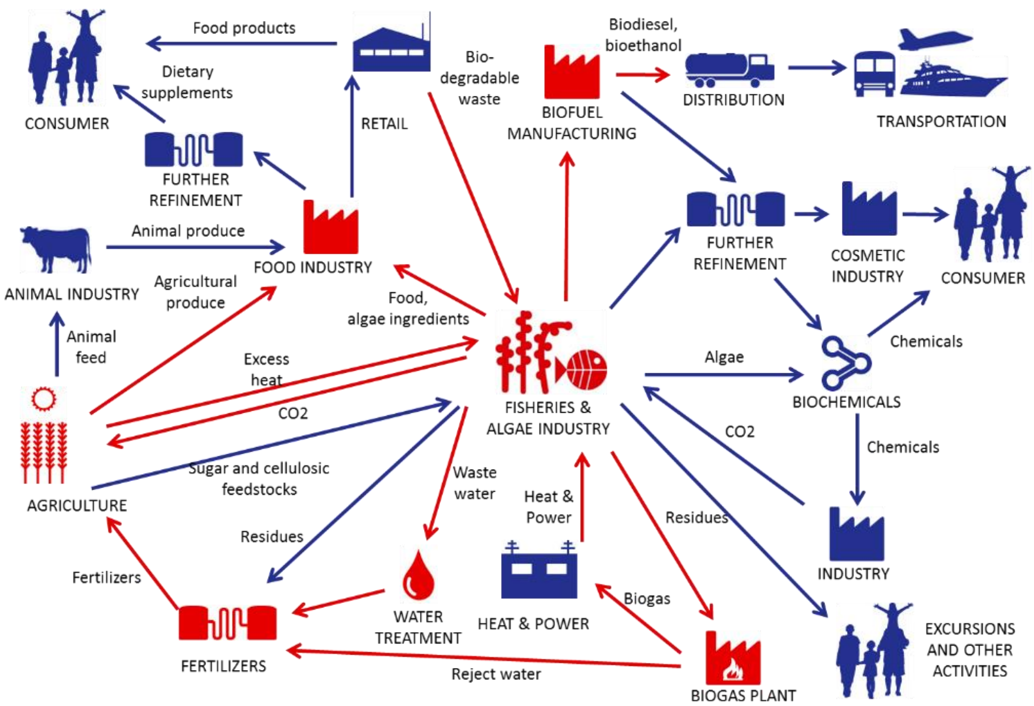


*Figure 5. The business ecosystem of Sybimar. The parts of the aquatic biorefinery covered by Sybimar's solutions are presented in red color.*

### Innovation development

Sybimar's innovations stem from making dry land fish farming a more profitable and environmental friendly business. Sybimar's innovations are cross-sectorial and combine know-how from various industrial processes. Sybimar's innovation is "The Closed Circulation Concept" that combines food and energy production into a unit where nutrients, water, waste heat and $CO_2$ are recycled back to the energy and food production.

The innovation activity of Sybimar is focused on development of new solutions that meet the current environmental legislation. Important aspect of innovation is piloting of new concepts in Sybimar´s own facilities, new modules are first piloted and then included in the overall concept.

The main innovation cooperation partners of Sybimar are the Technical Research Centre of Finland (VTT) and the Finnish Game and Fisheries Research Institute (RKTL). Through co-operation Sybimar's concepts have been broadened from local solutions to nationwide solutions and the R&D related to testing Sybimar's biodiesel at end use facilities has been possible. In the future, the research organizations may use Sybimar's facilities as their test environments.

The success factors of the innovation include Sybimar's strong, long-term know-how from the fish industry, but also public funding has been a key success factor, enabling Sybimar to invest in the facilities for piloting the concepts it develops. Fish farming binds capital strongly in the beginning, as the fish farms reach their full production capacity only after a few years of operation and thus funding of the investments at early stage is crucial.

The regulative changes in operating environment have also encouraged new development. The tightening national environmental laws related to aquaculture have made the increasing of open sea fish farming difficult and thus options for operating on dry land had to be developed.

The innovation path can be seen as systemic, since Sybimar's innovations are cross-sectorial and combine know-how from various industrial processes, and lead into entirely new overall concepts. Important areas of future innovation include energy efficiency, piloting opportunities and marketing and knowledge of the potential of algae.

**Key findings**

- Sybimar's innovation structure is based on piloting: All innovations are demonstrated at Sybimar's facilities.
- The innovation process is iterative and includes the piloting of several different inventions at the same time.
- The concepts combine multiple sectors and through modular concepts, resource efficient synergies and closed loops are sought after.

## Forerunner case Icelandic Ocean Cluster

**Business ecosystem**

The Icelandic Ocean Cluster is an Icelandic SME, which facilitates networking opportunities for ocean related industries in Iceland and worldwide. The main business of the cluster is to connect people and firms in ocean related fields and by that seek new opportunities across a variety of fields and regions. Its partners consist of well established, as well as cutting edge firms in ocean related industries. The business ecosystem spans the whole ecosystem from manufacturing of fishing gear, packaging equipment, processing equipment, software development for the fishing industry to advanced added value products, such as cosmetics and food supplements etc., which are based on fish or algae. Most companies sell their products under their own brand.

Today, the firms that belong to the Icelandic Ocean Cluster amount to nearly 60 in total.[40] The ocean cluster itself in total spans a large number of companies, including 70 technology companies, which manufacture and export ocean related gear and equipment.[41] The parts of the aquatic biorefinery ecosystem covered by Icelandic Ocean Cluster's activity are marked with a red circle in Figure 6.

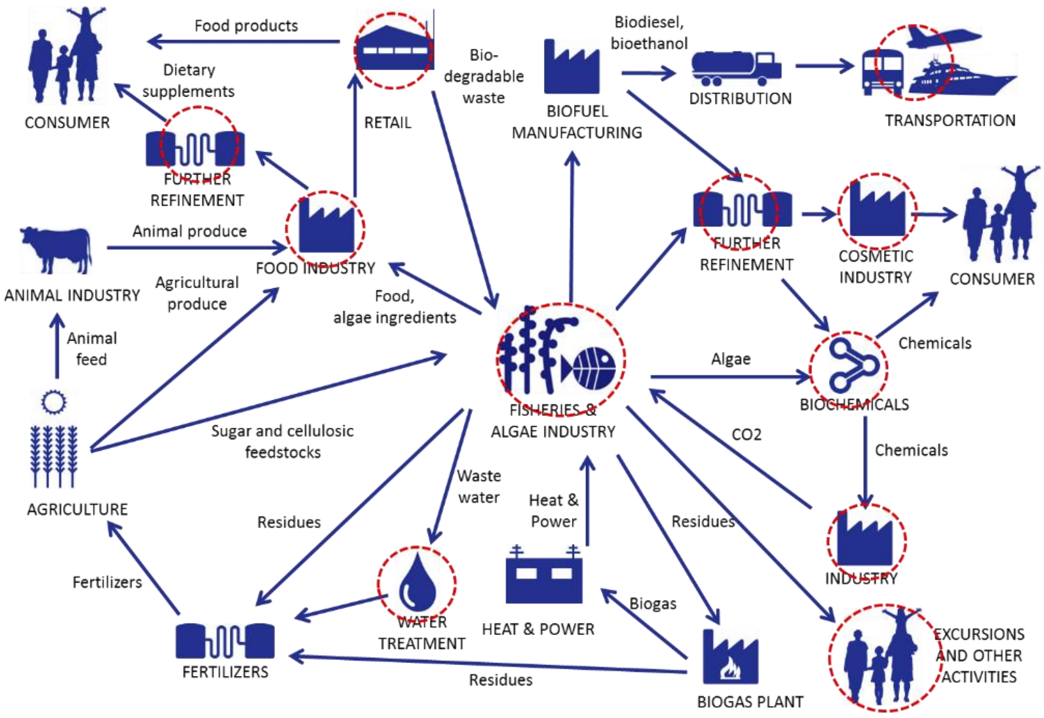


*Figure 6. Icelandic Ocean Cluster's business ecosystem. The parts of the aquatic biorefinery ecosystem covered by Icelandic Ocean Cluster's activity are marked with a red circle.*

## Innovation development

Iceland is characterized by the large number of small companies active in the ocean sector. Therefore there are challenges in being able to have the resources to innovate and to develop product and business ideas into commercial applications. Financing is often a bottleneck in innovation activities and cooperation is necessary to be able to capitalize the opportunities available in the value chain.

Cooperation is the essence of the innovation, and although the path of the innovation itself is difficult to define as systemic or linear in this case, Icelandic ocean cluster aids in developing systemic innovations for all companies involved. A number of ocean sector companies are situated in the Ocean House in Reykjavik. A new idea which was implemented for the ocean sector is that those who are involved in the cooperation have the possibility to work together under the same roof, which can create new synergies and facilitate cooperation.

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[40] http://www.sjavarklasinn.is/en/um-sjavarklasan/

[41] The Importance of the Ocean Cluster for the Icelandic Economy, Icelandic Ocean Cluster, University of Reykjavik, 2012

Currently the Icelandic Ocean Cluster is working on several major projects such as North Atlantic Marine Cluster Project (sponsored by NORA and Nordic Innovation) and Codland, research on the utilization of cod in the North Atlantic Ocean.[42]

**Key findings**

- Icelandic Ocean Cluster is an example of a successful networking organization.
- The cluster helps small companies in joining forces to share investments and to raise interest among investors, suppliers and buyers.

# NORDIC FUNCTIONAL BIO-BASED INGREDIENTS

## ACTORS AND LINKS IN THE BUSINESS ECOSYSTEM

Nordic Functional Bio-based Ingredients business ecosystem targets production of value-added functional ingredients from biomass. Functional ingredients are specific compounds that can be extracted from biomass and possess potential functionalities for end uses e.g. in nutritional supplements, cosmetics and various specialty chemicals uses. Biomass can originate from forests, aquatic resources or agriculture or from industrial side streams e.g. from the fisheries industry and food industry. Due to the possibility to use a variety of bio-based raw materials from many different sectors, the business ecosystem is potential in all Nordic countries.

For example, extracts from the Nordic berries and plants contain high amounts of functional compounds. Besides usage as ingredients in the food industry, functional compounds of berries provide value for nutritional supplements and for the cosmetic industry. In order to develop effective and sustainable bioeconomy concepts, all components of the raw material need to be utilized. E.g. when using berries, the berry seeds can be separated and used to extract seed oils for value-added applications in the cosmetics and nutritional supplements industries. The residual seeds can be utilized in bioenergy production and the rest of the berry material is used in jam and juice production.

Innovations of the business ecosystem include improved understanding on the potential, sourcing and processing chains of the biomass fractions and compounds therein, as well as formulating and commercializing the actual products. In addition to these, understanding their end use requirements, effects and connecting into client industries is the key to successful concepts and innovations. Ingredients are often used in consumer products, like cosmetics products or nutritional supplements, and therefore understanding of consumer preferences and linkages to retail chains are important. Functional bio-based ingredients used in consumer applications can benefit from the pure image of the Nordic nature. Ability to meet high quality and compliance requirements of the end products is also essential. The business ecosystem for Nordic functional bio-based ingredients is illustrated in Figure 7.

The companies chosen to exemplify the possibilities in the business ecosystem were **Chitinor AS** (Norway) and **DuPont Nutrition Biosciences Ltd** (Denmark). Chitinor is a manufacturing SME utilizing raw material from the fisheries and aquaculture sector. It is also an

[42] http://www.sjavarklasinn.is/en/um-sjavarklasan/

example of a company that only controls a small part of the value chain. DuPont Nutrition Biosciences (former Danisco) on the other hand is a multinational company, working in the field of functional ingredients and having the ability to control the entire value chain.

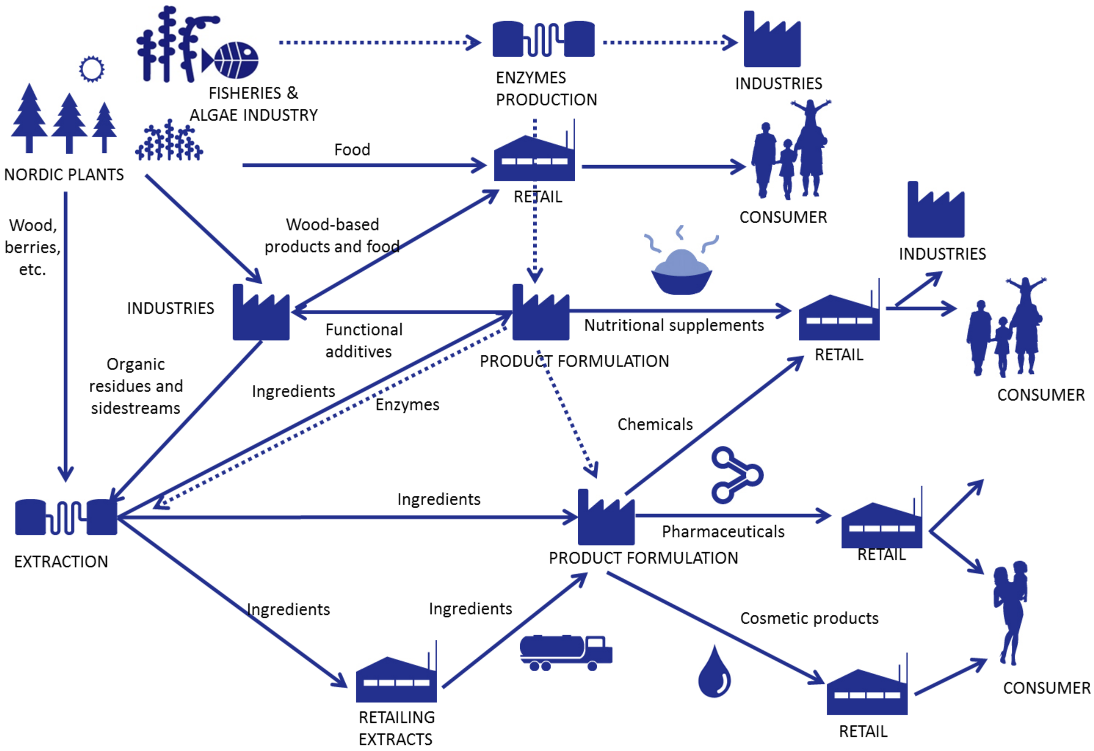


*Figure 7. The Nordic Functional Bio-based Ingredients business ecosystem.*

## Relevance for the Nordic Bioeconomy

The business ecosystem and potential of Nordic bio-based ingredients is, from the raw material potential perspective, especially relevant for Norway and Iceland, based on the volume of the fisheries and aquaculture sector in these countries, for Denmark, based on the volume of the agriculture and food industry, and for Sweden and Finland, based on the volume of the forestry sector. As the end products are value-added niche products, such as nutritional supplements and tailored cosmetics, the volume of the downstream client industries and especially the end product markets are relatively small in all Nordic countries. Due to this, realization of the business potential requires connecting into the global markets.

The ecosystem includes emerging value chains with growth potential. As the value added of the functional ingredients is especially high, the production systems are sophisticated and quality requirements high, the ecosystem is suitable for the Nordic countries with high knowledge intensity and competent work force. Especially due to high value addition and global nature of value chains the ecosystem provides potential for increased export income. The ecosystem has also various social benefits as it increases local and rural employment. In the business ecosystem both SMEs and large companies are present.

## Forerunner case Chitinor, Seagarden

### Business ecosystem

Chitinor (subsidiary of Seagarden) is a Norwegian SME, which produces chitin and the derivative chitosan, based on raw material from the shrimp peeling industry in north of Norway.

Customers of Chitinor are international, mainly in the European and Asian markets. The produced chitosan is delivered to cosmetic and pharmaceutical industries. Chitinor is present in only a small part of the value chain, extraction of chitin and production of chitosan. Chitinor is therefore very dependent on the other actors in its business ecosystem, the shrimp peeling industry and the client industries, the cosmetic and pharmaceutical industries. The parts of the Nordic Functional bio-based Ingredients ecosystem covered by Chitinor are presented in red color in Figure 8.

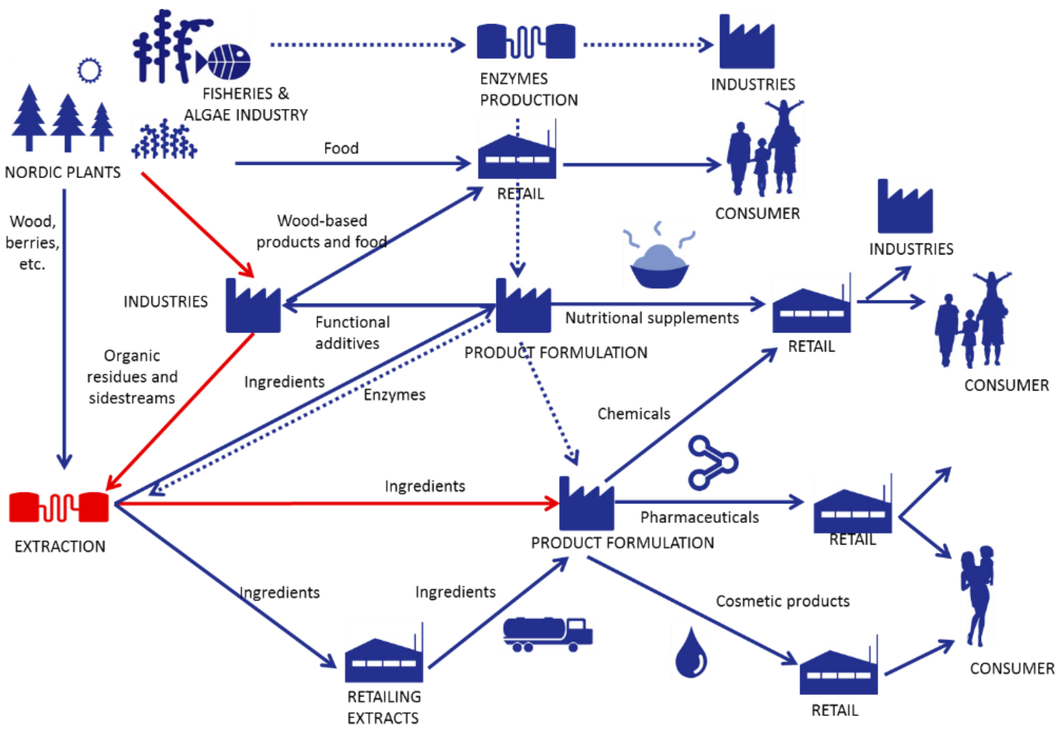


*Figure 8. The business ecosystem of Chitinor. The parts of the Nordic Functional bio-based Ingredients ecosystem covered by Chitinor are presented in red color.*

### Innovation development

The innovation of Chitinor is producing the cosmetics and pharmaceuticals ingredient chitosan from natural cold-water shrimp shells, without waste generation. It is competing against chitosan produced from farmed hot-water shrimp. Due to the high environmental load from the hot-water shrimp farming, the value chain of Chitinor has certain sustainability benefits.

Originally the pharmaceutical company Navamedic started Chitinor with the purpose of producing chitin, as a back-up for producing their pharmaceutical glucosamine product, which is made from chitin. Chitinor then wanted to move into the chitosan market, as it was seen as a vertical product with many possibilities. The knowledge of producing chitosan was available, but there was a need for a production plant. In 2012 Chitinor bought a chitosan producing plant in Tromsø and chitosan production was included in the product portfolio. The innovation path has been linear in its development from start, but the recent entrance into a new market by buying another company and facility was a systemic solution.

The company co-operates in research with a Norwegian and several European companies, and with a research organization in Norway. Approximately 1MNOK is put on research and development, where the focus is on technology development. About 10-40% of this is covered by funding from Innovation Norway.

The most critical success factors are related to process control and raw material sourcing. The raw material needs to reach the plant the same day, and thus the production must be in close vicinity to the raw material.

Important areas of future innovation are finding ways to compete in the existing and emerging markets for chitosan. In addition to the usage in cosmetics and pharmaceuticals, it can be used within for example water cleaning, agricultural improvement, fungus control and thus organic farming, dietary products and medical devices are potential applications. The market is very complex, and some markets are low priced due to an abundance of raw material. This is due to the large production of chitin derivatives from caught and farmed hot-water shrimp, which is very cheap to produce.

**Key findings**

- Innovation path started from a base product, which is relatively stable and reliable, and then moved further into more demanding products within the synergistic value chain.
- The company can take risks in developing new methods due to public R&D support system.

## Forerunner case DuPont Nutrition Biosciences (Danisco)

**Business ecosystem**

The multinational company, DuPont Nutrition Biosciences', main business is to produce food ingredients for the global food and beverage manufacturers, and industrial enzymes as well. Key raw materials include vegetable oils (such as palm oil, soy bean oil, rapeseed oil and castor oil), citrus peel, seaweed, locust beans, guar seeds, corn, wood pulp, soy meal and sugar. The raw materials originate from all over the world. Biomass availability is part of business strategy and new types of biomass are sought for as well.

Main applications are bio-based active ingredients e.g. for natural sweeteners, with a clear health and nutrition profile and enablers such as emulsifiers, pectin, gum and systems, which increase functionality to processed foods. The products are used in dairy and bakery products, ice cream, beverages, confectionery, food supplements, chewing gum etc. The enzymes include application industries as diverse as animal nutrition, detergents, bioethanol, textile treatment, carbohydrate processing and food and beverages. The production of emulsifiers, stabilizers, pharmaceuticals and enzymes are carried out at two factories in Denmark.

The majority of the company's sales are sold on the European market. DuPont Nutrition Biosciences controls, together with the rest of the group, most of the value chain. Cooperation is also extensive with both research partners and business partners. The parts of the Nordic Functional bio-based Ingredients ecosystem covered by DuPont Nutrition Biosciences are presented in red color in Figure 9.

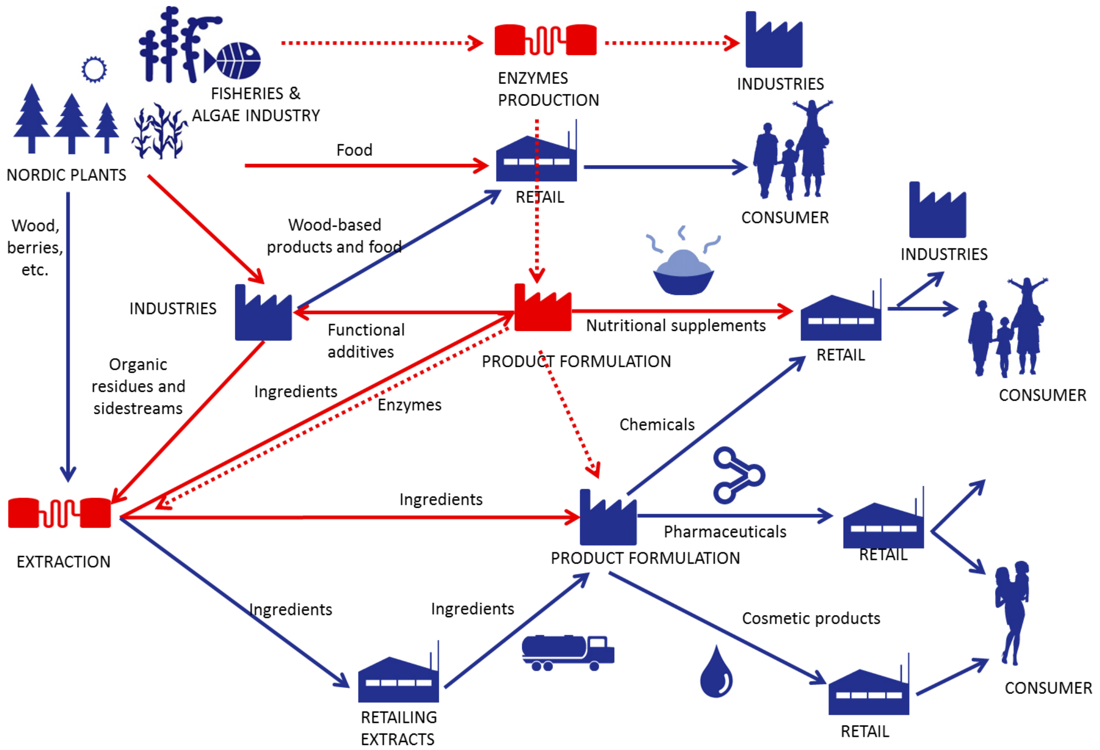


*Figure 9. The business ecosystem of DuPont Nutrition Biosciences. The parts of the Nordic Functional bio-based Ingredients ecosystem covered by DuPont Nutrition Biosciences are presented in red color.*

**Innovation development**

The application development and R&D activities are carried out in Aarhus, Denmark. The key innovation targets of DuPont Nutrition Biosciences are meeting the expectations from the food sector and the customers. The innovation is therefore market driven, with special focus on process efficiency and sustainability. DuPont Nutrition Biosciences has focused on operational efficiency targets and progress in their innovation process, in regards to life cycle assessment, sustainability assessment, renewable energy, CO2 emissions, health and safety, social responsibility employee engagement survey, food safety etc.  This has also been a way to meet the needs of the industry and future needs of society in terms of the global challenges in food, health and energy.

DuPont Nutrition Biosciences targets to brand the company in line with environmental demands and sustainability through the whole value chain from purchase of raw materials to the design of sustainable solutions.  Innovation and research annual investment is 10% within the whole Danisco group. The innovation development is end market focused and the company focuses on introducing new products to the market and creating demand.

DuPont Nutrition Biosciences has cooperated over the years with universities such as Copenhagen and Aarhus Universities and DTU. Industrial cooperation partners are the food producers such as Arla Foods and other large and small food producers. DuPont Nutrition Biosciences cooperates with several international research partners. The other Danisco subsidiaries in the other Nordic countries include Danisco Sweeteners Oy producing Sweeteners in Finland, Danisco Norway A/S producing cultures, enablers and sweeteners, and Danisco Cultor Sweden AB producing cultures. Danisco also cooperates with research institutes and universities in the Nordic countries.

DuPont Nutrition Biosciences has activities in research, development, production, distribution and administrative functions of the Danisco Group. DuPont Nutrition Biosciences is the parent company of a number of subsidiaries and owns all intellectual property rights within bio-based food ingredients developed by DuPont Nutrition Biosciences and the subsidiaries.

Future innovations are likewise focused on development from customer demand. New growth markets are in Asia, like China, where an increased number of women work and demand processed food products, similar to the development in the Western world. Globally DuPont Nutrition Biosciences and the Dupont Danisco group is one of the largest players in the field. Market growth rates expected on the enzyme markets is 6 – 8% for food applications, 8 - 10 % for animal nutrition and app. 15% for fuel ethanol enzymes.

