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Future Opportunities for Bioeconomy in the West Nordic Countries

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Summary in English:	This final report provides an overview of bioresources in the West Nordic region focusing on Iceland, the Faroe Islands and Greenland, their utilisation and future opportunities based on green growth. The report provides good basis for strategic identification of beneficial projects in the region. Based on the results, a specific action plan has been formed consisting of four main actions; 1. Create a West Nordic Bioeconomy panel, 2. Establish an interdisciplinary Centre of Excellence (CoE) for the West Nordic region, 3. Arctic bioeconomy II – Project focusing on opportunities in biotechnology and 4. Program focusing on "The Blue Bioeconomy".		
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Future Opportunities for Bioeconomy in the West Nordic Countries

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Future Opportunities for Bioeconomy in the West Nordic Countries

Executive Summary

This project was initiated to prepare the West Nordic countries for active participation in Nordic and European initiatives in the field of Bioeconomy. This final report provides an overview of bioresources in the region, their utilisation and future opportunities based on green growth, providing good basis for strategic identification of beneficial projects in the region.

Compared to other Nordic countries, the bioeconomy of the West Nordic countries is a larger part of the GDP. The marine bioresources are the most important part and of common interests to the West Nordic countries which call for close cooperation within the region. A West Nordic Bioeconomy panel could be a platform for promoting common policy, to identify opportunities and set a common strategy for the region. The economies in the West Nordic countries can also be reinforced by developing industries further based on sustainable and responsible utilization of available resources. The aim should be to create multiple value streams from each resource, to improve processes and to develop and apply new technologies with the goal of minimising waste and maximising value.

The knowledge available in the West Nordic fishing industry has increased in the last decade and knowledge and technological transfer between the countries and increased cooperation would strengthen the West Nordic countries. It is important to maximise processing yields within the fisheries. However, substantial increase in value addition is likely to occur in synergy between fisheries and the biotechnology. Combining strong industry, such as the fishing industry, with research, development and innovation within the biotechnology sector will benefit the economy of the West Nordic countries as well as turn the region into an attractive area for young educated people.

Along with the fishing industry, the aquaculture is growing in Faroe Islands and Iceland and sharing knowledge and experiences will benefit both parties. The strong aquaculture industry in northern Norway is also an important partner for Iceland and Faroe Islands in further developing the aquaculture industries in the North West Region.

The macro-algae are growing in abundance in the coastal waters of the West Nordic countries and have promising properties for future utilization. The macro-algae can be used as biorefinery feedstock for bioconversions to platform chemicals, speciality chemicals and energy carriers (e.g. ethanol or butanol) and bulk carbohydrates, proteins and derivatives can funnelled into in various value streams.

Research into more efficient utilization of feed, feed health promoting factors and new possibilities in feed production should be given greater attention. It is also important to explore opportunities across different sectors of the bioeconomy as well as new innovative sources of biomass for feed.

Agriculture in the West Nordic countries is challenging due to harsh weather conditions. More emphasis should be on research on new crop variants, such as grain or berries and their adaptation to the West Nordic environment. There are also unexploited possibilities in using greenhouses to produce locally grown vegetables. Along with research on new crop variants, further research on revegetation, soil conservation and grazing pressure in the West Nordic countries is needed along with research on effects of climate change on the Arctic and the living conditions there.

Opportunities within the bioeconomy are likely to have an impact on the inhabitants of the area and help to reverse the trend of young educated people, especially women, moving from the rural areas to the larger towns, cities and other countries. A possible solution to increase opportunities for highly educated people in the West Nordic Region, is to create an interdisciplinary Centre of Excellence (CoE) focusing on issues related to the region such as bioeconomy, environmental issues, social issues, energy production and on solutions to increase added value of production based on local or regional bioresources. Further, tourism in the West Nordic countries can provide opportunities and jobs. By combining the unique nature, wildlife, fisheries, local food production and activities such as horse riding, hunting tours, recreational sea angling, salmon fishing etc., and tourism can add considerably to the income of the people in rural areas as well as in bigger towns and cities.

The key is a sustainable approach to all activities in the West Nordic countries, whether it is food production, transportation, bio-technology or tourism. There are large unrealised opportunities within the different sectors in the West Nordic countries. However, when each sector is operating separately in "its own silo", the growth potential might be limited. If interdisciplinary cooperation is enhanced, the growth potential of the economy is far greater. Innovation, supported by strong infrastructure, is another key element in enhancing the bioeconomy, by exploring underutilized possibilities and growth opportunities within the West Nordic countries.

The initiatives supporting bioeconomy in the West Nordic countries whether local, regional or Nordic will have most impact if they can be paralleled with European and other international research and innovation programs. It is important for the West Nordic countries to promote common interests, provide inputs and influence agendas in international research and Pan-European innovation programs. Further, it is important to monitor calls under the H2020 and identify collaboration opportunities for innovation in the region. It is also important to use the supporting West Nordic infrastructure to strengthen development by promoting projects of regional interest to a larger European platform.

An interview with Dr. dr. Christian Patermann.

Dr. dr. Christian Patermann describes the bioeconomy and its importance for the West Nordic Region and the unique features of the West Nordic Region. Further, Dr. Patermann, reflects on the importance of a West Nordic Bioeconomy panel in order to focus the strategy and priorities for the region as well as the importance of establishing a Centre of Excellence to optimise the research, technological and innovative activities in the region. The interview can be viewed at the following site: http://www.matis.is/drpatermann

Actions identified in the project as necessary and plan for their realization

Action 1. Create a West Nordic Bioeconomy panel

- West Nordic Bioeconomy panel/forum from academia, industry and commerce, non-governmental organizations (NGO's) and policy institutions will be formed to identify common key issues important for the West Nordic region, identify opportunities, advise industry, governments and the public and promote common key issues and policy. The creation of this West Nordic Bioeconomy panel is important for active and targeted participation in larger context such as the proposed Nordic Bioeconomy panel, the existing European Bioeconomy panel in Brussels and national bicoeconmy panels in Europe. Clear strategy and focus for the region is vital in working towards strengthening the bioeconomy, as well as opening up new opportunities for research and innovation in the region. Focus will be on wide cooperation with existing networks and infrastructures as well as representatives of the proposed Nordic Bioeconomy panel, national European Bioeconomy panels and the European Bioeconomy panel.
- A key action is to establish stakeholder platforms, complementing the advisory activities of the West Nordic Bioeconomy panel, to discuss industrial opportunities, infrastructure and support system to enhance value creation from bioresources as well as to discuss the balance between use and protection of bioresources and how to secure biodiversity.
- Opportunities provided with the Galway statement are currently being reviewed for possibilities to initiate a wider Arctic collaboration which can be of great importance

for the Arctic bioeconomy. This could provide a valuable collaboration of the West Nordic Bioeconomy to the west (USA and Canada).

– Application will be sent to NORA for support to initiate the West Nordic Bioeconomy panel and stakeholder platform before March 2. 2015.

Action 2. Establish an interdisciplinary CoE for the West Nordic region

- An interdisciplinary CoE will focus on the regions uniqueness, sustainability, energy and value streams, socio-economic aspects and rural development with active participation of all stakeholders. This CoE will link different expert groups and local/national knowledge centres together also through a virtual knowledge network/consortium. Comprehensive long term financing and political support is needed to realise this action.
  - To establish the CoE, an application will be sent to NordForsk on the current call for establishing Nordic Centres of Excellence in Artic Research (application deadline 4th of March, 2015).
    - 15th of December, concept paper (one-pager) will be finalised
    - 15th of January, consortium has been formed
    - 1st of February, 1st draft of application
    - 25th of February, final draft of application
    - 4th of March, submission of application

Action 3. Launching the project Arctic bioeconomy II – Biotechnology

- Special project focusing on opportunities in applying biotechnology for value creation in the West Nordic countries will be initiated. As one highly interesting aspect of the bioeconomy is the application of biotechnology to increase value from biomass and produce high value products from biomass, including products and chemicals now produced from fossil based resources. Further, in the North there is plentiful available space for dedicated cultivation of biomass as ingredient for biorefineries. The development of next generation biomass resources to supplant fossil based feedstocks may be one of the most important tasks of today's industrial biotechnology.

The project will look at feasible biorefinery feedstocks available in the region and opportunities to create multiple value streams from such resources. Emphasis will be on utilizing (1) waste streams from traditional industries, such as the fish industry and agriculture, applying new technology with the goal of minimizing waste and maximizing value, (2) underutilized natural resources, including macro-algae and wood/plant based biomass and (3) micro-algae biomass that can be cultivated specifically for specialized biorefineries. Further, climate conditions and unique geological aspects of the region make the high North a valuable source of unique extremophilic organisms for a wide spectrum of biotechnological application this project will strive to explore these opportunities.

This project is founded on the project Arctic Bioeonomy (Future opportunities for bioeconomy in the West Nordic countries), taking further the mapping of bioresources by exploring the opportunities that can be realised by applying new technology.

- Application for funding has been submitted and approved by Ag-Fisk
- Application for funding has been submitted and approved by the NMR Arctic Co-operation Programme.
- Application for funding will be submitted to NKJ and SNS
- Cooperation will be sought from Nord-Gen and SNS

Action 4. Program focusing on "The Blue Bioeconomy"

- Marine bioresources are the most important biological resources of the West Nordic countries, as fisheries contribute extensively to the GDP in all three countries. In order to have a positive impact on value creation in the West Nordic countries, investment in research, innovation and technology along with strengthening the fish stocks is needed. The aim of the action should be to create a blueprint on how to maximize opportunities in the Blue bioeconomy in the West Nordic countries. Cross-national collaboration between institutes and industry in the area will be increased by this action.

- Three year chairmanship program focusing on the Blue bioeconomy led by the Faroe Islands will be initiated in 2015, focusing on the West Nordic region. The project will focus on four main themes: pelagic fish, white fish, algae and aquaculture.
- Close collaboration will be between the innovation part of the Icelandic chairmanship program 2015-2016, and the Faroese program and the Arctic bioeconomy project I &II, to create synergy.

Further Recommendations:

Establishing a research centre on new crop variants and land reclamation.

- More emphasis should be on research on new crop variants, such as grain or berries and their adaption to the West Nordic environment. There are also unexploited possibilities in using greenhouses to produce locally grown vegetables for domestic use in Greenland and the Faroe Islands. Along with research on new crop variants. Further research on land reclamation, re-vegetation, soil conservation and grazing pressure in the West Nordic countries is needed along with research on effects of climate change in the Arctic.

Adapting legislations regarding biodiversity research

- Laws and regulations regarding access and benefit sharing of geothermal biotopes in Iceland have been in place since 1999. Protection on benefits from biodiversity research should be expanded to cover the many different and unique biotopes for the region and put into legislation in Greenland, Iceland and Faroe Islands.

Streamlining and synergising Nordic research with European funding bodies

- It is important to streamline and synergize research efforts for better use the large variety of funding opportunities in Europe. Further, it is important to monitor calls e.g. SC2 and SC5 under the H2020 and identify collaboration opportunities for innovation in the region. It is also important to use the West Nordic funding bodies to strengthen and promote projects of West Nordic regional interest that will lead to synergic effects with European and pan-European funding bodies.

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The project was financed by The Nordic Council of Ministers Arctic Co-operation Programme, NKJ (Nordic Joint Committee for Agricultural and Food Research), AG-Fisk (Working Group for Fisheries Co-operation), SNS (Nordic Forest Research), NordGen (the Nordic Genetic Resource Centre) and Matis.

The Icelandic chairmanship program NordBio has also contributed to the project by initiating the mapping of waste as a source for value creation and by adopting identified opportunities in the West Nordic countries into the NordBio innovation program.

Special thanks to Þorsteinn Tómasson, his encouragement and contribution has been of great value to the project.

Clarifications

In this report the bioeconomy of the West Nordic countries; Iceland, Greenland and Faroe Islands will be discussed and when referring to all the countries, the term West Nordic countries will be used. Reindeer husbandry in northern Scandinavia will also be discussed.

All values are in Danish crowns (DKK), Icelandic values originally in Icelandic crowns have been converted to DKK using the exchange rate of 21,593 DKK to Icelandic crown which is the average mid-rate of the Central Bank of Iceland in 2012.

In the report several boxes with different colours appear in the text. In the blue boxes opportunities and possibilities are pointed out. In the beige boxes definitions, warnings, information and further clarifications are put forward. In the green boxes success stories and examples are displayed. An overview of the blue boxes is provided in Chapter 7.1.

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Foreword

Europe on its way into a biobased Economy – Perspectives for West Nordic Countries

By Dr. Dr. h.c. Christian Patermann
Director (ret.) European Commission

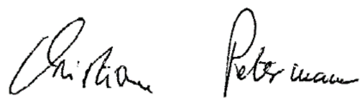
New knowledge about plants, animals, microorganisms and insects during the last decades has prompted deliberations, primarily from Europe and here by the European Commission, to use systematically and in a systemic way this new knowledge as the basis of a new economic concept, the biobased Economy, or simply the Bioeconomy. Having originally been a RTD concept, the so-called Knowledge-based Bioeconomy or KBBE, the bioeconomy is now regarded to be an economy as such using biological resources from the land and the sea, including waste (biomass) as inputs to food, feed, industrial and energy production. Its aims are twofold: produce sustainably new renewable raw materials in agriculture, forestry, fisheries and aquaculture, and/or process such feedstock into new value-added products in the Food, Feed and Industrial bio based and Energy industries. Living and working in such an economy might help responding to the many so-called grand challenges ranging from increased demand for high quality food and sustainably food and feed production to overcoming the limited resources of raw materials and energy via a true resource efficiency (“ more with less “), and last but not least help the transition from a fossil based chemical and energy industry into a more bio based oriented industry to successfully act towards climate and other global changes. The impact of such a paradigm change could however also affect many other industrial branches like building and construction, health care, fine chemicals, cosmetics, logistics and generally all so-called process industries. Biotechnologies, bio catalysis etc. will play a crucial role in these conversion and processing steps , even considering CO_2 not only as a greenhouse gas and climate killer, but an important raw material, for example in combination with Algae and bacteria to become their growth substrate for producing biomass.

The European Commission has issued in 2012 its first European Strategy for Bioeconomy “Innovation for Growth“. A few member states, like Germany, the Netherlands, Belgium (Flanders) Sweden, Finland, Denmark, Austria etc. have launched powerful nation strategies into enter the new bio based world, and the two superpowers USA and the Russian Federation have also announced in April 2012 their own blueprints resp. programmes embarking on a bio based economy. Others will follow soon. First regional efforts are underway in the Netherlands, Belgium, Germany and France to create Bioeconomy Regions as models.

I strongly congratulate the stakeholders in the West Nordic countries (Greenland, Iceland and Faroe Islands) to have started an intensive dialogue among themselves within the Nordic Union to identify the excellent opportunities of this new and important economic concept, so close to the Principle of sustainability and with so many affiliations to the potentials of the circular Economy. The unique features of this region on our planet, with its potentials under extreme climate and geographical conditions, but full of hopes for the future, represent a legacy to its inhabitants at least to cope with the unique features of the Bioeconomy: Carbon Neutrality, potentials for Growth, renewability and resources efficiency, but also chances for new innovative products. Who knows, whether successfully coping with this new concept of focusing on renewable biological resources will not be the basis for being copied by others in the future.

Good luck, Adelante, Avanti, Glück auf!

Dr. Dr. h.c. Christian Patermann



1. Introduction

The aim of this project has been to prepare the West Nordic countries for active participation in Nordic and European initiatives in the field of Bioeconomy. The objective is to enhance the beneficial effect for the area, contribute to further policymaking and to encourage sustainable utilization of natural resources and green growth. This final report provides an overview of bioresources in the region, their utilisation and future opportunities, providing good basis for strategic identification of beneficial projects in the region. Emphasis has been put on good communication with authorities and stakeholders in the NW-countries.

1.1. Definition of bioeconomy

The bioeconomy term has been proposed as a path towards the sustainable management of resources and economic growth. The term bioeconomy entered the global discussion in the recent decade and has now become a widely used definition. The term originates from the Seventh Framework Program of the European Commission and the Organisation for Economic Co-operation and Development (OECD) (Europian Commission, 2012; OECD, 2009). However, the term has been used in various forms and definitions and been mentioned in relation with food security, sustainable production and energy needs for a growing population.

The concept of bioeconomy or bio-based economy has become an important component of global policies, as can be seen both in the European Commission and the OECD and from the increase in scientific papers connected to the term from respected institutions and universities. The biological, social and economic challenges ahead, with the scarcity of natural resources and climate changes, underline the need for new approaches and innovation. This new way of thinking can lead us to the transformation from a fossil-based economy to a resource-efficient economy based on renewable materials produced through sustainable use of ecosystem services, i.e. a bio-based economy. A bio-based economy can be defined as an economy based on the sustainable production of biomass to increase the use of biomass products within different sectors of society. The objectives of bioeconomy are diverse, they include: The reduction of climate change impact, reduced use of non-renewable raw materials, increased added value from biomaterials concomitant with reduced energy consumption, recovery of nutrients and energy from waste and by-products as additional end-products, and to optimize the value and contribution of ecosystem services to the economy (NKJ, 2013).

The biological resources that can be identified are those which are currently being utilised and those that can be considered for utilisation. Utilised resources have an economic value represented by their contribution to the economy while unused resources do not have a current value, but a potential value that should be revealed. In addition to the identified resources, there is a category of undiscovered resources, hypothetical and even unconceived resources. The bioeconomy encompasses all of these but in this analysis, only identified biological resources will be considered.

The European Commission recently launched a bio-economy strategy for Europe under the name *Innovating for sustainable growth: A Bio-economy for Europe* (Europian Commission, 2012) to help drive the transition from an economy based on none renewable resources in Europe, with research and innovation at its core. The Nordic Joint Committee for Agricultural and Food Research similarly published a strategic document *Nordic Bio-economy Initiative* (NKJ, 2013) on a bio-based society in the Nordic countries, based on expected future trends within the sector and the increased need for a focus on biomass from agriculture as a renewable raw material in the development of bio-economy. Further, the OECD's report *The Bio-economy to 2030: designing a policy agenda* emphasises the evidence-based technology approach, focusing on biotechnology applications in primary production, health, and industry.

> *"An integrated ecosystem-based management approach requires that development activities be coordinated in a way that minimizes their impact on the environment and integrates thinking across environmental, socioeconomic, political and sectorial realms. The management of resource activities needs to be focused on realistic, practical steps that are directed toward reducing environmental damage, protecting biodiversity and promoting the health and prosperity of local communities. For such an approach to be successful, the relevant ecosystems need to be better understood, monitored and reported on. Actions must be based on clear objectives and a sound management structure, employing best available knowledge and practices, integrated decision-making and, where appropriate, a coordinated, regional approach." (Pame, 2014).*
>
> *Ecosystem approach*

The development of the economy of the world is to a large extent driven by technological progress and knowledge. With increasing knowledge, the view of the world changes and technological progress enables the industry, scientists, politicians and the general public to take on the challenges of the world in new and improved ways. Challenges dealing with population increase and natural resource scarcity have been prominent for the last 20 to 40 years. In order for the human population to survive, food security must be ensured. It is also preferable that the future human population´s living conditions should not be worse than they are now. This is in line with the sustainable development term proposed in the late 20th century to combat natural resource scarcity with the aim of keeping resource stocks constant (World Commission on the Environment and Development, 1987). From the economical perspective, sustainable development can be viewed in two ways. Firstly, in terms of utility, where the demand is that utility per capita should not fall over time. Secondly, in terms of resources, where the demand is that the society´s ability to generate well-being will be maintained.

This means that resource stock should be kept constant by only utilising the growth of the resource (Hanley, Shogren, & White, 2007). The definition of *bioeconomy* is also largely connected to the term *green growth*, which is used to promote or describe a path towards economic growth based on sustainable utilisation of natural resources, as opposed to traditional *industrial growth*.

According to Staffas, Gustavsson, & McCormick, (2013), the bioeconomy term has been developed as an extension of the sustainability term to account for the importance of increasing economic growth. Research and publications with topics such as *bioeconomy* or *bio-based economy* have increased dramatically in recent years. In 2000, publications on the topic were almost non-existent, but since then the number of publications referring to the bioeconomy has increased to approximately 60 per year and citations to over 500 per year (Stefánsdóttir, 2014).

The model in Figure 1, along with the European Commission definition, is in line with the vision and emphasis of the project presented herein. An economy where the reliance on non-renewable resources is minimized and exchanged for renewable resources, sustainable living standards and production where material and energy is renewed parallel to their consumption. Possible benefits of improved processes, resource- and co-product utilization and cooperation in the West Nordic countries needs to be supported with increased research and implementation of new solutions with eco-innovation, green growth, sustainable utilization and rural development at its core.

Definition of Bioeconomy in the report

The definition of bioeconomy can potentially promote several aspects. It has mainly been used in connection with economic activities focused on biotechnology (Staffas *et al*., 2013). Since 2005, several broader definitions of the bioeconomy have emerged, varying with respect to scope and issues covered (Staffas *et al*., 2013). Seven definitions can be found in the literature with each of them bringing different scopes and styles (van Leeuwen, van Meijl, Smeets, & Tabeau, 2013). (Staffas et al., 2013; van Leeuwen et al., 2013) studied official national approaches on the bioeconomy in the European Union (EU), United States, Canada, Sweden, Finland, Germany and Australia, and found that different definitions proposed seem to have a common ground in terms of specifying the resources and products of bioeconomy. They found, however, that the structures and aims of these national strategies and policies vary and the analysis is further complicated by the terms *bioeconomy* and *bio-based economy* having no clear definition. Furthermore, the national strategies are often based on requirements of the specific country with the emphasis on enhanced economy, employment and business possibilities. They often neglect to mention the aspects of sustainable use of biomass, resource scarcity, global perspective and how to measure progress. As such, Staffas et al., (2013) stress the need for increased research, development and demonstrations.

McCormik & Kautto, (2013) conducted an overview of the European bioeconomy, elucidating that the definition of bioeconomy vary greatly and is still evolving. However, the definitions show similarities regarding a broad sectorial focus and increased economic output and there is great optimism associated with developing an advanced bioeconomy in Europe. The concern, though, is the emphasis on presenting a technical fix and pre-empting alternative visions (McCormik & Kautto, 2013).

The European Commission (2012) defines bioeconomy as follows:

> The Bioeconomy … encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy ... (European Commission, 2012).

This implies that the bioeconomy is concerned with both primary and secondary activities. Other sectors may be connected with the bioeconomy as they might include services to bioeconomic activities.

In general the bioeconomy consists of activities concerning the production of biological resources, extraction of biological resources and production of products of added value from biological resources, consumption of biological goods and use of waste from the production chain of biological resources. The biological resources that can be identified are those which are currently utilised and those considered possible to utilise. Utilised resources have an economic value represented by their contribution to the economy while resources that are not utilised do not have a current value. Additionally, undiscovered or unidentified resources are a category worth exploring.