**Key findings**

- Innovation focus is on market-driven innovation, operational efficiency and sustainability.
- Large raw material, product and application portfolio and wide cooperation base characterize a multinational, leading ingredients company.

## ADVANCED BIOMATERIALS

### ACTORS AND LINKS IN THE BUSINESS ECOSYSTEM

Advanced biomaterials business ecosystem targets production of novel bio-based materials. These include e.g. bio-based composites, bioplastics and advanced cellulose materials such as nano and microfibrillated cellulose. The biomaterial products are often produced for bulk applications such as biodegradable packaging components, but highly specialized niche markets exist as well, such as using cellulose derivatives as carrier material in the pharmaceuticals. One special characteristic of the advanced biomaterials products is the high variety of the potential client industries, including car, electronics, construction, packaging and paper, chemical, cosmetics, food, feed and pharmaceutical industries.

The raw material potential for advanced biomaterial products is largely in the side streams and residues of the existing biomass-based industries, like food, feed and the forest-based industries. Some fractions, such as lignin from pulp production, can be extracted at the processing stage and refined into new biomaterial products. Similarly sawdust from sawmills may be utilized in biocomposite production. Agro-biomass based products are also being developed from side streams of agriculture. The benefits of utilizing mainly side stream based raw materials include overall resource efficiency and possibility for high value addition, as the raw material cost is low. Agriculture, forestry and forest industry are currently the main suppliers of the raw material in the advanced biomaterials value chain. For Denmark, Finland and Sweden, where these sectors are the largest, this ecosystem has large potential.

Common for advanced biomaterials is that they possess high potential to be used in multiple industries, replacing fossil components and offering new functionalities, but often require new innovations especially in product formulation. An example is nanocellulose that can be utilized in multiple end uses such as in advanced building products, novel bioplastics, fiber-reinforced composites, additives for paints, pigments and inks and cosmetic products[43]. However, tailoring of nanocellulose into all these potential end uses requires combining understanding of the material properties of nanocellulose and its interactions and performance in the various end uses and product formulations.

Generally, as many of the advanced biomaterials products are currently only emerging into commercial use, the role of the R&D organizations is strong in this business ecosystem. The business ecosystem is illustrated in Figure 10.

The companies chosen to exemplify the possibilities in the advanced biomaterials ecosystem were **Innventia** (Sweden) and **Valmet** (Finland). Innventia is an example of a large research company, functioning in the ecosystem of advanced biomaterials. Valmet (former Metso) is an example of a large and global technology provider, active in the biomaterials business. Innventia and Valmet have also jointly formed a novel value chain on lignin-based biomaterials which is described to exemplify the systemic innovation path for reaching a new market.

[43] Nanocellulose materials -Preparation, properties, uses, The Finnish Centre of Nanocellulosic Technologies, 20/4/2014, Available at: http://oske.ketek.fi/Nanocellulose%20center_Teknokeskiviikko%2020_4_2011.pdf, Accessed 23/1/2014

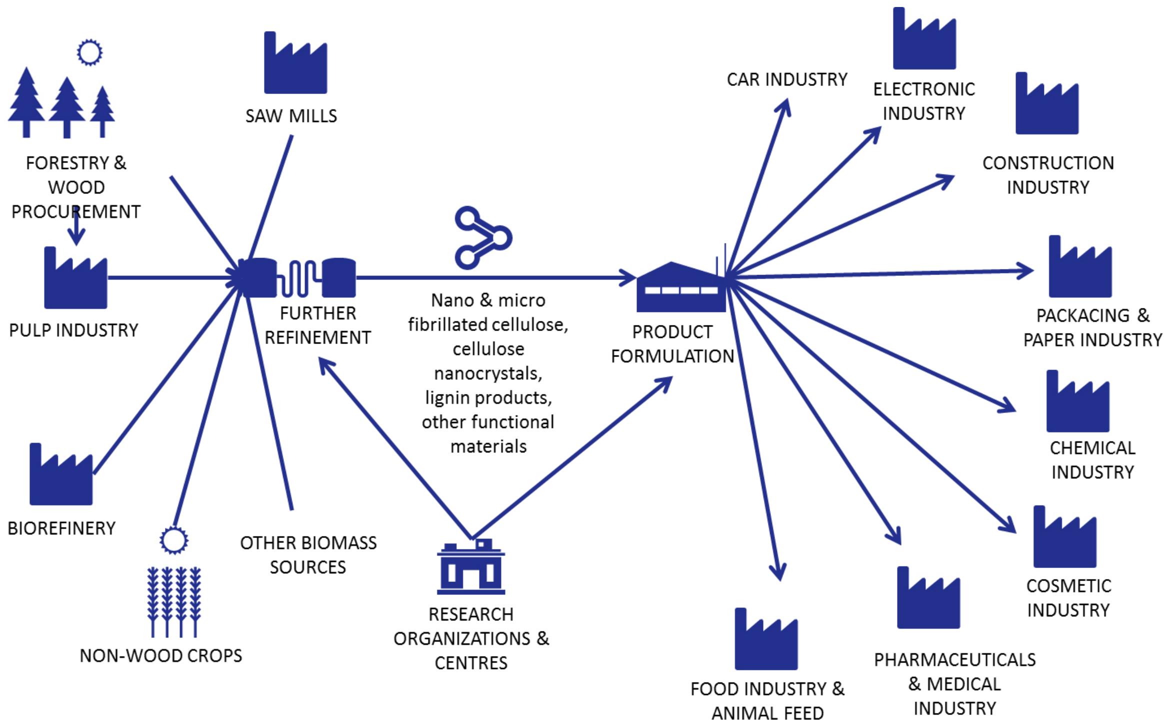


*Figure 10. The Advanced Biomaterials business ecosystem.*

## Relevance for the Nordic Bioeconomy

Agriculture, forestry and forest-based industries are the main suppliers of the raw material for the advanced biomaterials business ecosystem. Especially for Denmark, Finland and Sweden, where these sectors are the largest in the Nordic countries, this ecosystem has large potential. The products can be processed locally into intermediate biomaterials which are shipped and further refined close to the end use, or highly specialized biomaterials can be produced close to the raw material source. Raw material potential, value addition of the product and proximity of the client industries and end use markets define how the value chains are formed for each case.

The ecosystem includes emerging and innovative value chains with growth potential. High value addition of the products and global nature of many of the client industries support development of exports. Reduced imports of fossil products can also be achieved with local biomaterials production. The ecosystem has social benefits as it increases local employment. The biomaterial production from agro biomass is often run locally by small companies, while the biomaterials production from forest biomass is often incorporated in large scale production facilities, although small companies with niche markets also exist.

## Forerunner case Innventia

### Business ecosystem

Innventia is a Swedish research and development company, owned by mainly pulp and paper companies and the Swedish government. Innventia's research activities are connected to three business areas: biorefining, packaging solutions and material processes, which all rely on raw materials from the forest. The largest activities are within the lignin business and within the nano cellulose business, which both have a turnover of about 25 million SEK. Bioenergy, including gasification, bio-oil, pyrolysis, refining cellulose to ethanol and lignin to transportation fuel, and torrefaction, is also part of Innventia's business. In the bio-energy area company mainly focuses on system analyses on energy balances and economy, while the technology development is done on the customer side.

Innventia is present in many parts of the value chain, and in many phases of the innovation development. They cooperate with many companies in their research and development projects. Innventia co-operates mainly with KTH and Chalmer's University of Technology in Sweden, VTT and Aalto University in Finland, TFI and SINTEF and Trondheim University in Norway, and universities and research organizations in Europe and North America. On a project level, Innventia has co-operation with organizations in Iceland and Denmark. The parts of the Advanced Biomaterials ecosystem where Innventia is present are marked in red color in Figure 11.

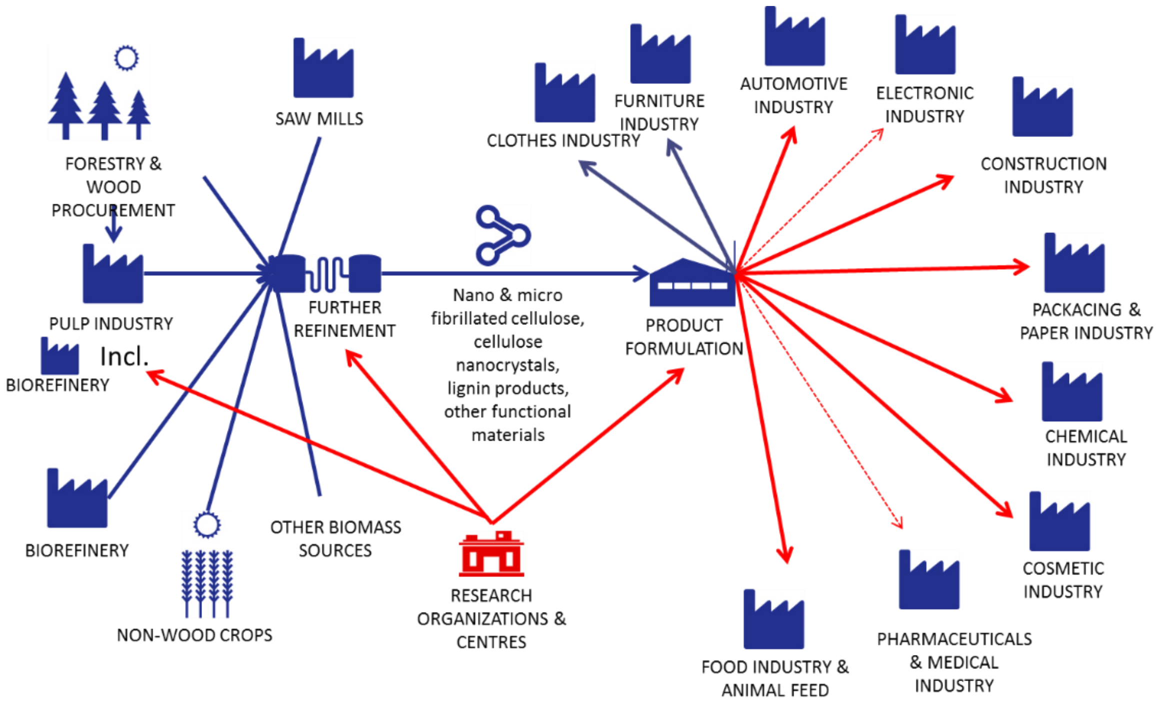


*Figure 11. The business ecosystem of Innventia's solutions. The parts of the Advanced Biomaterials ecosystem where Innventia is present are marked in red color.*

### Innovation development

Innventia strives to be at the forefront of technology and also to drive the front forward. Thereby a large part of the projects are started on the company's own initiative. Innventia also performs contract research, as well as some basic research to be able to keep the company at the forefront. The company generally works with projects, which have potential to be implemented industrially. Depending on the project the payback times range from under 1 year to over 5 years. The aim of Innventia is to co-operate with its customers throughout the development phase of the innovation. In some cases company secrecy policies tend to prevent this towards the end.

One of Innventia's innovations is the LignoBoost process, which was developed by Innventia and sold to Valmet (former Metso) as the product was ready to enter the market. The innovation path for the LignoBoost process is described in detailed in the innovation story below. The factors that made the innovation successful were several: rise in energy prices, popularity of green economy, good team work and different competences, top level of top companies recognized the innovation and also American companies joined the development. The innovation process followed was linear, but utilized the existing technology and infrastructure in a systemic way.

***Innovation story: LignoBoost***

*The idea for the LignoBoost process was born in a brainstorming session in the Eco-cyclic pulp mill project (KAM) in 1996. The vision was very clear but the definite goals of the project were not well defined. The general goal was to find ways to minimize resources used in the pulp mill including capital. Water and energy were the main issues and especially a surplus of excess high-pressure steam that at that time had a very low value for reuse. The goal was to minimize steam usage of organics in the recovery boiler and a university professor identified solution, removing the lignin from the black liquor, which was the start of the innovation. Innventia and Chalmers personnel worked together and evaluated what had been done in the area before, e.g. in North America. A few years later Innventia started a systematic project together with Chalmers University of Technology. The innovation had high credibility as the results after a learning period were reproducible at the laboratory and two patents were applied and granted. The project kept a low profile in the beginning.*

*The second phase was testing in real environment. Innventia rented a special filtration unit in pilot scale and received permission to perform trials in LignoTechs lignin plant in Sweden. (LignoTech is owned by the Norwegian company Borregaard). Shortly thereafter Borregaard decided to close the plant and this gave Innventia the opportunity to buy the plant. Financing was a problem and a bank loan was not a possibility as the terms (high interest rates) were not favorable. The process was however so interesting that both Stora Enso and Södra joined in and invested in the plant. Fortum Värme guaranteed to buy the produced lignin and evaluate it as bio-fuel in full scale. A grant was also received from Energimyndigheten. Venture capitalists would not take the risk. When the financing in the plant including new key-equipment and re-building of the existing process was secured the board of Innventia approved the plans. The plant was named LignoBoost Demo plant. The plant has raised much interest and was heavily visited.*

*The innovation was then bought by the Finnish company Metso (Valmet today) in 2008, and Metso then developed the technology further and commercialized the product. Innventia is still part of the development and performing calculations for companies who wish to buy the product. It is easier for Innventia to be objective in the development of the process as it is no longer its own.*

*First commercial LignoBoost plant was started up in Domtar's pulp mill in the USA in 2013. After the first commercialization, the markets have shown interest also in Nordic countries, and Valmet supplies the next LignoBoost plant to the Stora Enso Sunila mill in Finland. The start-up is scheduled for the first quarter of 2015.*

*The end product lignin has further innovation potential. Specialty chemicals and construction materials are promising markets for lignin derivatives.*

**Key findings**

- The innovation, the LignoBoost process, was so interesting that large companies wanted to invest.
- The innovation path of LignoBoost was linear (in-house research - pilot plant - commercialization), but with systemic elements like networking with North America, utilization and renewal of old industrial infrastructure and innovation being bought and commercialized by a technology company Valmet (former Metso).
- The innovation was very far developed before it was bought by a company, which made it easier to collaborate with research organizations and other companies.

## FORERUNNER CASE VALMET

**Business ecosystem**

Valmet is a Finnish company (the former Metso Pulp, Paper and Power unit that began its operations as Valmet on 31 Dec 2013). Valmet operates globally, offering products and services to pulping and fiber, board and paper, tissue, energy and biofuels and bio-based materials industries. Regarding the business ecosystem of advanced bio-based materials, it offers e.g. LignoBoost lignin recovery plants for pulp mills. The parts of the Advanced Biomaterials ecosystem where Valmet is present are marked in red color in Figure 12.

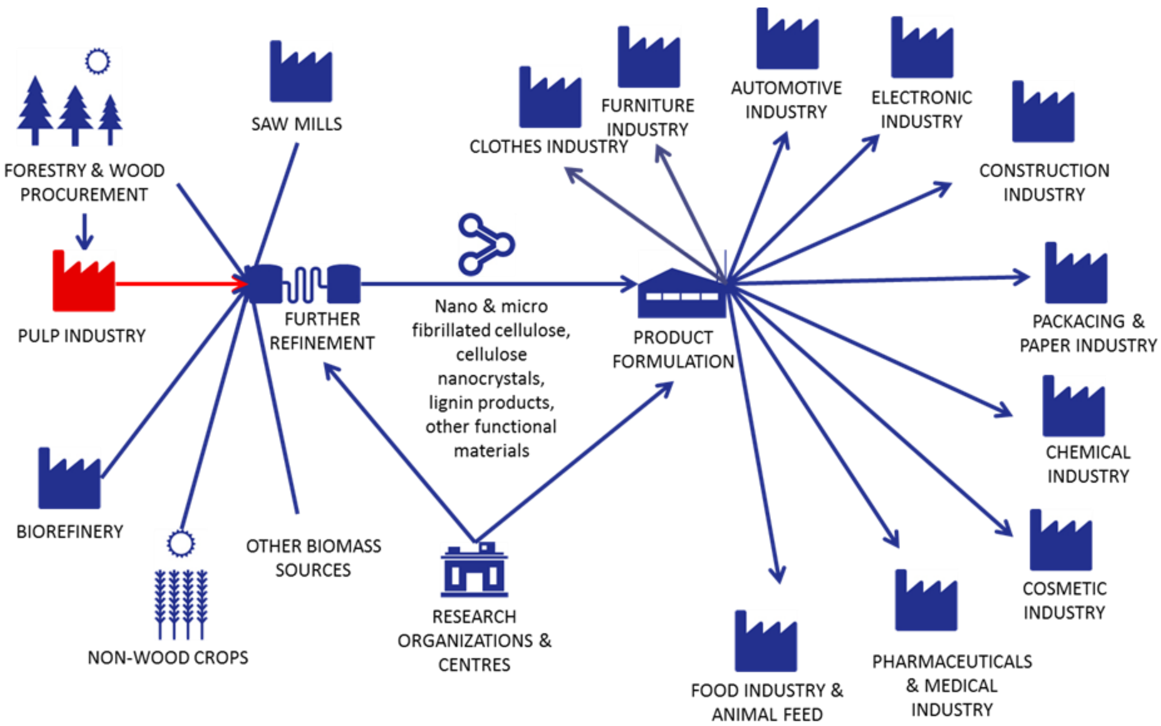

***Figure 12.*** *The picture depicts the parts of Valmet's business ecosystem related to the advanced bio-based materials ecosystem. One of Valmets new offerings is lignin recovery for pulp mills (in this ecosystem figure presented in red color).*[44]

**Innovation development**

Valmet's innovation process can take off from multiple starting points. Internal R&D can point out development and/or tailoring needs to existing solutions, or existing solutions are tailored and applied to new customer sectors or geographic regions, or totally new opportunities are identified. Initiatives may also be due to recognized business development needs, customer demand or due to need of scaling existing solutions. Many innovations complement the existing product portfolio and thus have a clear business potential.

Valmet's innovation process includes the cooperation with the client in most cases, especially regarding remarkable development projects. This innovation structure allows knowledge from multiple parties to be combined and can be seen as a win-win situation for all parties, according to Valmet. When all development parties - including research organizations, technology developer, and end user work together - they have a chance of learning from each other. It is crucial that every partner has a certain role and brings know-how to the process.

Valmet is also active in cooperation with research organizations. Previously it has been collaborating with universities and research in multiple, relatively small projects. Typically, university needs to have an industrial partner to receive funding, and Valmet has been able to contribute in these research teams with relatively small resource (typically around 10 000 €). However, this has not been seen as a productive collaboration model. The projects are often too small and too diverse. Instead, more of the research collaboration has recently been directed to projects, where Valmet can have more say in the research program. When the company has a research need, they are willing to put in more resources and buy the research as a service from the universities or other research organizations.

Examples of Valmet's innovations are LignoBoost and the pyrolysis technology. LignoBoost lignin separation plants are integrated with the pulp mill to recover and collect lignin from the black liquor. Lignin may be sold to customers for further refinement and product formulation purposes or to be utilized in energy production, replacing purchased energy.

The innovation process has elements of linear innovation structure. The technology was developed by a research organization, acquired by a technology supplier and then commercialized in one customer project, after which more market interest has been shown. There have been no strong elements of systemic innovation process, although some cooperation still exists among Valmet and Innventia.

As a comparison, it is interesting to look at another innovation by Valmet, the pyrolysis technology. This technology has over the years been developed by VTT, and recently piloted, scaled-up and commercialized in cooperation with VTT, Valmet, Fortum and UPM.  This de-

[44] General illustration of an Advanced bio-based materials -ecosystem, wherein Valmet focuses in transforming renewable raw materials into recyclable products and renewable energy. Valmet operates as a solution provider to multiple industries with focus on pulp, paper and energy sectors. Valmet's whole business ecosystem can be found in detail on the company webpages http://www.valmet.com/

velopment process is in line with Valmet's preferred innovation structure. It has multiple advantages, according to Valmet, such as established market demand and customer commitment.

In the case of LignoBoost, key success factor of making it commercial was Valmet's extensive market knowledge and strong position in the market. Although the technology was developed and even demonstrated by Innventia, it needed a partner for accessing markets.

In developing the pyrolysis technology, the success factors were somewhat different. Since the technology was developed together with end users (UPM and Fortum), it had a clear market demand. The end users were more committed to buying the technology as they had been part of the development and tailoring the process from the beginning. It is important to note, that in the co-development of pyrolysis plants, there were no conflicts of interests among the parties. This synergistic collaboration enables the change of information, open development and also the division of IPR. This type of collaboration follows a systemic innovation process, as knowledge and ideas are combined from research and market actors, at an early stage.

As general key success factors Valmet mentions the public funding, reinforcing own and customer funding, in the beginning of development and demonstration of new technologies.

**Key findings**

- Valmet's technology portfolio is well developed and can be implemented broadly. Valmet has both market pull and technology push innovations.
- Success behind Valmet's innovation is the know-how in commercialization. Valmet has a wide portfolio related to biomass conversion technologies and solutions and LignoBoost completes the portfolio. Thus, finding customers is relatively easy and through this established customer interface smaller companies focusing on R&D can find ways to commercialize their inventions.
- Valmet's innovation development, as demonstrated in pyrolysis case, can been seen as systemic: development is done together with research organizations and the clients from early stage, and thus knowledge from multiple actors can be utilized. Also, market need for the innovation is clear.

# BIOREFINERY CONCEPTS

## ACTORS AND LINKS IN THE ECOSYSTEM

Biorefinery is an integrated production system where various bio-based raw materials are used and various end products produced. The core difference to traditional linear production system is that the concept itself is optimized rather than one main product and side streams of a process. The aim is to utilize each component of the raw material efficiently and produce as much value as possible. The streams that will not end up as products can be used as heat and electricity for the process.

The raw materials of biorefineries can include biomass from forestry, agriculture and aquaculture. In addition to these primary biomass streams side streams of other biomass-based industries can be used. Potential raw material providing industries include forest, food and feed industries together with water and waste treatment.

The biorefinery concepts can include various technology platforms, such as thermal gasification, enzymatic processing, chemical catalysis and fermentation. Biorefinery concepts provide significant business potential for the technology providers, as investments in novel large scale production plants require significant amount of machinery, equipment, automation and supporting infrastructure. Services are also required, such as monitoring and measurement services and maintenance services.

The products of a biorefinery typically include biofuels, bio-based chemicals and biomaterials together with heat and electricity. The client industries for these products include the fuel distributors and retailers, chemicals industries and pharmaceutical industries to name a few. Biorefineries are tailored into various markets emphasizing the raw material, technology and product portfolio based on local needs. For example, in areas with scarce water resources water efficiency of processing is crucial.  The biorefinery concepts business ecosystem is illustrated in Figure 13.

The companies chosen to exemplify the possibilities in the biorefinery concepts business ecosystem were **SP Processum** (Sweden, based only on literature study), **Borregaard AS** (Norway) and **Sunpine AB** (Sweden). SP Processum is a development organization which targets filling of the missing links in the biorefinery business ecosystem, which in this case were piloting, infrastructure and cooperation possibilities. Borregaard is an established manufacturing company, which shows a highly developed biorefinery and has steadily approached new markets with product innovations. Sunpine is a biorefinery with a focus on a few products, where the raw material is used fully, with minimum waste generation.

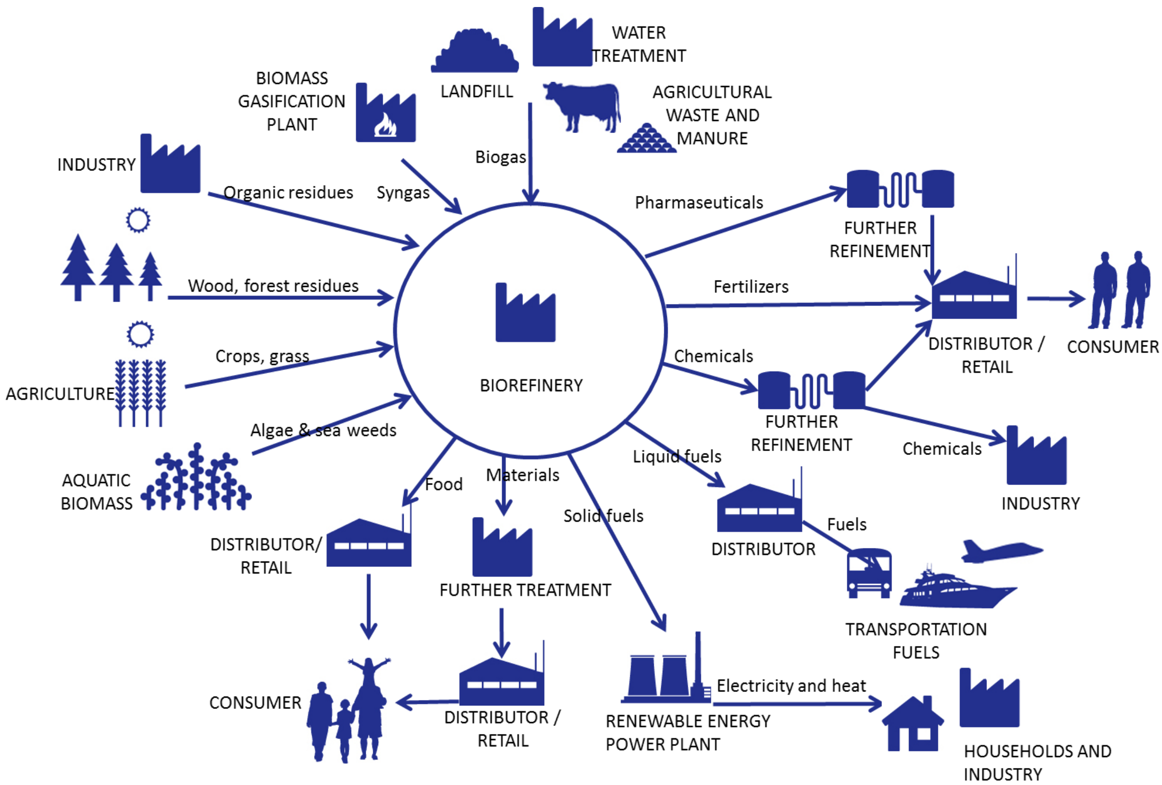


*Figure 13. The Biorefinery Concepts business ecosystem.*

SP Processum is an interesting example of a wood-based biorefinery cluster, which is located in northern Sweden. It involves companies and universities from Sweden and Finland.

The purpose of the cluster is to function as a uniting and central resource that provides knowledge, research resources, process management and piloting possibilities for the bioeconomy initiatives in Sweden. The financing is based on both public and private sources. Since 2008, research has been performed in 130 Biorefinery R&D projects. A general plan is the Bio4Energy, which consists of seven research platforms, each with an own strong research profile. Pilot plants include a torrefaction pilot, an algae pilot, dryer pilots, a wood fractionation pilot, a pelletizer pilot, a cellulosic ethanol demo, a chemical synthesis pilot, a viscose and spinning pilot, a pulping pilot, a membrane filtration pilot, unit operation pilots, gasification pilots, a TMP pilot and a chipping pilot.

Through the activities of Processum, the importance of among others, long term financing, demos and pilot parks, national policies that boost the demand for longer terms and tacit knowledge, have been acknowledged. As a result, it can be seen that the region is growing and networks are increasingly outside the region and that the concept has been successful in strengthening the existing industry structure. Problems faced are that network and credibility takes a long time to build and that the forest Industry in Northern Sweden are doing well in R&D, but big scale ups and commercialization are currently a big challenge. [45]

### Relevance for the Nordic Bioeconomy

The biorefinery concepts ecosystem is relevant for all Nordic countries. All Nordic countries possess significant biomass raw material streams from agriculture, aquaculture, forestry and/or biomass based industries. Biorefinery concepts provide an efficient means to utilize these raw material streams into various products with high overall value. The raw material and production mix can be optimized case by case to reflect the local characteristics and markets, and products with highest value can be sold to global markets.

The biorefinery concepts business ecosystem includes emerging value chains with growth potential. As discussed earlier, biorefinery technology solutions have high growth potential in the export markets, but there is plenty of potential for novel biorefineries in the Nordic countries as well. Globally focus of biorefinery investments is shifting towards lignocellulose and side stream based production concepts. Nordic countries have wide competence and resource base aligned with this focus. With Nordic biorefineries, imports of fossil products can be reduced, and export of value added products increased.

The biorefinery concepts ecosystem has also social and environmental benefits as the concepts typically increase local employment and material efficiency and decrease waste generation. Greenhouse gas emissions can often also be reduced when comparing to competing products. The ecosystem consists mainly of large companies, as biorefineries in most cases require significant investments in production plants. However, smaller and more modular biorefineries are also possible, especially in the future when technology becomes more mature and advanced.

[45] Presentation of SP Processum: *A wood-biorefinery cluster in northern Sweden*, by Clas Engström, CEO of Processum Biorefinery Initiative AB, at a Nord Regio event: http://www.nordregio.se/Global/Events/Events%202014/Bioeconomy%20ws/A%20wood%20biorefinery%20cluster%20in%20northern%20Sweden_Clas%20Engstr%C3%B6m.pdf

## FORERUNNER CASE BORREGAARD

### Business ecosystem

Borregaard is a large Norwegian company (500 Million euro turnover) running a Norway spruce based biorefinery. All activity aims at utilizing the raw material as effectively as possible. The raw material is acquired from both Sweden and Norway, as the plant is located close to the border. Products are made from both the cellulose and the lignin fractions of spruce and the residues are used in biogas production or for bioenergy. The main product from the cellulose fraction is specialty cellulose, which is used for production of cellulose ethers and acetates and has markets in Europe and Asia. The hemicellulose fraction is used in the production of bioethanol, which has markets in Norway and EU. The bioethanol is currently used to 80% in industry and 20% as a transportation biofuel, based on price competitiveness and the current mandate for transportation biofuels in Norway. Lignin is sold globally at all quality grades. Lignin is also the raw material for vanillin production. The concentrated residues from the processes are used for heat and power production and the diluted residues are converted to biogas for own heating purposes. In the end, 2-3% of the raw material exits the process as waste.  Borregaard has activities in very many value chains in the business ecosystem. The end products are not produced alone, but in cooperation with and tailored for the companies producing the end products. The parts of the Biorefinery Concept ecosystem where Borregaard is present are marked in red color in Figure 14.

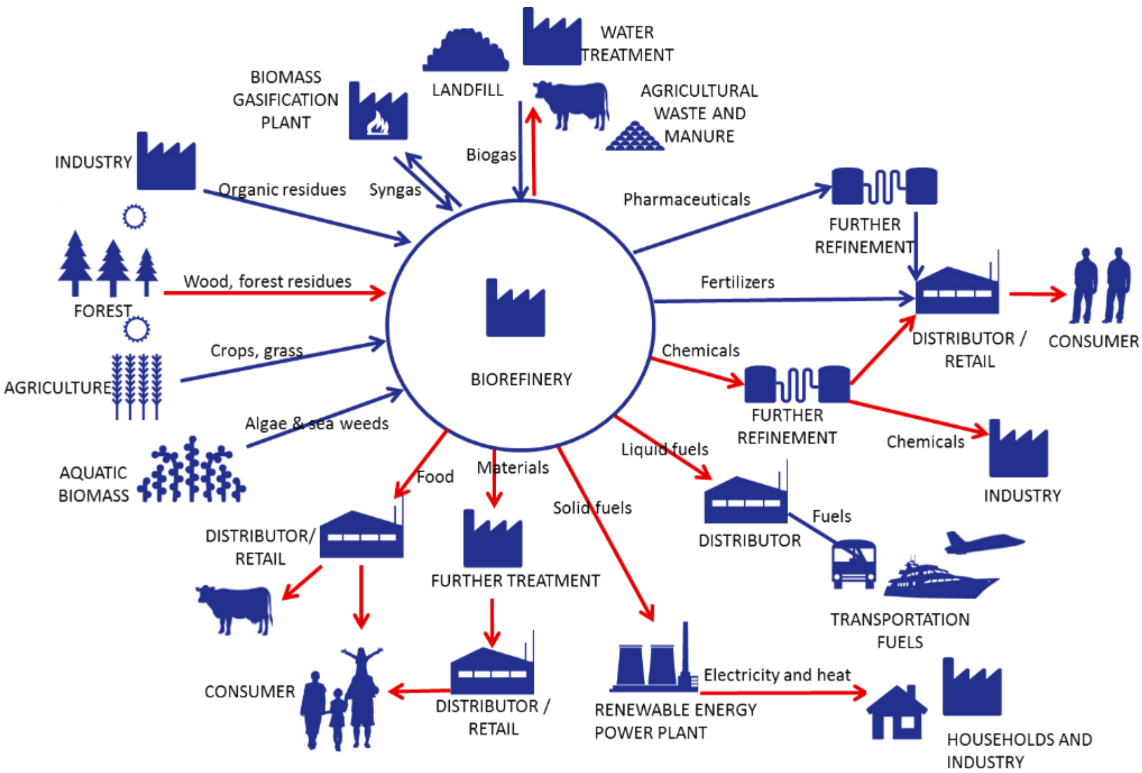


*Figure 14. Borregaard's business ecosystem. The parts of the Biorefinery ecosystem covered by Borregaard's solutions are presented in red color.*

### Innovation development

Borregaard has a very clear innovation strategy. All development and new products are made on the basis of the demand from the market and the customers. Innovation at Borregaard is top driven. Each business unit in Borregaard has innovations management teams with the responsibility to find partners, handle projects and resources and to terminate projects. Project termination is an essential part of the research and development activity. The innovation pool is larger in the beginning, but decreases as the research progresses, with the result that approximately one out of ten projects are continued to the end. 40% of the resources are set to projects that produce products within 1-3 years and 60% of the resources are set on projects that require more than 5 years to get the product into the market. The innovation path is systemic, both at the initial idea phase and the end development stages. 15% of the turnover results from new products that have been developed within the last five years. Innovation cooperation partners of Borregaard include its customers (30-50), research institutes, mainly SINTEF, NTU, UMB, INNVENTIA and institutes in Germany, UK and USA.

One specific Borregaard´s biorefinery concept of interest is The BALI process (Borregaard Advanced Lignin), which is based on sulfite pre-treatment, by which fractionation of lignocellulosic material (wood and agricultural residues) into cellulose and lignin can be done. The cellulose is subsequently converted to sugars by enzymatic hydrolysis, and the sugars are used for production of bioethanol or biochemicals.

The research was initiated as the company targeted growth in the area of lignin products. In 2008 the research started, and in 2010 governmental funding was granted for a pilot plant. The costs at the pilot plant stage are significantly higher than the research phase, and the granted funding from Innovation Norway (45 % of the total budget, 16 million euro (135 million NOK)) was essential for the continuation of the project. Early 2013, the pilot plant was commissioned, and it is now functioning as a demonstration plant. In 2014 it is planned that a decision to commercialize the project will be taken. New people with a biotechnology background were employed for the project. The research was performed in co-operation with SINTEF biotechnology and UMB, among others.

**Key findings**

- Borregaard has a top driven, systematic innovation structure with innovation management teams for each business unit. Innovation is market driven and end customers are engaged in innovation activities.
- The BALI process was developed because there was a large potential market for lignin and bioethanol.
- The high cost of wood in Scandinavia has been a major factor in making Borregaard a biorefinery that uses the raw material efficiently. Projects with high value addition are important for competitiveness.
- The need to work with forerunners in technology has made Borregaard seek partners with technology across national borders.

## FORERUNNER CASE SUNPINE

### Business ecosystem

Sunpine is a Swedish SME that produces crude tall diesel from pulping industry side stream crude tall oil for further refining into biodiesel. The upgrading from crude tall diesel to high quality diesel fuel is handled by Preem. Tall oil pitch is produced as a byproduct and used for heating purposes in paper mills or heat plants. Sunpine buys its raw material, crude tall oil from 10 pulp mills in Sweden and Finland. Thus, Sunpine's activity covers only a specific part of the value chain. The parts of the Biorefinery Concept ecosystem where Sunpine is present are marked in red color in Figure 15.

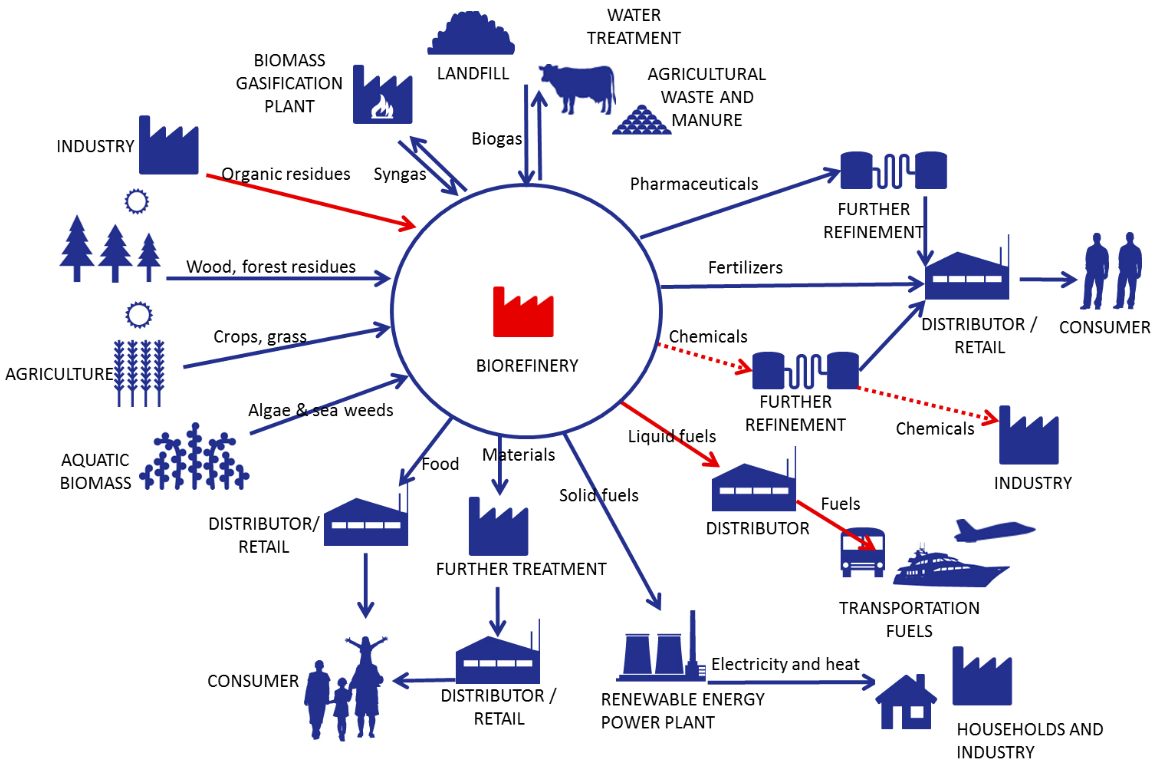


*Figure 15. Sunpine's business ecosystem. The parts of the Biorefinery ecosystem covered by Sunpine's solutions are presented in red color.*

### Innovation development

Sunpine has its own three person research team. Research is carried out in-house and in cooperation with Luleå University of Technology. The whole organization is based on research and development, as the plant is only three years old and the first of its kind in the world.

The idea for tall oil distillation and refining to biodiesel was born in 2001. Five years later the planning started for real and the innovation company Kiram was started. In 2008 environmental permit was granted and Preem joined the group. In 2009 the plant was built and production started in 2010. In 2013 the planned capacity was reached. Further innovation development possibilities include novel products from side streams, such as rosin production from tall oil pitch.

The innovation path seems to be linear when the different steps are studied, but the combination of knowledge and innovation at different companies is systemic. The companies have also managed to cooperate towards the same goal with mutual benefits.

Success factors were incitement from society and tax redemptions on green diesel, but also committed individuals were needed. Lars Stigsson had access to the university laboratory and he developed the cooperation consortium. Piteå is important as a cluster of knowledge having 2 large paper mills, small companies, open co-operation environment, Science Park (Chemrec and other small companies) and regional will to promote new uses of forests.

**Key findings**

- Very open innovation environment, all partners worked together although otherwise competing.
- Success factors for commercialization were incitement from society and tax redemptions on green diesel.
- Committed individuals were needed.
- The region participated and the right infrastructure was present. Piteå is important as a cluster of knowledge.

## BIOCATALYSIS

### ACTORS AND LINKS IN THE BUSINESS ECOSYSTEM

In biocatalysis bio-based catalysts are used to increase the rate of chemical reactions. Biocatalysis is applied in a number of industries. Biocatalysts are typically enzymes, proteins which are needed e.g. in multiple biorefining processes as well as in a number of industries such as food industry, for waste water and soil treatment and chemical, cosmetic and pharmaceuticals industry. Biocatalysts can process and modify biomass very selectively, leading to tailored biomass products and product properties.

Biocatalysts can be produced from multiple raw materials. Commonly yeast, bacteria and fungi are used as production organisms and provided with required nutrients. Novel biocatalysts are constantly screened from natural species and established industrial production organisms are modified with advanced biotechnological means such as recombinant expression to develop new biocatalyst products and optimize biocatalyst production. Biocatalysts can be produced at separate production facilities and then distributed to different end uses. On-site production of bio-catalysts is an emerging concept which has the advantage of avoiding the transportation of both raw materials and enzymes, as the side streams from biorefineries may be used as raw materials for enzyme production, and enzymes are utilized at their production site.

Screening and production of biocatalysts and development of applications of biocatalysts are knowledge intensive and research and development organizations play an important role in the biocatalysis business ecosystem. The biocatalysis business ecosystem is illustrated in Figure 16.

The company chosen to exemplify the possibilities in the biocatalysis business ecosystem is **ArcticZymes AS** (part of Biotec Pharmacon, Norway). ArcticZymes is an example of a company working in a niche market of biocatalysis, cold tolerant enzymes, but the products have global usage. The company also focuses on filling the missing links in the innovation system within biocatalysis, which in this case is providing research services for research institutes and companies that make the use of enzymes easy, thus allowing researchers to focus on their core activity.

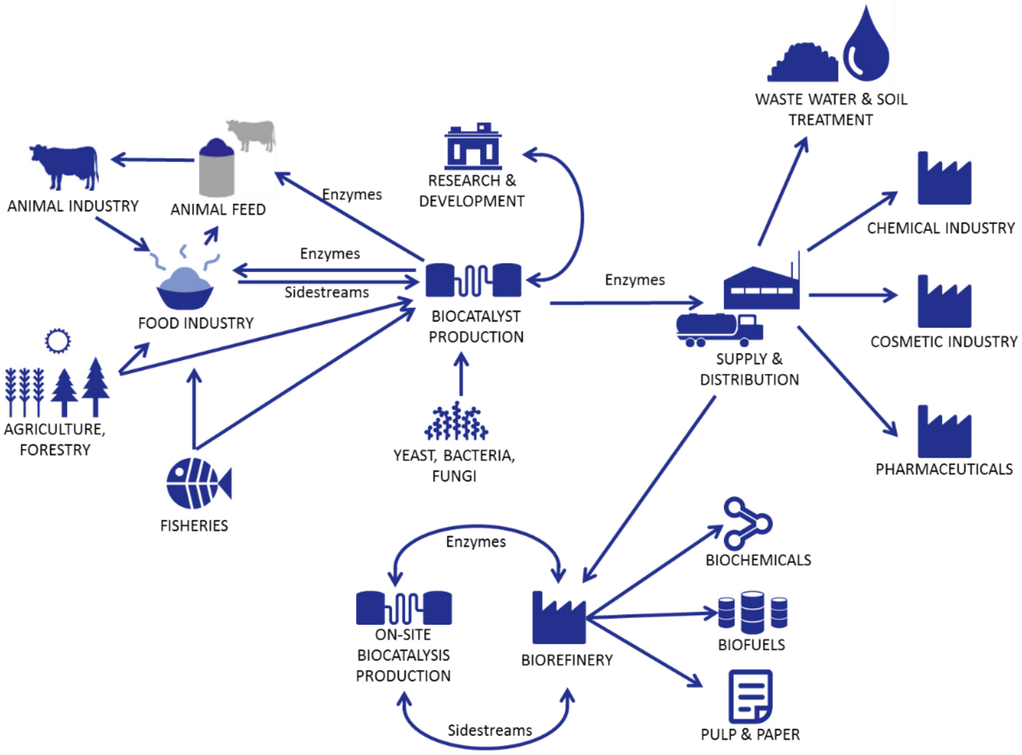


*Figure 16. The Biocatalysis business ecosystem.*

**An example** of a company operating in the Biocatalysis business ecosystem is ArcticZymes. ArcticZymes produces recombinantly expressed enzymes originating from various arctic species. It is a subsidiary owned by Biotec Pharmacon, which has a turnover of 196 MNOK (23.5 M€).[46][47]

The products are sold for research applications (molecular biological research and diagnostic markets), as bulk enzymes for production, or as product ingredients. Additional products include appropriate buffers, additives and work kits for user friendly solutions. 50% of the market is in USA and Canada and 50% in Norway. ArcticZymes has supply agreements with for example GE Healthcare Life Sciences, Affymetrix and New England Biolabs. All current products originate from fish or shrimps living in the cold seawaters in the Arctic Ocean. The preconditions for survival in these waters are “life systems” supporting life at very low temperatures. The cold-adaptation allows the use of simple heating steps for their irreversible inactivation.

[46] Biotec Pharmacon Årsrapport 2012

[47] company webpage: http://biotec.no/

ArcticZymes AS has a history dating back to the late 1980's with its foundation planted in the fishing industry of Northern Norway. In the mid-1990's Biotec Pharmacon acquired the technology for production of shrimp alkaline phosphatase and built a department for production of molecular grade enzymes. In June 2009 Biotec Pharmacon created ArcticZymes. The other part of Biotec Pharmacon, the subsidiary Biotec BetaGlucans AS, develops and manufactures immune modulating compounds for the human health sectors. Biotec Pharmacon is also connected to BioTech North, which is an emerging biotechnology cluster of enterprises and R&D organizations, closely cooperating with regional funding and development actors.

### Relevance for the Nordic Bioeconomy

The biocatalysis ecosystem is relevant in all Nordic countries. Biocatalysis production is knowledge intensive business which requires solid supporting research and development capabilities on biotechnology. These are available in all Nordic countries. Biocatalysts are products with high value addition and they serve the global markets in many sectors. In selection of production locations possibilities to support the business with competent workforce and R&D services ecosystem is important and this is an existing advantage in the Nordic countries. The ecosystem includes emerging value chains with growth potential, as global biocatalyst market is growing and novel applications are constantly developed. The ecosystem represents high value addition and it is essential technology applied in several other value chains in the bioeconomy.

The ecosystem has social and environmental benefits as production of biocatalysts increases local employment. The use of biocatalysts often increases material and energy efficiency and decreases waste generation in the customer industries. The ecosystem consists of both SMEs and large, globally leading players in the field.

## DECENTRALIZED BIOENERGY SYSTEMS

### Actors and links in the business ecosystem

Decentralized bioenergy systems supply renewable energy products while supporting the local development. Potential raw materials or fuels of the decentralized energy systems include biomass originating from agricultural or forestry side streams, industrial bio-based side streams and municipal bio-based waste streams. Bioenergy production systems may include biogas plants and combined heat and power production plants (CHP) which serve local municipalities, industry and transportation. Production of bioenergy may also be complemented with other renewable energy sources such as wind and solar electricity and geothermal heat to target entirely renewable local energy systems.

Decentralized bioenergy systems are potential in all Nordic countries. Small scale plants are suitable in low dense residential and industrial areas, which are typical for the Nordic countries. Furthermore, heat is produced as a by-product in bioenergy systems, and due to the Nordic climate this is an advantage.

Local collection and processing of biomass for energy production creates both direct and indirect jobs. In local concepts short radius of biomass transportation saves greenhouse gas emissions from logistics. When utilizing bio-based waste or residue streams that would otherwise be unused, the methane emissions caused by decomposition of organic matter can be avoided. Small scale bioenergy units can also act as back-up energy that supports the main grid electricity need. The uneven production of wind and solar electricity can be supplemented with bioenergy.

In order to ensure overall sustainability of decentralized bioenergy systems sustainable management of biomass resources must be taken care of. If primary biomass from forests or agriculture is used, it must be planned carefully not to have adverse effects on biodiversity, ecosystem services and nutrient balance. Nutrients can also be recycled by fertilizing land with fertilizers recycled back from the residues of the biogas process or ash fraction of the biomass combustion.

The decentralized bioenergy systems business ecosystem is illustrated in Figure 17.

The companies chosen to exemplify the possibilities in the decentralized bioenergy systems business ecosystem are **St1 Biofuels Oy** (Finland, based only on literature study) and **Bigadan A/S** (Denmark). St1 Biofuels is a company specializing on decentralized production of biofuels, mainly focusing on waste as raw material. The company is large in the field of transportation fuels and has recently moved in to the production of bio-based fuels. It also controls the whole value chain, from raw material to end product distribution. Bigadan is a company specializing on decentralized production of biogas. It is also an example of a company filling a missing link in the ecosystem, which in this case is funding for production plants.

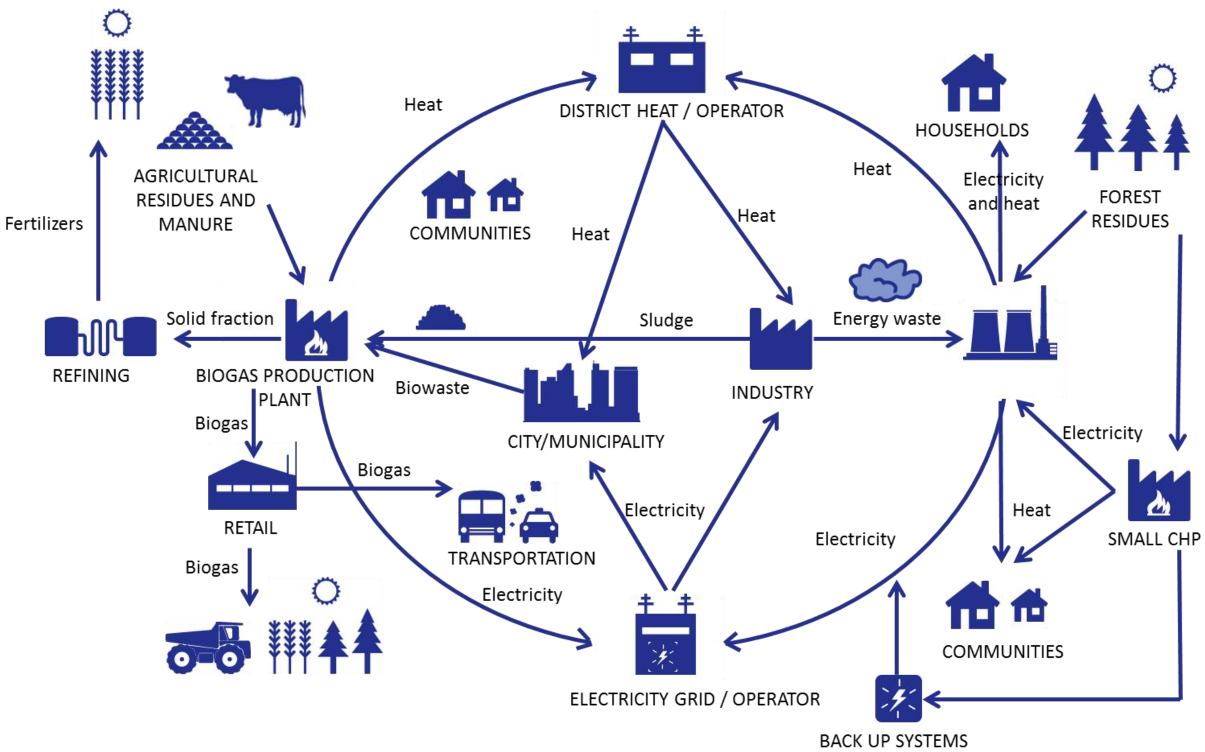


*Figure 17. The Decentralized Bioenergy Systems business ecosystem.*

**An example** of a company operating a decentralized bioenergy system is St1 Biofuels. St1 Biofuels is a Finnish company producing bioethanol from wastes and residues. St1 produces bioethanol at distributed plants, near the locations where biodegradable waste is generated. The 85 % ethanol from multiple production sites is transported into one, central refinery that produces 99,8 % ethanol, which can be mixed into transport fuels. Currently the feedstock include municipal biodegradable waste, waste from bakeries, outdated breads from markets, residues from soft drink and beer manufacturing and other sugar and starch rich residues from food industry. The ethanol plants also produce side streams that can be utilized e.g. as animal feed and for soil improvement, near the ethanol plants. Currently St1 has bioethanol production in five locations in Finland (Lahti, Vantaa, Hamina, Jokioinen and Hämeenlinna). Next step for St1 is to start producing ethanol from lingocellulosic residues such as sawdust, and a plant is being planned to Kajaani. St1 is a good case example of decentralized, distributed energy generation: Bioethanol is produced at the site where wastes are being generated. Thus, the wastes and residues are not transported long distances, instead only ethanol, which has higher energy content, is transported. Furthermore, St1 utilizes the trucks transporting fuels to the fuel stations for bioethanol transportation: As the truck leaves empty from the fuel station, it picks up the bioethanol from the production plant and transports it to the refinery.