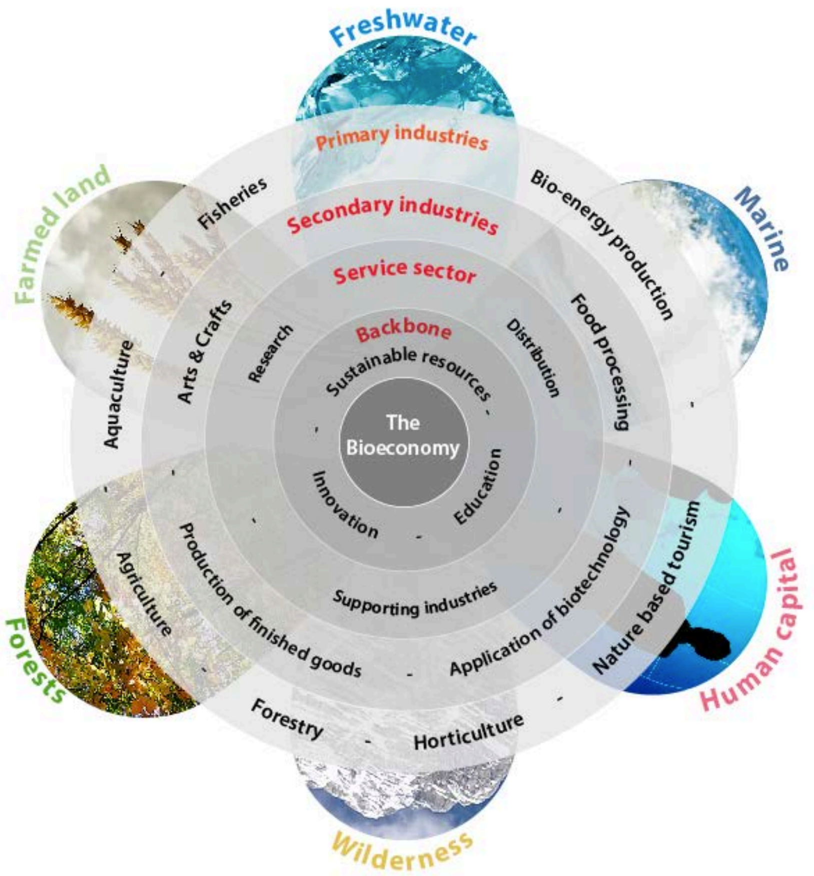


Figure 1. Proposed overview of the bioeconomy (Matis and the Environment Agency of Iceland).

Figure 1 presents a model on how the bioeconomy is defined in the present report developed by Matis, the Icelandic Food and Biotech R&D, and the Environment Agency of Iceland. This bioeconomy model endeavours to provide a visual overview of the build-up and interaction within the bioeconomy. The model identifies five main underlying sources of biological resources; wilderness, forests, farmed land, freshwater and marine, the sixth resource being human capital necessary for economical induction and utilisation of biological resources. The primary industries such as fisheries, agriculture and forestry have been placed on top of these basic sources overlapping with the resources. On top of the primary industries, the secondary industries and serving sectors are located, all overlapping different primary industries and sectors, emphasizing the importance of cross sectorial use of resources and side products and enhanced cooperation between sectors as a driver for stronger bioeconomy leading to economic growth. Finally, at the heart of the bioeconomy flower, three fundamental items have been identified as the backbone for a healthy and strong bioeconomy; sustainable use of resources, education and innovation capacity. These fundamental items are crucial in working towards a sustainable utilisation and optimal value creation within the bioeconomy.

1.1.1. Methodological framework for bioeconomy assessment

Bioeconomy could potentially have multiple ramifications but by defining a method or framework to assess a bioeconomy as proposed in this project, a significant step could be reached in its development. Several key factors were identified and documented regarding work towards methodological framework for bioeconomy assessment. During definition and elucidation of the term bioeconomy, it is necessary to go through the background and origin of the term bioeconomy with literary review and current definitions provided by various entities working on this subject. Economic, social and environmental dimensions of the bioeconomy concept should be explored in order to give a clear definition in synchrony with previous work and to structure concepts to be used in a bioeconomy assessment, including the sustainability within the bioeconomy, as well as the bio-based sectors and their drivers in relation to the rest of the bioeconomy. Special attention should be given to the connection between bioeconomy, food security and efficient use of resources. Evaluate the factors that will possibly scope the evolving bioeconomy and the types of policies that might be implemented to maximise the benefits of a bioeconomy assessment, as it is likely to be global and guided by principles of sustainable development and environmental sustainability.

The bioeconomy concept potentially offers a pathway for building a bioeconomy assessment methodology because no existing one addresses its needs. This should focus on the forming, creation and finally introduction of a new methodological concept for bioeconomy assessment. Such an assessment could be based on case studies on selected areas, small scale or nation-wide. In theory, the methodology contributes to a successful project in three ways. Firstly, it provides a framework for evaluating the problem the project is intended to address. Secondly, it forms a roadmap for the project, ensuring that all important stages are included. Thirdly, it provides a way of representing aspects of the developing project to stakeholders in the project through diagrams that generally form part of the methodology. It can be a complex process to create a methodological framework, but the process can be made easier by formalizing its steps.

A bioeconomy assessment methodology should take into account the West Nordic countries unique environment, involve the population, and promote environmental protection, resource utilization and sustainable development. The methodology could support:

- Activities stimulating innovation, such as development of cooperation between SMEs, education, and R&D organizations for improving business innovation and technology.
- Improving knowledge and skills of people in entrepreneurship, new technologies, marketing and promotion.
- Clustering in eco-friendly fishing and farming communities which emphasize sustainable and innovative utilization of local natural resources.

Bioeconomy Assessment methodology potentials

Local scale demonstrations, such as a case study, could assist in research and development on the bioeconomy, eco-innovation and utilization and increase and enrich regional cooperation. During a case study emphasis should be on mapping natural resources, industries working with natural resources, bio waste, co-products, under- and unutilized resources and everything that generally relates to the bioeconomy in order to spot opportunities for innovation and cooperation between local stakeholders. Case studies could assist in the methodological development and should focus on identifying driving forces of bioeconomy development in selected areas by analysing its key factors and conditions.

One of the most important steps in a bioeconomy assessment is opportunity analysis as it could potentially describe the opportunities available for a sector based on data from prior steps, such as data analysis, statistical evaluation and stakeholder interviews. Opportunity analysis should aim at innovation stimulating activities, such as development of cooperation between small and medium enterprises (SME's), the academy, research and development (R&D) organizations and industry for improving business innovation and technology, improving knowledge and skills of people in entrepreneurship, new technologies, marketing and promotion, clustering in eco-friendly innovation and production which emphasize sustainable and innovative utilization of local natural resources.

It is important that new opportunities are made visible and quantifiable. It could therefore be beneficial to develop indicators and other tools to evaluate the impact assessment that are related to social, economic and environmental factors. For example, the use of Life Cycle Assessment (LCA) within such a methodology could be considered to quantify in some form the expected impacts and results of implementing foreseeable opportunities.

The West Nordic countries are faced with major challenges related to general themes such as globalization, climate change and changes in human capital such as demographic changes and brain drain. The results from a bioeconomy assessment could prove beneficial for policy making in these areas. Bioeconomy is to be seen as a strategy and set of tools to solve a part of these problems. The West Nordic countries have different starting points and different approaches to address the challenges. Better and increased resource utilization sets the foundation of sustainability. The project described herein aims to share knowledge and to have an open exchange of experience and discussion as well as to increase the total knowledge base on the bioeconomy for the common good and leadership to enhance sustainable development. The project is in parallel with the European focus on bioeconomy and the need to strengthen the world's biomass production capacity to sufficiently feed the worlds growing population.

2. Bioeconomy in the West Nordic countries

A big part of the economy and environmental issues of the West Nordic countries fall under the umbrella of Bioeconomy. When writing a report about the bioeconomy in the West Nordic many issues can be related to all countries in the Arctic area. Here we will though only discuss the bioeconomy of the three countries that are a part of the West Nordic countries; Iceland, Greenland and Faroe Islands as these countries have much in common concerning the bioeconomy. The biological resources of agriculture, forests, wilderness, fresh water, marine and aquaculture in these three countries will be discussed and possibilities and opportunities of further utilisation of the resources identified. Along with these biological resources we will also discuss the reindeer herding in Northern Scandinavia as the circumstances of the reindeer herders are similar to other indigenous people in the Arctic. When referring to the area discussed in this report as a whole we use the term West Nordic countries (Figure 2).

Figure 2. Map of the West Nordic countries, Greenland, Iceland and Faroe Islands as well as the Arctic. Red line is the Arctic Circle (Source: www.nordphil.com).

2.1. Economical distinction of the West Nordic countries

The economic dimensions concerned with evaluating a bioeconomy are connected to measuring economic activity within the bioeconomy. This includes estimating the value added by these activities, their contribution to gross domestic product (GDP), the productivity of labour and capital, export value of products from the bioeconomy and their part in total export from the economy.

Evaluating economic dimensions of bioeconomy in the Nordic countries shows that the bioeconomy of the West Region of the Nordic countries can be considered different from the other Nordic countries. This region stands out from other Nordic countries as economic activities within the bioeconomy contributing are a big part of GDP although their added value is much less compared to the other Nordic countries (Stefánsdóttir, 2014). This economic similarities of the West Nordic that separate them from the other Nordic countries, provide grounds for these countries to join forces when it comes to emphasise and promote the regions common interest.

The common interests of the West Nordic countries are apparent as they distinguish themselves from the other Nordic countries when it comes to economic dimensions concerned with evaluation of the bioeconomy. West Nordic bioeconomy panel could have the mission to identify opportunities and to suggest a sound strategy for the West Nordic region in order to maintain and strengthen the bioeconomy in the region, as well as to communicate that strategy. It could serve as consultation venue and strategy forum, put common interest of the West Nordic countries more explicitly on the agenda of the Nordic Bioeconomy Panel, to be further feed into the European Bioeconomy Panel, setting EU strategy in the field. Furthermore, it could open up new opportunities for research and innovation in the region.

West Nordic Bioeoconomy panel

The opportunities in the West Nordic for product development are vast. The West Nordic countries depend more on export of unprocessed biomass than export of processed finished goods if compared with the other Nordic countries. Therefore innovation that increases processing and production of higher value finished goods is especially important in the West Nordic countries. This development of enhancing increased value of export of the West Nordic economy calls for research based support as well as practical support to industries and innovation.

During the Icelandic chairmanship in The Nordic Council of Ministers in 2014, the main emphasis has been on bioeconomy, as the program NordBio, focusing on Nordic bioeconomy, is the largest of three programs under the Icelandic chairmanship. The main objective of the tree year program NordBio is to strengthen the Nordic Bioeconomy by optimizing utilization of biological resources, minimizing waste and stimulating innovation thus enhancing the Nordic Bioeconomy. Important part of the NordBio program is innovation projects led by Matis. The first phase of these innovation projects focused on product development in the West Nordic countries, Iceland, Greenland and the Faroe Islands. The aim was to activate SME's as well as entrepreneurs in product development focusing on using underutilized local bio-resources for value creation. This focus on underutilized local bio-resources was decided on as a result of a status report from the current project on the

As a part of the NordBio innovation project, advertisements seeking ideas for product development projects were published in Iceland, Greenland and the Faroe Islands. In a single week, a total of 75 applications were submitted. The response exceeded the project organizers expectations, demonstrating the interest and need of such initiatives in the region. Simple application process and focus on sustainability and better use of resources instead of novelty is believed to be the cause of this large interest. Approximately 30 products were further developed based on the submitted applications, 26 of the products were exhibited at the "Nordtic conference" held in Selfoss, Iceland in June 2014.

West Nordic product development

bioeconomy of the West Nordic countries as it pointed out the need for innovation that increases processing and production of higher value finished goods in West Nordic countries. The results from the current project on the bioeconomy of the West Nordic countries will continue to be the foundation for such effort during the NordBio program as well as for future work within the West Nordic bioeconomy.

2.2. Food security and sustainability in bioeconomy

Sustainable development, food security, a bio-based society and green growth are some of the most pressing global challenges that societies in the West Nordic countries are facing. A sustainable and future-oriented community development as well as green economy is unthinkable without the production of food and other bio-based products. The present project aims to contribute to sustainable economic development in the West Nordic countries, through initiatives within the bioeconomy. The West Nordic countries have an economy based on raw material production using the materials and energy of its natural environment rather than final products with maximised added value. This is different from many service and manufacturing based economies. Hence, if these societies focus on increasing the value of their products combined with minimizing costs in the large resource based industries, this will positively affect the economy of the region. In particular, better use of resource (including less waste) can have vast impacts on the areas where the economy is almost totally dependent on the extraction and processing of marine raw materials.

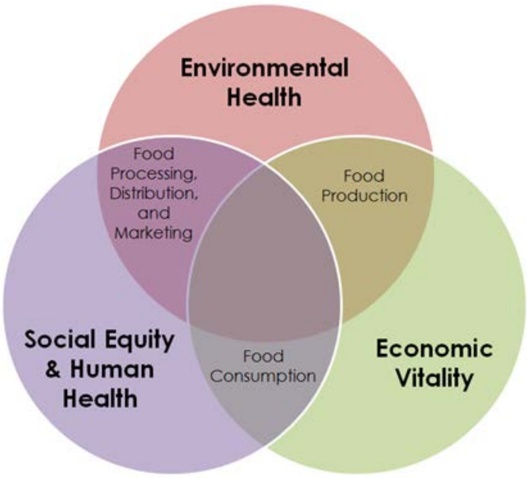


Figure 3. The three main subjects a healthy and sustainable food system has to focus on.

Food security is becoming a prominent and important topic in today's research and policy making. With climate change, an ever increasing human population and recent financial collapses, the significance of sustainable food production has attained greater attention. This attention has led to research and innovative ideas about the economic environment that food derives from, namely natural resources within the bioeconomy. In order to better understand the food security status of any area, country or region, it is essential to examine the import and export as well as production from natural materials. Such an assessment of the bioeconomy is a powerful tool to gain full overview of current situation and future opportunities regarding the utilisation of natural resources.

Food Security means that all people at all times have physical and economic access to adequate amounts of nutrition that is safe and culturally appropriate**,** produced in an environmentally sustainable and socially just manner, and that people are able to make informed decisions about their food choices.

Food Security also means that the people who produce our food are able to earn decent wages for growing, catching, producing, processing, transporting, retailing, and serving food.

At the core of food security is access to healthy food and optimal nutrition for all. Food access is closely linked to food supply, so food security is dependent on a healthy and sustainable food system.

A healthy, sustainable food system is a system that focuses on Environmental Health, Economic Vitality and Human Health & Social Equity (Figure 3).

What is food security and a sustainable food system?

Food security can sometimes seem an irrelevant term for western countries in the 21st century, with plethora of food on its markets. It is tempting to consider food security a problem pertaining to developing countries where prolonged shortage of nutrition is more common. However, looking back less than a century examples of food shortages was considered a problem in Iceland. Further, following the economic collapse in 2008, the cost of imported products in Iceland doubled when the exchange rate of the Icelandic currency devalued. This increased the price of necessities and fuelled inflation, demonstrating the vulnerability of food security in the modern world. With increasing population and, consequently, an increase in food demand combined with factors such as climate change and turmoil in international trading, the importance of having an ample supply of safe and secure food to feed a nation is emphasised (Ágústsson, 2009).

Behind the concept of food security lies a long interconnected chain that connects various production industries. Sustainability of feed, fertilizers and other necessities for food production and agriculture are also important. To be able to grow cattle or produce fish with aquaculture for example, feed production is essential. Although the feed could be produced in any given country, the raw materials are often produced and transported from around the world. Therefore, the production of cattle or fish is dependent on the import of raw materials. Feed and fertilizer are, therefore, an important factor in these food chains and affecting food security. The production method, use of energy inputs such as fossil fuels, coals or renewable energy should be considered as well. It is not realistic for each individual country to have a full and secure chain of food production, especially if it threatens sustainable utilisation of natural resources. The main emphasises must be on sustaining the natural environment so it can thrive in a new millennium with population increase and to enhance green growth. It is, therefore, important that developed countries recognise their responsibility not only in transporting food to developing countries, but also taking a leading role in driving technological advancements and information that can improve and change the food production in less developed areas, especially regarding sustainability. Present and future food production has global effects that reflect in the general debate and awakening surrounding this matter. Food waste has also gained increased attention, emphasising the effort of decreasing waste as a part of food security.

> In the West Nordic countries, the mobility between areas and to other countries is higher than the average level of the Nordic Region (Rasmussen, Roto, & Hamilton, 2013). However, migration from abroad to these areas also plays a significant role where individuals are seeking work in the resource industry. This migration has a considerable impact on the social composition of the Arctic regions (Larsen, Fondahl, & Rasmussen, 2013). Several groups play significant role in the migration into the area though two groups are the most dominant, women from Thailand and men from Poland (Rasmussen *et al*., 2013).
>
> *Mobility and migration in West Nordic Region*

2.3. Rural development – human capital

People in the West Nordic countries are living on the edge of the world in many senses. They are used to the ever changing weather, harsh environment and being dependant on what the land and sea can provide. The people in the West Nordic countries are, therefore, used to adapt to changes as a part of their livelihood. In the last decades, these changes have been more rapid due to both environmental changes and changes of the societies in the West Nordic countries. In many areas in the West Nordic countries the young people move to the bigger towns and cities for education and do often not return as there are more job opportunities in the cities with the result that the rural areas face ever increasing depopulation. The rural areas in the West Nordic countries can generally only provide jobs in the resource based industries such as fishing industry or agriculture and many young people and especially women find those jobs unattractive and hard labour and, therefore, move away to find more appealing jobs. In the last decade's women are majority of those seeking education in the West Nordic countries. As with other educated young people many of them are moving to the more populated areas, causing considerable brain-drain and gender imbalance in the less populated areas of the Arctic (Larsen *et al.*, 2013). Young people in the West Nordic countries are seeking more opportunities, economically and

> An interdisciplinary Centre of Excellence (CoE) focusing on issues related to the region such as bioeconomy, environmental issues, social issues, energy production and on solutions to increase added value of production of the region would benefit the rural development of the region. The CoE wold increase cooperation between the Nordic countries as well as with experts from other countries involved in Arctic research. The CoE would have multiple impacts, as it would turn the region into an attractive area for highly educated people as well as support and promote the economy of the area with research and innovation, create derivate jobs and increase the possibilities available in the area.
>
> *Arctic Centre of Excellence*

educationally, and moving from rural area to urban centres. This is causing social disruptions with ageing population with fewer productive members in the West Nordic countries societies with shortage of workforce and more people depending on the care sector.

2.3.1. Rural development in Faroe Islands

The Outer Islands Association has worked to create improved infrastructure for innovation in agriculture in the rural areas of the Faroe Islands. As a result, the Faroese state has created two funds, one for municipalities to improve infrastructure and one where individuals can apply for support to develop innovation in agriculture. The first project to receive support was an officially approved production facility on the island of Stora Dimun. The facility produces products for restaurants and grocery stores from sheep products - both meat and cured skins. It also sells products from horticulture. The investment has been a great success, and “product of Stora Dimun” has become a well-known brand on the islands. As a direct result, the population of the island has increased from two to eight. Stora Dimun has also served as an inspiration for other outer islands, and another approved production facility was built in Hattarvik on Fugloy with support from the municipality fund, as well as from the fund for innovation in agriculture. Furthermore, NORA has funded a project where Johanna Maria Isaksen produces rhubarb juice in her kitchen facility in Husar on Kalsoy.

Recently the Outer Islands Association has entered into cooperation with Research Park iNOVA in Torshavn and the Environmental Agency to create educational opportunities for small-scale agricultural producers. This project has received support from the North Bio initiative.

2.3.2. Rural development in Greenland

The urbanization that has been seen all over the world is also taking place in Greenland. There are 17 cities and 52 settlements in Greenland. Some of these settlements are very small, typically 30 - 75 residents, while there are only very few settlements with more than 200 people.

Table 1. Population in municipalities in Greenland (Source: Statistics Greenland, 2014).

	2012		2013		2014	
	January	July	January	July	January	July
All of Greenland	**56.749**	**56.810**	**56.370**	**56.483**	**56.282**	**56.295**
Kujalleq	7.417	7.302	7.151	7.189	7.088	7.024
Sermersooq	21.813	21.851	21.868	21.979	22.236	22.179
Qeqqata	9.638	9.668	9.620	9.517	9.436	9.465
Qaasuitsup	17.687	17.705	17.498	17.566	17.291	17.405
Outside municipalities	194	284	233	232	231	222

Several settlements are deserted and in the last 15 years, the population of the smallest settlements has dropped five percent in average each year (Nordregio, 2010).On July 1st 2014, there were 56.295

inhabitants living in Greenland. That is 13 more than on January 1st, this year, but 188 less than on July 1st 2013 (Table 1 and Figure 4).

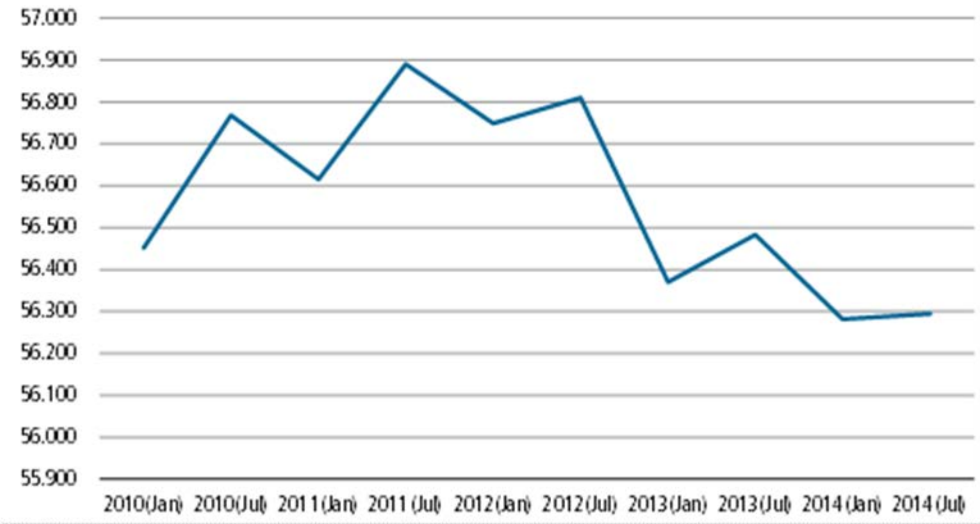


Figure 4. Total population in Greenland and recent development (Source: Statistics Greenland, 2014)

The urbanization combined with increased life length has resulted in that today pensions, disability pensions and employment within public services dominates more the economic base of the settlements compared to the past. According to Nordregio (2010), the settlements are relying on public service as an income resource, but hunting, fishing and sheep farming have been declining and is now more in the form of self-sufficient food supply (Nordregio, 2010). Along with the emigration of residents from the settlements the past few decades, the hunting and fisheries sectors´ role in maintaining the remaining settlements has diminished. However, the settlement residents are self-sufficient to a great extent through hunting and fishing. Generally, the number of women has declined by far the most in the settlements. Women also represent the largest group of people who emigrate from the country.