## Relevance for the Nordic Bioeconomy

The decentralized bioenergy systems ecosystem is relevant for all Nordic countries. Based on the current volume of the bioenergy sector, especially Sweden and Finland are strong, but all Nordic countries have bio-based waste streams that are currently not utilized and additional potential from sustainable primary biomass. All Nordic countries are also currently using fossil fuels which could be replaced by local bioenergy products. This would support local economy and reduce greenhouse gas emissions. The ecosystem includes emerging value chains such as biogas plants producing biofuels, heat, electricity and fertilizers and concepts with growth potential.

The ecosystem has also social benefits as it increases local employment and energy security. The ecosystem consists of both SMEs and large companies.

## Forerunner case Bigadan

### Business ecosystem

Bigadan's main business activity is to provide engineering and construction services to large-scale co-digestion biogas plants with a capacity larger than 100 tonnes/day. The typical plant capacity is 200-600 tonnes biomass/day. The raw material for the biogas plants are mainly biomass from farmers, such as manure and energy crops, and residues of the food industry (organic waste). Part of the biogas production includes a returning of the organic waste from the biogas process back to the farmers as nutrient recycling. Bigadan's products include large turnkey plants, engineering, process equipment, service and maintenance and operation of biogas plants.

When a new biogas plant is established, customers are typically power and gas companies and food waste processing companies. A biogas plant, which has been developed and will be run together with Dong Energy and Danish Crown, will be finalized in 2014. Dong Energy´s role is to upgrade the biogas and deliver it into the natural gas grid system. Dong Energy invests in the upgrading facility. Danish Crown is operating a slaughter nearby, which is the largest in Denmark and will supply organic waste from the production. Bigadan covers the technology and financial parts of the business ecosystem, and in all cases co-operation with end-users are necessary to establish.

Other large cooperation partners are E.ON (producer of electricity and gas) and ReFood-Saria (sustainable use of waste) among others. Bigadan´s cooperation partners are also suppliers of control systems and process equipment such as tanks, agitators etc. Bigadan also collaborates with partners in Sweden.

Over the years, Bigadan has managed to retain international experts to supplement their own know-how. Today they also have subsidiaries and affiliates in other countries so they can keep close contact with clients and suppliers as locally as possible.

The parts of the De-centralized Bioenergy Systems ecosystem where Bigadan is present are marked in red color in Figure 18.

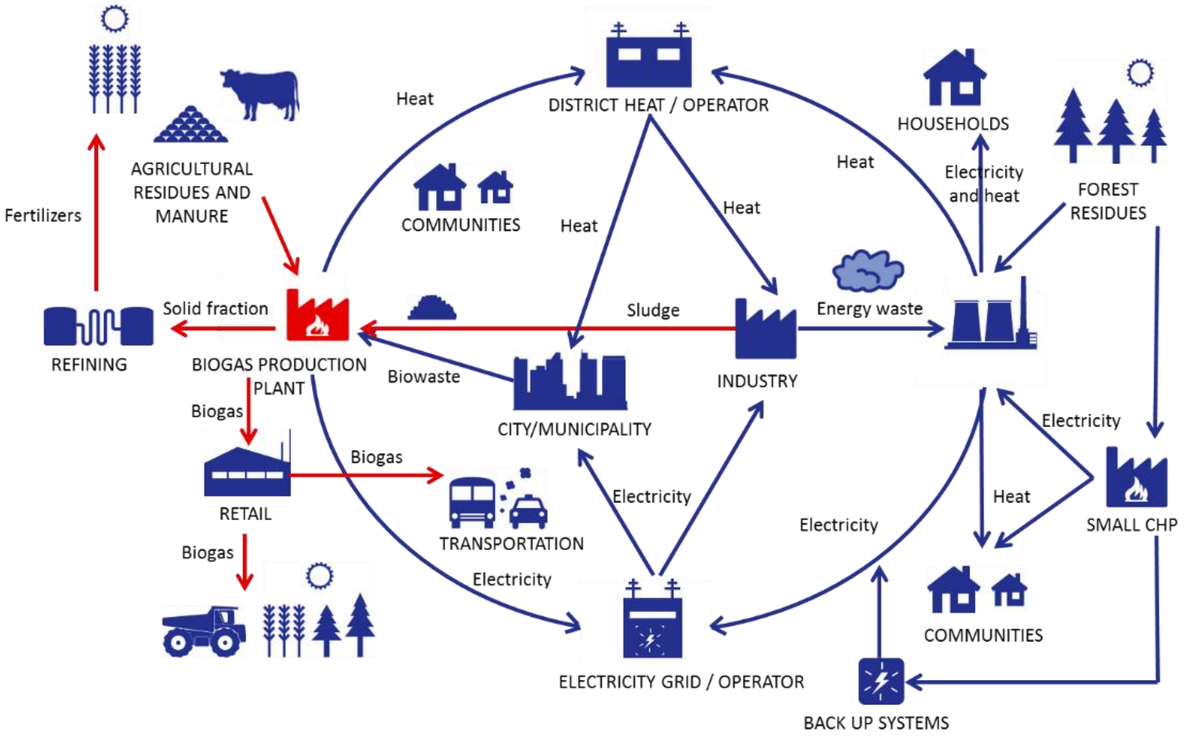


*Figure 18. The business ecosystem of Bigadan. The parts of the ecosystem of De-centralized bioenergy systems covered by Bigadan's solutions are presented in red color.*

## Innovation development

The innovation structure is a continuous development of process equipment in co-operation with suppliers and customers.  Bigadan spends 5-10 % of the income on research and development per year. Finding new types of (second generation) biomasses is one of the main R&D focus points**.** Bigadan are involved in the international project BIOMAN, funded by FP7-SME-2012, involving Technical institutes and universities from Denmark (TI and Aalborg University). In general Bigadan cover their development costs by themselves, and have not been involved in many research projects over the years. The innovation path is linear and the innovation is a technology push answering to the market need.

The biogas process is the traditional type, and addition of e.g. enzymes for the process has not been a success. The main efforts are concentrated on development of process equipment for optimal biogas production and finding new types of (second generation) biomasses such as straw, grass, and other residual biomass from agriculture. Also finding new ways of pretreating the biomass residuals for use in biogas production are important. Other focus areas include new techniques for achieving a better energy yield of the different biomasses, finding ways to standardize biogas plants making them cheap and easy to build and finding ways to standardize biogas plants making them cheap and easy to build.

Bigadan started more than 20 years ago, delivering technology for centralized biogas plants, owned by farmers and other delivers of waste. During a period Bigadan was bought by the large Danish company Krüger, where owner and cofounder of Bigadan Carsten Buchhave, also joined.  CB bought Bigadan from Krüger several years ago, and the activities are typically now involving ownership of new biogas plants.

Biomass availability and sustainability are important issues for the success of the innovation. Biomass availability has to be practically and financially sensible in order for it to be a success. That treatment, transportation etc. of new biomasses is practically and financially sensible.

Future innovations are needed in waste recycling and preservation of resources, which also are problems worldwide. EU has approved subsidies/aid for biogas-produced electricity, which will help the growth of the business.

**Key findings**

- Commercial anaerobic digestion plants also serve as test and development sites.
- The technology supplier company takes partial ownership of the biogas plant and thus functions as an investor.
- The main R&D efforts are concentrated on finding new types of (second generation) biomasses and finding new ways of pretreating the biomass residuals for use in biogas production.
- Biomass availability has to be practically and financially sensible in order for it to be a success.
- The most important obstacle has been lack of sufficient subsidies for green energy. There is a lack of political stability in this area.

## BIOECONOMY RELATED RECREATIONAL SERVICES

### ACTORS AND LINKS IN THE BUSINESS ECOSYSTEM

The business ecosystem of bioeconomy related recreational services includes here services related to tourism, cultural and recreational activities and health benefits of the natural environments. These services are linked to other business ecosystems of bioeconomy as they synergistically use the natural environment and set requirements on required infrastructure and environmental permits of the bio-based production.

Important actors of the bioeconomy related recreational services ecosystem include land owners, land managers and developers, excursion and recreation activity providers, travel agencies, accommodation and food services.

Ecosystem services provide a foundation for bioeconomy related recreational services ecosystem. Ecosystem services are similarly a foundation for other value chains through provisioning ecosystem services, supporting ecosystem services and regulating ecosystem services. Provisioning ecosystem services are services such as food, energy, and water. Supporting ecosystem services are services that are necessary for the production of all other ecosystem services such as nutrient cycling. Regulating ecosystem services are services such as carbon sequestration, waste decomposition, purification of water and air, and crop pollination. Therefore sustainable management of natural environments and ecosystem services is a key for all these synergistic uses.

The bioeconomy related recreational services business ecosystem is illustrated in Figure 19.

The company chosen to exemplify the possibilities in the ecosystem is **Pink Iceland** (Iceland). Pink Iceland is a company which develops ecotourism based on focused customer demand. The company functions as a connecting link between service providers in the business ecosystem.

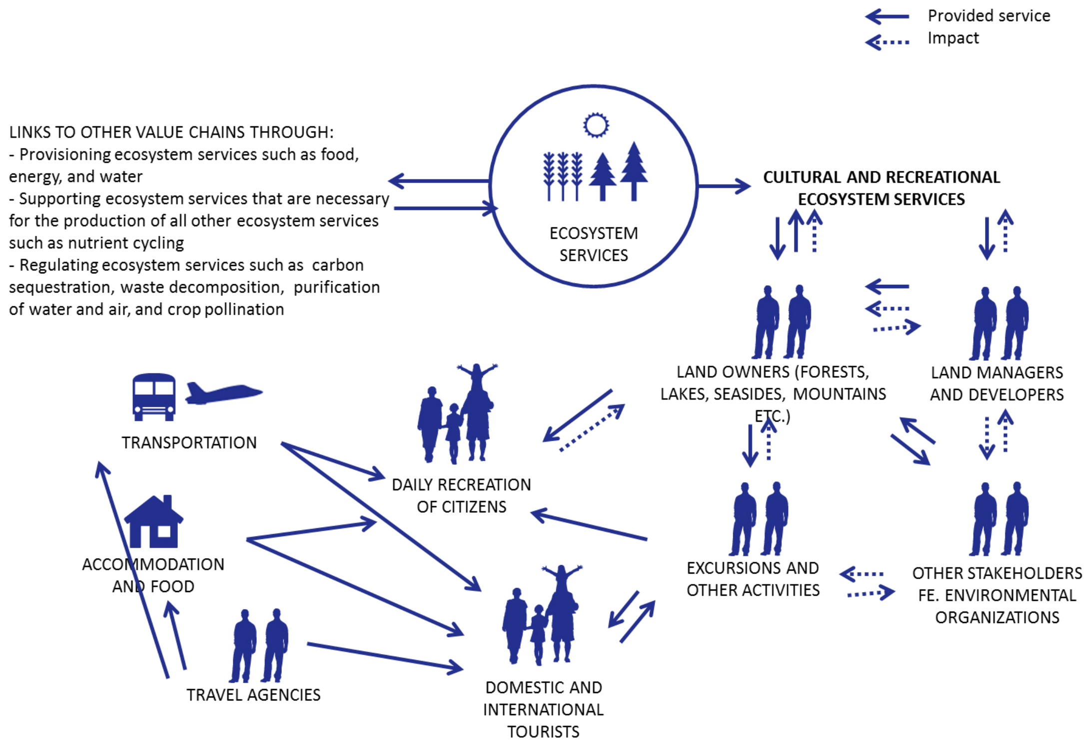


*Figure 19. The Bioeconomy Related Services business ecosystem.*

## Relevance for the Nordic Bioeconomy

The bioeconomy related recreational services business ecosystem is relevant for all Nordic countries. The Nordic countries are sparsely inhabited, and nature is always near. The ecosystem includes emerging value chains with growth potential.

The ecosystem has social and health benefits as it increases local employment and provides health promoting services. The ecosystem consists mainly of SMEs, but there is a possibility for large companies that combine the activity of smaller ones. The innovations are often linked to service offering and linkages between various complementing service providers.

## Forerunner case Pink Iceland

Iceland is a country where the tourism industry is a major contributor to the economy, although it is still in a developmental phase. Icelandic tourism is almost entirely based on the nature and ecology of Iceland. About 80-90 % of visitors to Iceland indicate that they visit Iceland because of the unique nature. This is also the foundation for the services provided by Pink Iceland.

### Business ecosystem

Pink Iceland is a small travel agency/tour and event company, which provides a broad range of tourism and travel related services. Pink Iceland specializes in day tours, weddings, events and festivals and specially organized trips. Both guided tours produced by Pink Iceland and by other service providers are offered. The target group of the company are gay and lesbian travelers. The concept provides LBGT travelers with high quality services where the service is both considering environmental factors and providing a good environment for the LBGT traveler. The services are provided by a network of service providers, which are quality controlled for sustainability and gay friendliness. All tours are conducted in small groups and involve high-end personal service. The web-site combines good design with broad, high quality, service offerings.

The concept involves integrating some environmental education into the tours. The company has recently taken into use a formal environmental system, which makes it possible to integrate environmental considerations to all aspects of the service offering. The parts of the Bioeconomy related Recreational Services ecosystem where Pink Iceland is present are marked in red color in Figure 20.

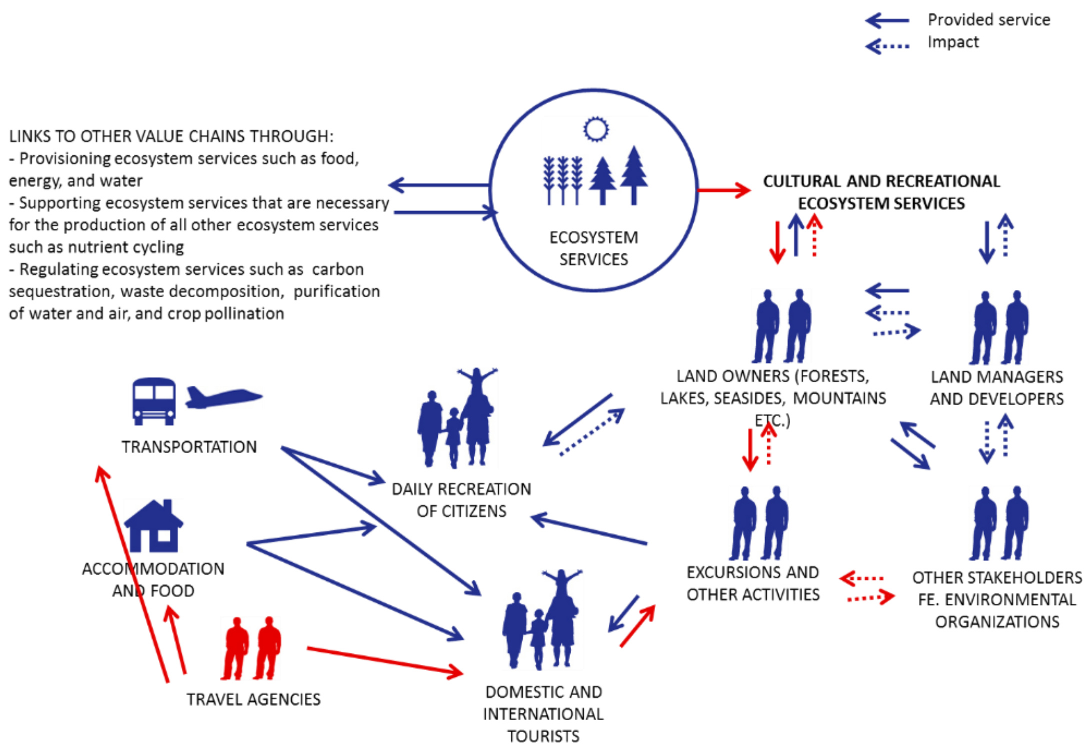


*Figure 20. The business ecosystem of Pink Iceland.*

**Innovation development**

The concept has evolved from the initial idea of the founders and now seems to develop based on customer demand. For instance the wedding service was developed based on customer wishes and is now a top selling service.

Pink Iceland was founded in March 2011. One of the founders had the idea for the concept for some years. She had studied tourism at the university and had worked for a whale watching company previously. The opportunity to participate in the Golden Egg entrepreneurship competition presented itself in 2011. In connection with the competition it was possible to evolve a business plan. The Pink Iceland project was chosen as the second runner-up out of a total of 150 entered projects. This provided a kick-start for the company. The company was in practice founded in the beginning of 2012.

Small streams of initial funding were helpful in the beginning of staring up the company. Pink Iceland received 200 000 ISK funding for the project and some more funding for a wedding service project. Pink Iceland received the Icelandic tourism innovation award for 2012. In addition an award has been received for the logo design.

The company focuses on a niche customer base, the gay and lesbian community. The original idea was based on the fact that such a service didn’t exist yet and that you could combine two offerings: great culture- and nature-based travel services with a gay friendly travel environment.

Success factors have been a focused idea and a clear marketing plan, which is followed-up regularly. Receiving some financial support has required some reporting on progress and having structure in the operations, which is seen as one success factor. It has also been important to have community support and to receive positive feedback in all stages of the development.

The developers have received offers for additional financing from investors to extend the concept to a broader customer base / to expand it abroad. However they have chosen to not expand at the moment in order to have control over the concept to guarantee high quality personal service – which are seen as key elements of the concept.

**Key findings**

- Comprehensive services for a small niche market
- High-end quality controlled personal service as key success factor
- Structured ways of working including having an environmental management system seen as a success factor as well as receiving positive feedback and community support
- The company has limited interest for expanding operations – more interest in having control over service quality and offering personal service, while investors are interested in participating in expansion.

## CONCLUSIONS FROM THE ANALYSIS OF BUSINESS ECOSYSTEMS

Novel growth areas and potential value chains are not seen in traditional sectorial analysis. Biochemicals can for example be produced from agro or forest feedstock and upgraded into pharmaceuticals. Due to this, added value is not seen specifically in any sector but dispersed along the sectors within the value chain. Therefore, in the business ecosystem analysis concrete business ecosystem illustrations and cases exemplify how bioeconomy innovations have been developed in potential value chains of bioeconomy which cut horizontally through the traditional sectors.

The seven business ecosystems analyzed were 1. Aquatic Biorefinery, 2. Nordic Functional Bio-based Ingredients, 3. Advanced Biomaterials, 4. Biorefinery Concepts, 5. Biocatalysis, 6. Decentralized Bioenergy Systems, and 7. Bioeconomy Related Services.

In the following, key findings and conclusions from the business ecosystem analysis are summarized. In addition to this, the volume of the different sectors of bioeconomy relevant for the business ecosystems analyzed is presented in the Appendix, in tables 7-13.

### INNOVATIONS ARE TAKEN INTO USE IN THE BUSINESS ECOSYSTEMS

For successful bioeconomy innovations, the business ecosystems are crucial when the novel processes, products, methods, services and systemic solutions developed are taken into use by actors in the concrete value chains and business ecosystems. As described earlier in Chapter 2 innovation by definition is a novelty taken into use, so without concrete business applications or applying of the innovations in society the innovations are not completed.

**Market access is the key**

In order to commercialize the bioeconomy innovations developed market access is required unless the innovations are of societal nature. However in most of the cases the Nordic domestic market is small in relation to the overall market potential of the bioeconomy innovations studied in various business ecosystems. At the end of the value chain, for further refining, distribution and as customers, international companies and end use markets are therefore needed. This is especially emphasized for the niche products with high value addition, such as bio-based ingredients for nutrition, cosmetics and pharmaceuticals which have global markets. Although international market access is a key for many bioeconomy innovations, the exact means and concepts for market entry are however case specific. However it can be concluded from the case studies that it is beneficial to engage end users in target markets as early as possible in the innovation development.

On the other hand, certain potential value chains are local, and such concepts can be applied and multiplied within the Nordic countries and market access is therefore more straightforward. Decentralized bioenergy systems business ecosystem is an example of such business ecosystem, which can be highly tailored for Nordic needs and significant home market is available.

**Technology and services of bioeconomy offer global business opportunities**

Manufacturing technology development is especially strong in Sweden and Finland and technology and service solutions can be incorporated in many business ecosystems of bioeconomy in various end use markets. Export of technology solutions has a very large potential, as technological solutions are needed in all bio-based value chains and industries. The main part of the markets is outside Nordic countries, as the Nordic share of the overall investments on bio-based production facilities is low. The turnover from the Nordic technology sector is currently 9% of the European total.

**Utilization of existing infrastructure lowers the commercialization threshold for novel bioeconomy innovations**

Existing infrastructure and services support the current industrial structure and established products. The development of new infrastructure for entirely new processes and products may be very expensive. Developing value chains in existing ecosystems and close to existing infrastructure will take down the costs and also reduce risks due to wider overall product portfolio of the entire business ecosystem. This was for example the case for Sunpine, where the existing infrastructure included raw material suppliers, technology providers and research institutes, and the end product buyer Preem aligned its own downstream processing development with Sunpine's novel refining plant investment. SP Processum on the other hand has deliberately developed an infrastructure with their cluster, which supports piloting efforts and lowers the costs for these. Borregaard has also evolved into a biorefinery, by expanding from its core infrastructure. Generally pulp and paper mills are interesting starting points for bioeconomy innovation, as can be seen from the examples above. They include a well-established infrastructure, in connection to raw material procurement, heat and electricity production and utilization, and wastewater treatment. Despite the many possibilities they provide, the pulp and paper mills are developed for mass production, which makes the step towards high value production slightly challenging.

**Importance of complementary actors in the business ecosystems**

Complementarity of actors is the essence of any functioning business ecosystem. The forerunner and example companies provide several examples of companies that have developed complementary activities in relation to the main actors in the business ecosystems.

One of the complementary activities required is facilitating networking and cooperation. This may include, for example, finding business partners, helping customers to find products or helping researchers to share knowledge and investments for piloting. The Icelandic Ocean Cluster helps small companies in joining forces so that they can share the costs of investments and become larger together and thus raise interest among investors, suppliers and buyers. SP Processum joins research and development efforts, and Pink Iceland helps customers to find the service providers.

Another type of complementary actors in the business ecosystems is piloting facilities. Processes that require economies of scale also need to be tested in larger scale, and the costs for pilot investments grow with size. Piloting facilities that can be rented for testing are a way to decrease the risk and also to improve the process already at an early stage. This is especially important in the bioenergy and biofuels sector and for the ecosystems of biorefinery concepts, decentralized bioenergy systems and aquatic biorefineries. Examples of these among the forerunner cases are Sybimar, which thanks to its modular concept enables piloting of several different inventions at the same time, SP processum, which provide piloting also for early stage research and Bigadan, which uses existing facilities for raw material testing and as show cases.

R&D service providers like Innventia complement the business ecosystems by carrying out R&D activities which support companies' research. ArcticZymes is another example of a R&D service provider simplifying the use of enzymes so that researchers can focus on their research.

The business ecosystems require many types of investors: the state, regions, organizations, private investors and the companies themselves. A complementary actor to the list of investors is for example the forerunner case Bigadan, a biogas technology provider, which also functions as an investor in the plants.

### Ensuring overall sustainability and holistic resource optimization across sectors

Bioeconomy innovations target resource-efficient use of valuable bioresources. Therefore the overall sustainability and resource optimization across the business ecosystems is important and must be ensured already in the innovation development process. The biorefineries are examples of production units which optimize resource usage and produce products for different sectors. The forerunner case Sybimar utilizes waste from the food industry sector, waste from the fisheries and aquaculture sector and produces nutrients and heat for the agriculture sector. The forerunner case Borregaard utilizes its raw material to 98%, which in many cases may be difficult for companies producing bio-based products. The forerunner case Sunpine utilizes one specific side stream from the forest industry sector to produce fuel for the transportation sector and returns the new side products to the pulp mill to be converted to heat and energy for the energy sector. Examples of resource optimization can also be found in the other business ecosystems. The forerunner case Chitinor uses peels from shrimps, which is already a waste, and are able to utilize it fully in their production.

### Positive impacts through local and rural employment

Regions benefit from bio-based industrial activities. Biomass is a local resource and will therefore employ local raw material suppliers. Similarly industrial and communal bio-based waste is a local burden and utilization of the waste will provide benefits for the region. In addition to this the construction and operation phases involve local employment. Active involvement and support from the region was mentioned as a success factor especially in the case of Sunpine. In addition to industrial activities local services business can benefit from rich natural environments ad bioresources by providing a basis for natural excursions and such tourism activities.

## SYSTEMIC INNOVATION ELEMENTS ARE EMPHASIZED

### Nature of the innovation path often combines linear and systemic elements

The forerunner cases give examples of how the case innovations have developed in the companies and their business ecosystems. In the forerunner cases systemic innovation development was emphasized especially in cases of Icelandic Ocean Cluster, Sybimar, Chitinor, Valmet, Innventia, Borregaard, Sunpine and Pink Iceland. Danisco and Bigadan seemed to have a more linear innovation approach, with systemic elements though.

Linear innovation and closed internal development tends to be slow. The new biomass based products are often competing against products that have had time to develop slowly to perfection and production methods that have been tuned to efficiency over decades. Natural competition has also removed the weaker value chains. Systemic innovation can utilize existing technology and co-development, and thus decrease time needed for development. This can be seen e.g. in the case examples of Valmet, Borregaard and Sunpine.

From the forerunner examples it can be seen that there is a difference in the focus and starting point of the innovation path. There are innovations developed to solve a specific problem, innovations developed to meet a market need and innovations developed to meet a policy need. A specific type of innovation in many of the forerunner cases and in bioeconomy specifically, is innovation to enable resource-efficient utilization of bioresources with maximized value addition. This requires efficient use of all process streams and upgrading of the streams into many products with as high value addition as possible.

### Benefits from existing competence and matching of best competences

Similarly as existing infrastructure gives a competitive advantage, benefiting from existing competences facilitates bioeconomy innovations. As bioeconomy innovations often combine cross-sectorial competences, finding the best matches and identifying the best available complementing competences outside own core areas are of utmost importance. Borregaard for example uses its own core competence for developing the fractionation of biomass into compounds, but employs new people with a specific background when moving into a new area or develops the products together with the end user company, which has the core knowledge about the product. Borregaard and Danisco are examples of companies which have moved into new markets of bioeconomy from their original competence bases in the forest industry and food industry respectively.

The forerunner cases provide a few examples of companies that have built holistic concepts with the help of technology or competence that they have acquired from elsewhere. For example Sybimar combines novel process modules with fish farming in the core and Valmet offers comprehensive portfolio to client industries by combining acquired technology into the overall portfolio. Chitinor acquired a production plant which enabled entering into the target market.

### Funding at crucial stages

Moving to the pilot stage in many of the forerunner cases was seen as the most crucial step. The costs for piloting often surpass the budgeted amounts, and there should be enough funding to get the process working after the pilot plant has been constructed. The forerunner case Borregaard can buffer the losses in the piloting phase with its already stabilized production lines. The forerunner case Sunpine managed to get the first show cases working with the help of small supports that were crucial in the start-up phase. Also for the technology supplier Valmet, the public funding has been very important, by reinforcing own and customer funding in the beginning of the development and for demonstration of new technologies. For Sybimar, the full production capacity in fish farms can be reached only after a few years of operation and thus funding of the investments at early stage is crucial. Also many ideas do not work, but finding the ones that do work requires many trials and failures. For example Chitinor can take the risks of developing new methods due to the public R&D support system.

### How the innovations have reached the market

Market access was discussed already earlier from business ecosystem perspective. From innovation point of view the drivers behind successful market entry can be various. In the forerunner cases studied, drivers of market access differed a lot. For Sunpine incitement from society and tax redemptions on green diesel were the key issues. Chitinor first started with a backup chemical and then moved forward to more challenging products. Innventia´s lignin recovery innovation was commercialized after it was acquired by Metso. Pink Iceland launched its innovative service concept backed by an entrepreneurship competition. To conclude, market entry strategies can be very different and case specific, but approaching the market entry as early as possible can guide the innovation towards most potential market applications.

### Focus of future innovation

The focus of future innovation is business ecosystem and case specific issue, but some general remarks can also be made.

The Nordic countries have a brand of being pure, close to nature, and knowledge intensive. For the bioeconomy, these are essential attributes, and as country marketing already is focused on these, it is easy to build upon and enhance the branding even further. High value added products from Nordic bioresources could increasingly benefit from this synergy. Innovation in the future could also focus on better utilizing this asset in marketing and branding of bio-based products.

In the interviews with the forerunner companies the following areas of future innovation were highlighted: resource and energy efficiency, utilization concepts of novel biomass resources such as algae, applying and tailoring existing bio-based intermediates and products into novel markets, upgrading of intermediate products and development of novel service concepts. One specific example of future innovation potential is residues from forest industry and agriculture including lignin, which contains a great potential as a source for replacing petrochemical aromatics.

# OBSTACLES AND SUPPORT

## OBSTACLES

Several obstacles related to innovation in the Nordic bioeconomy can be identified. Many of the obstacles are related to the nature and specific features of emerging bioeconomy. Lack of capital and funding is a key challenge in the emerging bioeconomy, since the investments have a long life cycle and are capital intensive and at the same time the emerging bioeconomy sector is not familiar to investors and even to potential customers. Thus also first industrial scale plants are challenging to establish.

In addition, unstable operating environment is largely due to the changing regulation related to some of the biggest drivers of bioeconomy such as carbon prices and to unclear markets prospects related to the use of fossil resources. Also cross-cutting nature of bioeconomy would require, if not a breakdown of traditional sector borders, at least a more active communication and cooperation between the sectors. The properties of bio-based raw materials (e.g. typically low energy density and high moisture content, heterogeneity of the raw materials, varied availability) set certain limits to operations.

Market access is crucial especially in the Nordic countries, since the home markets are relatively small, whereas global markets are growing. Lack of actors in ecosystems is also a Nordic challenge; the number of actors and investors is relatively small compared to many other markets such as the US.

Some of the obstacles are common to several other sectors besides bioeconomy, e.g. difficulties in commercialization and too little experience in open innovation among multiple parties. However, also these aspects are crucial in development of bioeconomy and should not be overlooked.

Many of the obstacles identified below require funding and investment support as well as regulative changes. However, to overcome many of the obstacles means such as providing up-to-date information and platforms for interaction may prove to be very beneficial. Branding of bioeconomy and bringing the companies, researchers, financiers and politicians together may facilitate conversation and thus improve cooperation between R&D actors and markets, funding possibilities and creation of more suitable regulation for promoting advanced, value added bioeconomy sectors. Recognizing the possibilities of emerging bioeconomy, communicating them and thus a possible change in attitudes is a key to overcome at least some of the obstacles.

Following are descriptions of the most evident identified obstacles. They have been divided according to the enablers and assets needed for the innovation in bioeconomy: Financial capital, Markets, Smart policy, Ecosystem, Intellectual property, Infrastructure, Human capital and Natural capital. More on these enablers and assets as a part of the bioeconomy innovation model can be found later in Chapter 6.

## Financial capital

### Remarkable need of capital and lack of financing

Production of bio-based products is often based on remarkable capital investments for production. Large companies with existing cash flows and healthy balance sheet are likely to be able to finance the needed investments, this can be seen for example in the energy industries investments on bioenergy, but SMEs are struggling with the financing. Compared to, for example, other typical growth industries, such as IT, bioeconomy related businesses are resource and investment intensive. There are too few financiers focused or interested on bioeconomy. Lack of financing exists partly because **bioeconomy as a sector is not familiar to the financiers**. Bioeconomy is either considered a totally new sector with no track record, which increases the risk level associated to it, or bioeconomy may be seen as the same old forest or other traditional industry, and thus as not attractive to financiers. The truth lies somewhere in between, new innovations are built on strong, almost centuries old competence of utilization of bio-based raw materials.

## Markets

### Difficulties in commercialization

Many bio-based innovations have difficulties in commercialization. Research organizations focus on research, and do not actively take existing ideas and develop them further. In addition, **innovations are often technology driven, instead of being market driven**. When the innovations are not developed together with the end customer, or at least with the market needs in mind, markets and customers are difficult to find. Other obstacle for commercialization is **the lack of piloting and demonstration possibilities.** Potential innovations need to be tested, not only in laboratory scale but also in larger scale before full commercialization. Especially SMEs and research organizations lack the resources for this demonstration in a scale that would allow testing in industrial scale.

### Access to markets and limited market knowledge

The Nordic market is relatively small and Nordic companies should seek global markets, especially related to new high added value products such as advanced biomaterials and biochemicals. However, especially among SMEs, market knowledge is limited. Many companies also lack the resources for increasing market knowledge, and establishing market channels and export is challenging for SMEs. The lacking abilities for making business plans also complicates the attraction of investors.

### Unclear market outlook

The development of the markets for bio-based products and services is partly unclear, although several drivers point to increasing growth of the market, such as climate change and resource depletion. At the same time drivers against bioeconomy such as shale gas findings and decreasing oil prices are also emerging.

**Lead-markets do not exist**

Besides for biofuels, no lead-markets exist for bio-based products in the Nordic countries. Public procurement could create demand for bio based products, but as for now, this does not exist[48].

## SMART POLICY

Regulatory measures are a strong driver on the market of some bio-based products (such as EU targets on renewable energy in transportation). They can be unpredictable, and not all innovators and companies have enough resources to understand and take advantage of the changes in the regulatory environment. Also, the regulation might be developed by politicians with lacking understanding of bioeconomy. Currently, the regulation gives incentives to biofuel production. However, production of biochemicals, advanced biomaterials or other high value added products is not encouraged. Thus, due to the regulation, the raw material is being used for lower added value production (energy) and the production of higher added value products is hard to make profitable.

**Long and slow regulatory procedures, innovations are not recognized by existing laws**

In many cases it takes several years to obtain the necessary regulatory approvals to set up a new production plant. The legislation is very complex, and often the authorities are not experienced with bioeconomy related projects. Furthermore, new innovations are not recognized by existing regulation. This requires a dialogue with regulators, aiming to adaptation of the regulation to new ways of operating.

## BUSINESS ECOSYSTEM

**Lack of actors in the value chains and ecosystems**

Lack of crucial actors in the emerging bioeconomy value chains and ecosystems might be an obstacle.  More key actors might be needed, so that ecosystems can develop, even in to industrial symbioses.

**Crosscutting nature of bioeconomy innovations**

Many of the innovations and value chains of bioeconomy are crosscutting and thus involve new type of cooperation with different actors and combining different disciplines. In existing structures it is not often easy to cross the existing borders thus discouraging the development of bioeconomy. Systemic innovation would require collaboration among different disciplines, public and private actors and companies of different sizes.

## INTELLECTUAL PROPERTY

**Lack of references and track record**

In many emerging areas of bioeconomy there is a lack of references and track record. Bioeconomy investments are often based on innovations and emerging technologies without proven track record or references. This raises the question of risk management and risk sharing. This is likely to affect (negatively) to the ability to get financing to the investments as well as customer's willingness to adapt new technologies and products. This is valid, not

[48] E.g. in the US, BioPreferred-program guides public procurement towards bio-based products.

only for private companies as investors and customers, but also for public bodies through public procurement.

**Too little experience of open innovation and cooperation**

Many companies see other companies in the value chains and business ecosystems as competitors rather than valuable partners. This is a problem in the case where close cooperation, trust, and industrial symbiosis are needed for innovation and growth.

**Unclear and diversified beneficiaries in business ecosystems**

In the emerging bioeconomy value chains where, for example, the waste stream of one actor is a raw material of another actor, the beneficiaries of new value chains might be nonconventional, and environment being one of the main beneficiaries. This is not always considered when decisions are made by the individual actors. As well, often the long term benefits of bioeconomy innovations are not fully considered.

### INFRASTRUCTURE

**Infrastructure does not support new innovations**

Existing industrial and other infrastructure in the Nordic countries can be partly transferred to the use of the emerging bioeconomy, but not all structures are flexible enough to support the innovations. In addition to the fixed industrial structures in many related industries (forestry and agriculture, food industry, forest industry, construction industry), other societal and economic aspects, such as land use planning, might be limiting factors to the development of bioeconomy.  For the old and conventional industry, it might be hard to renew itself.

### NATURAL CAPITAL

**Questionable access to raw materials**

Questions related to the raw materials of bio-based products and services might be difficult. The storage (production not continuous during the year) and transportation (often large volumes) needs need to be considered. Cost-effective transportation distance is often limited, and the availability of the raw material depends on the competitive uses, and the ability to pay on the raw material might vary remarkably between different end users.

## SUPPORT MEASURES

The support needed to enable the development of bioeconomy related innovation and its commercial applications is dependent on several factors: The available raw material, the traditionally strong sectors with good competence and cutting edge innovation, the growth potential of the sectors, the existing industrial infrastructure, the size and maturity of existing companies, the size of the domestic and international markets, and finally the existing knowledge and R&D infrastructure. These differ between the Nordic countries. The support which is provided needs to take into account the specific needs and conditions in each country.

In the following, RDI focused public support (R&D funding, facilitation of research cooperation, piloting and demonstration, and new business development) is described in more detail by country. In general, all Nordic countries have a good track record in being successful in innovation support in international comparison.

### DENMARK

The main stakeholders supporting innovation nationally and for important sectors of the bioeconomy are Denmark’s Innovation Foundation and publicly funded technological institutes

(GTS). An important tool for promoting commercialization of innovations is the Innovation Denmark program.

**Denmark's Innovation Foundation** - the foundation for strategic research, advanced technology and innovation[49] - is a key player in the Danish innovation system and has an annual budget of approx. 1.5 billion DKK. The foundation is responsible for implementing grants for research, technology development and innovation, based on societal and commercial challenges and needs.

Sector specific financing for bioeconomy sectors is provided by:

- Research programs under the Danish Energy Authority[50]
- Grants from the Danish Ministry of Climate and Energy[51]
- Green development and demonstration projects (GUDP)
- Grants from the Danish Environmental Protection Agency
- Grants from Markedsmodningsfonden[52]
- Grants from Grøn Omstillingsfond[53]
- Grants from Højteknologifonden[54]
- Grants from EU-funds and Nordic Innovation a.o.

**GTS institutes** are important stakeholders in the Danish innovation support system. These are approved technological institutions, which contribute with technological development and demonstration activities for companies. Some examples of bioeconomy related GTS institutes are:

- AgroTech specializes in providing cutting-edge knowledge of research and solutions for the food and non-food industry, nurseries and suppliers to the agricultural industry. AgroTech has many activities within in bio-resources (biomass and bio-materials), environmental technologies and services for bio-energy production.
- The Danish Technological Institute specializes in improving the ability of small and medium-sized companies to exploit new technologies and management tools with interdisciplinary approach to innovation. Services span wood, food production, biochemistry and chemicals sectors as well as energy production.
- FORCE Technology specializes in product and concept development, design, production optimization and operation and maintenance of industrial plants in the fields

49 http://fivu.dk/en/research-and-innovation/councils-and-commissions/revision-of-the-danish-research-and-innovation-system

50 EUDP,

51 Ecoinnovation

52 Markedsmodningsfonden

53 Grøn Omstillingsfond

54 Højteknologifonden

of e.g. Energy, climate and environment, maritime technology especially concerning inspection, testing, calibration, verification and certification.

**The Innovation Denmark program** is one of the most important tools of the Danish Council of Technology and Innovation for promoting commercialization of innovations. The program includes the following services and offerings, which aim to promote innovation and commercialization of innovations, especially in SMEs:

- Innovation consortia, where at least two companies collaborate with research institutions, can receive public funding for the consulting.
- Innovation vouchers give access for SMEs to buy consulting services from a knowledge institution (for instance a GTS institute) for a concrete development project.
- Innovative collaboration projects between businesses and public knowledge institutions that are unable to obtain other funding can be funded if the innovation projects benefit entire industries.
- New forms of research-business collaboration projects where large and small national and international innovation and research projects are operated in collaboration between academic and research institutions and enterprises
- Knowledge Pilot grants access to subsidized highly educated labor for SMEs.
- Innovation Agents promotes knowledge transfer to small businesses. Businesses with up to 250 employees can have a free innovation check carried out by an Innovation Agent from a GTS institute. At the same time the company gets support for applying for the above listed services.

**The Innovation Network Program** includes 22 competence and innovation networks (cluster organizations). Each network has pools for innovation projects where companies and researchers work together to solve concrete challenges. They also carry out idea generation processes and matchmaking activities.

**Innovation Incubators** support startup companies in different ways. There are six regional innovation incubators. They provide professional counselling, pre-seed and seed capital for entrepreneurs and new innovative enterprises. The innovation incubators operate at the earliest stage of the investment chain, where venture capitalists and other private investors are reluctant to engage.[55]

**Green policy** has been a major driver for innovation in Denmark. Some important drivers of innovation has been the green policy in Denmark. Many regulatory measures and laws have pushed innovation, such as the goals which were set in the Energy plan (from 2012)[56], the

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[55] http://fivu.dk/en/research-and-innovation/cooperation-between-research-and-innovation/commercialisation-and-entrepreneurship/the-innovation-incubator-scheme

[56] http://www.kebmin.dk/sites/kebmin.dk/files/klima-energi-bygningspolitik/dansk-klima-energi-bygningspolitik/energiaftale/Faktaark%201%20-%20energiaftalen%20kort%20fortalt%20final.pdf

Green Growth plan[57], The Aquatic Environmental Action Plans (I, II, III and IV), The Pesticide Action Plans, Water Plans etc. Also EU-directives within the environment etc. are key drivers.

## FINLAND

In Finland, the main public supporter for RDI focused activities is Tekes - The Finnish Funding Agency for Technology and Innovation. In addition, the Finnish Innovation Fund Sitra and the Academy of Finland are supporting RDI in bioeconomy.

**Tekes - The Finnish Funding Agency for Technology and Innovation** funds RDI activities in companies, research organizations, and universities. Tekes is a remarkable supporter of the bioeconomy related RDI, and has three focus areas that fit well with bioeconomy: 1) Natural resources and a sustainable economy, 2) Intelligent living environment, and 3) Vitality of people. Main activities related to bioeconomy include Green Growth Program providing funding and other support for companies to generate innovations enabling significant leaps in energy and material efficiency and to create foundation for the development of new value networks based on green growth. In addition, several other Tekes programs are supporting bioeconomy, such as BioIT which helps small and medium enterprises in the bio sector to develop their business activities and to bring players in the bio sector and ICT together, and programs related to innovative cities, functional materials, growth from renewables, and smart procurement. In the recent years, Tekes has increased its focus on SMEs.

**Sitra – The Finnish Innovation Fund** initiates public discussion and funds the development of new business concepts and systemic changes, focusing more on concept development and less on research. Regarding bioeconomy focus is on resource efficiency, industrial symbiosis, and green growth. Sitra has been successfully initiating the cooperation of companies in this field.

**Academy of Finland** funds high quality scientific research. Main activities include Centers of Excellence and Programs. So far bioeconomy as such has not been a focus area in the funding, although Academy of Finland has been active in funding scientific research in many of the relevant sectors of the bioeconomy.

**Finnish Bioeconomy Cluster FIBIC Ltd** is one of the Strategic Centers for science, technology and innovation (SHOK) in Finland, and focuses on initiating bioeconomy related research. Fibic is a link between research and companies and turns science and technology into sustainable bio-based solutions, and is partly financed by public research funders, partly by companies. Focus of FIBIC is on biochemicals, biomaterials, and technologies.

In addition, SHOKs on the fields of energy and the environment CLEEN Ltd, metal products and mechanical engineering FIMECC Ltd, built environment innovations RYM Ltd, and health and wellbeing SalWe Ltd are operating in the area of bioeconomy thus supporting RDI on the field.

The main research institutes for bioeconomy in Finland are:

- Finnish Forest Research Institute Metla is an independent research organization under the Ministry of Agriculture and Forestry. The focus is on forest biomass.

57 Growth plan for water, bio- and environmental solutions

- MTT Agrifood Research Finland is leading research institute developing sustainability and competitiveness of the food system.
- Technical Research Centre of Finland VTT is an applied research organization providing technology solutions and innovation services to companies. Its focus is on food, bioenergy and biofuels, bio-chemicals, and biomaterials as well as bioeconomy-related technologies.

By steering policies on entrepreneurship, innovation, energy, regional development, natural resources, agriculture and sustainable development Ministries of Employment and Economy, Agriculture and Forestry, as well as Environment are in a crucial position on impacting the development and growth of bioeconomy in Finland. Innovation support measures include aim to focus larger share of public procurement on cleantech, and to provide national funding for projects and investments which can be seen as piloting or demonstrating new technologies or otherwise supporting policy targets. The upcoming bioeconomy strategy is likely to introduce further support measures.

### ICELAND

The main national institutions supporting innovation in bioeconomy are the Icelandic Centre for Research and Innovation Center Iceland. An important project focused on the ocean cluster is the Icelandic Ocean Cluster, which aims to support ocean related research, innovation and business development. An important financing entity is the state owned New Business Venture Fund (NSA Ventures).

**RANNIS - Icelandic Centre for Research** administers the main public competitive funds and strategic research programs in Iceland. That includes the two principal funding instruments for research and technical development, the Icelandic Research Fund and the Technology Development Fund. The role of the Technology Development Fund is to support research and development activities, which aim towards innovation in industry.[58] The funding can be 1 – 50 million ISK per project.[59]

Rannis also coordinates and promotes Icelandic participation in international cooperation in the field of research and innovation. It coordinates Iceland's participation in Horizon 2020, the EU framework program for research and innovation.

**Innovation Center Iceland** is a leading R&D and business support institute in Iceland. The goal of the center is to increase innovation, productivity and competitiveness of Icelandic business by doing innovative technology research, diffusing knowledge and giving support to entrepreneurs and start-up companies.

The activities of Innovation Center Iceland are divided into two domains: technology research and consulting, and innovation and entrepreneur services. The research and consulting sector includes applied research and testing, basic research in key areas, consultation and technology transfer. The innovation and entrepreneur services include the **IMPRA innovation center**. It assists entrepreneurs in the start-up, growth phase and management of SMEs. It operates an Incubator Center, which offers support and facilities to start-up companies working on innovative business ideas. It also runs an Enterprise Europe Network office

[58] http://www.rannis.is/rannisenglish/

[59]Interview, Vihjalmur Arnason, Icelandic Ocean Cluster

(EEN) to encourage co-operation between Icelandic and European companies.[60] The maximum funding provided by Innovation Center Iceland for development projects is 1 million ISK.

**New Business Venture Fund (NSA Ventures)** provides financing for interesting innovative start-up companies in different fields including bioeconomy sectors.[61] It is the main venture capital investor in Iceland and provides seed funding. The New Business Venture Fund is an independent entity owned by the Icelandic state. The earnings are used for further development, investment in innovative and pioneering firms holding promise and research into their operating environment. Lack of seed funding is generally a problem in Iceland.[62]

Buying shares in innovative companies is subject to a reduced tax. This is one way to promote commercialization of innovations. This support measure has existed for a few years and has seemed to be effective.[63]

**The Icelandic Ocean Cluster (I.O.C) provides innovation support for the ocean cluster.**[64] The Icelandic Ocean Cluster, which is a company financed by member companies, has been created to support cluster development.[65] It does not provide financing for companies or for research, but instead concentrates on market development and innovation support in all ocean related sectors: tourism, shipping, aquaculture, production of ocean related added value products. These can be for instance advanced fish derived biochemical, food supplements or cosmetics. The Icelandic Ocean Cluster promotes knowledge transfer and networking.[66] It has recently mapped the ocean cluster and quantified its economic impact in Iceland.

One of Iceland Ocean Cluster's projects is an international action research program with the objective of increasing utilization of fish in the North Atlantic Ocean. The focus is especially on by-products, parts of the fish not typically considered for production purposes. The Iceland Ocean Cluster conducts research on fish utilization in the North Atlantic and develops co-operation between different stakeholders locally and internationally by offering networking opportunities.[67][68]

About 20 companies in the ocean cluster are located in the Ocean Cluster House, in Reykjavik. There is an innovation center run by Innovation Center Iceland located in the Ocean Cluster House.[69] [70][71]

**Other types of support**

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61 http://www.nsaventures.is/About/

[62] http://www.nsa.is/

[63] Interview, Vihjalmur Arnason, Icelandic Ocean Cluster

[64] The most important sectors are aluminum production, fishing and aquaculture and tourism.

[65] http://www.sjavarklasinn.is/en

[66] Interview, Vilhjalmur Jens Arnason, Icelandic Ocean Cluster

[67] Institutions and firms from Canada, Greenland and Iceland are already engaged in this project.

[68] http://www.sjavarklasinn.is/en/fullnyting/

[69] In cooperation with Eimskip, Icelandair Cargo, Brim, Mannvit and Innovation Center Iceland.

[70] Institutions and firms from Canada, Greenland and Iceland are already engaged in this project.

[71] http://www.sjavarklasinn.is/en/fullnyting/

An Innovation Congress is organized annually by the Icelandic Centre for Research (Rannis), Promote Iceland, Innovation Centre Iceland and the New Business Venture Fund. The topic is related to research, development and marketing issues. The goal is to increase understanding of the interplay between science, technology and knowledge and product production and marketing.

## Norway

The main national institutions, which support innovation in bioeconomy are the Norwegian Research Council and Innovation Norway. These are national organizations, which focus on all sectors of importance for the Norwegian economy and employment, including important sectors of the bioeconomy. Private research institutes also play a large role in Norwegian support system.

**The Norwegian Research Council** provides key research-policy input to the Government and is the chief allocating agency for research funding in Norway. It is the primary governmental funding agency for research and provides research funds for universities, institutes and companies. The activities and strategic efforts of the Research Council are based primarily on the guidelines and principles established for Norwegian and EU research policy. The time span of planning is about 10 years. The budget of the research council is about 7.7 billion NOK.[72]

**Innovation Norway** is the main governmental agency for industry development nationally and regionally. The focus is on market development lower in the innovation chain. Innovation Norway focuses on bioeconomy sectors important for the Norwegian economy such as the ocean sector and forestry.

Innovation Norway provides support for innovation, helps with setting up start-up companies, supports export efforts of companies by establishing contact networks and by providing market knowledge etc. The agency helps companies with exports and market related activities. Some key areas where Innovation Norway is active are providing networking opportunities, informing companies of new technologies, which could be applied to old processes, educating investors to understand new innovative sectors and business areas, and in general facilitating knowledge transfer between companies and researchers. There are for instance efforts to facilitate knowledge transfer across sectors (for instance between marine sector and agricultural sector on intelligent usage of wastes of biological origin). The agency has representation in most regions in Norway and in 30 countries and has 750 employees in total.

Linked to Innovation Norway is also industrial cluster co-operation. Certain programs exist which seem to work well. There are also centers of excellence linked to research- research driven innovation. These two tools are ways to promote and support innovation.[73]

**Industrial Biotech Norway** is a networking promotion organization in the bioeconomy field – a type of innovation network. The focus areas are forestry, fishing and aquaculture and to some extent advanced applications in the food sector and agriculture. Industrial Biotech promotes knowledge transfer between sectors and between researchers, companies and investors. Tries to teach investors about opportunities in the bioeconomy sectors and that risk is

72 http://www.forskningsradet.no/en/Policy_and_strategy/1138785831474

[73] Interview, Rolf Wolff, Sintef

manageable. One ambition is also to make traditional industries use new technology. One project of Industrial Biotech has been establishing a Marine cluster in the North of Norway.

Particular for the Norwegian innovation system is that there are many **private research institutes**. The research institutes mainly focus on contract research for companies. The main goal is applying research results to industrial applications. The background for why such a large part of company and industrial application related research is done in co-operation with research institutes is, that there are few large industrial companies with in-house R&D departments. Thus, applied research is in many cases outsourced to private institutes. This seems to be fairly unique in the innovation landscape of the Nordic countries.[74]

The main private research institutes relevant for the bioeconomy are:

- SINTEF, with research on all important bioeconomy sectors. It is the largest research foundation with 2000 employees. It is a non-profit foundation.
- Paper and fiber institute (PFI) focuses on paper an fiber products and advanced wood based products
- International Research Foundation of Stavanger (IRIS) is an independent research institute with research and research-related activities in petroleum, new energy, marine environment, biotechnology, social science and business development.
- Norwegian Institute for Agricultural and Environmental Research (Bioforsk) is a national R&D institute under the Norwegian Ministry of Agriculture and Food, with about 500 employees.
- The Norwegian Seafood Research Fund (FHF) is the Norwegian seafood industry's tool in managing the industry's investments into industry-based R&D. The objective is to create added value for the seafood industry. FHF and some other fishing and aquaculture research and development is financed by the industry itself through a tax on exports of all seafood (currently 0,3%).

## SWEDEN

Swedish R&D is characterized by strong dominance of large firms in the business sector and relatively high rates of growth within the service sector.[75] One historic reason behind the Swedish success in commercializing innovation has been cooperation and collaboration regarding public procurement, which has driven demand and supported innovation. The Swedish innovation system is also characterized by a high number of public and private funds that finance R&D on the national, regional and sector level.[76] The main agency promoting commercialization of innovations is VINNOVA.