Fishing and hunting have traditionally been essential to the existence of the Greenlandic settlements. Jobs at the local fish factory can provide the economic basis for a settlement. If a seafood trading facility closes permanently or temporarily, the settlement is without real business and revenue opportunities.

It is often the large companies that ensure the existence of settlements. Through an extensive network of trading posts and factories the larger fishing companies creates jobs that small fishing companies would not have financial capacity to obtain. The big companies may have capacity to keep operation open for several years even though it is not profitable. After election in March 2013 the new government abolished subsidies to settlements factories but instead implemented substitute of eight million DKK for municipalities to reduce unemployment by initiatives like maintenance on dwellings.

This substitute does not include quota allocation to regions, except for one example were 2,500 tons of cod were delivered for two factories in the south. This is thought to be more of a short solution instead of a long time initiatives for many rural communities (Berthelsen, 2014).

2.3.3. Rural development in Iceland

In the report “Community, Economy and Population Trends in regions with long-term decline in population” published by Icelandic Regional Development Institute, 30 Icelandic municipalities where population declined by 15% or more in the period 1994 - 2011 were examined. The municipalities are principally located in the northwest, northeast and southeast of Iceland, in addition to Dalabyggd (West Iceland) and the Westman Islands off the south coast. The drop in population (Figure 5) in these regions varied from a little over 12% to about 50% during the period in question. In some communities population has begun to rise again in recent years.

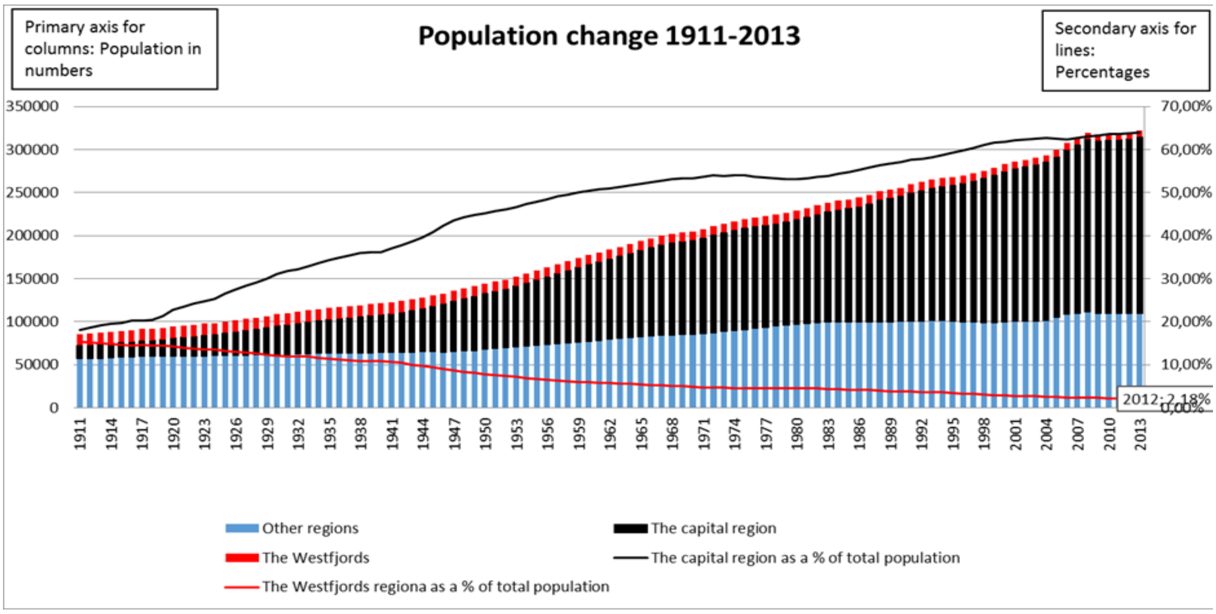


Figure 5. Population change in Iceland from 1911 to 2010 (Hagstofan 2014).

A clear difference emerges in population trends in rural and urban areas: for example, in one region the rural population has declined 30%, while in an urban centre in the same municipality the decline is only 5% (Þorgrímsdóttir, Karlsdóttir, Þórðardóttir, & Árnason, 2012).

The population of the Westfjords (North West Iceland) has been in steady decline since 1911. There has been growth in population in other regions of Iceland and most of the growth has occurred in the capital region. The Westfjords as a region face a great challenge in terms of the size of population, the current population is also getting older and there is a significant lack of productive people in the area that are at 20 - 40 years old. The imbalance is particularly serious among educated young women, but research has shown that this group is particularly likely to relocate from the countryside to Reykjavik due to more diverse employment opportunities (Gunnarsdottir, 2009).

Talknafjordur is a small community in NW Iceland with around 300 residents in southern Westfjords where extensive development is taking place around aquaculture. The impact is great and aquaculture now employs about 40 people in the village. Additionally, various services have been established in order to service the aquaculture business. Four aquaculture companies are operating in Talknafjordur; Tungusilungur, Fjardalax, Dyrfiskur and Arnarlax. It is estimated that employments by these companies will increase by at least 20% per year over the next three to four years (Indriðason, 2014).

Economic boom in Talknafjordur

Region like Westfjords, experiencing negative economic development and depending on fisheries and agriculture receive rural support from Icelandic authorities. In many communities reasonable large fishing companies are the back-bone of the economy and often they are involved in R&D development in their profession. Recently tourism and aquaculture are becoming more important like in Southern Westfjords were ambitious projects are undergoing in salmon and trout farming (Karlsdóttir, Þorgrímsdóttir, Þórðardóttir, & Árnason, 2012).

3. Arctic environment

The Arctic's natural environment and the industries around it create enormous biomass with a large portion currently un- or underutilized. While much of the biomass is currently wasted and is a source of cost, it can in fact be a huge economic opportunity. Many areas lack relevant capabilities as well the cross-industry cooperation needed to complete the R&D projects necessary to realize substantial economic and societal gains which are possible from eco-innovative and sustainable utilization of the biomass.

Eco-innovation encompasses a wide range of current and potential products, technologies and services but they all reduce the use of natural resources and decrease the release of harmful substances into the environment (Eco-innovation Observatory, 2010). The two major interrelated components of eco-innovation are based on renewable energy and resource efficiency. The activities proposed in this project will enable the West Nordic countries to accelerate eco-innovation in the areas by supporting the final beneficiaries to develop valuable tradable products which will drive growth, increase competitiveness and ultimately help create new, attractive jobs in the areas. Increased regional and eventually national resource efficiency will lead to the replacement of more traditional products with novel eco-innovative products with significantly less environmental impacts and lower carbon footprints.

Figure 6. The area known as Arctic and sub-Arctic as the area is identified in the AEPS declaration. The sub-Arctic areas are south of the Arctic Circle (AMAP, 1998).

3.1. The Arctic area

In the late 1980s international cooperation in the Arctic area increased and led to adoption of the Arctic Environmental Protection Strategy (AEPS) in 1989 when the countries concerned in welfare of the Arctic, Canada, Denmark/Greenland, Iceland, Norway, Sweden, Soviet Union and United States agreed upon the AEPS as a mean of protection of the Arctic (AMAP, 1998). In order to work together in the area of the Arctic and the areas of the sub-Arctic (Figure 6) these countries instituted five programs each aimed at various subjects. Several other programs and international agreements have been agreed upon in order to protect the Arctic in the best ways possible and since 1996 the Arctic Council is responsible for continuing the work under the AEPS (AMAP, 1998).

3.2. The Arctic Flora and Fauna

More than 21 thousands species of mammals, birds, fish, invertebrates, plants and fungi are living in the Arctic where these species have adapted to the cold and harsh environment, (CAFF, 2013). Many of these species are endemic to the Arctic and the unique ecosystems such as tundra, wetlands, ocean shelves, ice caps and the high sea-cliffs were millions of birds live in the summer. The short growing season with low temperatures, permafrost causing surface ponds and sea-ice cover are all characteristic to the Arctic and structuring the species and ecosystems in the diverse environment of the Arctic. On a global scale, the Arctic and sub-Arctic waters (Figure 6) are very valuable with over 10% of the fish and 5.3% of the crustaceans being caught in those waters (CAFF, 2013). In addition, commercial fishing generates the most income of any provisioning services in the Arctic.

> *"The Arctic Council Declaration was formally adopted in Ottawa, Canada in September, 1996 by its eight member states, namely Canada, Denmark, Finland, Iceland, Norway, Sweden, the Russian Federation, and the United States of America. The working groups of the Arctic Environmental Protection Strategy (AEPS): AMAP, CAFF, EPPR and PAME were integrated within the Council at the AEPS Ministerial meeting held in Alta, Norway in June 1997" (Arctic Council, 2014). Various intergovernmental and regional forms of co-operation between Arctic nations and other stakeholders (especially indigenous organisations) have emerged over the last 20 years, such as the Arctic Council, the Barents Euro-Arctic Council and the Northern Forum (Arctic Council, 2014).*
>
> *Arctic Council Declaration*

The Arctic is vulnerable to changes driven by the warming climate and higher CO_2 in the atmosphere and the climate change is by far the most serious threat to the Arctic. The ice on which many species depend is melting which forces the mammals to change their feeding behaviour and reproduction spaces with reduction in numbers and productivity as a consequence. Other possible effects of the warming climate in the Arctic are changes in the snow cover, changed distributions of ice-associated marine productivity, the increased frequency of wild fires, changed insect distribution and abundance, along with more extreme weather events and storms (CAFF, 2013).

3.2.1. The characteristics of the Arctic fauna

Relatively few mammals live in the Arctic as only 67 species of terrestrial mammals and 35 species of marine mammals are known to inhabit the Arctic. The species living in the Arctic are highly adapted to the cold and harsh environment and have the ability to survive in extreme conditions. The threats the animals in the Arctic have been facing used to be overexploitation but in the later decades climate change and pollution are proofing to be an even greater threat. Overexploitation of pelagic fish and its impact on wild seabird's species has to be considered. Overexploitation is not only a matter of maximizing catches but the is an argument and public pressure to reduce fishery on pelagic species in order to conserve enough fish to keep up a population of birds dependent on this food. The seabirds are not directly overexploited by catching and hunting but the population could be decreased due to overexploitation of food resources. The mammals have been subject to hunting in large numbers for some centuries and some of them are subject to major decline in numbers due to the hunting (CAFF, 2013). In the recent decades some of these species have recovered and by combining cultural tradition and modern science-based monitoring sustainable harvest by the indigenous people is possible.

As many of these species are high in the food chain they are prone to contaminants such as organohalogen compounds which are increasingly found in the Arctic food web (Letcher *et al.*, 2010). Other compounds such as polychlorinated biphenyls (PCBs) found in Greenland shark (Lu *et al.*, 2014) and in black-legged kittiwake and northern fulmar in Svalbard (Nøst *et al.*, 2012) and polybrominated diphenyl ethers (PBDEs) found in seven different marine bird species in Iceland (Jörundsdóttir, Löfstrand, Svavarsson, Bignert, & Bergman, 2013) can have severe influences both on the animals and birds and the people that hunt them or pick their eggs which also have shown traces of contaminants (Jörundsdóttir *et al.*, 2009).

The climate change is threatening many of the Arctic species by changing the environment they are adapted to and making living and breeding more difficult for the animals. For example the melting of the ice is known to have great influences on the polar bear as it needs the ice when hunting food for the puppies. The melting of the ice is also believed to have great impact on the permafrost in the Arctic as warmer climate will mean more melting of the permafrost which can change the ecological environment many species are dependent on.

The Nootka lupine was introduced to Iceland for use in afforestation areas as a soil conservation method in the mid-fifties and was widely sown by the Soil Conservation Service in land reclamation areas. It is now naturalized in most areas and spreads actively where sheep grazing is not heavy. Around 1970 the Nootka lupine was introduced in Greenland where it became popular garden ornament and has been used for reclamation of eroded areas. It is now found in several areas in the fjords of South West Greenland. The Nootka lupine was also introduced to Faroe Islands shortly after 1970 but there it is mainly used as garden ornament but has not spread as heavily as in Iceland and Greenland due to heavy sheep grazing in most areas (Magnússon, 2010).

Nootka lupine, *Lupinus nootkatensis*

3.2.2. Invasive plants

Some of the plants that have been introduced to the Arctic area have proofed to be invasive and could threaten the biological diversity in the areas where they have been imported. One of the plants that has proofed to be invasive is the Nootka lupine, Lupinus nootkatensis, which was introduced to Europe from North America late in the 18th century (Magnússon, 2010). Imported plants have been used in afforestation in Iceland and Greenland where the most common species are the Sitka spruce (*Picea* *sitchensis*), Lodge pole pine (*Pinus contorta*), Russian larch (*Larix sukaczewii*), and Poplar (*Populus trichocarpa*) along with several other species used in less amount as garden ornaments or in horticulture (Eysteinsson, 2013). Import of plants to Iceland is allowed only if the consignment is accompanied by a phytosanitary certificate and the plants have to be free from quarantine pest, however, some plants are altogether forbidden to import (MAST (Icelandic Food and Veterinary Authority), 2014). Import control of plants and a quarantine system has to be set up in Greenland in order to avoid further damage of crops where there have already been found several plant diseases that are known to cause considerable damage to vegetable and potato crops elsewhere in the world and do so in Greenland as well (de Neergaard, Stougaard, Høegh, & Munk, 2009). Import of plants to Faroe Islands is forbidden except under strict conditions.

3.3. Environmental issues in the Arctic

The Arctic and sub-Arctic environment has flourishing fauna. The marine ecosystem comprises of a divers flora and fauna as a result of the cold water masses flow into the North Atlantic from the north, meeting warmer water masses flowing from the south. However, both for aquatic and terrestrial fauna of the Northern hemisphere are relatively more specialised in their living and the food chains are shorter compared to temperate and tropic climate. This results in that the Northern ecosystem is more vulnerable to changes in climate and food availability. Environmental issues should, therefore, be highly prioritised by the Nordic countries to ensure sustainability and environmental quality forming the bioeconomy.

3.3.1. Environmental issues in bioeconomy

Sustainably utilisation of resources are important, especially in the fisheries as there is a growing demand to companies from the market to use more environmentally friendly production methods. Other environmental matters such as waste treatment and taking care of processing water from the fisheries activities are also important. The utilisation of Icelandic marine resources has improved significantly in recent years but continued vigilance and improvements are needed to keep up with future resource scarcity and increasingly complex regulations within EU.

There are opportunities for fisheries in the West Nordic countries to improve environmental issues as well as turning an existing problem into a valuable product. The fisheries discharge is a large amount of organic waste discarded into the ocean; a waste that needs oxygen for microbial degradation. The large amount of biological materials discarded to the environment is harmful as it induces undesirable anaerobic bacterial growths that produce harmful waste products as well as resulting in nutrient enrichment of the marine environment. The most commonly disposed material from fish factories are fat, organic matter, nutrients, salts, oil and detergents (Björnsson, 2012).

The highest proportion of disposed biological material in Icelandic fish industry comes from filleting and skinning the fish. Protein loss in Icelandic fish industry could be reduced by 50%, from 1.800 tons to 900 tons, with relatively crude filtering of production water. This is around 2% of total protein production lost in the process (Björnsson, 2012). Collecting materials that are currently not being used in the industry and turn it in to a profitable product is beneficial for the industry, as well as reducing the amount of disposed organic material by 34% (Þórarinsdóttir, Stefánsdóttir, & Arason, 2005). New developments in filtering techniques and processing technology will be of importance for improved processing methodologies in the future.

There is a global trend of raised awareness about economic, social and environmental cost of discards from fisheries with growing emphasis on optimal use of fishery by-products and to utilise the by-products as a valuable resource. Today, by-products coming directly from the fisheries *e.g.* from trimmings of the fish and other residues from filleting are used to produce fish protein. Approximately seven million tons a year from wild catch are destroyed/discarded as non-commercial product from fisheries in the world. From these discards alone around half a million tons of fish oil could be produced, equal to 80% of the need of fat for the salmon industry in the world. According to Food and Agriculture Organization of the United Nation (FAO), around 86% of world fish production (136 million tons) was utilized for direct human consumption, but 14% (21.7 million tons) of the remaining fish production was destined to non-food consumption, of which 75% (16.3 million tons) was used for fish meal and fish oil for aquaculture.

3X Technology´s most important product is ROTEX machinery used mainly in fisheries around the world as bleeding equipment as well as for cooling and thawing of fish for processing. The machine is water intensive and customers have urged 3X Technology's to find solution to recycle processing water, as use of water is expensive, as well as the increased environmental concern regarding disposal of waste water. To solve this problem, the company developed a filtration system, FiltreX to meet these market needs. The equipment was tested at fish- and shrimp factories in Isafjardarbaer in Iceland to estimate the value that FiltreX can return to potential customers in form of better utilization of processing water and improved environmental affairs of food processing. Possible "spin-off" of the project could be the potential for food producers to capture valuable materials (*e. g.* proteins) from the processing water, which could deliver greater value to fish producers (Thordarson, Hognason, & Haraldsson, 2013).

Today the shrimp factory is collecting more than one ton per day of valuable protein material that was previously discarded to the sea, and making a reasonable profit from the operation. This is a win-win situation were the project returns profit to the company and is environmental friendly by reducing biological waste to the ocean.

Win-win project in Isafjardarbaer

The residual of 5.4 million tonnes was used for non-food purpose, ornamental, bait, pharmaceutical and direct feed for animals (FAO, 2014).

Wild fish is a limited recourse in the world, with many fish species currently being overfished, underlining the importance of farmed fish as an addition to future protein source for many countries. Fish farming is expected to be an important world-wide protein provider with limited environment effects.

The growth in aquaculture is accompanied with increasing concerns over the environmental and social costs associated with the exploitation of the natural resource base on which it depends. In the Faroe Islands, aquaculture permits are managed by the Faroese Food- and Veterinary authority. Only a limited number of permits are given to reduce the risk of fish diseases, parasites and effects on the environment. After a series of disease outbreaks in the early 2000s, including infectious salmon anaemia (ISA), the demands for stringent regulation were emphasised in order to create a more sustainable and stable aquaculture environment. These demands resulted in the "Faroese Veterinarian Act on Aquaculture," one of the most stringent and comprehensive aquaculture veterinarian regulatory regimes in the world. Regulations have been tightened to prevent disease outbreaks from recurring. Aquaculture farming areas are totally separated and boats used in aquaculture are not allowed to move between different farming areas. Strong currents ensure that fresh sea water continuously flows through and around the cages. Mortality is generally low due to the strict management regime. New regulations, comparable to legislation in Faroe Islands and Norway, have been introduced in Iceland (Alþingi (Althingi the Parliament of Iceland), 2014). However, the responsibilities for permits and licenses are complicated, involving multiple agencies and overlapping requirements with unsatisfactory capacity and unclear authority and process (OECD, 2014). Effort has been taken to reduce the regulatory burden to speed up the process.

The growing human population and the global problem concerning the environmental impacts of production and consumption, call for immediate and increased actions regarding the pressure on the earth's ecosystem. By using a tool like LCA, a greater efficiency in production, transport and usage can be accomplished, which can drastically lower the outputs of harmful materials entering the atmosphere. The life of every product starts with the design/product development, and from that point adoption of resources and raw materials, production, use and finally the end of life activities. LCA is a methodology used to estimate and evaluate the environmental impacts of a product's life cycle. LCA is a standardized methodology by the ISO standard 14040 series (ISO, 2014).

LCA methodology

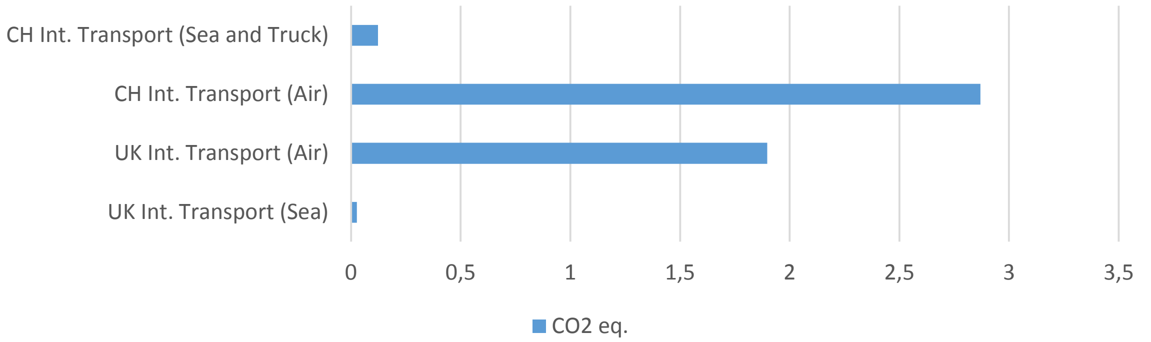


Figure 7. Calculated carbon footprint of cod loins with international transport, sea and air measured in equation of CO_2 per kilo of production

Matis published a report following a project "LCA of fresh Icelandic cod loins" in September 2014 (Smárason, Viðarsson, Thordarson, & Magnúsdóttir, 2014) where the carbon footprint on Icelandic fresh fish production was estimated and compared with fish production from Norway and also with other food production in Europe. The functional unit was one kg of fresh cod loin caught in Icelandic waters (by small line-boats, larger long liners and trawlers), processed and packaged in Iceland and transported to wholesalers in UK and Switzerland, by airfreight and sea containers. Data from catching, processing, transport and including waste and disposal, was collected in accordance with ISO 14040 for LCA and NS 9418:2013 on carbon footprint, estimating overall environmental impacts. The difference using airfreight and sea containers were stunning as shown in Figure 7 with comparison on exports to UK and Switzerland.

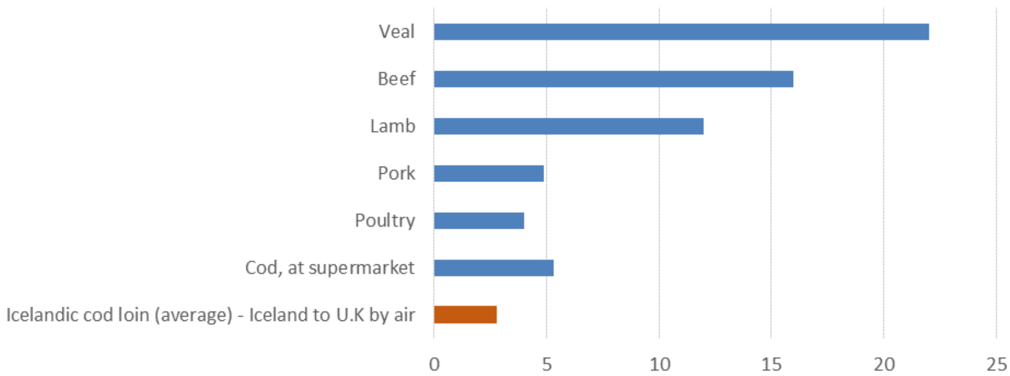


Figure 8. Carbon footprint of various protein production compared with Icelandic cod loin in kg CO_2/kg product. Meat results are from Buchspies et al. (2011), fish results are from (Smárason et al., 2014).

Figure 8 shows results from Buchspies, Jungbluth, & Tölle, (2011) of various protein productions compared with Icelandic fish, where the Icelandic result is an average of the carbon footprint of all types of fishing methods used in Iceland**.** This demonstrates that fish protein in general releases far less greenhouse gas compared to most meat products, even despite of being airfreighted from Iceland to the UK.

OECD, (2014) recommends Iceland to adopt the national spatial planning strategy and extend the planning framework to coastal waters and the ocean as well as to streamline environmental permitting and licensing procedures to reduce administrative cost. Further, OECD recommends to keep environmental risk in line with the potential economical achievement using adequate administrative capacity to pave the way for future decisions.

Subsidies in agriculture in Iceland are well above the average compared to other OECD countries, being environmentally harmful as they maintain a large numbers of grazing animals. This large number of animals causes unnecessary strain on the environment causing soil erosion and desertification, which are one of the most worrying environmental problems in Iceland. OECD recommendations are to reform the subsidies to sheep farmers to reduce negative environmental impacts for meeting environmental performance standards in Iceland (OECD, 2014). The negative impact of grazing is though limited by the *Farmers Heal the Land*, a program implemented by the government by the Soil Conservation Service.

Harmful government subsidies

Eutrophication is one of the most pressing environmental problems in dense areas of Europe and has influences on water streams and lakes as well as the oceans the water flows into. Agriculture in the West Nordic countries is relatively free of eutrophication from fertiliser and other materials used. This is mainly because of low population density in the countries and strong currents in the coastal waters. However the soil degradation is a serious environmental problem in Iceland due to overexploitation through the centuries. The reason is the volcanic origin of the soil, usually consisting of basaltic tephra, which is sensitive for the loss of vegetation because of overexploitation and harsh weather conditions through the centuries. In Greenland the ice covered area and harsh weather conditions have to be taken into account when arable land is utilized. In Faroe Islands the weather is more humid than in the other countries, which means the soil is more prone to landslides if the soil is overexploited. Other environmental issues in the Arctic are for example effects of climate changes and influences of oil, gas and mineral distractions along with dams and other structures affecting water flow in freshwater systems which can have drastic affairs on environment such as wetlands, estuaries and near shore marine habitats (CAFF, 2013).

3.3.2. The effects of climate change in the Arctic

For the last century average temperatures in the Arctic have increased at a double rate compared to the world average. Seasonal ice in the Arctic has reduced for the last 30 years and a dramatic change in snow coverage is clearly visible. These changes will have major impact on the balance of ecosystems (CAFF, 2013) as well as posing significant risks and hazards to communities. The Arctic is expected to experience the most dramatic changes and undergo faster warming than any other region due to polar amplification.

Direct and indirect social, environmental, economic and health impacts are expected to follow, such as decreased crop yields, heat stress in livestock and wildlife, and damage to coastal ecosystems, forests, drinking water, and fisheries. Melting of the sea ice is likely to affect populations of marine mammals, polar bears and the subsistence livelihoods of communities. Various Arctic wildlife populations already have been forced to adapt to changes in their habitats.

Fish stocks in the Arctic are dependent on algae blooms that provide food for small crustaceans and animal plankton. These in turn provide the basis for the enormous stocks of fish that live in the Arctic seas. Climate change would increase sea temperature, a factor that is extremely important for the survival, spawning and distribution of young fish. Furthermore, there are concerns that the nature of algae blooms along the ice edge could change as the ice retreats further inwards. Imbalances could also arise in respect of timing and locations that would be detrimental to fish stocks that are dependent on animal plankton for their food.

The sea has a tremendous ability to absorb CO_2. The ocean absorbed about 26% of all the carbon released as CO_2 from fossil fuel burning, cement manufacture, and land-use changes over the decade 2002 - 2011 (Quéré *et al*., 2012). The increase in greenhouse gas emissions has led to changing chemistry of the seawater, a process called ocean acidification which leads to an ongoing decrease in the acidity of the oceans (Quéré *et al*., 2012). The biological, social and economic effects of ocean acidification are likely to be extremely significant for the Arctic regions. Effects on the marine ecosystems are likely to have significant impacts on future fisheries, marine mammal harvesting and marine tourism. A large gap in knowledge currently prevents reliable projections of these impacts (AMAP, 2014). The Arctic Council States are responsible for more than a quarter of global CO_2 emissions, and should therefore consider taking a leading role in addressing the global ocean acidification issue. Scientific evidence shows that immediate reduction in CO_2 emissions slows down the acidification of the Arctic sea (AMAP, 2014).

It is clear that the Arctic region is facing dynamic times ahead; filled with both dangers and opportunities. Going forward, the focus must be on limiting risk and nurturing of the opportunities with research and development in sustainable practices. One of the key elements in that prosperity is research and advancements in the bioeconomy, with eco-innovation and green growth at its core.

3.3.3. The possible effect of a major oil spills on bio resources in Arctic oceans.

As the Arctic ice cover is diminishing due to climate change, new industrial opportunities arise as access to oil resources increases. The retreat of the ice cover also results in the polar sailing route is open larger parts of the year. The result of this is that one of the major threats to the coastal and marine ecosystems in the Arctic is pollution from oil spills which could have large ecological impact due to difficulties of containing and cleaning the oil in troubled weather and seas (CAFF, 2013). Hence, the difficulties and cost of cleaning an oil spill in the Arctic are likely to be higher and the implications for all parties involved greater. The environmental impact of an oil spill in the Arctic is suggested to be prolonged compared to warmer latitudes as oil decomposes more slowly due to colder temperature and less sunlight (AMAP, 1998; Jörundsdóttir *et al*., 2014). Further, low water temperatures cause slower growth rates, longer generation times and longer life span of many high latitude organisms, the time scale of impact and recovery following e.g. oil spills, could be longer in Arctic and sub-Arctic waters compared to warmer regions (AMAP, 1998). Bivalve molluscs, such as blue mussels, are highly affected by oil spills and studies indicate that individuals from pristine environment are more vulnerable to sudden exposure, such as oil spills, compared to individuals from more polluted areas (Albaigés, Morales-Nin, & Vilas, 2006; Halldórsson, Svavarsson, & Granmo, 2005; Stephensen *et al*., 2000). For animals higher in the trophic level, both seabirds and fur-bearing mammals are vulnerable to oiling as well as small cods that spawn under the ice. Exposure to oil affects the quality of fishery products for human consumption by imparting to them undesirable compounds, risking food safety, damaging marketing image and destroying livelihood of primary producers dependent on marine and coastal environment.

3.3.4. Possible mitigation measures and means to minimise damage

Information on current environmental situation, effects and degradation of an oil spill in the Arctic is vital in organizing national and international responses. Further research is, therefore, needed as this is not entirely comparable to warmer regions (AMAP, 1998). Technology and use of best practices in oil exploitation can minimize the frequency of oil spill events as well as the environmental impacts during an oil spill. The use of international standards is mandatory to reduce negative environmental and socioeconomic effects from oil and gas activities. This is particularly important when new areas are exploited and developed, as there may occur additional risks different from the existing fields and sites. In some areas, regulatory systems and legal regimes need to be updated and redesigned to protect human health, rights of indigenous residents and the environment.

3.3.5. Further needed research

Assessment of pollution sources, concentration gradients and long-range transport of pollutants, especially emerging pollutants, are crucial for the Arctic and sub-Arctic regions. Information on habitat fragmentation as well as socio-economic conditions and human health are lacking and will have to be gathered. Research to improve technology, oil spill clean-up and behaviour of oil in sea-ice are needed along with comparative studies of socio-economic effects of the oil and gas activity. Information on native flora and fauna as well as the ecological interaction are also necessary as introduction of novel species are always a risk with increased human activity. Introduction of new species in isolated ecosystems such as on islands as in the West Nordic countries can bring with it pathogens and parasites the plants and animals have no antidote against and can lead to great changes in the ecosystem along with financial losses because of less crop or animals dying.

4. Identifying and quantifying biological resources

When considering the bioeconomy on a country level, it is of interest to identify biological resources within each country's territory. This information will allow the identification of constraints which limit the countries utilisation of their biological resources. The country's territory consists of its land cover and fishing limits. Within these limits all biological resources, their production and use, define the bioeconomy.

Utilisation of terrestrial biological resources is constrained by the size and composition of the land available as well as the countries latitude. These constraints limit the production of crops and livestock breeding. Thus the size and composition of land has to be determined by categorising it by its state. For each lands cover category, the analysis should identify the biological resources available which consist of the flora and fauna. Within agriculture, all biological resources should be known by mapping farmers' activities. The same applies to forestry which, however, can also be found wild and is identifiable with land cover classification. Resources in wilderness will not be as easily identifiable but estimates are often available for species currently utilised. Same applies to wild species found in fresh water.

Utilisation of marine resources is primarily constrained by the size of territorial waters but also by the species thriving within the territorial waters, where the main resources of the sea are the fish stocks. Fish stocks that are currently utilised are those that are of most value as other species may have unknown value. Other marine organisms, such as the marine flora, are also part of biological resources that are increasingly being used.

Some resources cannot be classified as either land or marine resources, such as aquaculture. Aquaculture uses resources from both categories, as it exists both on land and in the marine, depending on the species bred as well as the environment present at the aquaculture site. Furthermore, there are potential resources within the category of discarded biomass (waste) and by-products.

4.1. Waste

Organic waste is often an unutilized resource which in many cases ends up being discarded, leading to an increased environmental effect and less resource efficiency, as well as being costly for the industry. There has been a development within the area of waste handling and treatment of waste in Europe where the focus has been on reducing the disposal of organic waste, e.g. through recycling. This development demands that organic waste is treated as a resource, instead of waste. One of the main barriers regarding recycling is a lack of interaction between supply and demand. Mapping of the organic waste fractions, in order to create demand, is therefore an important contribution to promoting recycling.

The project *Organic waste as a resource for innovation* is an ongoing cooperation project between Umhverfisstofnun (The Environment Agency of Iceland) and Matis, funded by the Nordic Council of Ministers. In the first part of the project, mapping of organic waste in Iceland, Greenland and the Faroe Islands will be carried out, focusing on by–products and waste from the fishing industry and slaughtering. Fishing industry is the largest industry in the three countries but agriculture is also important since it promotes sustainability in the countries. Iceland, Greenland and the Faroe Islands all have in common that they are remote islands where the nations are highly dependent on import of supplies. Mapping of organic waste and by–products is therefore important and can encourage innovation and sustainable economy of the nations.

Organic waste as a resource for innovation

Many West Nordic communities lack a sound waste management and are currently recycling limited amount of the waste (Gunnarsdóttir *et al*., 2014). The fishing industry is one of the most important industries in all the West Nordic countries, e.g. in Greenland where it generates about 14,000 tonnes of waste each year, whereof only about 20% is utilized (Nielsen, Nielsen, Maj, & Frederiksen, 2006). The amount of fish processing waste that is landfilled annually in Iceland is not as large as in Greenland (see Table 2) since a large part of this category is utilized for different purposes, e.g. production of fish meal and fish oil. Table 2 shows the approximate amount of organic waste that is collected separately and landfilled yearly in Iceland during the period of 2010 to 2012. The amount of slaughterhouse waste that is landfilled each year fluctuates considerably (Table 2) where fish processing and catering waste are more stable categories with less fluctuation between years. However, there has been an overall downward trend in the amount of organic waste being landfilled in Iceland over the past decade is, regardless of category.

Table 2. Approximate amount of organic waste separately collected and landfilled annually in Iceland in 2010-2012 (Umhverfisstofnun, 2014).

Organic waste category	Amount landfilled (tonnes/year) in 2010-2012
Slaughterhouse waste	6,000-9,000
Fish processing waste	2,000-3,000
Catering waste	300-500

An investigation of the composition of household waste in the capital region of Iceland in 2005-2007 showed that the proportion of organic waste (food waste) was 25% (Sorpa, 2007). The total amount of mixed household waste was 237 kg/person in 2007 (Umhverfisstofnun (Environmental Agency of Iceland), 2014), which means that the amount of organic waste was 59.3 kg/person annually.

A similar investigation on composition of household waste in Greenland was carried out in Sisimiut, which is one of the largest towns in Greenland (approx. 5,400 inhabitants). It showed that the annual amount of waste was 133 kg/person, where bio waste (food, food waste, flowers, etc.) was the primary category, or 42.8% (56.9 kg/(person year) (Eisted & Christensen, 2011). Compared to the average Danish household waste composition, where biowaste counts for 33.8% of the total amount (Eisted & Christensen, 2011), it can be seen that the proportion of biowaste is considerably higher in Greenland, while it is lowest in Iceland (25%). However, it should be noted, that the numbers from the Icelandic investigation are not fully comparable to the Greenlandic and Danish numbers, since more than just food waste is included in the term "biowaste" in the Greenlandic and Danish investigations. Those results are summed up in Table 3.

Table 3. Proportion of biowaste out of total amount of household waste in Iceland and Greenland (Danish number shown for comparison). Ref; 1) Sorpa, 2007, 2) Umhverfisstofnun, 2014, 3) Eisted and Christensen, 2011.

Country	Proportion of bio waste out of total amount of household waste (%)	Amount of biowaste (kg/(person year))
Iceland	25[1]	59.3[2]
Greenland	42.8[3]	56.9[3]
Denmark	33.8[3]	NA

The majority of waste in Greenland is disposed of in open dumps with little environmental protection (Eisted & Christensen, 2011). In general, increased recycling of organic waste in West Nordic countries communities can therefore serve as both environmental protection as well as encouraging local and national innovation, strengthening sustainable economy.

4.2. Methodology of identifying and quantifying biological resources

For quantification of land resources, a method for categorising the state of land has to be chosen. This method should preferably be applicable to all countries and take into account the diversity of the countries investigated. For the purpose of mapping biological resources, the method should categorise agricultural areas and other vegetated areas from barren land. For the purpose of such a mapping, FAO and United Nations Environment Programme (UNEP) have developed a classification system to classify land cover (LCCS) (Gregorio & Jansen, 2000) whereas other databases such as the Coordination of Information on the Environment (CORINE) classification in Europe are compatible in most cases with the FAO's LCCS (Weber, 2009).

The CORINE programme is a European cooperation which is intended to gather data on land cover of European countries. The main purpose of CORINE is to gather comparable information on the environment for all European countries and use this information to follow development in Europe's land use (Árnason & Matthíasson, 2009). The information gathered within the programme provides quality data on land resources available in the European countries, and this data should be used to assess land cover and resources when available.

Classification of land cover according to the CORINE standard divides land into five main classes which are further subdivided resulting in 44 land-cover classes. For the analysis of biological resources land connected to biological resources will only be considered. Total land area is also of importance in order to identify how much land can be cultivated. The mapping of land-cover should be done with square kilometres, however, for comparison of specific land-cover classes between countries ratios can also be informative.

Subclasses of agricultural areas are of particular interest for the bioeconomy, since they identify areas where the creation of added value from biological resources can be found. Within the class of forest and semi-natural areas some subclasses are representative of biological resources. The subclasses for forests should be considered but also natural grassland, moors and heathland. Other classes and subclasses are not considered as biological resources in themselves, although some organism in these areas will be considered a biological resource.

The CORINE classification is not available for Greenland and Faroe Islands, however, much effort is being put into a project called Arctic Spatial Data Infrastructure which will map the whole Arctic area and will be published in 2014 (Landmælingar Íslands (National Land Survey of Iceland), 2014). For countries where CORINE land cover classification is not available, approximation on comparable categories should be used. The information of the land composition in Greenland and Faroe Islands has been found in several reports, books and websites as cited in this report where necessary and will in most categories be comparable with classification used in the CORINE classification of Iceland. The composition of land in the West Nordic countries is significantly different from the composition of many other countries. For example, there are significantly larger areas in the West Nordic countries that are not cultivatable compared to other European countries.

The mapping of production, export and import is necessary for the evaluation of consumption status related to food security. The development of the production, export and import will be an important indicator for the development of food security. Additionally, these indicators can be used for further analysis on opportunities for better utilisation of biological resources, for food and other production.

Evaluation of the production is necessary for assessing the status of food security and economic benefits. Using production weight can be beneficial for evaluation of food security but have the disadvantage that aggregation over industries is not applicable. By using “added value”, the costs of products between steps within the industrial value chain is taken into account and thus has the advantage to allow aggregation over industries. Further, the use of added value allows summation of different kind of goods which are then weighted by their value.

The quantitative dimension of the bioeconomy represents biological resources available. Data on biological resources in most countries is available from several institutions based on different classes of resources. This data is generally presented per species.

Biological resources are quantified by number of livestock, slaughtered animals and areas of agricultural land, both for grazing and for crops of all kinds when agricultural resources are quantified. Resources of livestock are the animals that can be slaughtered for consumption without harming the sustainability of the stock. Resources of wildlife can be quantified by number of hunted animals and birds as well as number of caught wild fish and marine resources can be quantified by the weight reports from fishing vessels. Resources of wildlife are the animals hunted or caught without reducing the reproduction size of the species. Marine resources are also the sustainable fishing the stocks of fish can provide without doing damage to the future spawning stocks. Most of the data is available from statistics offices in each country and other references will be noted as well in order to have the best information available of the quantification of biological resources of the West Nordic countries.

4.3. Agriculture

Agriculture is the cultivation of animals and plants, however, these two classes of biological resources each need different methods for quantifying their respective resources. The most obvious suggestion for quantification of animal resources is to use numbers of animals as a basis for further analysis. Data for farmed animals should be accessible in most countries but some difficulty may arise when evaluating the number of species with a short life span. Thus the number of animals on a yearly basis might give a better estimate on the resource size, or measurement of annual production in weight. Areas used for crop cultivation give an estimation of the quantity of resources. For cultivation of vegetables and berries in the West Nordic countries, greenhouses are most often used and thus total area covered by greenhouses give an approximation of production possibilities. Agriculture has been conducted in all three countries in the West Nordic countries ever since the settlement in Iceland and Faroe Islands but only since the beginning of 20th century in Greenland (Þorvaldsson, 1994). Agriculture is relatively important in all of the countries investigated and is considered one of the main support of economy in these countries though it is relatively less important today compared to earlier.

4.3.1. Opportunities and threats in the breeding of new plant varieties in the Arctic

The current climate changes will have serious effect on food production globally and regionally. The agriculture needs to prepare for future changes in the climate and specific plant breeding programs should be part of such preparations. However, there are economic and political challenges. The number of species of crops included in breeding programmes in the Nordic and Arctic regions is decreasing where breeding has stopped on several crops relevant for Arctic agriculture, including some important grass species, all root/tuber crops and almost all vegetables. In the beginning of the 20th century, there were eight to ten different breeding companies and institutes only in Sweden. Today, there are two companies actively involved in breeding of crops as well as one active program on breeding of fruit and berries at the Swedish University of Agricultural Sciences. In Finland there is one enterprise, Boreal, actively involved in breeding of crops species, in Norway only Graminor is actively involved in crops breeding and in Iceland the Agricultural University is actively involved where the breeding programme on barley is well recognized. Cultivars as 'Skegla', 'Ískaría', 'Íslómur', and 'Ísskúmur' have been released where the focus for barley breeding in Iceland has been on early maturity, wind resistance and maturity at low temperature.

To get a better understanding of how key actors in the Arctic food system see the situation, an online survey was conducted. The work was carried out by Nordic Genetic Resource Centre, and in cooperation with national institutions. In the survey different claims related to plant breeding and farmers access to varieties and variety testing in the region was presented. Key institutions covering plant breeding enterprises, research institutes, farmers' organizations, authorities, non-governmental organizations (NGOs), and others were invited to participate. Approximately 90% of the responses strongly agreed or agreed on the claim that there is a need for new crop varieties for the Arctic. The majority agreed that a small market limits the breeding of new crop varieties in the region. Furthermore, the majority strongly agreed to the claims that a Nordic co-operation on plant breeding is important for the Arctic. To the claims on variety testing the majority responded that there was not a proper testing of varieties and that both the breeding enterprises' support and the official support for variety testing is limited.

The stakeholder survey showed a need of new varieties but the main trend has been on consolidation and centralization of breeding enterprises, less state ownership and support to plant breeding, and close-down of breeding in many agricultural crops and in almost all vegetable crops. If this trend continues, farmers' access to good varieties could be restricted in the future and the production of local food will be limited to a few (major) crops. Facing the great challenges with climate change and trends in plant breeding, there is a need for change. New structures for identifying biodiversity and genetic resources for climate change must be developed. A Public-Private-Partnership for pre-breeding has been established in the Nordic region. The purpose of the partnership is to support the development of Nordic plant breeding, satisfying the long-term needs of the agricultural and horticultural industries, specifically regarding adaptation to climate change. Projects involving ryegrass, barley and apple have started. However, to discover genetic resources for climate change adaptation and include these breeding co-operations across disciplines, broader cooperation with e.g.

enterprises is needed. A long-term commitment and long-term partnership is needed where, however, funding is often only secured for only one or very few years. Considering that climate change will have big impact on the food system in the Arctic region, there is a contradiction between the need of new varieties, as identified in the present study, and the recent changes in plant breeding and research efforts for Arctic agriculture. To meet future challenges new structures and initiatives for identifying genetic resources for climate change must be established. The chain "gene bank – breeding – seed companies – farmers" needs to be supplemented by new networks and linkages. To accomplish and sustain successive activities and use of plant genetic resources, efficient and comprehensive collaborative networks between institutions must be maintained, crossing national borders and developing joint solutions in the production of cereals, potato, vegetables, fodder crops, berries, etc.

Experimental cultivation of cereals is carried out in Faroe Islands with barley the most promising and important cereal. The aim is to produce barley for feed. In Faroe Islands barley was grown for centuries but as the labour and money moved from the agriculture towards fisheries and fish industries in the first half of the 20th century, the barley production in Faroe Islands gradually decreased and finally came to an end about 50 years ago.