**Swedish Governmental Agency for Innovation Systems (VINNOVA)** is Sweden's innovation agency. Vinnova's goal is to promote sustainable growth by improving the conditions for innovations, as well as funding needs-driven research. Vinnova focuses on innovations linked to research and development. The focus lies in some chosen key area: information and communication technology (ICT), biotechnology, working life, materials, transportation and bringing products to production. Vinnova has no specific program for bioeconomy development, but several programs with related themes for instance in forestry or food production

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[74] Interview, Ole Marvik, Marit Valseth, Innovation Norway

[75] http://charlesedquist.files.wordpress.com/2012/10/small-country-innovation-copy.pdf

76 No longer possible to the same extent due to globalization and procurement rules.

sectors exist. Vinnova has several different action areas to stimulate innovation and commercialization of innovations. Special focus has been set on development of SMEs.

Some examples of innovation support measures are listed below[77]. They are not bioeconomy specific:

- SME development is promoted through programs like Forska&Väx (Research&Grow) and VINN NU. VINNOVA stimulates small and medium-sized enterprises to actively invest in international development partnerships, through programs such as Eurostars and Eureka.
- VINN Excellence Centers provide a forum for collaboration between the private and public sectors, universities and colleges, research institutes and other organizations that conduct research.
- Berzelii Centres focus on excellent basic research. They aim to collaborate actively with stakeholders from the private and public centers and to put research results to concrete use in the form of commercial applications.
- VINNVÄXT is a program that takes the form of a competition for regions. The aim is to promote sustainable growth by developing internationally competitive research and innovation environments in specific growth fields.
- A recently development has been to start with strategic innovation sectors. Five have been chosen through a bottom-up approach where the stakeholders who wish to co-operate suggest a theme, which needs to be in line with the national strategies. [78]

Vinnova is also a national contact for EU 2020 and other framework programs and supports with applications for EU funding. Vinnova manages funds of 2 billion SEK and has 200 employees.

In addition, **Swedish financing support** involves a very high number of different sources of finance. The public sector finances R&D through grants paid directly to higher education institutions (HEIs), which receive the largest part of the funds, and through support for research councils and sectorial research agencies. The Swedish Research Council (Vetenskapsrådet) finances basic research in Universities and projects for about 5 billion SEK in chosen focus areas.[79]

Sectorial research agencies fund R&D aimed both at meeting the knowledge needs of individual sectors and at fostering the development of society. In all, Sweden has some 20 sectorial research agencies with resources for R&D. Jointly with regional R&D units, municipalities and county councils allocate about SEK 2.7 billion to research and development. In addition, several publicly funded research foundations provide research funding in excess of SEK 1 billion annually.

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[77] http://www.vinnova.se/en/Our-acitivities/Innovativeness-of-specific-target-groups/Individuals-and-Innovation-Milieus/

[78] Strengthening cluster based development support was one suggestion in the OECD Review of Swedish innovation policy from 2013. These are similar to Finnish SHOCKs.

79 http://www.vr.se/inenglish/researchfunding.4.12fff4451215cbd83e4800021418.html

In addition to public sources of funding described above, Sweden has many private funding sources (foundations). Many provide substantial grants for research in their respective fields. These private non-profit organizations contribute SEK 2.3 billion to Swedish research.[80]

Some examples agencies having a role in the innovation system in Sweden[81]:

- The Knowledge Foundation (KK-stiftelsen) aims to stimulate competitiveness by creating conditions for innovation and creativity, and by strengthening the links between academia and industry.
- The Swedish Foundation for Strategic Research (SSF) is an independent organization that supports research in the natural sciences, engineering and medicine.
- The Swedish Agency for Economic and Regional Growth (Tillväxtverket) is a government body that aims to foster greater enterprise growth and sustainable, competitive business and industry throughout Sweden and focuses especially on regional development in chosen sectors. These involve close co-operation with local companies and industries.
- The Swedish Energy Agency (STEM) provides funding especially for energy related research in sustainability related sectors.
- The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) finances especially projects in the sustainability field.

## HOW THE CURRENT SUPPORT MEASURES TACKLE THE OBSTACLES

A wide variety of support measures promote the development and growth of bioeconomy in the Nordic countries, directly and indirectly. Although the main focus of this study is on innovation, not only innovation oriented support is valid for understanding the drivers for innovation and growth on bioeconomy. At least the following forms of support are highly relevant to tackle the obstacles of innovation and growth in bioeconomy:

- **R&D funding.** Most countries provide financial support for most phases of the innovation process: support for basic R&D and for some applied research in chosen sectors as well as support for the more market oriented activities (start-up financing and other market related support). The way, in which this support is organized, differs and depends on partly historical factors as well as the structure of industry and what type of focus for the activities has been chosen. Support for bioeconomy related projects exists if the sectors are nationally important or if bioeconomy related development programs have been established to promote sectors deemed to have good potential in the future. In all countries, a remarkable share of both public and private R&D funding is currently focusing on bioeconomy, either directly or indirectly. Public R&D has been used to stimulate companies to increase their innovation activities in the field, and to stimulate R&D organizations to focus research activities on bioeconomy. Traditionally, this has been seen as the most influential support for innovation.

80 http://www.vr.se/inenglish.4.12fff4451215cbd83e4800015152.html

81 http://sweden.se/business/innovation-in-sweden/

- **Facilitation of cooperation.** Due to crosscutting nature of bioeconomy, cooperation is crucial for totally new innovations on bioeconomy. R&D funding and organizational structures are slowly reflecting this increasing need, and thus, aiming at bringing together different actors, industries, and disciplines in larger scale. In addition, all Nordic countries have some type of network of innovation centers and start-up incubators, which are run by different types of governmental establishments. However the available resources and practical applications of the support as well as specific projects differ between the countries. Networking, which has developed for some sectors, can be helpful in connecting different types of companies and stakeholders. Networking has in some cases facilitated transfer of customer requirements to researchers and information on technological innovations from research to companies. Cross-sector co-operation can raise awareness of solutions with applications other sectors.
- **Piloting and demonstration.** Piloting and demonstration is highly relevant for the implementation of new innovations in bioeconomy. An infrastructure for R&D actors for small scale piloting supports the R&D work. For real scale pilot and reference plants, often remarkable investments are needed (from 10 to 100 million euros upward). This is often the bottleneck of the introduction of new bioeconomy innovations to the market, and support for these types of projects is needed. Cross-border co-operation and some governmental support may be required to set up these plants. Help is for instance available for seeking EU support for bioenergy production demonstration projects (in Sweden).
- **New business development and growth**. As bioeconomy opens up new concepts, business models, and value chains, it opens up possibilities for new business development as well. The new business development can be done by existing companies, but often new companies are needed to fulfill the gaps in the new value chains. As well, the value creation and earning models might differ remarkable from the traditional earning models. Thus the support for new business development is seen relevant for bioeconomy. A general weakness in the provided support is the lack of funding for especially smaller ventures wanting to commercialize operations. In Iceland there is a lack of seed funding, but in other countries the lack of funding is especially related to sk. “competent money” - investment funds provided by investors. The support provided by the governmental institutions has not been able to remove the obstacles to financing, which especially SMEs experience. Additional focus seems to be needed on helping to connect venture capitalists to potential companies in the bioeconomy sector and to hone the skills of the fledgling companies for making business plans and to market the concepts to venture capital providers. It is essential to be able to show the commercial potential of bioeconomy related concepts in the commercialization stage.
- **Demand-driven support.** The market of bio-based products and services is partly created by regulatory measures. This is especially clear in the case of bioenergy and biofuels. EU has introduced several financial and legislative measures to support the growth of demand on this area. The mandatory targets in EU for the share of renewables in energy production and transportation have been a strong driver for introduction of new technologies and products in biofuels. As well, for example the Emission Trading Scheme aimed at increasing the demand for cleaner products and technologies, however, due to low price of emission permits its impact hasn’t been too strong. In addition, the customer behavior might encourage innovation for example in the food industry. So far there are few regulatory or legal incentives to support and develop the market for bio-based products. An under used way to support bioeconomy development has been public procurement of innovative products and services. Few

requirements exist for considering bio based products in public procurement, which could enable establishment of lead markets and provide references for especially SMEs looking for growth opportunities.

- **Raw material availability.** Growth of bioeconomy is highly based on the availability and price of raw material as this often is a crucial factor in the competitiveness of bio-based value chains compared to the competing, often oil-based value chains. Agricultural, marine, and forestry policies as well as waste legislation have an impact on raw material availability and price. However, their real impact on innovation might be difficult to assess.
- **Growing competence.** Competence is often seen as a prerequisite for innovations in bioeconomy as both companies and RDI actors need competent people. Thus universities and other education institutions have a role in ensuring that the competence of the workforce supports innovation in bioeconomy.

In order for the support measures to better tackle the obstacles identified, some areas for further development include networking and developing a common understanding of the roles of different stakeholders, making processes for seeking support and financing easier for SMEs, promoting demand by including criteria for bio-based materials in public procurement as well as promoting cross-sector transfer of existing or new applications for existing processes in already established sectors. In addition, venture capitalists should be included in the networks to ensure they are better able to recognize the potential of commercially viable bioeconomy concepts. Lastly, it can be discussed whether the support provided for R&D and other activities in the innovation process provides the necessary focus to find solutions based on customer needs. More focus may be needed to link the support to finding commercially viable applications with the markets and customers.

# CONCLUSIONS AND RECOMMENDATIONS

The total volume of the key sectors of bioeconomy in the Nordic countries is currently 184 000 M€ presenting 10 % of the total economy in the Nordic countries[82]. Bioeconomy includes very diverse sectors. Agriculture, fisheries, aquaculture, and forestry are a crucial part of bioeconomy. Food, forest, bioenergy, biofuels, chemicals, and plastics industries process bio-based raw materials into intermediate and end products to serve various client industries and consumers. The technology sector manufactures machinery and other technological solutions and associated services which are needed in bio-based value chains. Water and waste management are closely linked to bioeconomy as well. Bioeconomy-related service sector includes also recreational activities and tourism which are linked to nature.

The largest innovation and growth potential of bioeconomy seems to be in its crosscutting nature. New innovation and growth is likely to occur where companies, industries, sciences, resource flows, and actors interact and crosscut, thus opening up new opportunities to use raw materials and competences in creative ways. The following interesting crosscutting growth areas of the bioeconomy in the Nordic countries were identified: bio-based chemicals, advanced biomaterials, biofuels and bioenergy, biorefineries, resource-efficiency and industrial symbiosis, and bioeconomy related services.

[82] See Chapter 2.1 for methods of this approximation.

Both market potential evaluation and interviews indicate that of these, biofuels offer currently interesting potential for innovation and growth as they benefit from a variety of supporting policy measures and most of the current strategies and investments are focused on biofuels. From the biochemical and biomaterials point of view, the regulatory support mechanisms impact on the market even negatively. This may limit the innovation and growth on these areas. Nevertheless new business has been developed in these areas without regulatory support, which is highly encouraging and longer term growth potential is promising in advanced biomaterials and biochemicals. Interviewees mentioned especially the aromatic compounds of lignin and advanced biomaterials. As well, the service sector includes attractive growth potential, and innovation on service sector can demand fewer resources than development of technologies and products.

Bioeconomy is highly important both nationally and regionally, and provides growth opportunities which are likely to result in economic growth, jobs, and sustainable development. The Nordic countries have great assets to take advantage of the potential of bioeconomy. This is due to, at least, the extensive bio-based resources as well as strong refining and technology industries and competent and well-educated workforce. Many Nordic companies have great prerequisites to innovate and grow on the area of bioeconomy. As well, the political decision makers are seeing the potential of the bioeconomy and thus promoting it nationally, regionally, and locally.

Based on the analysis carried out within the study the key conclusions and recommendations of the study are described below. Innovation in the area of bioeconomy in the Nordic countries would benefit from the following elements, which could be emphasized in Nordic Innovation and policy development and planning of innovation programs and support mechanisms.

In general it is recommended, that all potential connections to other on-going projects in Nordic Innovation and Nordic initiatives that Nordregio, Nordforsk and Nordic Innovation currently have, are mapped out against these recommendations and developed further to utilize potential synergies.

## SYSTEMIC INNOVATION MODEL NEEDED FOR THE GROWTH OF BIOECONOMY

The development and growth of bioeconomy requires **systemic change** and innovations linking value creation across companies, sectors, and resource flows. Thus, innovation and business opportunities need to be identified across the boundaries of the traditional sectors and different sciences. The key constituents of the systemic innovation model in the Nordic bioeconomy are briefly summarized below and the framework in Figure 21.

Innovation in bioeconomy is driven by a variety of **assets** and **enablers**. The **assets** are strongly bioeconomy specific. **Human capital** and **intellectual property** are the most important intangible assets, which provide the bioeconomy related competence and required background for new innovations. Human capital includes bioeconomy competences the various actors possess in universities, research institutes, companies and public organizations. Intellectual property gives competitive edge to build on existing innovations. **Natural capital** and **infrastructure** are the most important tangible assets regarding innovation in bioeconomy. **Natural capital** consists of the value of the natural environments, ecosystems, ecosystem services and the natural resources – assets like forests, fresh water, flora and fauna. Sustainable use of natural capital and ensuring of the renewal and maintaining of this capital is a crucial question in bioeconomy. **Infrastructure** consists of assets such as current industrial production facilities (like pulp, paper, and food industries) and supporting infrastructure like logistics infrastructure and energy grid. These make it possible to further develop new innovations synergistically utilizing the current infrastructure.

**Enablers** in contrast are more generic in nature. They have bioeconomy specific elements, but serve many other sectors in addition to the bioeconomy and even conflicting interest are possible. The enablers are required to untap and develop the potential of the assets described in the previous paragraph. The most important enablers include **markets**, **financial capital**, and **smart policy**. All of these can either drive or hinder innovation, and thus development and growth in bioeconomy. **Markets** often do not distinguish whether a product is bio or fossil based: performance and price are the most important factors. Bio based products have some unique properties based on which they can generate entirely new markets. E.g. enzymes are bio-based products with no fossil alternative and have developed an entirely new global market. Also sustainability is emerging as a factor in product differentiation in the market. Bio-based lead markets have also been created by regulation e.g. in the area of biofuels. **Financial capital** is very important factor especially in capital intensive innovations in bio-based production. For the emerging bio-based chains to receive financial capital, it is important to develop business cases that are comparable to fossil based chains and can compete on funding on techno-economic means. This requires low cost feedstock with no sourcing risks (sustainability or availability), effective conversion technology and low technology risk, and ensured market offtake with reasonable and stable price level. **Smart policy** means coherent regulatory frameworks, which support sustainable utilization of assets of bioeconomy with high value addition and positive cumulative effects in the economy. Policies which affect bioeconomy affect also other sectors and systemic view on removing of the regulatory bottlenecks is required. E.g. sectorial policies in forestry, energy and agriculture need to be aligned and looked at from a broader perspective. With this approach raw material utilization can be directed towards the highest possible value addition and efficiently.

The assets and the enablers provide the main building blocks of innovation in bioeconomy. However, without **the fundamentals of the systemic innovation model**, the full potential of the innovation in bioeconomy will not be realized. **Crosscutting understanding** on resource flows and other assets, as well as enablers is a prerequisite on both business and policy level to take advantage of the systemic potential. In practice bio-based resource flows and side streams between the various sectors need to be looked at in a holistic view: if certain flows or compounds are available in many industries, new value added production may be possible to develop based on the summed feedstock potential of the various sectors. Another example may be potential of expert services: for example characterization of process waters can be applied in many sectors, but tailoring the service to sector specific needs requires crosscutting understanding. (**Piloting and) demonstration** is crucial for the market access of the innovations in bioeconomy, which is often problematic. As innovations in bioeconomy often require remarkable investments on production infrastructure it is important to minimize the technology risk related to the investment. This is done by piloting the technology in small scale and increasing the production scale step wise, making incremental innovation possible and keeping the scale up risk manageable. By piloting and demonstration also end users, markets and financiers can better understand the potential of the innovation and are encouraged into deeper cooperation and investing on the innovation development. **Linkages, networks, and interaction** among the actors are needed, as no individual company by itself can develop or implement remarkable systemic innovations. Companies can form R&D consortia and joint ventures, and universities and research organizations can provide these consortia with research services. Intellectual property or technology can also be licensed or purchased, as this is often more cost and time efficient than in-house development. For forming of these partnerships networks and linkages are needed: the actors need to have a constantly updating understanding of the best actors in their field and associated fields and sectors. Cooperation creates dynamic **business ecosystems** where new value chains are formed, synergistic assets are shared, and synergies in resource flows create successful **industrial symbiosis** where, for example, the waste of one company is a raw material for another company. All this drives for **value addition** and **sustainability**, which gives the ultimate reasoning for bioeconomy in the Nordic countries: better well-being and environment. As bio-based resources are limited, it is important that they are managed sustainably, and used for the best possible uses: with high value addition, with cascading uses and multiple benefits for the society. Thus, it can be concluded that without value addition and sustainability the innovations in bioeconomy have no value.

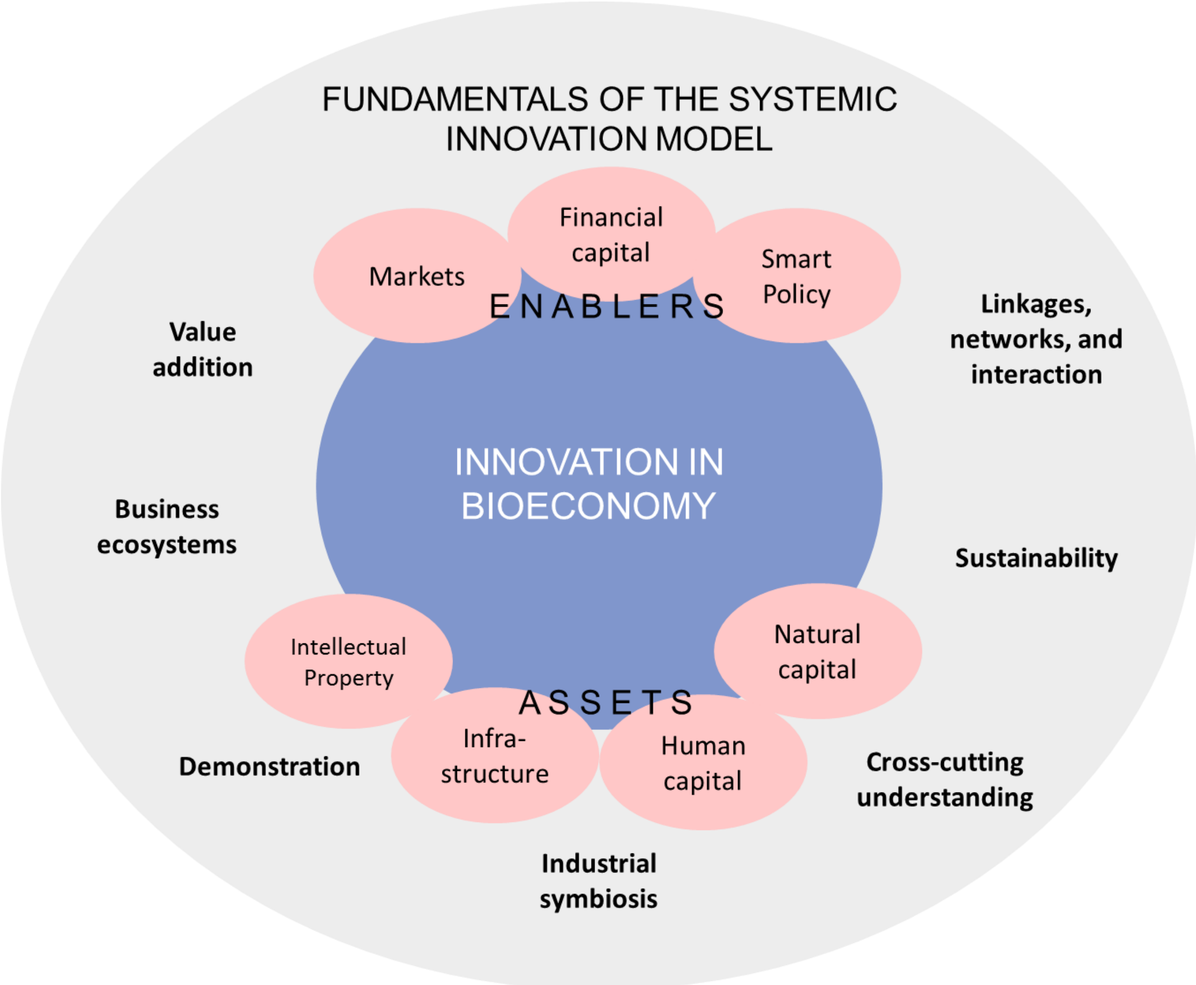


*Figure 21. Framework for innovation in bioeconomy by the systemic innovation model*

The framework is useful in assessing whether the potential innovations in bioeconomy possess the crucial elements in terms of assets, enablers and fundamentals. It can be used as a check list, or as a background material when developing new programs in the area of bioeconomy. For example the business ecosystems highlighted earlier in this study could be assessed against the framework in order to identify strong and weak points and identify priorities for further development of these areas.

In the context of bioeconomy the value added of the systemic innovation model is likely to be a lot higher than that from the traditional linear innovation model. However, more communication is needed to make sure that this approach and its potential is understood.

***Recommendations***

- *To better support systemic innovation, make sure that the Nordic and national innovation programs and R&D funding in the area of bioeconomy increasingly target cross-sectorial, cross-company, cross-science, and cross-nation cooperation.*
- *Communicate the fundamentals, assets, and enablers of innovation in bioeconomy together with growth potential of bioeconomy actively among national, regional, international and business decision makers to make sure that the full potential of the innovation in bioeconomy is understood and exploited.*
- *Coordinate and link regional and national programs on bioeconomy in the Nordic countries to support common goals.*
- *Recognize that both policy focused and research focused strategies are likely to be needed to support the growth and development of bioeconomy in the Nordic countries. Policy strategies making sure that the operating environment is optimal, and research strategies identifying the RDI priorities.*
- *Utilize the developed framework for systemic innovation model in bioeconomy in assessing potential of innovations in bioeconomy. For example the highlighted business ecosystems in this study could be assessed with the framework in order to identify strong and weak points and identify priorities for further development.*

## ASSETS

### INTELLECTUAL PROPERTY

Intellectual property forms an important intangible asset on which novel bioeconomy innovations can be built. Proper IPR management ensures that commercialized innovations provide revenue to the original innovators. As R&D cycles are often time consuming and expensive in the capital intensive biomass processing industry, it is very important that IPR is managed properly. In development consortia IPR management should be addressed at an early stage to ensure smooth process as innovations occur. With proper IPR management the developed innovation is also easier to sell or license to outside partners if needed. The methods of IPR management vary: e.g. when technological and methodological innovations are being developed patents are important. On the other hand with new service concepts and more systemic innovations other means are utilized in order to secure competitive edge. Also when open innovation concepts are applied, more informal ways of ensuring mutual benefits are required and need to be developed.

***Recommendations***

- *Make sure that IPR management issues are addressed properly in all development projects of bioeconomy. One practical mean could be pre-requisite of having a proper IPR management plan in all R&D project plans when public R&D funding decisions are made.*
- *In order to support open innovation in bioeconomy, methods for ensuring mutual benefits for all participants should be developed and best practices shared.*

### HUMAN CAPITAL

Human capital or competences is a prerequisite for innovations in bioeconomy as both companies and RDI actors need competent people. Universities and other education institutions have a role in ensuring that the competence of the workforce supports innovation in bioeconomy. In emerging growth areas of bioeconomy new skills and competence mixes are needed. Good dialogue and cooperation between various universities and education institutions together with industry is required in order to ensure a good match between skills needs and graduated students.

***Recommendations***

- *Identify required competences and skills in bioeconomy innovations together with universities, education institutes and the industry. The process could be coordinated on the Nordic level.*
- *Align education programs to reflect the identified skills needs.*
- *Support researcher mobility in order to develop the cross-disciplinarity and novel competence mixes in Nordic bioeconomy.*

### Natural capital

Natural capital, i.e. the natural environment, ecosystems and ecosystem services form the tangible basis and starting point for all bioeconomy. In order to safeguard availability and quality of natural capital for next generations, ensuring the sustainability of management of natural capital is of utmost importance. This means utilization of natural resources such as land, forests and fresh water only to the extent that does not threat their renewal capacity. It should be ensured that no net loss of natural capital takes place – i.e. the resources used or ecosystems that have been disturbed are compensated. In practice this means e.g. planting new forests where wood is harvested and conserving habitats elsewhere if certain production sites affect critical habitats. It is also important to make sure that synergistic use of natural capital can take place: biomass-based production and recreational activities can co-exist without adversely impacting the various ecosystem services provided. Some value chains and business ecosystems of bioeconomy are building on natural environments which have very little human impact, like ecotourism utilizing the natural parks. On the other hand some value chains utilize cultivated land with limited value as an ecosystem, like biofuel industry utilizing the energy wood plantations. Nevertheless in all value chains minimized ecological footprint and proper sustainability assessment methods are the key.

***Recommendations***

- *Increase knowledge base and awareness of natural capital and ecosystem services as a basis of all bioeconomy.*
- *Develop and share best practices on how to better understand sustainable management of natural capital in the context of bioeconomy and in concrete value chains.*
- *Develop and share best methods to assess and ensure overall sustainability of bioeconomy, including methods to comprehensively assess sustainability-related impacts of bioeconomy and methods to valuate various different benefits of natural capital.*

### Infrastructure

Infrastructure consists of assets such as current industrial biomass refining facilities and supporting infrastructure like logistics infrastructure and energy grid. These make it possible to further develop new innovations synergistically utilizing the current infrastructure. The current infrastructure in the Nordic countries is strong and should be utilized to maximum benefits. Good examples of this approach include e.g. biochemicals production in the pulp and paper industry production sites (as in the Borregaard forerunner example described earlier) and side stream-based biofuels production next to a food industry production site (as St1

Biofuels is operating). When existing industrial infrastructure can be used, initial investments are smaller and both parties benefit from resource synergies.