Experiment in Faroe Islands

There is an increased interest in new and useful plant varieties to grow in the Arctic and there are several research projects being conducted on such plants. The Agricultural University in Iceland (earlier The Agricultural Research Institute) has carried out research and development of cereal cultivation in Iceland. A project on barley breeding started in 1960 and is still active 50 years later. Barley breeding has been successful and created adapted cultivars for the region. Barley is the cereal best suited for cultivation at high latitudes (Reykdal *et al*., 2014) and is expected to be important for northern agriculture in the future. Barley is of particular interest from a nutritional point of view since it contains health promoting dietary fibres. Considerable agricultural land is available to expand cereal cultivation in the West Region of the Nordic countries, for example in Iceland. It has been estimated that annual production of cereal (barley) in Iceland could be increased from about 15 thousand tons to 50 thousand tons per year (Sjávarútvegs- og landbúnaðarráðuneytið (Ministry of Industries and Innovation), 2011).

The increased interest on research of cultivation of cereals in the Arctic area, reaches outside the West Region of the Nordic countries as Orkney (Scotland), North-Norway and Newfoundland (Canada) have shown their interest and the research aims to find a range of varieties well-suited to North Atlantic conditions and for these varieties to be tested locally for growth and quality characteristics. Regional use of cereal grain crops for food and feed will reduce the reliance on imported grain and reduce the carbon footprint of the final product and finally support policy makers to obtain the overall goal of the future bio-economy by incrementally decreasing the use of petroleum based products.

> The current amount of sheep on the Faroe Islands can pose difficulties for sheep farming relating to the sustainability of grazing. The situation of the grazing area can change very quickly if the amount of sheep increases and can have drastic consequences for the grassland. More research is needed to verify the amount of sheep the grassland can carry. In Iceland the Soil Conservation Service has great experience in assessment of sustainable utilisation of grazing areas and has done a lot of research of the subject.
>
> *Sheep grazing in Faroe Island*

4.3.2. Agriculture in Faroe Islands

The agriculture sector in the Faroe Islands has limited production, both because of the availability of resources and the weather conditions. The CORINE programme and full land cover classification is not available for the Faroe Islands, therefore, the classification of land has to be undertaken by using other methods. According to the book "Føroya náttúra: lívfrøðiligt margfeldi" (Nature of Faroe Islands: Biological multiplicity) (Fosaa, Gaard, Gaard, & Dalsgarð, 2006), the total land area of the Faroe Islands is 1,400 km^2 of which the areas of grassland, infield and water are the most interesting for the bioeconomy. These areas cover together 1,200 km^2 or around 85% of all land. The most dominant vegetation in the Faroe Islands is grassland which is found from sea level to the mountaintops and is used for grazing or as pastures area supporting the sheep farming. The sheep are driven into the mountains in spring and gathered in the autumn where they are mostly kept indoors during winter. The grassland is often seen as being wilderness, however, the grass has been adapting to this for a millennium since the start of sheep grazing on the land in the Faroe Islands. Grassland is by far the largest area with 1,100 km^2 or around 76% of the total land area. This area is also sometimes referred to as the outfield where infield is usually cultivated land used for the production of winter fodder. A total of 108 km^2 fall into this category and is the area inside the city/village borders. The local production does in most cases not satisfy the domestic market and therefore large amounts of agricultural products have to be imported.

Sheep have been on the Faroe Islands for a millennium. The number of sheep which use the outfield as grazing area is around 70 thousand according to public records. On average, there are 57 sheep per km^2. However, it is difficult to find reliable data for the number of sheep, both because there are no official requirements for registration of individual sheep, and also because the majority of sheep are slaughtered at the farmers' home. Additional to these 70 thousand sheep, it can be assumed that around 5 thousand are being kept on private fenced plots, resulting in the total number of sheep to 75,000 (Table 4) (R. Djurhuus, 2013). The average litter size for the sheep on the Faroe Islands is one lamb per ewe.

Table 4. The amount of animals in Faroe Islands and the commercial production of meat and vegetables in tonnes and value in thousand DKK Source: (Johannessen, 2014).

	Number	Tonnes	Value (1,000 DKK)
Sheep	75,000	956	68,832
Cattle	1,990	80	1,920
Potatoes		60	660
Kohlrabi		20	400

In 2010, the total number of cattle was less than two thousand (Table 4), of which half were older than two years (R. Djurhuus, 2013). The exact use of the cattle is not stated other than 919 were registered as milking cows. Cattle are primarily used for milk production in the islands and the dairy industry is the largest single contributor of agricultural products in volume. The production of milk was seven million litres which is an average of 7.7 litres per cow. There is only one producer of dairy products, and the cooperative is owned by the farmers that deliver the milk for the production. There are no exports of any products in this category. The import of meat and edible offal is quite extensive, compared to what is produced within the country. Meat from bovine animals is the most imported but also swine, chicken and sheep meat are imported in large amounts (Table 5). Besides meat, the import of milk products and eggs are also quite significant.

Table 5. Import in Faroe Islands of agricultural origin in tons and value in thousand DKK (TAKS, 2013).

Description	Import weight (Tonnes)	Import value (1,000 DKK)
Meat	2,439	70,814
Milk, eggs and honey	1,714	44,955
Vegetable products	4,448	32,938

The production of vegetables is limited (Table 4) and mostly for private use. Other agricultural production includes potatoes, eggs, as well as geese, chicken, ducks and horticulture. Of these the potatoes probably have the highest importance. Most of the other products are produced privately and are therefore not included in any statistics.

4.3.3. Agriculture in Greenland

The CORINE programme and full land cover classification is not available for Greenland, therefore, the classification of land has been done by referring to reports and other information where the classes are somewhat comparable. The size of Greenland is 2.2 million km^2 but more than 80% of it is covered with ice and only 410 thousand km^2 are ice free. (Statistics Greenland, 2013). The average summer temperature is usually below 10°C and most of the soil is permafrost. The precipitation is limited in Greenland, where it is more extensive in South Greenland compared to the northern part of the country (Jensen, 2003). Of the ice-free areas, the forests cover two km^2 according to Forest report from FAO (Nord-Larsen, Bastrup-Birk, & Johannsen, 2010). Agricultural land is 2,420 km^2 but only 0.1 km^2 (1,071 ha) are arable and used for producing hay for winter fodder for livestock (Grønlands statistik, 2013). Further, there are about 0.001 km^2 (10 ha) used for production of potatoes and vegetables (Grønlands statistik, 2013). Coverage of lakes and rivers has not been classified though some research has been conducted (Jensen, 2003). The total cultivated land was approximately 1000 ha in 2012 (Greenland Agricultural Advisory Service, 2014).

The agricultural land available in Greenland has to be carefully utilized in order not to overexploit it. Along with the sheep and the tame reindeer there are also the wild reindeer grazing in similar areas. All animals have to be taken into account when the carrying capacity of the grazing land is valued in order to keep the grazing sustainable.

Sustainable grazing in Greenland

Greenland Agricultural Advisory Service keeps track of livestock in Greenland but the figures are partly estimates (Table 6) (Greenland Agricultural Advisory Service, 2013).

Table 6. Animals in farms in Greenland in 2014 (Source: Greenland Agricultural Advisory Service, 2014).

	Mother sheep	Ewe lambs	Ram	Ram lambs	Wether	Total	Horses	Dogs	Cats	Hens	Cattle
Nanortalik	1774	268	37	17	61	**2157**	12	6	4	18	0
Qaqortoq	3225	548	86	28	32	**3919**	21	17	5	65	18
Narsaq	11320	2129	236	126	144	**13955**	106	92	33	125	107
Paamiut	0	0	0	0	0	**0**	0	0	0	0	0
Nuuk	0	0	0	0	0	**0**	0	0	0	0	0
Total	**16319**	**2945**	**359**	**171**	**237**	**20031**	**139**	**115**	**42**	**208**	**125**

Sheep ranching occurs in South-Greenland and the sheep farms use most of the land classified as agricultural land (Jensen, 2003). In 2010, there were 49 farms in Greenland and most of them in the Narsaq district (Grønlands statistik, 2013). The total of 125 cattle is located in six farms (Greenland Agricultural Advisory Service, December 2013). The average size of farms in Greenland is about 22.5 hectares (Rambøll Management Consulting, 2014). Rapid changes are in the agriculture in Greenland, from 2002 the number of farms has decreased 22% to the year 2012 when the number of farms was 44. However, each farm has more sheep than before (Grønlands statistik, 2014). Three farms have less than 300 sheep and only one farm had less than 100 sheep in 2012, where 17 farms had more than 500 sheep (Grønlands statistik, 2014). Beekeeping has increased since 2010 and in the summer 2014 there were 21 active beehives in Greenland (Guldager, 2014).The Government subsidies the agriculture in order to produce meat for the local market in Greenland and there is an import tariff on foreign sheep and lamb (Rambøll Management Consulting, 2014).

Although residents of Greenland have historically not placed much importance on agriculture, the climatic conditions of the land for agriculture are improving in the southern region. This has allowed farmers to expand the production of existing crops. However some negative effects have been seen in relation to drought in most areas. Cattle ranging has also recently started in Greenland and there seems to be possibilities both in Nuuk area and South West Greenland, which could reduce and minimize import of beef and other products from cows.

Opportunities in agriculture in Greenland

A modern slaughterhouse is run for slaughtering lambs as well as cattle, musk and reindeer (Rambøll Management Consulting, 2014). The slaughterhouse has a capacity of 35,000 lamps annually, which are 10,000 more animals than earlier. However, the numbers of lambs delivered are only about 22,000 (Table 7) (Neqi A/S, October, 2014).

Table 7. Slaughtered animals in numbers in 2013 – 2014 (Source: Neqi A/S, October, 2014).

Year	Lamb no.	Sheep no.	The average kg	Lamb in all tonns	Cattle no.
2013	20,337	1,522	14,57kg	331	19
2014	20,072	2,258	14,68kg	343	29

Reindeer are also farmed and the number of tame reindeers is approximately 3,000 (Grønlands statistik, 2013). The meat production in Greenland, number of slaughtered animals and the value of the meat produced in Greenland in 2010 is listed in Table 8.

Table 8. Number of slaughtered animals, tons of meat produced and value of meat production in Greenland in 2010 in thousand DKK (Grønlands statistik, 2013).

	Number	Tons of meat	Value (1,000 DKK)
Lamb	21,113	349	19,877
Sheep	1,241	31	830
Reindeer	194	7	103

No production of eggs, milk or any milk products are registered in official figures in Greenland, hence these products are imported (Table 9). However, most farms have chickens for private use. The potato production is approximately 130 tonnes annually, which responds to approximately half of the annual consumption in Greenland (Rambøll Management Consulting, 2014). There is, however, an increased interest in Greenland to grow more vegetable and with warmer climate it could be possible (Lyall, 2007). Other production includes rhubarb, turnips, some lettuce, strawberries and tomatoes, where most of this production is home grown and consumed by the growers and hence there are no public figures of the production (Rambøll Management Consulting, 2014). The grass for hay which is produced in Greenland is harvested before it reaches full maturity and used for animal feed (Rambøll Management Consulting, 2014).

Table 9. Value of import and export of agricultural origin in Greenland in 2010 in thousand DKK (Grønlands statistik, 2013).

	Import	Export
Meat and meat preparations	175,378	264
Dairy products and birds eggs	106,408	0
Vegetables and fruit	137,134	9

In 2013, the Government of Greenland established an Agricultural Commission that finished its report in March 2014. The most important work of the Commission is to show the way for increased self-sufficiency primarily of lamb, reindeer, cattle and not least vegetables. The recommendations from the Commission are now under preparation for implementation. The recommendations are dealing with three main items:

a) Revision of the relevant laws and bylaws so they are updated and modernised.
b) A financial plan for renewal of the houses, including barns and other constructions
c) Focus on cost-saving initiatives and energy-saving initiatives, including sun energy and hydropower.

4.3.4. Agriculture in Iceland

The area of Iceland is 103.4 thousand km^2 of which 61.4 thousand km^2 are not considered as biological resources. Of agricultural areas, only three subclasses were identified in Iceland; non-irrigated arable land, pastures and complex cultivation patterns. Together these cover 2.5 thousand km^2 which is only

2.4% of Iceland's total area (Árnason & Matthíasson, 2009). The CORINE classification only identifies areas which are greater than 25 hectares and thus this is most likely an underestimation of agricultural areas. This limitation also affects the ability to subdivide the area. Total area of forests in Iceland is about 1,300 km^2 which is 1.3% of Iceland's total area. According to CORINE classification land should be considered to be pastures if it is used for animals but to be classified as natural grassland if that is not the case. In Iceland there is not a distinct difference between these classes and the estimates will most likely be improved with future updates (Árnason & Matthíasson, 2009). The classes of moors and heathland and natural grassland can be considered as biological resources of Iceland but are currently unused. They cover 38,870 km^2 in total.

Table 10. The total number of Icelandic livestock in 2010 (Matvælastofnun (Icelandic Food and Veterinary Authority), 2013)).

	Total number	Females
Sheep	479,605	374,332
Horses	77,196	28,880
Cattle	73,781	34,241
Pigs	3,615	3,549
Goats	729	

The Icelandic Food and Veterinary Authority (MAST) collect data on the Icelandic livestock (Table 10). This data comes from inspectors who visit the farms each spring and also from farmers who provide data each autumn. The proportion of female livestock gives a better estimate on the resource´s production capacity. These numbers do not give complete information on offspring over a whole year. Numbers for pigs only include sows and boars while numbers of sheep include some lambs. However, they do not include the total number of lambs born each year.

Agriculture in Iceland has been practiced in some form since settlement and has been one of the key factors in the country's prosperity, food production and security and even employment through the ages. The agriculture industry produces various products that are known for their freshness and quality. The Icelandic agricultural policy aims at producing and supplying food for the domestic market and habitat needs (Bændasamtök Íslands (The Farmers Association of Iceland), 2013). The main purpose of breeding livestock and poultry is food production. This is production of meat from slaughtered animals and products from live animals such as milk and eggs. The Icelandic livestock bred for food production includes sheep, cattle, horse, pigs and poultry.

Agriculture in Iceland

Poultry breeding in Iceland is primarily breeding of chicken for meat production and hens for egg. The numbers of chicken are only numbers from Icelandic farms at a specific time rather than on annual basis. To obtain numbers of chickens on annual basis numbers of slaughtered chicken could be used. In 2010, a total number of 4.4 million poultry were slaughtered (Matvælastofnun (Icelandic Food and Veterinary Authority), 2013)). Breeding of turkeys, ducks and geese is small compared to chicken breeding.

Domesticated animals in Iceland in 2010 utilised for fur production include mink (37 thousand animals), few foxes and some rabbits (Matvælastofnun (Icelandic Food and Veterinary Authority), 2013)).

Icelandic farmers have to be careful when the grazing capacity of the available land is assessed (OECD, 2014). Both sheep and horses have great impact on their grazing areas if the animals are too many in each area. Great effort is being spent in order to keep the consequences to a minimum and the Soil Conservation Service of Iceland and the farmers have been working together to minimise the damage and combat desertification. Ecosystem degradation is by far the largest environmental problem in Iceland and vast areas have been decertified after over-exploitation through the centuries, magnified by volcanic activity and harsh weather conditions. Great care has to be taken to avoid further harm to the land and to revegetate damaged areas.

Sustainable agriculture in Iceland

Around 400 farmers around Iceland utilize the eider duck for eiderdown. The eider duck has been protected by law in Iceland since 1847 and the collection of eiderdown is totally sustainable as the eider sheds some down to keep the eggs warm and leaves it in the nest when the chicks hatch. The farmers protect the eider in the nesting ground against foxes and predatory birds and collect the down from the nests, clean it and sell for use for example in down comforters and jackets. The eider appreciates the protection and is more likely to lay eggs in a protected ground as the bird feels safer there than in the open. In 2012 the export of eiderdown was 3,081 kg and the value was DKK 23.5 million (GHJ, 2013).

The horsemanship in Iceland is connected both to agriculture, sportsmanship and tourism but no official overall strategy for the sector has been agreed upon except for the improvement of the stock. Horse breeding belongs in the agricultural section, whereas horse competition is a part of the sports in Iceland and the many horse renting firms are a part of the Icelandic tourist industry.

The total value of the Icelandic horse stock is estimated to be up to 100 million DKK, with the value of Icelandic horse export estimated around 50 million DKK per year (Möller et al., 2009). Horse export jumped in numbers in 2008 due to currency devaluation when 2.100 horses were exported. Adding horses sold domestically to export, about 9000 horses or 10-12% of the total stock was traded each year. The value of exported horsemeat in 2008 was 5.3 million DKK and increased appreciably from previous year (Möller et al., 2009).

According to Hulda Geirsdóttir at the Horse Breeding Association of Iceland it is difficult to estimate the value of the Icelandic horse stock. The industry has many branches related to horse breeding, such as taming, horseshoeing, meat production and veterinarians. She estimates that 250 companies are related to the horse industry with 1 or more employee, and about 25.000 Icelanders are involved in activities related to horses. The Icelandic horse is one of many attractions for the tourists visiting the country and there are several horse renting companies offering both short and long riding tours. Two universities in Iceland offer horse related studies and many foreign students as well as Icelanders attend the programmes.

From 1990, the overall meat production from Icelandic agriculture (including sheep, horse, cattle, pigs and poultry) has been growing steadily, from 17 thousand tons in 1990 to 29 thousand in 2012. During the reference year of 2010, a total of 27 thousand tons of meat was produced as shown in Figure 9. The import of meat and dairy products to Iceland is very limited due to high taxation including protective taxes, due to the policy of sustainable agriculture production in Iceland. In 2010, 700 tons

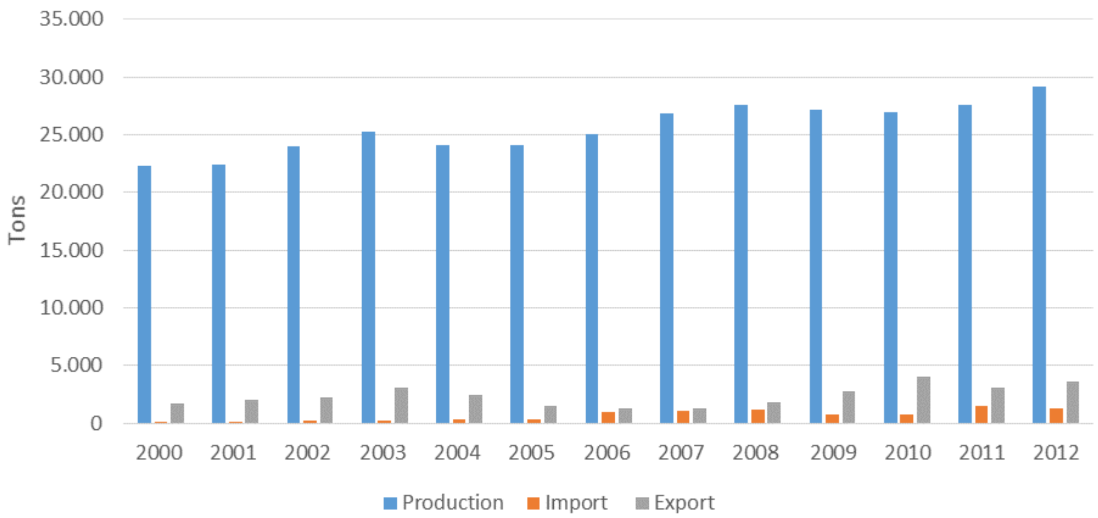


Figure 9. Production of meat in Iceland with import and export from 2000 – 2012 (Hagstofa Íslands, (Statistics Iceland), 2014).

of meat was imported to Iceland at the value of around 22 million DKK, the import in the years 2011 and 2012 was twice as much, 1.5 thousand tons and 1.3 thousand tons, respectively. Export of meat was 4 thousand tons at the value of 110 million DKK (Figure 9).

Milk production in Iceland follows the same principles and policies as meat production, i.e. to manage sustainable production for the domestic market where production volume, import and export is shown in Table 11. Export of dairy products has, however, increased in recent years, from 60.9 tons in 2004 to 1,250 tons in 2010. Production of milk in Iceland in 2010 was 123.2 million litres (Hagstofa Íslands (Statistics Iceland), 2014).

Table 11. Production volume of milk in Iceland with import and export value of dairy products in million DKK (Hagstofa Íslands, Statistics Iceland) 2014).

	Production	Import	Export
Litres/tons	123,200,000	280	1,253
Value	593	12	25

Vegetable production was not prominent in Iceland until the 19th century due to Iceland's geographical location and environmental conditions. In the beginning of the 20th century people began growing vegetables in gardens near their houses to provide for their families and some decades later, geothermal heat was utilised for greenhouse production of vegetables and the foundation of a new sector was born (Sigurðsson, 1995). As a country located in the middle of the North Atlantic Ocean, condition for vegetable production and horticulture in general does not seem to be acceptable. But with geothermal heat and almost 100% renewable and secure supply of energy, Iceland could potentially saturate the domestic market, promoting further food security and save large amount of currency with less external trade. For the cultivation of many exotic types of vegetables in Iceland, producers are limited to geothermal heat and electricity for greenhouse production and the production has to be located where geothermal heat and electricity delivery is available.

Skyr is an Icelandic cultured dairy product and an important part of Icelandic heritage dating back to the settlement of the country. At that time skyr production existed in the other Nordic countries as well but seems to have vanished except for in Iceland. Modern skyr is produced from pasteurized skimmed milk and sometimes flavoured with berries, vanilla and other ingredients. Skyr is considered very healthy, high in protein, vitamins and calcium and low in fat. Skyr is very popular in Iceland and has been gaining markets in the US, UK and Scandinavia. 25 million skyr canisters are expected to sell in Scandinavia alone in 2014, a 20% increase from 2012, due to interest in protein rich food.

Skyr – Delicacy with history

In 2002, following the elimination of customs duties, subsidies system was introduced for domestic production of tomatoes, cucumbers and paprika. The goal was to lower prices for consumers of imported and domestic horticultural products, increase the efficiency and competitiveness of domestic manufacture and generally supports the production and marketing (Arnarson & Kristófersson, 2010). This resulted in production increase (Figure 10) that indicates that domestic production of tomatoes, paprika and cucumbers is serving the market better and their production is driven by market forces (Þorkelsson *et al.*, 2012).

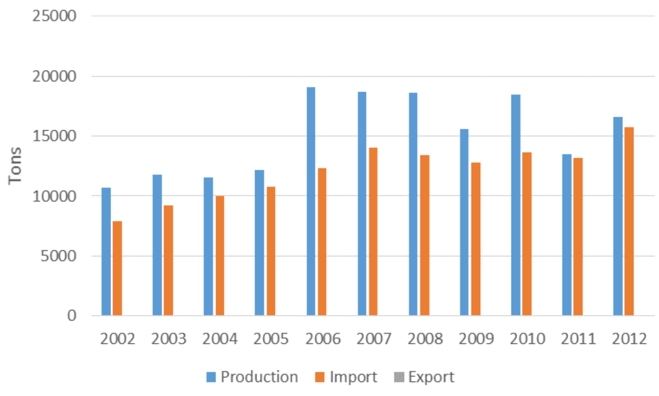


Figure 10. Production of vegetables in Iceland with import and export volumes (Statistic Iceland, 2014)

Crop production in the year 2010, other than hay, was 13 thousand tonnes of cereals and 18.5 thousand tonnes of vegetables. Production of potatoes forms the largest part of vegetable production, where 12.5 thousand tonnes of potatoes were produced in 2010. Hay production was not included since it is considered part of livestock breeding. In 2010, total hay production was over two million cubic metres (Stefánsdóttir, 2014).

Cereal farming, a new branch in Icelandic agriculture, is indeed marginally feasible due to climate conditions. However, it has brought new thinking into feed production. Field rotation has replaced haymaking from permanent hayfields, often 20 – 50 years old, and has generally benefitted the agriculture as a whole. Barley is the main cereal crop in Iceland as it is the cereal that is best suited for cultivation at high latitudes. Barley production has increased in Iceland over the last decade, from almost 10 thousand tons in 2003 to almost 17 thousand tons 2012. Barley yield is though heavily dependent on weather conditions, e.g. the barley yield was considerably lower in 2013 than in 2012 due to bad summer conditions.

In order to restore eroded land in Iceland, several plant species have been used such as the Nootka lupine, *Lupinus nootkatensis,* Blue-Lyme grass, *Leymus arenarius,* Bering's tufted hairgrass, *Deschampsia beringensis,* and Italian ryegrass *Lolium multiflorum* along with several others species. In cooperation with the Soil

Large portion of consumed vegetables in Iceland are imported. About 45% of overall fresh vegetables were imported in 2010, 13,660 tons with value of over 93 million DKK. Consumers in Iceland prefer and opt for Icelandic vegetables over foreign. As such, the opportunity to increase domestic production is relatively large. There is a need to examine further use of vegetables in other food products such as tomatoes in salsa sauces, horticulture value chain and storage methods (Þorkelsson *et al.*, 2012).

The salad and berry production in Iceland has been increasing in recent years, and there is still a great opportunity for further increase. It has been publicly stated by the Icelandic Association of Horticulture Producers (Bjarni Jónsson, managing director), that a long term strategy is needed for the business framework of the horticulture sector, including electricity price strategy. A well-executed supportive strategy would result in a great increase in production, increased food security and self-sufficiency.

Opportunities in vegetable production

Conservation Service in Iceland farmers have done a great deal of land restoration but there is still a lot of work to be done on eroded land in Iceland.

4.3.5. Summation of agriculture

Agriculture in the West Nordic countries is limited by the unfavourable environment. Greenland and the Faroe Islands also suffer from how small part the arable areas is of the total area of land. The coverage of the arable areas and the weather are the most limiting factors in agricultural production however there are methods available that can be used in order to utilise the land in the best sustainable way.

> The use of greenhouses in Greenland and Faroe Islands to produce vegetables for domestic use is a possibility in order to increase production of vegetables in areas not suited for outdoor cultivation. The early sowing in the greenhouses can positively affect the vegetables production and is worth further research.
>
> *Greenhouses in West Nordic countries agriculture*

For all countries investigated, it is important to estimate the carrying capacity of the land used for sheep grazing, as well as for reindeer in Greenland. In the harsh environmental surroundings of the West Nordic countries, the grazing is one of the most vulnerable factors in keeping the sheep farming sustainable and in Iceland the sheep farming is far from being sustainable in large areas. Both in Greenland and the Faroe Islands, farmers are willing to produce more meat for the domestic market but the grazing area is a limiting factor in both countries. In order to increase the domestic meat production, farmers have to bear this fact in mind and should be ready to find other ways to feed the animals if suitable grazing areas are not available, such as having enough hay or other fodder available. Grazing during winter can have negative effects on the grassland and feeding the sheep with hay or other fodder as well can ease the pressure on the grazing area. If hay or fodder has to be imported, the benefit of having domestic meat production has to be valued versus the import. The production of eggs and chicken can also be a possibility for farmers in Greenland and Faroe Islands, however, most of the feed will very likely have to be imported. Greenland could possibly increase fish waste utilization by diverting fish waste into feed production fit for mink farming, if possibilities of mink farming in Greenland were explored.

> The most promising opportunities in agriculture in the West Nordic countries are to emphasise the clean air and water when growing vegetables and producing meat from sheep and reindeer, *i.e.* the clean and healthy production the farmers in the West Nordic countries can provide in a sustainable way.
>
> *Opportunities in West Nordic countries agriculture*

Producing vegetables for domestic use in greenhouses can be utilised in both Greenland and Faroe Islands, even though these countries do not have the geothermal heating the Icelandic horticultural producers have. Greenhouses with limited heating to keep them free from frost during winter can make a great difference in early sowing followed by growing plants inside and then planting out in open areas during the summertime. By using this method the production can be maximized at a relatively low cost as well as replacing imported vegetables and increasing job opportunities. The current climate change can possibly stimulate the growth of the horticulture in the Arctic though it will also bring new and unforeseen consequences such as more droughts in summertime as well as more wind and rain in wintertime due to the changes in the atmosphere. Novel pests in form of e.g. insects and fungi might also be a future problem related to higher temperatures in the Arctic. Due to drought the need for water in vulnerable areas can be addressed with irrigation and water distribution systems in order to prevent crop failure.

The future of agriculture in the West Nordic countries lies in the opportunities of clean air and water which the intense farming of Europe can hardly keep up with. With growing tourism in the West Nordic countries the need for food increases and the market for the agricultural production in each country grows as well. In order to meet this growing market, the farmers have to be well aware of recent developments in production, innovation and marketing opportunities and keep up with the latest trends in the food market. The people living in the area can also benefit from the new food market opportunities and will be able to buy healthy and sustainable food produced nearby which also leads to less transportation, increased sustainability in food transport as well as less use of governmental currency for import of goods. If the domestic production exceeds the domestic market demand, the possibility of export is available. In the West Nordic countries the domestic market will though be the most prominent market in terms of sustainability and interests of the producers regarding job security and increased income.

4.4. Forestry in West Nordic countries

The utilisation of forests depends on the forest type available and both the total area covered by forests and as well by the area per forest type should be considered when quantifying the forest resource. Different categories of forests should be quantified by the area they cover as well as wild life integrated in the forests should be considered a part of the forest wilderness.

Today, bioeconomy from forests in Iceland, Greenland and the Faroe Islands are minor, however, increasing forestry will lead to further value in the future. Interest in products from forests other than timber is increasing in Europe and utilisation of various materials from the forests is growing where picking of mushrooms, herbs and berries is becoming more and more popular. Research regarding health and traditional knowledge of the products and the value of the natural products from forests are gaining more interests and, therefore, more financial support.

4.4.1. Forestry in the Faroe Islands

There are no natural forests on the Faroe Islands, only small parks and afforestation areas that cover less area than 1 km^2. With such small forests on the Faroe Islands, there is also very little production of food or other products from this resource.

4.4.2. Forestry in Greenland

Forest cover in Greenland totals 2.2 km^2, most of it natural birch woodland and about 10% reaches above five metres in height (Nord-Larsen *et al*., 2010). A few plantations with conifers have been planted in South Greenland, functioning as arboretums for conservation of gene pools and serving as indicators of climate change through the effect on the northern distribution of trees. The largest plantation, the Greenlandic Arboretum located in Narsarsuaq in South Greenland, was commenced in 1976 and developed up to present day, with more than 100 thousand trees and 120 different species (Københavns Universitet, 2014). The Arboretum plays an important leading role in determining which tree species are able to grow in South Greenland. Many species which have been tested in the Arboretum are already being used within horticulture in South Greenland, enriching the gardens in towns and communities in Greenland. A further side-effect of this development will be the establishment of small plantations, the production of x-mas trees, windbreaks and horticulture in South Greenland and other subarctic areas. These plantations are all publicly owned (Nord-Larsen *et al*., 2010). Other wooded land is estimated to cover about 77 km^2 and mainly consists of low bushes of *Salix glauca, Betula pubescens* and *Alnus crispa* which hardly ever reach over two meters in height (Due & Ingerslev, 2000). Some birch forests and woodlands in Greenland are threatened with overgrazing by sheep but have not yet been protected from grazing (Due & Ingerslev, 2000).

No forest products are registered in Greenland. The native birch forests can provide berries and mushrooms for households in small quantities though, but no official figures are available of the amount picked and used. As the mean summer temperature is almost nowhere above 10°C, annual tree growth is limited and therefore forestry in Greenland is estimated not to be possible for commercial industry (Statistics Greenland, 2010).

4.4.3. Forestry in Iceland

An ongoing survey of the Icelandic forests suggests that the total area covered by forests in Iceland is 1,850.4 km^2, where almost 1,000 km^2 are covered by natural birch forests, 500 km^2 are natural birch shrub land and 380 km^2 are cultivated forests (Wöll et al., 2014). Mushrooms and berries are picked in the forested areas and used for households where no official figures are being collected of the amount picked and used. Mushrooms and berries are also picked for resale and birch sap is collected for producing syrup. The total extent of this is unknown but it is estimated that 100 – 200 kg of fresh mushrooms are collected from individual forests based on information from forest farmers. Berries are also picked by the general public and sold to commercial industry producing various products

Since 2009 wooden chips from Icelandic forests has been sold to Elkem Iceland, a factory producing ferro-silicon for the steel industry, situated at Grundartangi in West-Iceland. Elkem uses the chips as a carbon source in the ferro-silicon production and is the biggest buyer of wood from Icelandic forests. Total Icelandic timber sales topped 4,000 m^3 for the first time in 2013 (Eysteinsson, 2014) and in the next five years, the amount of timber available from Icelandic forests is calculated to be around 6,000 m^3 every year (Heiðarsson, Ísleifsson, Óskarsson, & Reynisson, 2014).

Icelandic forestry and alloy production

where volumes up to 100 - 500 kg per person have been mentioned. Collecting birch sap for commercial use is relatively new in Iceland and where production volumes from each producer can reach up to 100 - 200 litres, however, there are still few producers on the market. It is not known how many forest owners are selling their forest products commercially but as the forests in Iceland are growing, the number and volumes of products from the forests being used are also increasing.

The Icelandic government has established a grants scheme, the Regional Afforestation Projects (RAP), in cooperation with farmers and landowners. According to the RAP Act of 2006, the aim is to increase employment in rural areas during the afforestation phase and in the long-run create an economically sustainable forest as a resource in Iceland with a forest cover of 5% of the lowland area. The nationwide effect of the RAPs during 2001 – 2010 on rural employment in forestry was on average 81 jobs annually and additionally around 50 jobs were created each year by indirect effects on the regional economy (Magnúsdóttir, 2013). As of 2010, 15,500 hectares have been afforested, with more than 30,000 hectares have been contracted into the grants scheme and will be afforested in near future. The forest resource in Iceland will continue to grow and expand and will provide timber, jobs and further use of a natural resource in the future.

4.5. Wildlife

The stock size of wild animals can only be estimated as the information necessary for a true stock numbers is lacking. Number of hunted animals will be used instead of stock size and the resources of wilderness valued from the number of hunted animals.

4.5.1. Wildlife in Faroe Islands

Situated in the middle of the North Atlantic the amount of wildlife on the islands is limited, the only wild land mammals which can be considered as a part of the bioeconomy is the hare. The birdlife on and around the islands is, however, very rich, and several seabird species are hunted.

The hare was brought to the islands from Norway in 1855 (Fosaa *et al.*, 2006), and soon adapted to the Faroese conditions. There are annual fluctuations in the stock size can, where the size depends on weather and vegetation. According to a research from 2013, around 7 thousand hares were killed in

2012 (Table 12). It is estimated that around half of the stock is killed every year due to hunting and the stock size is, therefore, estimated to be around 14 thousand hares (Magnussen, 2013).

Table 12. Number of wildlife hunted in 2012 in the Faroe Islands (Faroe Marine Research Institute and Magnussen).

Species	Summer	Winter
Seabirds		
Fulmar	75,000	-
Puffin	50,000	1,000
Common Guillemot	5,000	5,000
Razorbill	5,000	5,000
Shearwater	3,000	-
Shag	1,000	1,000
Gull	1,000	-
Gannet	450	-
Other wildlife		
Hares	-	7,000

A wide range of seabirds are hunted on the Faroe Islands, both during summer and winter (Table 12). The numbers presented are mostly estimates and not exact hunting number as limited hunting statistics are available. The puffin population has declined in the recent years resulting in the introduction of a hunting ban protecting the species. It should be noted that these numbers are average numbers for the last 20 years and the puffin an example of a species that is currently not hunted at all. Wild geese are also to some extend rearing on the islands and thousands of wild geese land on the islands when migrating, however, hunting of the geese is banned.

Many different species of whales and dolphins live in the waters surrounding the Faroe Islands, most of which are protected by law. Nevertheless, some whale species are hunted and whale hunting has been a tradition in the Faroe Islands for centuries. However, the number of whales killed each year can vary significantly. In the year 2013, over 1000 pilot whales were hunted as well as 430 dolphins (Faroe Statistics, 2014). The whales are mostly hunted with a so-called drive hunt, where the animals are driven with boats to the shore and killed in very shallow water, instead of hunted with a harpoon from a whale boat. The drive hunts are non-commercial and regulated by national legislation and are organised on a community level where all interested parties can participate. No comprehensive stock estimation of long finned pilot whales have been conducted since 1989, when the stock in the North Atlantic was estimated to be 778 thousand individuals, later estimations have not shown large deviations (Bloch, 2008). The pilot whales hunted by the Faroese belong to this stock and in the year 2010, 800 pilot whales were hunted. Research conducted in the years 1986-1998 showed that the average weighs of an hunted pillow whale was 72 kg, where 38 kg are meat (tvøst) and 34 kg are blubber (spik) (Bloch, 2008). This would result in a production of around 304 tonnes of meat and 272 tonnes of blubber for the year 2010.

The grey seal is the only breeding seal species in the Faroe Islands, but it has not been subject to any systematic field survey, thus the total stock number is unknown. Previously, seals were hunted in the Faroe Islands, but this is no longer permitted.

Imports and export of wildlife cannot be separated from import and export of other animals in the custom reports. Imports of wildlife are however not likely to be high and what is imported will in most cases be wildlife which does not exist on the Faroe Islands.

4.5.2. Wildlife in Greenland

Numbers for wild animals being caught are collected by the Ministry of Fisheries, Hunting and Agriculture from the hunters who have to provide the information of their catches before they can have their license reissued and the numbers are published every year online (Grønlands statistik, 2013). Number of hunting licenses were in total 7,600 in 2010 (13.5% of population in Greenland) where professional hunters account for 2,000 licences and spare time hunters for 5,500 licenses (Statistics Greenland, 2013). The most hunted seal species in Greenland in 2010 were the harp seal, individuals younger than four years old, and the ringed seal (Figure 11), accounting for 83.5% of the total of seals caught (Statistics Greenland, 2013).

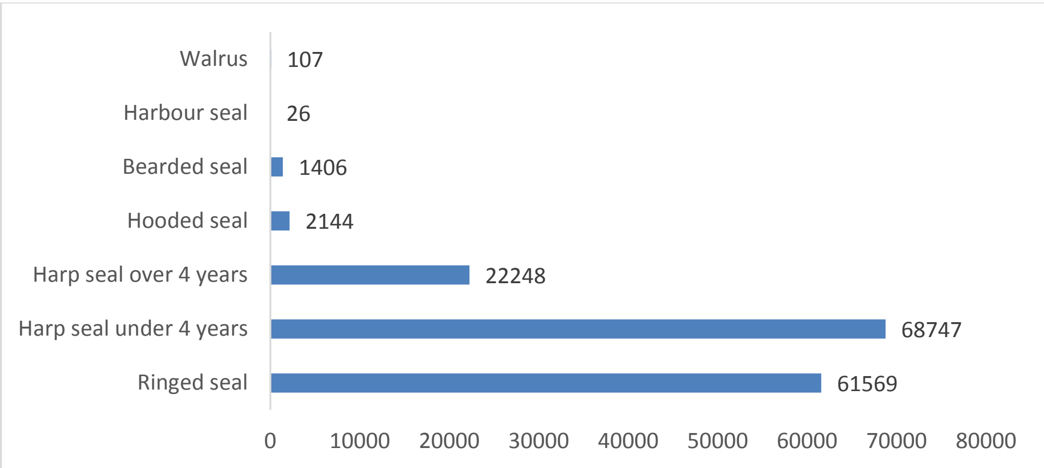


Figure 11. Numbers of seal hunted in Greenland 2010 (Statistic Greenland, 2013).

In 2010, three thousand whales (large whales as well as small cetaceans) were caught in Greenland, where the harbour porpoise was the most common species hunted as more than two thousand animals were caught (Statistics Greenland, 2013). Approximately 170 thousand birds were caught in Greenland in 2010, where guillemot was the most common prey (Figure 12) (Statistics Greenland, 2013).

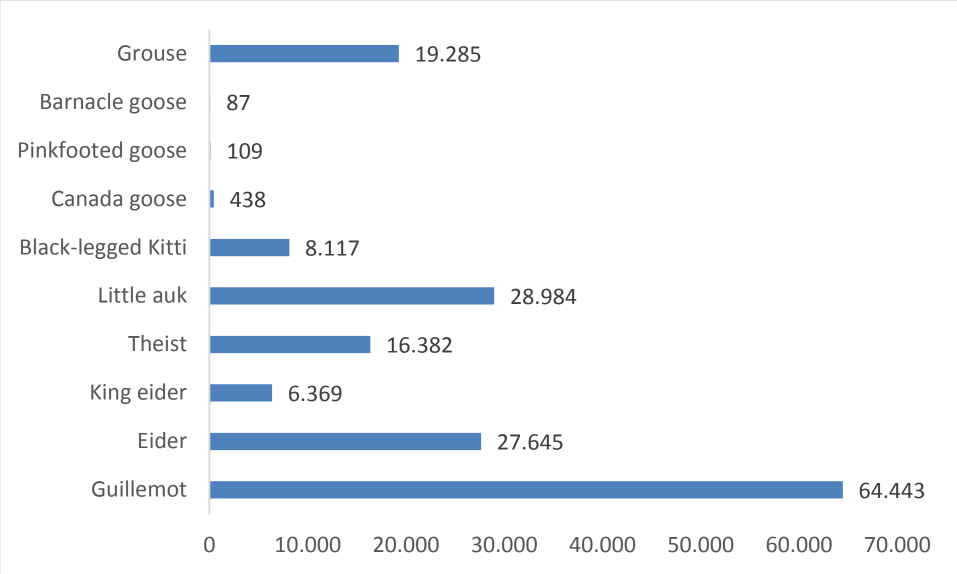


Figure 12. Numbers of birds hunted in Greenland 2010 (Statistic Greenland, 2013).

Of all wild animals hunted in Greenland in 2010, seals were the most frequent prey, where 156 thousand individuals were hunted (Grønlands statistik, 2013). The meat from the seal is used both for human consumption and as feed for sledge-dogs, and finally, the skins are sold for processing (Ministry of fisheries, hunting & agriculture, rev.2012). In 2009, EU banned commercial trade with seal products, including sealskin and seal meat, affecting adversely the Greenland seal industry despite the so-called Inuit exception, which in principle allows Greenland to continue trading with seal products (Ministry of fisheries, hunting & agriculture, rev.2012). The Inuit exception though, has not worked as intended and about 150,000 sealskins are currently unsold in Greenland (Ministry of fisheries, hunting & agriculture, rev.2012). More than half of the skins from caught seals are sold for tanning to Great Greenland Ltd., the only tannery of Greenland (Grønlands statistik, 2013).

Table 13. Amount of sealskins sold in Greenland in 2010. Value is stated in thousand DKK (Grønlands statistik, 2013).

	Number	Value (tDKK)
Ringed seal	21,244	5,858
Harp seal	48,190	12,313
Other seals	6	2

Table 13 shows the number and value of sealskins sold in Greenland in 2010, whereas skins from other species are not accounted for. The skins are sold either wet or dry and hunters received a subsidy from the Greenland authorities for each skin sold in 2010 (Grønlands statistik, 2013). This subsidy was introduced following a severe drop in global market price, following campaigns against sealing in the late 1970's and early 1980's. The seal hunting in Greenland is conducted sustainably according to reports from North Atlantic Marine Mammal Commission (NAMMCO) and Greenland Institute of Natural Resources. The tradition of sealing is to utilise the whole animal of the seals so there is very little waste. The legality of EU´s ban of trade with seal skin was raised by Canada and Norway at the World Trade Organization (WTO) panel, who concluded that the ban was not illegal. The effects of this verdict has yet to be seen. However, according to the WTO, the Inuit exemption should be modified so all Inuit communities are given the same exemption and trade conditions. The EU has not yet decided how to implement the conclusions from the WTO Panel.

Polar bears and walruses are caught in Greenland, however, they have been subject to hunting quotas since 2006 (Grønlands statistik, 2013). The meat and the skins of the polar bear are almost exclusively used for personal uses or for households, hence, no official numbers on the amount of meat is available (Table 14) (Jensen, 2003). Walrus meat is used as food for human consumption as well as feed for sledge-dogs and the tusks are sold as souvenirs for tourists. The export of walrus products requires a Greenland export permit (Jensen, 2003). Further, whale meat as well as meet of other wild animals in Greenland can be sold to few local processing plants e.g. Lilleholm (Grønlands statistik, 2011), however, hunting is only allowed via licenses and all hunting is to be reported to the authorities (Jensen, 2003). Total number of hunted animals as well as meat volume sold to the processing plants and value is shown in Table 14.

As frequently mentioned before, neither official figures nor estimates of volume or value of meat used in households are available at Statistics Greenland and, therefore, is an obvious mismatch between number of animals and volume of meat in Table 14, the table of hunted animals and sold meat. The numbers of caught animals and sold meat does not have to match to each other because much of the harvest is used for private purposes. In a report by Rasmussen (2005) the value of meat used in households is estimated DKK 130 million pr. year and the amount of meat used as feed for sledge dogs is estimated to be between 3.500 and 8.100 tons of feed (Rasmussen, 2005).

Table 14. Number of wild animals, whales and seals hunted in Greenland in 2010, meat sold for processing produced in tons and value in thousand DKK) (Grønlands statistik, 2011). Meat used in households is not included in the figures (except number of hunted animals).