***Recommendations***

- *Share information on existing industrial production sites which could be interesting locations for new innovations of bioeconomy. This could be done e.g. by a common Nordic platform combining information from the regional development organizations.*
- *In R&D projects developing process and product innovations include an element of screening possible existing industrial production sites with potential synergies when applicable.*

## ENABLERS

### FINANCIAL CAPITAL

**Matching of competent capital and innovations of bioeconomy**

Although the business and innovation potential of bioeconomy is remarkable, access to capital is often one of the main limiting factors of development. There are multiple reasons for this problem. The amount of “competent capital”, i.e. venture capital companies or business angels is limited in the Nordic countries in comparison with e.g. Northern America and Asia. Many actors in venture capital are not experienced in the area of bioeconomy and also the volume of required investments in capital intensive bioprocessing investments is limiting the amount of investors. Large companies can also provide capital to innovations in bioeconomy through corporate venturing. This approach is quite popular in Northern America and also Central Europe. The potential innovations in the Nordic countries should be better introduced to these and other possible financing partners in order to improve the current situation.

***Recommendations***

- *Market key Nordic bioeconomy initiatives jointly to the international financiers in order to achieve funding for crucial steps in the innovation development, such as demonstration plants.*
- *Launch a high-level matching event of bioeconomy in the Nordic countries.*

### SMART POLICY

**Streamlining regulatory environment with innovation targets of bioeconomy**

The regulatory environment is currently partly contradictory with innovation targets of bioeconomy. In the knowledge-intensive Nordic countries high value added knowledge intensive products and innovations of bioeconomy are sought for. On the other hand, the current regulative support for bioenergy and biofuels can make it more favorable to produce bioenergy or biofuels from the biomass instead of e.g. bio-based chemicals, where value addition is significantly higher. A more systemic approach across the different policies would make the operating environment more stable and favorable for knowledge and capital intensive production investments in various areas of bioeconomy. This could be supported by providing the regulators and policy makers with more information on bioeconomy: its importance, potential and needs.

***Recommendations***

- *Identify the most crucial contradictory regulatory incentives for innovation in bioeconomy and make recommendations on how to solve these issues. Based on this study regulatory incentives for bioenergy and biofuels can be contradictory to targets for high value addition from bioresources. Another area that could be studied is ensuring*

*that regulatory barriers do not hinder development of novel concepts for side stream utilization. These issues could be first thoroughly addressed on a Nordic level.*
- *Benchmark the regulatory and operating environment of bioeconomy in the Nordic countries against each other and some leading global examples to find out best practices and encourage development of the regulatory environment regarding innovation in bioeconomy.*

### MARKETS

**Supporting the development of a strong Nordic bioeconomy lead market**

As mentioned earlier, often large part of the global market potential is outside the Nordic countries. That being said, there exists also several market segments where Nordic demand for bio-based products could be remarkable and supported through public procurement preferences. Bioeconomy could be promoted by public procurement both on national, regional, and local level. In addition to the support for the development of Nordic lead markets of bioeconomy by public procurement the global market access can be supported by a similar approach. If the first commercial scale demos are easy to obtain in the Nordic countries, it opens doors to global markets as the concept is demonstrated in industrial scale.

***Recommendations***

- *Streamline strategies with public procurement and benchmark good practices in public procurement to support innovation in bioeconomy. Especially practical and applicable sustainability assessment methods need to be developed for various products of bioeconomy and their public procurement processes.*
- *Develop voluntary measures for supporting advanced, sustainable bio-based products. These may include voluntary agreements and ambassador programs, and establish grounds for improved future regulation.*
- *Promote Nordic success stories on the products and services on bioeconomy in the Nordic countries, EU and globally to increase market awareness.*

## FUNDAMENTALS OF THE SYSTEMIC INNOVATION

### SUSTAINABILITY

Sustainability of bioeconomy is a complex issue. Environmental sustainability involves many aspects, such as effects on climate change, land use, biodiversity, material and energy efficiency, environmental effects, waste management and effects on nutrition recycling. In addition to environmental sustainability also social sustainability needs to be assessed and ensured. In order to make sure that innovations of bioeconomy are sustainable, they should be benchmarked with competing value chains with best available methods. Sustainability is also a global issue – as value chains and indirect effects often are globally dispersed, the sustainability assessment needs to take a broad look. Some aspects of sustainability are already included in regulation, e.g. environmental impact assessment is mandatory for production plants and for biofuels national systems for biofuel sustainability have been set up in the EU countries. Nevertheless, sustainability of bioeconomy innovations needs to be assessed already in the R&D phase to make sure that developed innovations are sustainable. Applicable methods are under development, and up-to-date understanding of best methods for sustainability assessment needs to be constantly developed. In this public R&D programs and universities and research institutes can help. Sustainability should be a horizontal theme in all development efforts of bioeconomy.

***Recommendations***

- *Make sure that up-to-date knowledge on sustainability assessment methods of bioeconomy is available and developed further in R&D programs and nationally. Best practices and methods should be shared between the Nordic countries.*
- *Include sustainability as a horizontal theme in all innovation efforts of bioeconomy.*

## LINKAGES, NETWORKS AND INTERACTION

### Engage end users and whole value chain in innovation activities

In order to make the innovation truly market driven and support commercialization, which has often been the weak point in Nordic and European innovations, development of cooperation between research, companies and end users is required. The whole value chain needs to be engaged in the innovation activity, especially engaging end users at early stage is important. This leads also to increased market knowledge and market access, and help with export activities in the commercialization phase. As many innovations in bioeconomy are systemic, i.e. they target introducing completely new products, value chains or services, the development consortium must be wide enough to ensure that a holistic approach can be applied. End user engagement applies to all innovations: business innovations or societal innovations alike.

***Recommendations***

- *Launch bioeconomy innovation programs and funding instruments for the Nordic countries, which specifically target projects with early end user engagement.*
- *In addition, make sure to engage end users and partners with market access in innovation activities, and promote iterative development approach, where innovations are tested in the market in early stage, and next development stages are designed based on market feedback. This type of approach could be very easily applied e.g. to R&D targeting service innovations in the area of recreational activities and ecotourism.*

### Build on the complementary Nordic strengths and synergies

Importance of sectors of bioeconomy varies greatly between the Nordic countries. In Finland and Sweden e.g. the forest-based industries are very strong, whereas in Denmark agriculture and food sector are emphasized and in Iceland and Norway fishery is emphasized. The renewable energy resources for processing purposes are also remarkable and varying: Norway and Sweden have extensive hydropower, Iceland thermal heat, Denmark agro biomass and wind power and Finland and Sweden forest biomass. Fresh water availability is an asset as well. On top of that all countries are knowledge intensive and strong R&D competences are linked to national sectorial focus areas.

This provides a good basis for Nordic cooperation in bioeconomy, where strengths of the different countries and regions are effectively used and systemic innovations developed based on bio-based resources and their holistic management and utilization. It is important to be able to build around the strongest assets and mutually benefit from cooperation. Identifying of common Nordic areas of interest in bioeconomy innovation would support successful development of bioeconomy in all the Nordic countries and their regions.

***Recommendations***

- *Build R&D cooperation and programs on the complementary strengths and synergies of the Nordic countries. Examples of areas which based on this study are highly relevant in all Nordic countries include decentralized energy concepts, which could be tailored into local circumstances and multiplied across the Nordic countries and advanced high value addition bio-based ingredients which build on unique Nordic natural compounds. Also ecotourism service concepts could benefit from cross-national development, in order to develop wider and more diversified service portfolios.*
- *Identify common areas of interest between the industry and the research community which help streamline e.g. communication and initiatives towards European Commission on the potential and needs of the Nordic bioeconomy and to increase awareness on the potential of the Nordic bioeconomy and catalyze partnership formation.*
- *Develop joint Nordic funding applications for R&D funding programs like Horizon 2020 where bioeconomy is already highly prioritized.*
- *Don't neglect the traditional bioeconomy sectors but understand that emerging bioeconomy innovation is built on the existing actors and the business ecosystems enriched with new players and concepts.*
- *To better understand the sectorial synergies develop statistics so that in the future a better estimate of the size of bioeconomy can be made especially regarding related technologies and services, as well as emerging areas of biochemicals, and biomaterials in different uses.*

### Connect globally

As world-class competence can be maintained and developed only on focused areas, global partners are often needed in innovation to complement the strong Nordic competence areas and enable a more holistic approach in innovation. Global partners bring also credibility. Nowadays research carried out only in one country is often not enough to convince the international funding organizations. Nordic cooperation in this field could be beneficial, Nordic competences together form a very attractive partnership opportunity in the global scale in several areas of bioeconomy.

In many sectors of bioeconomy the growing markets are also situated outside the Nordic countries. In order to best utilize this potential, the reverse innovation, or utilization of innovations developed in the emerging markets can be potential. This would mean that market needs and product innovations from the emerging end use markets of bioeconomy outside the Nordic countries would be linked with Nordic innovations on how to utilize and process the Nordic biomass streams into valuable intermediate and end products. This type of approach would be beneficial especially for niche product areas like bio-based ingredients, where value addition of products is high and customer segments have very specific and focused needs.

***Recommendations***

- *Promote and support global research partnership formation by, for example, increased mobility of researchers and partnership platforms.*
- *Make sure that the strengths and competences of the Nordic bioeconomy and its actors are identified and listed so that they can be easily communicated globally.*
- *Aim at promoting stronger Nordic links to growing global markets which would require e.g. bringing together the potential actors across the value chains and facilitating global partnership formation between Nordic actors and actors in the potential target markets.*

**Better linkages and complementarity of applied and basic research**

Applied research is highly relevant for innovation bioeconomy. In addition to companies and research organizations, applied research can be carried out also in universities. The benefits of this approach include accumulation of industrial knowledge at universities and more effective research, when specific goals are set. One additional benefit of applied research is that applied research is often crossing traditional research fields and it thus develops new linkages. University researchers can also take part in company-led applied research and thus learn from other partners and sectors involved in those projects. The risk in this approach is that innovation of radical new things might be suppressed. The above may thus lead to only incremental development. Therefore, basic research is always needed for complementary benefits. The synergies between basic and applied research on bioeconomy could be exploited more effectively to make sure that systemic innovations are built and brought into market. Better linkages between basic and applied research would thus be one of the keys of bioeconomy innovation and highly beneficial for all actors.

***Recommendations***

- *Put focus on the applied research to exploit the full potential of the cumulated competence on bioeconomy in Nordic research and help bring it to market innovations.*
- *Support cross-sectorial applied research on bioeconomy in universities.*
- *Improve linkages between basic and applied research on bioeconomy e.g. by linking research programs and streamlining focus areas.*
- *As a specific content area with lot of potential applied research on bioeconomy related services could be supported and encouraged. There is a lot of cumulated research on ecosystem services, services linked to bioeconomy products and technologies, design or other intangible asset in the Nordic countries. However, the innovation models on these are far less developed than on products and technologies, and often success can be gained with reasonable investments.*

## Value addition

Value addition of bioeconomy has manifold interpretation. On one hand it simply means the direct value addition across the value chain, from value chain inputs all the way to outputs. E.g. value addition of processing biofuels from forest residue. On the other hand, value addition can look at the issue on a wider perspective: what is the value addition of the value chain including indirect effects seen e.g. in linked sectors and in the regional or national economy. In order to address this issue, bioeconomy value chains should be benchmarked. Important question is whether the raw materials used are in the right use? Could they have more valuable uses? Does their utilization provide more value addition than in the competing value chains? These questions are important to generate maximum benefits for society from the national natural capital but also to generate business that can prosper in tight competition. Although there is abundant bio-based raw materials currently available, regulation affects the operating environment and natural capital has a limited supply. These questions are therefore justified and should be thought of when developing the innovations.

***Recommendations***

- *Develop and share practical methods for assessment of value addition in bioeconomy innovations, including the indirect effects in linked sectors and the regional economy.*
- *Include initial assessment and benchmarking of value addition in R&D programs and projects of bioeconomy when applicable.*

## Demonstration

**Improved access to demonstration and piloting infrastructure**

Piloting and demonstration is the pre-requisite for commercialization of new production processes and products. Improved access to industrial scale testing facilities would improve innovation commercialization potential of bioeconomy. Successful proof of concept is often required for external funding. Especially for SMEs this can be a critical issue. Funding and access to demonstration infrastructure of SMEs could also be improved by supporting strategic partnering. Nordic cooperation is needed to ensure an effective cooperation between the existing infrastructures and to avoid overlapping in the investments. As well, development and marketing of the infrastructure is a potential area of cooperation.

***Recommendations***

- *Develop a Nordic virtual tour of the piloting and demonstration infrastructure, to improve awareness of the infrastructure available and make it possible to create service business around the assets of the demonstration infrastructure.*

# APPENDIX 1: NACE CODES

**NACE codes used in the calculation of the sectors.**

The NACE codes were examined and the categories relevant for Bioeconomy activity were picked out from the total. The following categories and subcategories were included in the calculations:

| | |
|---|---|
| **Sectors included in bioeconomy** | |
| **Agriculture** | |
| A1 | Crop and animal production, hunting and related service activities |
| **Fisheries and aquaculture** | |
| A3 | Fishing and aquaculture |
| **Forestry** | |
| A2 | Forestry and logging |
| **Food industry** | |
| C10 | Manufacture of food products |
| C11 | Manufacture of beverages |
| C12 | Manufacture of tobacco products |
| **Forest industry** | |
| C16 | Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials |
| C17 | Manufacture of paper and paper products |
| **Bioenergy and biofuels** | |
| B-100100 | Electricity and heat from biomass and waste |
| | Biofuels |

| | |
|---|---|
| **Emerging technologies, where biomass-based products may replace the current fossil-based products** | |
| ***Building and construction*** | |
| F | Construction |
| ***Textile industry*** | |
| C13 | Manufacture of textiles |
| C14 | Manufacture of wearing apparel |
| C15 | Manufacture of leather and related products |
| ***Chemical and plastics industry*** | |
| C20.1 | Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms |
| C20.2 | Manufacture of pesticides and other agrochemical products |
| C20.3 | Manufacture of paints, varnishes and similar coatings, printing ink and mastics |
| C20.4 | Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations |
| C20.5 | Manufacture of other chemical products |
| C20.6 | Manufacture of man-made fibers |
| C22 | Manufacture of rubber and plastic products |
| ***Pharmaceutical industry*** | |
| C21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations |
| ***Services*** | |
| I | Accommodation and food service activities |

***Technologies (that could be directly included)***

| | |
|---|---|
| C28.3 | Manufacture of agricultural and forestry machinery |
| C28.9.3 | Manufacture of machinery for food, beverage and tobacco processing |
| C28.9.5 | Manufacture of machinery for paper and paperboard production |
| ***Technologies (that may be partly relevant for the emerging bioeconomy)*** | |
| C28.1.1 | Manufacture of engines and turbines, except aircraft, vehicle and cycle engines |
| C28.1.2 | Manufacture of fluid power equipment |
| C28.1.3 | Manufacture of other pumps and compressors |
| C28.1.4 | Manufacture of other taps and valves |
| C28.1.5 | Manufacture of bearings, gears, gearing and driving elements |
| C28.2.1 | Manufacture of ovens, furnaces and furnace burners |
| C28.2.5 | Manufacture of non-domestic cooling and ventilation equipment |
| C28.9.4 | Manufacture of machinery for textile, apparel and leather production |
| C28.9.6 | Manufacture of plastics and rubber machinery |
| C33 | Repair and installation of machinery and equipment |
| ***Wastewater treatment*** | |
| E36 | Water collection, treatment and supply |
| E37 | Sewerage |
| ***Waste treatment*** | |
| E38 | Waste collection, treatment and disposal activities; materials recovery |
| E39 | Remediation activities and other waste management services |

***Services, installation and repair, are included in each sector.***

# APPENDIX 2: STATISTICAL DATA

*Table 4a. Volume of bioeconomy in the Nordic countries, as measured by turnover.*[83]

| Sector | Finland | Source | % of total | % of total bio | Sweden | Source | % of total | % of total bio | Norway | Source | % of total | % of total bio | Denmarl | Source | % of total | % of total bio | Iceland | Source | % of total | % of total bio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 4 822 | 2 | 1 % | 11 % | 14273 | 3 | 2 % | 21 % | 3670 | 5 | 1 % | 11 % | 11484 | 1 | 3 % | 31 % | 269 | 6 | 1 % | 8 % |
| Fisheries and aquaculture | 171 | 2 | 0 % | 0 % | 157 | 8 | 0 % | 0 % | 5800 | 4 | 1 % | 17 % | 540 | | 0 % | 1 % | 846 | 6 | 4 % | 24 % |
| Forestry | 4 232 | 2 | 1 % | 10 % | 8378 | 3 | 1 % | 13 % | 602 | 4 | 0 % | 2 % | 698 | | 0 % | 2 % | 1 | 6 | 0 % | 0 % |
| Food industry | 9 813 | 1 | 3 % | 23 % | 16065 | 1 | 2 % | 24 % | 19520 | 4 | 3 % | 56 % | 19 808.7 | 1 | 5 % | 54 % | 2433 | 6 | 12 % | 68 % |
| Forest industry | 20 523 | 2 | 6 % | 49 % | 23816 | 3 | 4 % | 36 % | 4800 | 4 | 1 % | 14 % | 2608 | 1 | 1 % | 7 % | 30 | 6 | 0 % | 1 % |
| Bioenergy and biofuels | 2639.9 | 1 | 1 % | 6 % | 4055.5 | 1 | 1 % | 6 % | 238.1 | 1 | 0 % | 1 % | 1677.6 | 1 | 0 % | 5 % | 0.0 | 1 | 0 % | 0 % |
| *Total bioeconomy* | 2 640 | 1 | 1 % | 0 | 4 055 | 1 | 0 | 0 | 238 | 1 | 0 | 0 | 1 678 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| Total economy | 351829.5 | 1 | | | 662910.4 | 1 | | | 562638.2 | 1 | | | 428387.1 | 1 | | | 19913 | 6 | | |

*Table 4b. Volume of other sectors relevant for the bioeconomy in the Nordic countries, as measured by turnover.*[84]

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[83] The turnover of bioenergy and biofuels is calculated from MtOE, using average price for heat and electricity in the countries (Eurostat). For CHP the ratio 1/3 electricity and 2/3 heat was used. Sources:

1 Eurostat, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

2 Statistics Finland, stat.fi

3 SCB Statistics Sweden, scb.se

4 SSB Statistics Norway, ssb.no

5 Statistical Yearbook of Norway 2013/no. 349

6 Statistics Iceland, statice.is

| Sector | Finland | Source | % of total | | Sweden | Source | % of total | | Norway | Source | % of total | | Denmark | Source | % of total | | Iceland | Source | % of total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building and construction** | 24 154 | 1 | 7 % | | 48888 | 1 | 7 % | | 39111 | 1 | 7 % | | 22698 | 1 | 5 % | | 1 | 6 | 0 % |
| **Textile industry** | 947 | 1 | 0 % | | 1188 | 1 | 0 % | | 884 | 1 | 0 % | | 1199 | 1 | 0 % | | | | 0 % |
| **Chemical and plastics industry** | 8 334 | 1 | 2 % | | 12546 | 1 | 2 % | | 8519 | 1 | 2 % | | 6657 | 1 | 2 % | | 1 | 6 | 0 % |
| **Pharmaceutical industry** | 1 403.5 | 1 | 0 % | | 5500 | 8 | 1 % | | 880.0 | 1 | 0 % | | 8 583.9 | 1 | 2 % | | 0 | | 0 % |
| **Technologies** | 9 209 | 1 | 3 % | | 11189 | 1 | 2 % | | 6421 | 1 | 1 % | | 13180 | 1 | 3 % | | 414 | 6 | 2 % |
| **Services (accomodation and food services)** | 5390.2 | 1 | 2 % | | 10919 | 1 | 2 % | | 7124 | 1 | 1 % | | 5803.9 | 1 | 1 % | | 480 | 6 | 2 % |
| **Water treatment and supply** | 861 | 1 | 0 % | | 477 | 1 | 0 % | | 54 | 1 | 0 % | | 778 | 1 | 0 % | | 4 | 6 | 0 % |
| **Waste treatment** | 1 506 | 1 | 0 % | | 4373 | 1 | 1 % | | 2626 | 1 | 0 % | | 2050 | 1 | 0 % | | 35 | 6 | 0 % |

7 European bioeconomy M

[84] The turnover of bioenergy and biofuels is calculated from …

1 Eurostat, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

2 Statistics Finland, stat.fi

3 SCB Statistics Sweden, scb.se

4 SSB Statistics Norway, ssb.no

5 Statistical Yearbook of Norway 2013/no. 349

6 Statistics Iceland, statice.is

*Table 4c. Volume of bioeconomy in the Nordic countries and EU, as measured by turnover.*

| Sector | Total Nordic | % of total | % of total bio | EU27 | Source | % of total | % of total bio | Nordic / EU 27 |
|---|---|---|---|---|---|---|---|---|
| **Agriculture** | 34518 | 2 % | 19 % | 381000 | 7 | 2 % | 21 % | 9 % |
| **Fisheries and aquaculture** | 7 513.6 | 0 % | 4 % | 32000 | 7 | 0 % | 2 % | 23 % |
| **Forestry** | 13911 | 1 % | 8 % | 269000 | 7 | 1 % | 15 % | 5 % |
| **Food industry** | 67 639.7 | 3 % | 37 % | 951112.7 | 1 | 4 % | 53 % | 7 % |
| **Forest industry** | 51777 | 3 % | 28 % | 283702 | 1 | 1 % | 16 % | 18 % |
| **Bioenergy and biofuels** | 8611.2 | 0 % | 5 % | 36325.3 | 1 | 0 % | 2 % | 24 % |
| ***Total bioeconomy*** | 183 970 | | | 1782027.3 | | | | 10 % |
| **Total economy** | 2025677.9 | | | 23701840 | 1 | | | 9 % |

*Table 4d. Volume of other sectors relevant for the bioeconomy in the Nordic countries and EU, as measured by turnover.*[85]

| Sector | Total Nordic | % of total | | EU27 | Source | % of total | | Nordic / EU 27 |
|---|---|---|---|---|---|---|---|---|
| **Building and construction** | 134852 | 7 % | | 1548602.7 | 1 | 7 % | | 9 % |
| **Textile industry** | 4218 | 0 % | | 190176 | | 1 % | | 2 % |
| **Chemical and plastics industry** | 36057 | 2 % | | 757000 | 1 | 3 % | | 5 % |
| **Pharmaceutical industry** | 16 367.4 | 1 % | | 213269.01 | 1 | 1 % | | 8 % |
| **Technologies** | 40412 | 2 % | | 387066.81 | 1 | 2 % | | 10 % |
| **Services (accomodation and food services)** | 29716.9 | 1 % | | 467512.8 | 1 | 2 % | | 6 % |
| **Water treatment and supply** | 2174 | 0 % | | 59609 | 1 | 0 % | | 4 % |
| **Waste treatment** | 10590 | 1 % | | 133394.7 | 1 | 1 % | | 8 % |

[85] The turnover of bioenergy and biofuels is calculated from …

1 Eurostat, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database
2 Statistics Finland, stat.fi
3 SCB Statistics Sweden, scb.se
4 SSB Statistics Norway, ssb.no
5 Statistical Yearbook of Norway 2013/no. 349
6 Statistics Iceland, statice.is
7 European bioeconomy

*Table 5. Amount of people employed per sector*

| Volume of bioeconomy in Nordic countries | Finland | | Sweden | | Norway | | Denmark | | Iceland | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Employ-ment | Source | Employ-ment | Source | Employ-ment | Source | Employ-ment | Source | Employ-ment | Source |
| Agriculture | 128 400 | 2 | 65 000 | 3 | 43 600 | 5 | 183745 | | 4 800 | 6 |
| Fisheries and aquaculture | 1 800 | 2 | 1 000 | 3 | 13 200 | 5 | 2367 | | 4 900 | 6 |
| Forestry | 25 000 | 2 | 40 000 | 3 | NA | 5 | 5041 | | NA | |
| Food industry | 38 300 | 2 | 56 000 | 3 | 49 253 | 4 | 49732 | | 4 100 | 6 |
| Forest industry | 59 700 | 2 | 65 000 | 3 | 17 508 | 4 | NA | | NA | |
| Bioenergy and biofuels | NA | | NA | | NA | | NA | | NA | |
| Building and construction | 58 100 | 2 | 320 000 | 3 | 210 034 | 5 | NA | | NA | |
| Chemical and plastics industry | 1 600 | 2 | NA | | 12 747 | 4 | NA | | NA | |
| Pharmaceutical industry | 4 100 | 2 | NA | | NA | | NA | | NA | |
| Technologies | NA | | NA | | NA | | NA | | 9 100 | |
| Services (tourism and nature) | 32 100 | 2 | 2 122 000 | 3 | NA | | NA | | NA | 6 |
| Water treatment and supply | 2 700 | 2 | 5 000 | 3 | 8 017 | 4 | NA | | NA | |
| Other bio economy related sectors (waste treatment) | NA | | NA | | NA | | NA | | NA | |
| Total economy | 2 509 500 | 2 | 4 628 000 | 3 | 2 364 200 | 4 | NA | | 179 000 | 6 |

*Table 6. Export in M€ per sector*

| Volume of bioeconomy in Nordic countries | Finland | | Sweden | | Norway | | Denmark | | Iceland | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Export (M€) | Source | Export (M€) | Source | Export (M€) | Source | Export (M€) | Source | Export (M€) | Source |
| Agriculture | NA | | NA | | 5715 | 5 | 19866 | | 82 | |
| Fisheries and aquaculture | NA | | 2216 | 3 | 1730 | 5 | NA | | 1669 | |
| Forestry | 68 | 2 | NA | | NA | | NA | | NA | |
| Food industry | 515 | 2 | NA | | 6457 | 5 | 14094 | | 10 | |
| Forest industry | 11262 | 2 | 13861 | 3 | 2295 | 5 | NA | | NA | |
| Bioenergy and biofuels | NA | | NA | | NA | | NA | | NA | |
| Building and construction | 100 | 2 | NA | | 27533 | 5 | NA | | NA | |
| Chemical and plastics industry | 1347 | 2 | 14773 | 3 | 1671 | 5 | NA | | NA | |
| Pharmaceutical industry | 932 | 2 | NA | | NA | | NA | | NA | |
| Technologies | NA | | NA | | NA | | NA | | NA | |
| Services (tourism and nature) | NA | | NA | | NA | | NA | | 386 | |
| Water treatment and supply | NA | | NA | | 1051 | 5 | NA | | NA | |
| Other bio economy related sectors (waste treatment) | NA | | NA | | NA | | NA | | NA | |
| Total economy | 54221 | 2 | NA | | 309921 | | NA | | 4826 | |