	Number of hunted animals	Tons of meat sold for processing	Value (1,000 DKK) meat sold for processing
Musk ox	2,485	29	976
Polar bear	127		
Caribou	12,721	4	103
Fin whale	5	5	90
Minke whale	187	26	562
Harbour Porpoise	2,077	0	9
Seals	156,247	9	113

With the right publicity and marketing effort, the sealing in Greenland could make good livelihood for the Inuit hunters and draw the attention of the fashion industry to the furs as a valuable material and sustainable living of the Inuit in harmony with the nature. The meat and other products from the seals can also ensure food security in underdeveloped countries as a protein supplement.

Opportunities in sealing in Greenland

It should be noted that in Greenland it is custom to use the word *caribou* for wild reindeers but the word *reindeer* for the semi-domestic animals. Caribou was the most hunted terrestrial animal in 2010 (83%), where in total 15 thousand terrestrial mammals (Table 14) were caught (Statistics Greenland, 2013). Reindeer husbandry has been conducted in Greenland since 1952 and still is conducted in South West Greenland as by 2014 there are still two companies operative with about 3000 reindeer (International Centre for Reindeer Husbandry, 2014; Statistics Greenland, 2013). (See further discussion in chapter 4.6. Reindeer husbandry).

Caribou are hunted in Greenland and in 2010 a total of 12,721 animals were hunted (Statistics Greenland, 2013). The majority of meat and skins from caribou is used in households or sold locally, resulting in that there is only four tons of meat accounted for in public records in Greenland for the year 2010 (Table 14).

Musk-ox was originally found in the North and Northeast of Greenland and has been successfully introduced to West Greenland between 1962 and 1965, where 27 musk-oxen were relocated in the Kangerlussuaq area. Hunting of musk ox is only allowed by permit and is popular as trophy-hunting by the tourists where a certified guide is required for the hunt. All meat and hides are required to be brought home with the hunters for use in private households or to be sold locally. However, often the trophy-hunter keeps the hide and the scull with the horns (Jensen, 2003). In August 2014, 19 musk-oxen were transferred to South Greenland, from Ivittuut area to Nanortalik area. It is estimated that in less than 10 years, the animals will have reached a population size that necessary for sustainable hunting, trophy hunting and tourism.

The population size of the caribou stock is divided into few groups in different areas of Greenland. The biggest herd (ca. 98,000 animals) is found in West Greenland in the area of Kangerlussuaq/Sisimiut and is named after the area (Cuyler, Rosing, Mølgaard, Heinrich, & Raundrup, 2011; revised 2012). This herd is estimated to be bigger than the area is believed to be able to carry without harming the vegetation and it is speculated that without attempts to decrease the numbers of the herd, it might crash abruptly in the near decades (Cuyler *et al*., 2011; revised 2012). Other herds of caribou are the central Akia/Maniitsoq herd (ca 31,000 caribou, 2010) (Cuyler *et al*., 2011; revised 2012) and the southern Ameralik/Qeqertarsuatsiaat herd (ca 15,000 caribou) (Cuyler, Rosing, Heinrich, Egede, &

Mathæussen, 2007). Other herds are found in smaller numbers and are scattered around the West-coast of Greenland.

Hunting animals from motorized vehicles in Greenland is generally prohibited and are likely to drive the caribou away from their preferred range of habitat and can therefore further reduce the desired intake of winter food. In the areas where the largest herds are wintering it is almost impossible to reach the majority of animals by foot as the caribou remain in the higher elevations due to less snow in autumn in the area (Cuyler et al., 2011; revised 2012). If winter hunting with motorized vehicles would be allowed it would have to be with very strict regulations and much effort to follow-up the hunting in order not to make the situation of the animals worse than it already is.

Large caribou herds increase the risk of overexploitation of the area which can consequently affect the herd lives in increasing the risk of animals starving to death at wintertime, calves dying at birth due to malnutrition and the females not being able to feed their calves as they lack nutrition themselves. Such circumstances can lead to abrupt collapse of the herd which can take a very long time to recover and can also influence the ecosystem nearby. Further research and actions to decrease the size of the herds in an effective way are essential in order to prevent the overexploitation and abrupt collapse of the herd.

The risk of too many caribou in the Kangerlussuaq/Sisimiut herd

Import and export from wild animals cannot be separated from other categories in Standard International Trade Classification (SITC) in Greenland.

4.5.3. Wildlife in Iceland

Numbers of hunted wild animals are collected by The Environment Agency of Iceland and published online annually. Very few wild species are hunted in Iceland where bird hunting is the most common hunting activity. In 2010, the total number of birds hunted was 283,000 individuals. Ptarmigan is the most hunted bird species followed by different goose species. One of the species hunted is reindeer, but they were imported to Iceland in the late 18th century and have since lived wild in the East of Iceland. In 2010 1,229 reindeers were hunted in Iceland (Figure 13). The Nature Institute of East Iceland, Natturustofa Austurlands, publishes estimates on the reindeers stock size and in 2010 the stock was estimated to be 6,400 reindeers, suggested the hunting quota of just over thousand animals (Þórisson & Þórarinsdóttir, 2011).

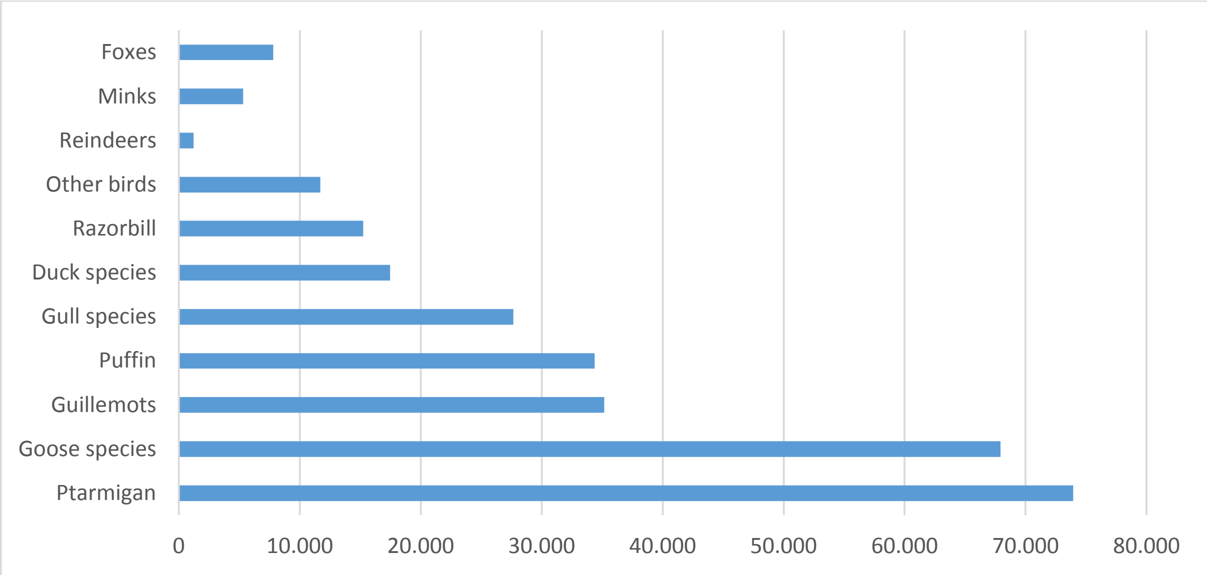


Figure 13. Number of wild animals hunted in Iceland in 2010.

American minks and arctic foxes can also be found wild in Icelandic nature, however, the arctic fox is the only native terrestrial mammal in Icelandic nature. In 2010, 5,000 minks and 8,000 foxes were hunted in Iceland.

There has been some confrontation between whale watching companies and the whale hunting industry, the former believing hunting whales is bad for the business. On the other hand, the whale hunting industry claims that hunting and watching can coexist, as the hunting takes place far from the watching sites.
Whale watching is the fastest growing sector within the tourist industry with 10 whale watching companies offering service to tourists, mostly located in Reykjavik and Husavik in North Iceland. In 2000, around 61,000 tourists participated in whale watching, in 2008, the number had increased to approximately 115,000. In 2009, the numbers of tourists purchasing a whale watching tour reached a staggering number of 125,000. The annual growth rate has been approximately 12% from 2000, and around 20 – 25% of total tourists visiting Iceland are going whale watching.
No research exists indicating that whale hunting affects the whale watching business and increased hunting does not seem to have been holding back the interest of tourists.
On the other hand, fishermen are concerned about predation of growing whale stock and are favouring whale hunting. According to Agnarsson, (2010), annual hunting of 150 mink whales and 150 fin whales could strengthen commercial fish stocks and create extra value from fishing of around 46 million a year. Beside this increase of fishing, value creation from whale hunting could be substantial.

Whale hunting or whale watching?

Commercial whaling of fin whales and common minke whales is permitted in Iceland. In the year 2010, the Icelandic whaling fleet caught 148 fin whales and 60 mink whales. After 2010 the hunting of fin whales stopped until 2014 and whaling of mink whales decreased to 52 in 2012. The Icelandic Marin Research Institute recommends a quota of 229 minke whales from 2014 to 2015 and 154 fin whales (Marine Research Institute, 2014). Fishing of seals also occurs in Iceland. In 2010, there were 451 seals hunted, but of these, 259 were by-catch (Stefánsdóttir, 2014). It has been estimated that whaling in Iceland, hunting 150 fin whales and 150 mink whales, could create jobs for around 100 full-time equivalent units. Estimated value for hunting and processing whales in Iceland is over 46 million DKK a year in Iceland (Agnarsson, 2010).

4.5.4. Summation of the wildlife

There are great opportunities for the nations in the West Nordic countries in using the traditional wild life hunting and serving gourmet dishes for the increasing tourism in the area. Some of the finer restaurants in Reykjavík are specializing in Icelandic traditional dishes and use the fine meat of game to satisfy their guests. In the awakening of New Nordic food and other projects aimed at using local materials and traditions for new and exotic food, vast opportunities await chefs and cooks of the West Nordic countries. Since the majority of this meat has mainly been used in private households so far, e.g. in Greenland and Faroe Islands, the knowledge and know-how of the meat preparation is already available. Linking this traditional knowledge with new and innovative views of the Nordic chefs is an exciting possibility for restaurants in the West Nordic countries to serve food with the wild flavour of the Arctic.

> Hunting tours in the West Nordic countries are already popular therefore combining the hunt with sustainable use and by protecting areas in the countries must be a focus point. Many species of seal, reindeer and musk-oxen in Greenland are currently underutilised and can be sustainably hunted to a larger extent. Hunting trips with tourists can provide the Inuit a living as guides and help the natives to utilise the wild species found in their surroundings. Birdlife in Greenland is also rich. Birding for tourists is also an unutilised area that needs to be focussed on in the coming future.
>
> *Hunting tours in the West Nordic countries*

Selling furs from seals and meat, skin, wool and horns from reindeer and musk-oxen from Greenland is considered to be one of the opportunities in the West Nordic countries. However, this needs extensive research in finding and creating new markets that approve of the sustainable ways the Inuit are hunting their prey and the necessity for the Inuit to make a living of their land and resources.

4.6. Reindeer husbandry

Reindeer husbandry is conducted in 9 countries; Norway, Finland, Sweden, Russia, Greenland, Alaska, Mongolia, China and Canada (International Centre for Reindeer Husbandry, 2014). The term “Reindeer husbandry“ covers wide aspects such as the economy, the social and biological sustainability of the reindeer herding industry as well as the legal rights included in the reindeer herding such as permit to fish in rivers in the herding area. However, the term ”Reindeer herding“ is used for the practical work with the reindeers (International Centre for Reindeer Husbandry, 2014). Domesticated reindeers are a valuable part of the culture and identity of many of indigenous people in the Arctic as well as a component of the terrestrial ecosystems. Reindeer herders have through the ages developed unique management of the pastures which is both sustainable and provides a living based on the animals and their surroundings in harmony with the nature. They are now facing significant changes due to the climate change as well as the impact of industrial development on their grazing land. Reindeer and musk-oxen husbandry could be an important part of the Arctic Bioeconomy and this report will focus on reindeer husbandry in Fennoscandia and Greenland.

4.6.1. Environment and ecology

The reindeer husbandry in Norway, Finland and Sweden is entwined in the history of the Sámi people in northern part of Scandinavia as a way of living. The reindeer herding is not only of cultural and social importance but has as well an economic impact for the Sámi people.

In Norway, Sweden and Finland, specific legislation applies for reindeer herding, covering the duties and rights of the Sámi people as well as external interests. This legislation is important for the Sámi people and their way of living. International cooperation between reindeer herders is of importance and several research projects and cooperation are ongoing among reindeer herders in the Arctic.

Reindeer husbandry was introduced in Greenland in 1952 when 300 reindeer were imported from Norway to West Greenland. Several Sámi herders accompanied the reindeer to teach the Inuit to herd the reindeer (International Centre for Reindeer Husbandry, 2014). The reindeer stock in West Greenland grew to over 4,500 animals in the 1960's, discontinued in 1998 in West Greenland due to several reasons, however, in South West Greenland the reindeer herding succeeded fared better and by 2014 there are still two companies operative with about 3000 reindeer (Ministry of Fisheries, Hunting and Agriculture, 2014).

"Reindeer adapt their eating to the grazing access. Studies show that reindeer eat over 200 different kinds of plant species. If a reindeer can select, it prefers to eat the newest parts of a plant because it can absorb the elements better as they do not contain plant fibres. Reindeer is a ruminant and has a special ability to absorb lichens. In winter, lichens are the main diet but also hanging lichens and other plants under the snow. In winter lichen can constitute approximately 40-90% of a reindeer's diet. In the summer reindeer graze on herbs and leaves and in autumn fungi is an important source of nourishment." (International Centre for Reindeer Husbandry, 2014)

What do reindeer eat?

The reindeer herders are currently facing several threats and challenges such as climate change, predation and poaching. The loss of pastures for the reindeer due to development of roads, power lines, dams, etc., also threatens the lifestyle of reindeer husbandry (Pape & Löffler, 2012). The economy of reindeer husbandry is often uncertain as it is dependent on unpredictable forces such as nature and weather, predation and other unforeseen circumstances. The reindeer depend on diverse and accessible pastures with good forage supply during summer, and on lichen as their main forage during winter. The summer pastures allow the reindeer to gain fat in order to survive in winter time when food is scarce, however, the pastures are often vulnerable against ecological degradation due to heavy grazing. This can result in both fewer and smaller calves as well as a higher number of animals starving to death during winter. Climate change can have a positive impact on of the growth in the pastures, however, it can additionally lead to an increase in the insect harassment in summer which allows the reindeer less time to graze, hence leading to leaner animals in autumn (Pape & Löffler, 2012). In some areas artificial feed has been provided in the wintertime, however, this is expensive and due to seasonal cycles in the reindeer metabolism, the artificial feed is sometimes not suitable for the animals.

4.6.2. Opportunities for reindeer husbandry

Combining tourism and reindeer husbandry is a feasible approach and would increase the value of reindeer herding. Servicing tourists and focusing on diverse activities results in higher income than the income from meat production alone. Integrating tourism with reindeer husbandry can have a positive effect in raising society´s awareness regarding the importance and challenges that the reindeer husbandry faces. Raising the awareness of these challenges is vital for future sustainability of reindeer husbandry.

Combining reindeer husbandry and tourism sustainably is a feasible way to increase value and raise society’s awareness regarding the lifestyle of the reindeer herders.
Further utilisation of side products of the reindeer is also a good approach to increase the sustainability and income for the reindeer herders. The reindeer’s fur is highly valuable if used in the fashion business with focus on the cultural and sustainable way of producing the skins.

Opportunities for reindeer husbandry

As the demand for reindeer meat in the Scandinavian markets is increasing, the need to utilise the whole animal in a sustainable way has received increased attention. Using the term “waste” instead of “raw materials” may in itself prove to hinder innovative thinking with regards to fully utilising the reindeer´s raw materials. The remains of the animal can be seen as problematic in the slaughterhouses where local knowledge on processing technique and utilisation of the different parts of the reindeer is often not applied. Projects aimed on increasing knowledge on how to handle side products are, therefore, highly relevant. By increasing the focus towards on other types of products of the reindeer instead of only to the main products, meat and furs, the value for optimal production can be maximised. For comparison, other industries such as the pig farming industry, receives a higher income from the side products than from the meat alone (“main product“). In Greenland, musk-oxen farming is also a possibility where several relocations have shown success. The purpose could both be meat production, skin, wool and horn production and trophy hunting and musk-oxen safaris.

Funding opportunities for research in the field of utilising side products are often more accessible than for research on meat quality itself. The reindeer husbandry could learn from the experience of other meat producers to change side products from a problem in the form of waste into a valuable product. When looking at utilising raw materials it is important to keep the culture of the reindeer herders in mind and their old traditions and knowledge as this could lead to new products. New products from reindeers could consist of using the fur and skin of reindeer for the fashion industry, as this exotic material could have high value when produced in a sustainable and cultural way. Additionally, various side products from other meat producers, such as the rump, penis, heads and legs, have been sold to China. Bones, stomach, bowels, kidneys, liver, etc. can be sold or used in special gourmet food especially if these side products have roots in the traditional food of the Sámi people. However, the EEA legislation (Regulation (EC) No 1774/2002) concerning animal by-products not intended for human consumption and the disposal thereof, has to be kept in mind when novel products are developed.

Information is important both up and down the value chain. Information to the herder/farmers is valuable for them to manage their resources. Information for the distributers and consumers can also be very valuable, for example traceability and/or origin information. Further work has to be put in gathering and distributing information for them to be useful and serve their purpose.

Valuable data information for reindeer herders

Possibilities regarding reindeer feed have to be explored with the special needs of the seasonal metabolism of the reindeer in mind. One of the possibilities is side products from other biomass as feed for reindeers.

In order to effectively model the reindeer husbandry in Fennoscandia, all the data must be compiled along with studies available in the Nordic. Trends can then be monitored as well a better overview of factors affecting the reindeer herds by looking at a longer period, predator numbers, weather and other influencing factors. Experience from other fields can be used, such as forestry and fisheries and there is a possibility to apply the resource based models used in those fields to reindeer husbandry. Case studies from reindeer herding may assist in recognising the social aspects of other resource management cases, such as the fishery and vice versa.

4.7. Fresh water

Although fresh water is not considered a biological resource, biological resources can often be found in fresh water, such as fresh water fish species. These resources are constrained by the area covered by fresh water. Stock estimates for fish in fresh water are often not accessible and thus catch statistics for the estimation of fresh water fishing is recommended. A distinction between fresh water and salt water fishes is not possible in the general tariff classification and thus it is not possible to separate the two with regards to import and export. Therefore, fresh water fish is included either in the section of marine resources or aquaculture, depending on the species.

4.7.1. Fresh water in Faroe Islands

Streams and lakes are few and small in Faroe Islands covering only about 0.9% of the total land area or 12 km^2. The main resources found in fresh water are salmon and trout. Additional to the small stock of wild salmon in Faroese lakes, the organisation Føroya Sílaveiðufelag hatches salmon eggs and releases the parr/smolt into different lakes for sport fishing purposes. Around 30 thousand parr/smolt are released every year, but the catch differs between years by a factor of ten, as in good years over thousand salmons can be caught whereas, 2012 the number was only 107 salmons (Joensen, 2013). Small numbers of different species of trout are also present in some lakes, but no statistics are available for these. The production is limited and has little effect on import or export of fresh water fish.

4.7.2. Fresh water in Greenland

The fresh water species found in Greenland are mainly salmon and arctic char (Jensen, 2003). The only fresh water salmon river in Midwest Greenland is Kapisillit, which has its own population of salmon. All other salmon caught in Greenland are of mixed stock Atlantic salmon originating from North America and Europe (ICES, 2013). Salmon is mainly caught with gillnets along the west coast of Greenland. Only fishermen with a license for salmon fishing can sell their catch to local processing factories, restaurants and local market. However, the general public is allowed to fish salmon for private consumption. The allowed amount for trade to processing factories is regulated with an agreement with the North Atlantic Salmon Conservation Organization (NASCO), where e.g. in 2012 the amount was 33 tons and all export is banned (Sheehan *et al*., 2013).

The arctic char can be found in lakes, streams and near the coast and is caught by fishing rod or a net near all inhabited regions in Greenland, mostly for private use (Jensen, 2003). The use of nets has to follow very strict regulations in order to prevent overexploitation. There is no quota on fresh water arctic char or salmon for private consumption. The river, Kapisillit, has an ongoing conservation process that is expected to be finalised in 2015.

4.7.3. Fresh water in Iceland

According to CORINE land cover classification, water covers over 1,000 km^2 as water bodies and 800 km^2 are water courses. The most used biological resources from these water areas is wild fish. The three main species of fresh water fish are salmon, sea trout and river trout (Table 15).

Table 15. Numbers of fresh water fish caught in 2010 in Iceland (Institute of Fresh Water Fisheries).

	Salmon	Sea trout	River trout
Angling	74,961	48,798	33,514
Of which released	21,476	7,841	2,397
Net fishing	15,903	-	-
Total fishing	**90,864**	**48,798**	**33,514**
Total catch	**69,388**	**40,957**	**31,117**

Fresh water fishing in Icelandic rivers is very popular but expensive where companies and affluent individuals, both natives and tourists, buy a large portion of the licenses available. Further information of the amount and the income of the fresh water fishing can be found in Chapter 6, Nature based tourism in the West Nordic countries.

4.8. Fisheries

The availability of the marine resources is represented by two measurements, the length of the coastline and the total area within the exclusive fishing zones of the specific countries. However, these are not measurements of the marine biological resources. The marine resources can differ significantly dependent on location and climate. Thus, measurements for biological resources available within the exclusive fishing zone must be identified. The marine fauna consists of the marine stocks present in the exclusive fishing zone. For estimation on the quantity of these marine stocks, a stock size estimate would be most appropriate. These are available in many countries, but are often limited to the most commonly utilised species. For comparison of quantity of biological resources between different countries, the numbers for total catch will be better comparable since the stock size estimates might not be available for the same species. The marine flora has not yet been utilised extensively but is receiving increased attention with enhanced research. Utilisation of the marine flora is, therefore, expected to increase in the near future which will give a better idea of the resources available and their value.