# APPENDIX 3: TABLES ON VOLUME OF SECTORS ESPECIALLY RELEVANT FOR THE BUSINESS ECOSYSTEMS

*Table 7. Aquatic biorefinery ecosystem versus volume in the Nordic countries.*

| Volume of bioeconomy in Nordic countries | Finland | Sweden | Norway | Denmark | Iceland | Total Nordic | EU27 |
|---|---|---|---|---|---|---|---|
| | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) |
| Agriculture | 4 822 | 6429 | 3670 | 11484 | 269 | 26 673 | 381000 |
| Fisheries and aquaculture | 171 | | 5800 | 540.4 | 846 | 7 357 | 32000 |
| Forestry | 4 232 | 8378 | 602 | 698 | 1 | 13 911 | 269000 |
| Food industry | 11 271 | 14273 | 21942 | 17 865.1 | 2433 | 67 785 | 780000 |
| Forest industry | 20 523 | 23816 | 4800 | 2608 | 30 | 51 777 | 283702 |
| Bio industry | | | | | | | 800 |
| Bioenergy and biofuels | 2 640 | 4055 | 238 | 1678 | 0 | 8 611 | 36325.329 |
| *Building and construction* | 24154 | 48888 | 39111 | 22698 | 1 | 134852 | 1548603 |
| *Chemical and plastics industry* | 8 334 | 12546 | 8519 | 6657 | 1 | 36 057 | 757000 |
| *Pharmaceutical industry* | 1 403.5 | 12500 | 880.0 | 8 583.9 | 0 | 23 367 | 213269.01 |
| *Technologies* | 37 019 | 47308 | 23971 | 26296 | 414 | 135 009 | 1435906.7 |
| *Services* | 5 390 | 10919 | 7124 | 5804 | 480 | 29 717 | 467512.8 |
| Water treatment and supply | 861 | 477 | 54 | 778 | 4 | 2 174 | 59609 |
| Wwaste treatment | 1 506 | 4373 | 2626 | 2050 | 35 | 10 590 | 133394.7 |

*Table 8. Nordic Functional Bio-based Ingredients ecosystem versus volume in the Nordic countries.*

| Volume of bioeconomy in Nordic countries | Finland | Sweden | Norway | Denmark | Iceland | Total Nordic | EU27 |
|---|---|---|---|---|---|---|---|
| | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) | Turnover (M€) |
| Agriculture | 4 822 | 6429 | 3670 | 11484 | 269 | 26 673 | 381000 |
| Fisheries and aquaculture | 171 | | 5800 | 540.4 | 846 | 7 357 | 32000 |
| Forestry | 4 232 | 8378 | 602 | 698 | 1 | 13 911 | 269000 |
| Food industry | 11 271 | 14273 | 21942 | 17 865.1 | 2433 | 67 785 | 780000 |
| Forest industry | 20 523 | 23816 | 4800 | 2608 | 30 | 51 777 | 283702 |
| Bio industry | | | | | | | 800 |
| Bioenergy and biofuels | 2639.9126 | 4055.4742 | 238.14827 | 1677.6332 | 0 | 8611.1683 | 36325.329 |
| *Building and construction* | 24153.6 | 48888.3 | 39111.2 | 22698.1 | 0.826196 | 134852.03 | 1548602.7 |
| *Chemical and plastics industry* | 8 334 | 12546 | 8519 | 6657 | 1 | 36 057 | 757000 |
| *Pharmaceutical industry* | 1 403.5 | 12500 | 880.0 | 8 583.9 | 0 | 23 367 | 213269.01 |
| *Technologies* | 37 019 | 47308 | 23971 | 26296 | 414 | 135 009 | 1435906.7 |
| *Services* | 5390.2 | 10918.8 | 7124 | 5803.9 | 480 | 29716.9 | 467512.8 |
| Water treatment and supply | 861 | 477 | 54 | 778 | 4 | 2 174 | 59609 |
| Wwaste treatment | 1505.9 | 4373.2 | 2625.8 | 2050.1 | 35 | 10590 | 133394.7 |

*Table 9. Advanced Biomaterials ecosystem versus volume in the Nordic countries.*

| Volume of bioeconomy in Nordic countries | Finland<br>Turnover (M€) | Sweden<br>Turnover (M€) | Norway<br>Turnover (M€) | Denmark<br>Turnover (M€) | Iceland<br>Turnover (M€) | Total Nor-dic<br>Turnover (M€) | EU27<br>Turnover (M€) |
|---|---|---|---|---|---|---|---|
| **Agriculture** | 4 822 | 6429 | 3670 | 11484 | 269 | 26 673 | 381000 |
| **Fisheries and aquaculture** | 171 | | 5799.5123 | 540.40268 | 845.67683 | 7356.5919 | 32000 |
| **Forestry** | 4 232 | 8378 | 602 | 698 | 1 | 13 911 | 269000 |
| **Food industry** | 11271 | 14273.4 | 21941.954 | 17865.1 | 2433.259 | 67784.713 | 780000 |
| **Forest industry** | 20523 | 23816 | 4799.9581 | 2608.3 | 29.649876 | 51776.908 | 283702 |
| **Bio industry** | | | | | | | 800 |
| **Bioenergy and biofuels** | 2639.9126 | 4055.4742 | 238.14827 | 1677.6332 | 0 | 8611.1683 | 36325.329 |
| ***Building and construction*** | 24153.6 | 48888.3 | 39111.2 | 22698.1 | 0.826196 | 134852.03 | 1548602.7 |
| ***Chemical and plastics industry*** | 8 334 | 12546 | 8519 | 6657 | 1 | 36 057 | 757000 |
| ***Pharmaceutical industry*** | 1403.5 | 12500 | 880 | 8583.9 | 0 | 23367.4 | 213269.01 |
| ***Technologies*** | 37 019 | 47308 | 23971 | 26296 | 414 | 135 009 | 1435906.7 |
| ***Services*** | 5390.2 | 10918.8 | 7124 | 5803.9 | 480 | 29716.9 | 467512.8 |
| **Water treatment and supply** | 861 | 477 | 54 | 778 | 4 | 2 174 | 59609 |
| **Waste treatment** | 1505.9 | 4373.2 | 2625.8 | 2050.1 | 35 | 10590 | 133394.7 |

*Table 10. Biorefinery concept ecosystem versus volume in the Nordic countries.*

| Volume of bioeconomy in Nordic countries | Finland<br>(M€) | Sweden<br>(M€) | Norway<br>(M€) | Denmark<br>(M€) | Iceland<br>(M€) | Total Nordic<br>(M€) | EU27<br>(M€) |
|---|---|---|---|---|---|---|---|
| **Agriculture** | 4 822 | 6429 | 3670 | 11484 | 269 | 26 673 | 381000 |
| **Fisheries and aquaculture** | 171 | | 5799.5123 | 540.40268 | 845.67683 | 7356.5919 | 32000 |
| **Forestry** | 4 232 | 8378 | 602 | 698 | 1 | 13 911 | 269000 |
| **Food industry** | 11271 | 14273.4 | 21941.954 | 17865.1 | 2433.259 | 67784.713 | 780000 |
| **Forest industry** | 20523 | 23816 | 4799.9581 | 2608.3 | 29.649876 | 51776.908 | 283702 |
| **Bio industry** | | | | | | | 800 |
| **Bioenergy and biofuels** | 2639.9126 | 4055.4742 | 238.14827 | 1677.6332 | 0 | 8611.1683 | 36325.329 |
| ***Building and construction*** | 24153.6 | 48888.3 | 39111.2 | 22698.1 | 0.826196 | 134852.03 | 1548602.7 |
| ***Chemical and plastics industry*** | 8 334 | 12546 | 8519 | 6657 | 1 | 36 057 | 757000 |
| ***Pharmaceutical industry*** | 1403.5 | 12500 | 880 | 8583.9 | 0 | 23367.4 | 213269.01 |
| ***Technologies*** | 37 019 | 47308 | 23971 | 26296 | 414 | 135 009 | 1435906.7 |
| ***Services*** | 5390.2 | 10918.8 | 7124 | 5803.9 | 480 | 29716.9 | 467512.8 |
| **Water treatment and supply** | 861 | 477 | 54 | 778 | 4 | 2 174 | 59609 |
| **Wwaste treatment** | 1505.9 | 4373.2 | 2625.8 | 2050.1 | 35 | 10590 | 133394.7 |

*Table 11. Biocatalysis ecosystem versus volume in the Nordic countries.*

| Volume of bioeconomy in Nordic countries | Finland (M€) | Sweden (M€) | Norway (M€) | Denmark (M€) | Iceland (M€) | Total Nordic (M€) | EU27 (M€) |
|---|---|---|---|---|---|---|---|
| **Agriculture** | 4822 | 6429 | 3669.5768 | 11483.893 | 268.96096 | 26673.43 | 381000 |
| **Fisheries and aquaculture** | 171 | | 5799.5123 | 540.40268 | 845.67683 | 7356.5919 | 32000 |
| **Forestry** | 4232 | 8378 | 602.22327 | 697.71812 | 0.844832 | 13910.786 | 269000 |
| **Food industry** | 11271 | 14273.4 | 21941.954 | 17865.1 | 2433.259 | 67784.713 | 780000 |
| **Forest industry** | 20523 | 23816 | 4799.9581 | 2608.3 | 29.649876 | 51776.908 | 283702 |
| **Bio industry** | | | | | | | 800 |
| **Bioenergy and biofuels** | 2639.9126 | 4055.4742 | 238.14827 | 1677.6332 | 0 | 8611.1683 | 36325.329 |
| ***Building and construction*** | 24153.6 | 48888.3 | 39111.2 | 22698.1 | 0.826196 | 134852.03 | 1548602.7 |
| ***Chemical and plastics industry*** | 8 334 | 12546 | 8519 | 6657 | 1 | 36 057 | 757000 |
| ***Pharmaceutical industry*** | 1403.5 | 12500 | 880 | 8583.9 | 0 | 23367.4 | 213269.01 |
| ***Technologies*** | 37 019 | 47308 | 23971 | 26296 | 414 | 135 009 | 1435906.7 |
| ***Services*** | 5390.2 | 10918.8 | 7124 | 5803.9 | 480 | 29716.9 | 467512.8 |
| **Water treatment and supply** | 861 | 477 | 54 | 778 | 4 | 2 174 | 59609 |
| **Wwaste treatment** | 1505.9 | 4373.2 | 2625.8 | 2050.1 | 35 | 10590 | 133394.7 |

*Table 12. Decentralized Bioenergy Systems ecosystem versus volume in the Nordic countries.*

| Volume of bioeconomy in Nordic countries | Finland (M€) | Sweden (M€) | Norway (M€) | Denmark (M€) | Iceland (M€) | Total Nordic (M€) | EU27 (M€) |
|---|---|---|---|---|---|---|---|
| **Agriculture** | 4 822 | 6429 | 3670 | 11484 | 269 | 26 673 | 381000 |
| **Fisheries and aquaculture** | 171 | | 5799.5123 | 540.40268 | 845.67683 | 7356.5919 | 32000 |
| **Forestry** | 4 232 | 8378 | 602 | 698 | 1 | 13 911 | 269000 |
| **Food industry** | 11271 | 14273.4 | 21941.954 | 17865.1 | 2433.259 | 67784.713 | 780000 |
| **Forest industry** | 20523 | 23816 | 4799.9581 | 2608.3 | 29.649876 | 51776.908 | 283702 |
| **Bio industry** | | | | | | | 800 |
| **Bioenergy and biofuels** | 2639.9126 | 4055.4742 | 238.14827 | 1677.6332 | 0 | 8611.1683 | 36325.329 |
| ***Building and construction*** | 24153.6 | 48888.3 | 39111.2 | 22698.1 | 0.826196 | 134852.03 | 1548602.7 |
| ***Chemical and plastics industry*** | 8333.8 | 12546.4 | 8518.9 | 6657.2 | 0.6 | 36056.9 | 757000 |
| ***Pharmaceutical industry*** | 1403.5 | 12500 | 880 | 8583.9 | 0 | 23367.4 | 213269.01 |
| ***Technologies*** | 37 019 | 47308 | 23971 | 26296 | 414 | 135 009 | 1435906.7 |
| ***Services*** | 5390.2 | 10918.8 | 7124 | 5803.9 | 480 | 29716.9 | 467512.8 |
| **Water treatment and supply** | 861 | 477 | 54 | 778 | 4 | 2 174 | 59609 |
| **Wwaste treatment** | 1505.9 | 4373.2 | 2625.8 | 2050.1 | 35 | 10590 | 133394.7 |

*Table 13. Bioeconomy related services ecosystem versus volume in the Nordic countries.*

| Volume of bioeconomy in Nordic countries | Finland | Sweden | Norway | Denmark | Iceland | Total Nordic | EU27 |
|---|---|---|---|---|---|---|---|
| | (M€) | (M€) | (M€) | (M€) | (M€) | (M€) | (M€) |
| **Agriculture** | 4 822 | 6429 | 3670 | 11484 | 269 | 26 673 | 381000 |
| **Fisheries and aquaculture** | 171 | | 5799.5123 | 540.40268 | 845.67683 | 7356.5919 | 32000 |
| **Forestry** | 4 232 | 8378 | 602 | 698 | 1 | 13 911 | 269000 |
| **Food industry** | 11271 | 14273.4 | 21941.954 | 17865.1 | 2433.259 | 67784.713 | 780000 |
| **Forest industry** | 20523 | 23816 | 4799.9581 | 2608.3 | 29.649876 | 51776.908 | 283702 |
| **Bio industry** | | | | | | | 800 |
| **Bioenergy and biofuels** | 2639.9126 | 4055.4742 | 238.14827 | 1677.6332 | 0 | 8611.1683 | 36325.329 |
| ***Building and construction*** | 24153.6 | 48888.3 | 39111.2 | 22698.1 | 0.826196 | 134852.03 | 1548602.7 |
| ***Chemical and plastics industry*** | 8333.8 | 12546.4 | 8518.9 | 6657.2 | 0.6 | 36056.9 | 757000 |
| ***Pharmaceutical industry*** | 1403.5 | 12500 | 880 | 8583.9 | 0 | 23367.4 | 213269.01 |
| ***Technologies*** | 37018.9 | 47307.9 | 23971.4 | 26296.4 | 414 | 135008.6 | 1435906.7 |
| ***Services*** | 5390.2 | 10918.8 | 7124 | 5803.9 | 480 | 29716.9 | 467512.8 |
| **Water treatment and supply** | 861 | 477 | 54 | 778 | 4 | 2 174 | 59609 |
| **Wwaste treatment** | 1505.9 | 4373.2 | 2625.8 | 2050.1 | 35 | 10590 | 133394.7 |

# APPENDIX 4: INTERVIEW QUESTIONNAIRE

Interview questions – Stakeholders

YOUR ORGANIZATION

1. What is your background and role in the company? Bioeconomy knowledge?
2. Could you describe the purpose of your organization in your own words?
3. How much funding do you grant per year?
4. To which areas? What type of businesses? Co-operation requirements?
5. What other support measures do you provide?
6. Could you provide examples of:
   a. Nordic collaboration partners?
   b. National collaboration partners?
   c. Other international collaboration partners?

SECTORS OF THE BIOECONOMY

7. Which sectors of the bio-economy are the most important in your country?
8. What is the contribution of these sectors to the economy and to employment?
9. What has been the growth rate of these sectors? (historical perspective of change in the sector)
10. What are the most important stakeholders promoting innovation in the sectors or nationally?
11. Can you specify how have these sectors developed into sectors of importance (available resources, R&D, well developed ecosystem, good demand for services and products domestically or internationally, available competence, public measures to develop sectors etc.)? Drivers and critical success factors?
12. What are the future prospects of these sectors? How do you see that they will develop in the future?
13. What sectors of the bio-economy do you think have good potential to develop into sectors of importance in the future? Can you name some good case examples?
14. Why do you think these sectors will have good potential (domestic or international demand for products or services, available raw material, available competence, advanced R&D, new radical innovations expected in the future, good ecosystem, etc.)?
15. What kind of innovation support or other enablers can promote their development into sectors of importance? What would promote innovation of new products and services?
16. What will enable the commercialization of the products and services?

INSTRUMENTS, WHICH AIM TO PROMOTE INNOVATION AND DEVELOPMENT. BARRIERS TO INNOVATION

17. What kind of national or sector specific initiatives and support mechanisms exist, which promote innovation or the commercialization of innovations in the bio-economy sector?

    a) Regulatory instruments

    b) Financial Instruments

    c) Other supporting measures

18. Can you name the most important public and private stakeholders in the innovation system?

19. What are the main existing obstacles to innovation and commercialization of innovations in the bio-economy sector or specific sectors of the bio-economy? (Obstacles created by the policies such as regulatory environment, skewed financial incentives, lack of supporting measures etc., or by other types of barrier such as for instance lack of financial resources, lack of competence, workforce, domestic demand, R&D, missing stakeholders in the ecosystem etc.)
20. What kind of support to promote innovation and commercialization of innovations in the bio-economy sector is needed? Are there any sector specific initiatives or support mechanisms to support innovation in the bio-economy sector, which you could suggest?
21. What could the government do and what could other stakeholders do?
22. Which are the important strategies and agendas drawn in your country?

Interview questions – Case studies

GENERAL INFO OF YOUR COMPANY

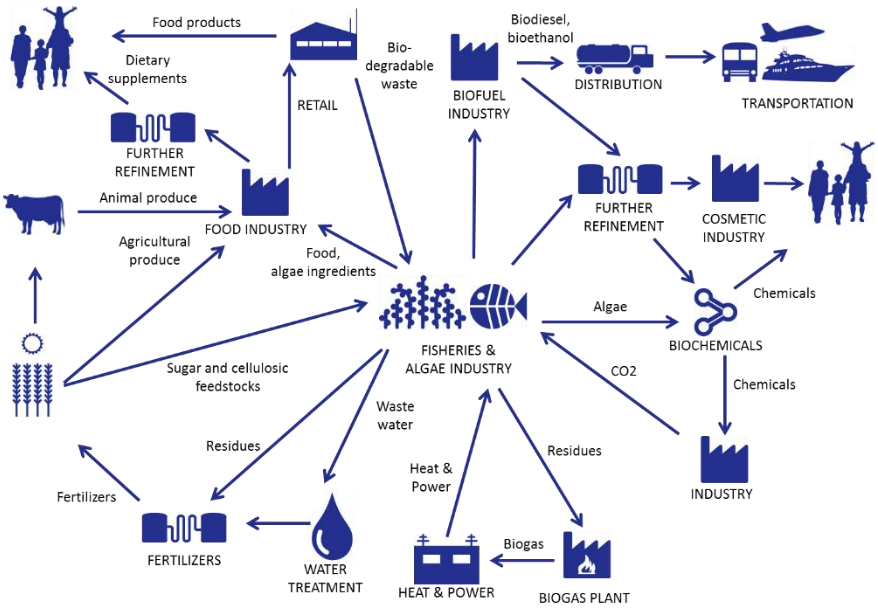
*Describe the purpose of the questions and the desired outcome. Ecosystems of companies and research.*

1. What is the main business of your company?
2. Could you describe your business model?
   a. What is the company structure?
   b. Ownership?
   c. Core business?
   d. What is outsourced?
   e. Co-operation partners (business, service, and research)?
   f. Raw material suppliers?
   g. End product buyers?
3. What is your innovation structure/process?
4. How much funding is spent on research and development per year?
5. How much funding is granted by others?
6. What do you consider to be a reasonable pay-back time for an improvement?
7. What do you consider to be a reasonable pay-back time for an innovation?

THE INNOVATION

*Describe the purpose of the questions and the desired outcome. Role of research, development, and innovation in bioeconomy.*

8. Describe the innovation
9. Critical success factors for the innovation
10. Do you find that biomass availability and sustainability is an issue for the success of the innovation?
11. How would you place the innovation in the general ecosystem showed in the picture?
12. Which parts are controlled by your company?
13. Does this innovation comply with your company's general innovation structure/process?



HISTORICAL PERSPECTIVE

*Describe the purpose of the questions and the desired outcome.*

*We wish to follow the historical path of a specific innovation.*

*Do we also wish to follow the historical path of the company?*

14. The historical path of specific innovations/ business development in your company, important collaboration partners (companies and research organizations).
15. Growth in which markets (historical perspective)
16. Change in turnover (historical perspective)

SUPPORT MEASURES FOR THE INNOVATION

*Describe the purpose of the questions and the desired outcome.*

17. What kind of National or sector specific initiatives or support mechanisms have been useful for innovation or commercialization of innovations?

OBSTACLES FOR THE INNOVATION

*Describe the purpose of the questions and the desired outcome.*

18. What are the main existing obstacles to innovation and commercialization of innovations?

GROWTH POTENTIAL For the company

*Describe the purpose of the questions and the desired outcome.*

*Identify areas, Identify barriers, Identify limits, Identify potential*

19. How do you see your future?
20. Strategies and agendas?
21. Planned and recent investments?
22. In which areas do you intend to grow?
23. What are the driving forces?
24. How do you see the future of the bioeconomy sector in general?

NORDIC CO-OPERATION innovation and company

*Describe the purpose of the questions and the desired outcome.*

25. Do you collaborate with stakeholders in any other Nordic country?
26. In which way?
27. How did the collaboration start?
28. How does it work? Obstacles?

# APPENDIX 5: INTERVIEWEES

| Stakeholder | Country | Interviewee | Position in organization |
|---|---|---|---|
| Bigadan | Denmark | Karsten Buchhave | CEO |
| Borregaard | Norway | Gisle Johanssen | Senior Vice President R&D and Business Development |
| Chitinor | Norway | Rigmond Abelsen | CEO |
| Danisco | Denmark | Conny Twisttmann | Senior researcher |
| Danish Agriculture and Food Council | Denmark | Bruno Sander Nielsen | Chief consultant |
| Icelandic Ocean Cluster | Iceland | Vihjalmur Arnason | Managing Director |
| Industrial Biotech network Norway | Norway | Ernst Kloosterman | Managing Director |
| Innovation Norway | Norway | Mari Valseth | Senior Advisor |
| Innovation Norway | Norway | Ole Marvik | Sector Head, Health and Life Sciences |
| Innventia | Sweden | Peter Axegård | Directorof Biorefining Business Area |
| Joensuun Tiedepuisto | Finland | Harri Välimäki | Development manager |
| Joensuun Tiedepuisto | Finland | Timo Tahvanainen | Development manager |
| Pink Iceland | Iceland | Eva Maria Lange | Founder |
| SINTEF | Norway | Rolf Wolff | Adviser |
| Sunpine | Sweden | Magnus Edin | CEO |
| Sybimar | Finland | Rami Salminen | Managing Director |
| Valmet | Finland | Marita Niemelä | Vice President, Strategy |
| Valmet | Finland | Jussi Mäntyniemi | Director, Technology |
| Vinnova | Sweden | Martin Svensson | Head of Technology Development Department |

# Table of Abstract

**Series title, number and report code of publication:**
Nordic Innovation publication 2014:01

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**Organisation(s):**
Nordic Innovation, Gaia Group, AgroTech

**Title (Full title of the report):**
**Creating value from bioresources - Innovation in Nordic Bioeconomy**

**Abstract:**
The objectives of this study were to identify the innovation-oriented challenges as well as areas with high growth potential within the Nordic bioeconomy. The study produced background data concerning the volume and constituents of bioeconomy in the Nordic countries using NACE codes. According to the estimate, the total turnover of the key bioeconomy sectors in Nordic countries is roughly 184 000 M€, this is 10% of the total economy. Key findings from the business ecosystem analysis show that market access is the key step to successful bioeconomy innovation, along with end user involvement and utilization of existing infrastructure. Areas within bio-based chemicals, biomaterials, biofules and bioenergy, biorefineries, resource-efficiency and industrial symbiosis and services based on ecosystem services have high innovation and growth potential of bioeconomy.

The obstacles of innovation in Nordic bioeconomy are lack of capital and funding, unstable operating environment due to changing regulation, market access and lack of number of actors involved in the ecosystems. Areas for further development to better tackle the identified obstacles include networking and developing a common understanding of the roles of different stakeholders, making processes for seeking support and financing easier for SMEs and promoting cross-sector transfer of existing or new applications for existing processes. Venture capitalists should be included in the networks to ensure they are better able to recognize the potential of commercial viable bioeconomy concepts. More focus may also be needed to link the support to finding commercially viable applications with the markets and customers.

**ISBN:**
ISBN 978-82-8277-056-9 (Print)
ISBN 978-82-8277-055-2 (Digital)
(URL: http://www.nordicinnovation.org/publications)

**Language:**
English

**Name of Nordic Innovation funding program (if relevant):**

**Commissioned by (if relevant):**

**Name of project:**

**Project acronym (if relevant):**

**Nordic Innovation project number:**
P 13047

**Pages:**
113

**Date:**
March 2014

**Keywords:**
Bioeconomy, volume of bioeconomy, growth potential, innovation, systemic innovation, linear innovation, Nordic Region, business ecosystem, aquatic biorefinery, advanced biomaterials, biocatalysis, natural capital, human capital, forerunner, smart policy, infrastructure, sustainability

**Publisher:**
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# Creating value from bioresources

## Innovation in Nordic Bioeconomy

Bioeconomy development promotes a more resource-efficient circular economy based increasing-ly on renewable energy, products and materials produced through sustainable use of ecosystem services from land and water. A greater focus on research and innovation can provide us with new products derived from biomass and new services required for realization of the bioeconomy de-velopment. The bioeconomy development helps combat climate change, reduce waste and create new jobs.

The objectives of this study were to identify the innovation-oriented challenges as well as areas with high growth potential within the Nordic bioeconomy. As a starting point, the study also pro-duced important background data concerning the volume and constituents of bioeconomy in Nor-dic countries.

According to the estimate, the total turnover of the key bioeconomy sectors in Nordic countries is roughly 184 000 M€ including agriculture, fisheries and aquaculture, forestry, food industry, forest industry and bioenergy and biofuels. This is 10 % of the total economy in Nordic countries. The share is highest in Iceland, where the key sectors of bioeconomy stand for 18 % of the total econ-omy, and lowest in Norway with a 6 % share. In all countries, the largest contributors to bioecono-my include forest industry or food industry. This shows the economic importance of intermediate and end product processing in the bio-based value chains.

The largest innovation and growth potential of bioeconomy seems to be in its crosscutting nature. The following interesting crosscutting growth areas of the bioeconomy in the Nordic countries were identified: bio-based chemicals, biomaterials, biofuels and bioenergy, biorefineries, re-source-efficiency and industrial symbiosis and services based on ecosystem services or supporting the above mentioned areas of products and creating value without tangible material flows and including design.

Nordic Innovation is an institution under Nordic Council of Ministers that facilitates sustainable growth in the Nordic region. Our mission is to orchestrate increased value creation through international cooperation.

We stimulate innovation, remove barriers and build relations through Nordic cooperation

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