> Wild fish stocks are by nature renewable resources, provided they are sustainably utilized. For nations like the West Nordic countries that depend heavily on fisheries there is a need to maximise the sustainable yield (MSY) of the fish stocks to boost the value creation as well as productivity throughout the value chain in the fish industry. This calls for new thinking, focusing on multiple value streams development and implementation of new processes and technology including biotechnology.
> "Maximum sustainable yield is a broad conceptual objective aimed at achieving the highest possible yield over the long term (an infinitely long period of time)" (ICES, 2011)).
>
> *Importance of fisheries for the West Nordic countries*

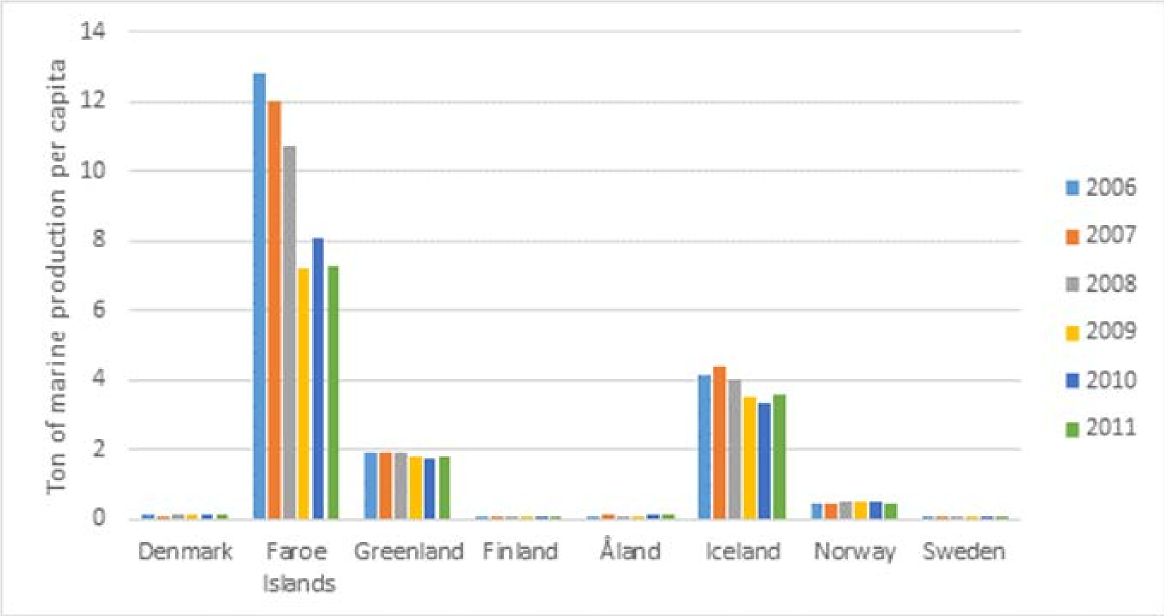


Figure 14. Amount of caught marine production in ton per capita in the Nordic countries in the period 2007 - 2011 (Nordic Static Yearbook 2011).

The fish stocks in West Nordic countries are currently relatively well managed (Figure 14) even though there are fluctuations as seen for stocks in other marine areas. Eight costal countries are part of the Arctic Ocean having jurisdiction of its exclusive economic zones; Canada, Denmark, Faroe Islands, Greenland, Iceland, Russia, Norway and USA. The characteristic of the commercial fishing in West Nordic countries is a single species fishery, with few large fish stocks. In the past, illegal fisheries have been significant in international waters, however, following the United Nations developments and the Convention on the Law of the Sea (United Nations, 2014), as well as domestic cooperation, implementation of rules and law enforcements have been successful. Fisheries are important for the West Nordic countries, which reflect in total catch per capita from 2006 to 2011 for the Nordic countries (Figure 14). Even though fisheries are important for Scandinavian countries, they are not as large part of their economy as for the West Nordic countries.

National accounts of economic activity measure the value added of all industries and represent the value added of an industry as its contribution to GDP. However, some industries seem to contribute more compared to what is represented in national accounts. Industries that seem disproportionally big can be considered to structure an economic base on which others depends. From observations on an economic base, a theory of base industries has been developed (Roy, Árnason, & Schrank, 2009). In the Faroe Islands, Greenland and Iceland, fisheries are the most important industry and could be identified as the structure of the economic base of these countries as illustrated in Table 16.

Table 16. Fisheries of the three West Nordic countries, value in tons and thousand DKK.

Fisheries 2012	Faroe Islands	Greenland	Iceland
Demersal fishing (tons)	128,855	147,600	457,533
Pelagic fishing (tons)	231,617	38,014	991,015
Total tons	**360,472**	**185,614**	**1,448,548**
Demersal value (1.000 DKK)	787,758	817,287	5,211,041
Pelagic value (1.000 DKK)	1,168,406	49,033	2,165,053
Total value (1.000 DKK)	**1,956,164**	**866,320**	**7,125,874**
Fisheries contribution to GNP	24.40%	Coastal value	11.30%
Workforce	295	3,500	9,200
Workforce (percentage)	11%	12%	5.40%
	(Statistics Faroe Islands, 2014)	(Statistics Greenland, 2014)	(Statistics Iceland, 2014)

Trade between the three West Nordic countries within the marine segment is substantial, mostly though commerce of raw material and fish feed. Iceland imported 12,000 tons in 2012 of raw material from the Faroe Islands, mostly pelagic fish, and worth of DKK 38 million. The import from Greenland was 19,000 tons worth of DKK 36 million.

4.8.1. Fisheries in the Faroe Islands

Catch fisheries and aquaculture are the two most important contributors to the Faroese economy, contributing with over 91% of the total export in 2012 (Statistics Faroe Islands, 2014). These industries are mostly based in the primary sector, where a part of it flows directly into the secondary sector, the fish processing industry. The direct input of the fisheries sector to the Faroe Island´s GDP was 24.4% in 2012. Catch fisheries was 40% of the export in 2012, contributing almost DKK two billion to the economy (Johannessen, 2014). Almost three thousand people are employed in the fishing industry (both primary and secondary sectors) in the Faroe Islands. This represents 11% of the work force.

Figure 15. The Faroese exclusive economic zone (EEZ).

The total volume of fish caught in the Faroe Islands exclusive zone (Figure 15) in 2012, was over 360,000 tonnes, of which pelagic fishing represented 231,000 tonnes and demersal species 129,000 tonnes. The total catch value of fishing was DKK two billions. The value of pelagic species was DKK 1.2 billion, while the value of the demersal fisheries was DKK 788 billion.

In terms of export volumes from catch fisheries, pelagic species dominate, in particular mackerel followed by herring. However, when looking at the export value, the importance of demersal species increases, such as cod and saithe (Figure 16).

The fish stocks in Faroese waters are the property of the Faroese people, according to Faroese law, and shall be managed for the public good. The fish stocks are currently managed by two different systems; there is an effort system for some species while there is a quota system for others (Johannessen, 2014). All commercial fishing is administered by The Ministry of Fisheries which is also responsible for the conservation of stocks as well as optimising these resources in the most sustainable way. The owner of a fishing vessel must have a fishing licence to be able to fish commercially. A vessel is given a certain number of days within the Faroese exclusive zone. The allocation of days was originally set in 1996 as decided by the parliament, with restriction on transferability between vessel categories, grouped by type and gear. There is a mandatory notification process to the Fisheries Inspection Service that applies to all fishing licence holders and there is generally no cost involved in getting a licence from the Ministry of Fisheries. Besides being regulated by controlling capacity and fishing days to protect stocks, Faroese fisheries are regulated by gear and area restrictions.

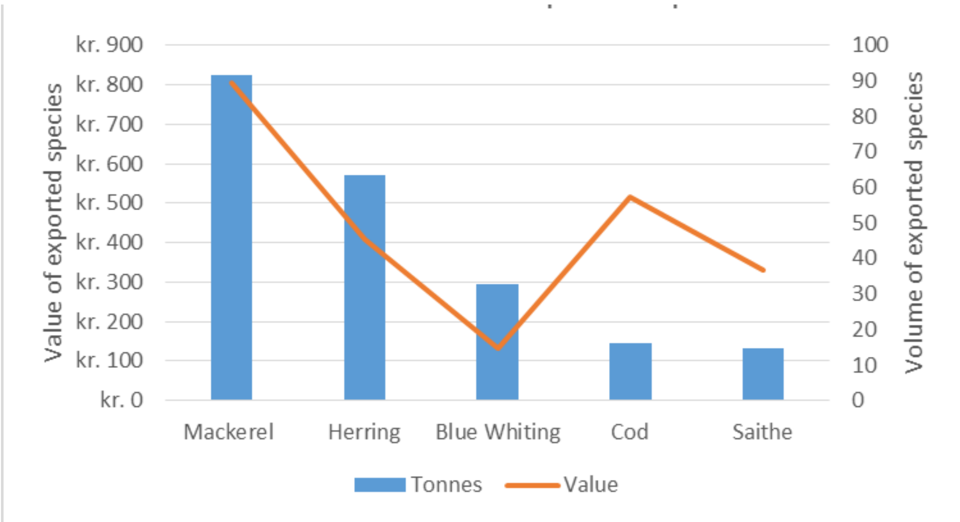


Figure 16. The top five exported species in 2013 from Faroe Islands, value in million DKK and volume in thousands of tonnes (Faroe Statistics, 2014).

Previous years the landings of fresh fish in Faroe Islands have declined considerably for several reasons, but mostly because of declining demersal fish stocks. At the same time, the importance of pelagic fisheries have evolved substantially, mostly because of progressive fishing of mackerel (Johannessen, 2014).

Table 17. The total number and number of operational ships of the Faroese fleet divided by groups (D. R. Djurhuus, 2014). (D. R. Djurhuus, 2014; Føroya Reiðarafelag (Herálvur Joensen) pers. comm., 2014; Vørn Fiskiveiðieftirlitið, 2014).

Groups	Definition	Number	Operational
1/2	Trawlers	**36**	**36**
3	Longliners > 110 tonnes	**16**	**14**
4 (A+B+T)	Larger coastal vessels > 15 tonnes	**31**	**29**
5 (A+B)	Smaller coastal vessels < 15 tonnes	**532**	**309**
Others	Gill-netters	**9**	**3**
Others	Pelagic trawlers	**11**	**11**

The Faroese Fishing fleet consists of about 103 vessels above 15 gross tonnage (GT), ranging from small, wooden coastal vessels to the most sophisticated ocean-going factory trawlers (Vinnuhúsið (House of Industry), 2014). The Faroese vessels operating in Faroese waters have fishing licences within the "National System of Fishing Days" referred to as "Fiskidagaskipanin". The costal fleet is separated in three groups, 4A, 5A and 5B, where the authorized fishing gear is jig and long line (Table 17). The costal fleet is allocated fishing days, group 4A were allocated thousand operating days in 2012 but the 5A/5B just under 11 thousand days. The total number of the costal fleet in 2013 was 532 but only 309 of them were operational (with catch value more than DKK 400,000 annually). The main challenge for the costal fleet is insufficient fish stocks in Faroese waters, and increasing number of closed areas to protect spawning stocks (D. R. Djurhuus & Konráðsson, 2014). The system is regulated by the Faroese Law of Commercial Fishing[1].

4.8.2. Fisheries in Greenland

Fishing is by far the most important export sector in Greenland's economy. Fishery export accounted to DKK 2.4 billion in 2013 and represented 91% of merchandise exports (Ögmundsson, 2014). The resources are managed by the Greenland Government and regulated by quotas and licenses, with these decisions based on stock estimations to ensure a sustainable use of the natural resources of the country.

Figure 17. Map of the four municipalities in Greenland and the National Park of Greenland.

Greenland total GDP was DKK 11.3 billion in 2012 (Grønlands statistik, 2013). The fisheries sector turnover in 2013 was DKK 3.7 billion with total fish export from Greenland at DKK 2.4 billion, with prawn dominated to the extent of 47%, Greenland halibut 26% and cod 5% (Ögmundsson, 2014). The numbers employed by fisheries and agriculture in 2012 was 3,532 individuals, which is around 13% of the total workforce in Greenland (Rambøll Management Consulting, 2014). The fishing and hunting industry are important to the national identity of Greenland and these industries constitute as livelihood for many families, especially in the smaller settlements. The sparsely populated settlements alongside the coast are entirely dependent on marine resources of fishing and hunting (Figure 17).

The fishery consists of offshore fishery and coastal fishery, costal fisheries operating within the three nautical miles from the coastline. Maximum size of a coastal vessel is 120 GT and is obliged to land all catch to a processing factory at shore. There is also a large amount of subsidiary fishery. The Greenlandic fishing fleet is comprised of old and new vessels and is being restructured. The offshore fleet is exceptionally modern and well consolidated with two major companies (Royal Greenland and Polar Seafood) controlling the greater share of the market. The fleet is privately owned but the shares of Royal Greenland are 100% owned by the Government. In contrast, the coastal fleet is quite antiquated (Table 18) and will require substantial investments to ensure liquidity and profitability. The fishing fleet can be divided in three segments: Offshore fleet, coastal fleet and dinghies. Table 18 shows

[1] The Law of Commercial Fishing was designed and implemented in 1994 as an attempt to recover from the serious economic crisis of the time. Before 1994 a quota system regulated the fishery.

the number of vessels as well as their location, dinghies are excluded as their registration is not mandatory, but their number is estimated around 1.500.

Table 18. Number of fishing vessels according to operation, age and location (Berthelsen, 2014).

Municipality	Total number of registered vessels	Age	Offshore vessels
Kujataa (south)	38	43.9	1
Sermersooq (mid)	86	42.3	10
Qeqqata (mid)	63	46.9	2
Qaasuitsup (north)	107	44.9	3
Total	**294**		**16**

Foreign fleets around Greenland contribute to Greenland's fisheries. With the introduction of the 200 nautical mile Economical Exclusive Zone (EEZ) in 1977, the foreign fleet was drastically reduced. Their presences are negotiated partly through bi- and multinational agreements.

The limit between the coastal and offshore fishery is vessels below and above 120 GT. Vessels above 120 GT are not allowed to fish within the three nautical miles zone. However, shrimp fishing vessels above 120 GT are allowed to fish on a coastal license without limitations as well as within the territory of 200 nautical miles from shore, as long as the vessels do not have processing on board. Large trawlers with processing on board are only allowed to operate outside the three nautical miles zone.

In the shrimp fishery there is an Individual Transferable Quota system (ITQ) and a set Total Allowable Catch (TAC). The Greenland halibut fishery is also applied ITQ for vessels. Dinghies are exempted from the quota within the TAC boundaries. The offshore fleet is capitalized by the market but the costal fleet by government loans or subsidised by the authorities.

Altogether, fishing in recent years has been moderately growing in Greenland both in regards to production volumes and income. In general, however, there is a need for reform to combat overcapacity, low productivity in some parts of the sector and a strong need to modernise the fishing fleet, which is today in large parts composed of older and relatively small vessels. This calls for long-term, stable and attractive framework conditions for the Greenlandic fishing industry. Distribution of licenses is one tool. Another possible tool is to develop a taxation structure that supports a healthy economy and treasury and at the same time enables the sector to continue to develop.

Future development in Greenland fisheries

The Greenlandic shrimp fishery will presumably be significantly limited in the coming years as recruitment of the stock has been poor for several years and there is yet no biological basis for replacing it with fishing for cod. Despite new fishing opportunities, the overall profit from fishing faces major challenges as the shrimp fishing comprises such a considerable part of the sector's income. A reduced shrimp stock or even a collapse will have considerable consequences for the economy of Greenland.

Until recently, Greenland did not focus on fishing pelagic species, which constitutes a large part of the fishing activities in other parts of the North Atlantic. However, the East Greenland waters are currently undergoing major environmental changes. Due to increased sea temperatures, species such as mackerel and herring are now appearing in East Greenlandic waters. In 2013, the allocated quota was 15 thousand tons however, 70 thousand tons were caught. Exploratory fishing of pelagic species has been carried out the years 2011 - 2014 with promising results. If research indicates that there are grounds for larger pelagic fisheries in the future, the development will require a significant adjustment of the fishing industry with investments in new equipment, application of new fishing methods, developing new knowledge of the fishery and utilization of new fishing grounds, etc. Further, new fisheries activities may also have consequences for the processing factories on shore. Greenlanders have great expectations for future profit from pelagic fishing in its waters, but the quota set for mackerel in 2014 was 100 thousand tons, 10 thousand tons with expected value of blue whiting, 10 thousand tons of silver smelt and 15 thousand tons of herring (Ögmundsson, 2014).

Other areas of the Greenlandic fisheries are significantly less productive compared to fisheries in neighboring countries. Economic prosperity can be foreseen for Greenland, if the country´s fisheries are able to develop to Icelandic and the Faroese standards. Laws and regulations that increase the incentive of consolidation and concentration of fisheries, will consequently lead to greater economic benefit for the country.

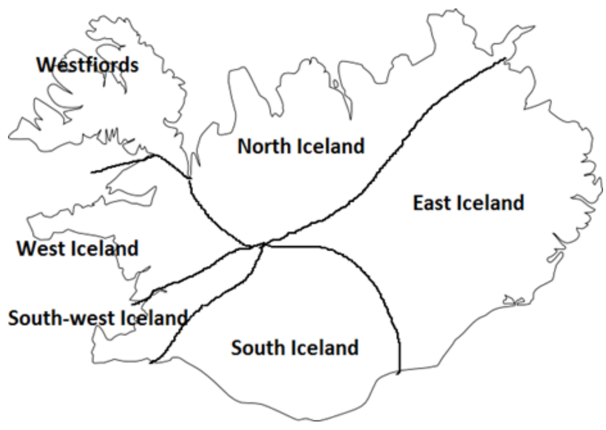


Figure 18. The six fishing regions in Iceland.

4.8.3. Fisheries in Iceland

The Icelandic coastal fleet is a successful story, including around 2,000 vessels with high productivity and a profitable business. A costal vessel is categorised as being less than 20 meters long and below 30 GT. The fleet is an important contributor to the national economy of Iceland and is considered a key element for regional development and settlements in the country (Figure 18). More than 97% of the coastal catches in Icelandic waters are demersal species, the rest being crustaceans and pelagic species. Cod is by far the most important fish caught by coastal vessels, followed by haddock. The coastal fleet has significant role in Icelandic economy landing more than 12% of the total demersal catch, at the value of one billion DKK 2012. Around 1,600 fishermen are working full-time within the coastal fishing and approximately 700 have temporary employment.

In recent years the fishing industry has proven particularly important contributing to Iceland's recovery from the financial crash in 2008. To support future economic growth, it is crucial that the industry retains its current high level of productivity and captures further improvement opportunities available to expand the value of this constrained resource (McKinsey & Company, 2012).

Good productivity in Icelandic fisheries

The fishing industry creates the basis for Iceland´s economic prosperity, and it remains the most important export industry of the country with 43.8% of its exported goods in 2013 (Statistics Iceland, 2014). A series of reforms has enabled Iceland to establish a highly efficient fishing policy, both biologically and economically. The financial return in Icelandic fish industry has been good, and since the financial crash the gross share of capital, EBITDA has been close to 30% (Vigfusson, Gestsson, & Sigfusson, 2013) and Iceland generates high export revenues per capita from fisheries with almost 3.5 tons of catch per capita (McKinsey & Company, 2012). Fisheries product imported to Iceland are mostly bait for long line, around 700 tons in 2012 with a value of DKK 5.7 million. The Icelandic fishery is returning a high profit, driven by both high capital intensity and high utilization yield of raw material. The gross value added per worker is among the best in the world fish industry (McKinsey & Company, 2012).

The coastal fleet is largely operated from small fishing villages that have been severely affected by the commercialisation of the fishing industry in the last decades. Aggregation of quota shares and operational optimisation by the largest seafood companies has left these small traditional fishing villages with little or no fishing quotas, affecting regional development. In some cases the costal fleet, depending on a separate costal quota system is now the backbone for employment in these fishing villages. Therefore, the coastal fleet is highly important for the survival of the small fishing communities around the country (Thordarson & Vidarsson, 2014).

Coastal fishing and small fishing communities

Fisheries are the most important industry in Iceland, with direct input to Gross Domestic Product (GDP) 11.3% in 2012 and directly employs over 9,000 people (Statistics Iceland, 2014). Total volume fished the year 2012 was 1,149,000 tons, with demersal fishing of 458,000 tons and pelagic fishing of 991,000 tons. The total value of demersal fishing was DKK 5,211 million and pelagic fishing of DKK 2,165 million combining to the grand total of DKK 7,126 million. Total export from fishing in 2012 was 748,631 tons of product, but import was only 58 thousand tons, mostly landing of pelagic species landed as a raw material for production in Iceland (Statistics Iceland, 2014). The value of marine export was over DKK 12 billion in 2012.

Figure 19. Indoor drying of cod heads is a feasible option independent of weather condition.

The raw material yield of the Icelandic fishing industry has improved in recent years, today 72% of the cod is utilized for value creation and the yield is still improving. Producers have been aiming for maximising the utilization of the catch, collecting side product like fish heads, bones, liver, roes, stomach and etc. that are valuable export products. The value of this export was around DKK 463 million in 2011 (Vigfusson et al., 2013).

The most important co-product in Icelandic fisheries is stock fish, traditionally produced by outdoor drying by cold air and wind on wooden racks. However, indoor drying has become more common in recent years, as weather conditions are not always adequate for outdoor drying. Indoor drying as shown in Figure 19 has the advantage of being more controlled and less dependent on weather and/or seasonal effects. Moreover, drying time is shorter with the possibility of drying all year around giving more consistent dried product as well as flies and insects are prevented from contaminating the final product.

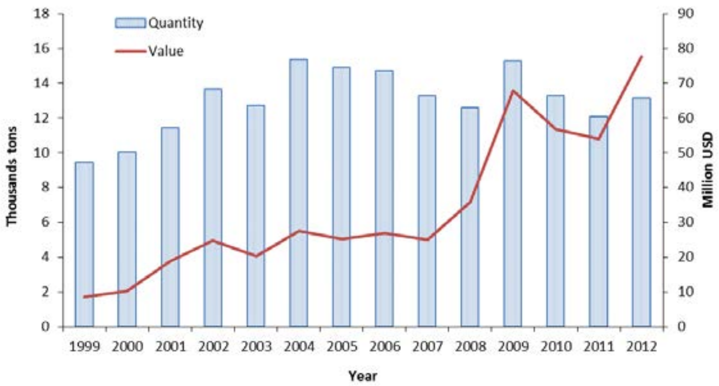


Figure 20. Evolution of quantity and value of dried fish products exported from Iceland to Nigeria 1999-2012 (Statistic Iceland, 2014).

Majority of stock fish for the Nigerian market is produced in Norway and Iceland, and is mainly produced from cod heads. Currently, approximately 5% of Iceland's aggregated seafood export goes to Nigeria. The export value to Nigeria, comprising mainly from dried cod, haddock and saithe, has increased the last ten years from about DKK 144 million to 574 million in 2012 (Figure 20), making Nigeria one of the 10 largest buyers of Icelandic seafood products (Statistics Iceland, 2014). The opportunities in the Icelandic fishing industry are in building a quality reputation and brand around Icelandic fisheries and market the Icelandic fish as premium marine product in the future (McKinsey & Company, 2012).

In 2012, Iceland exported 27,000 tons of fresh fish of the value DKK 1.5 billion (Gíslason, 2014). Export of fresh fish portions increased by 78% in the first 10 months of 2013 and according to marketing experts, this development is likely to continue (Marko Partners, 2014). Around 90% of fresh fish export is cod and haddock and most of it is exported to France, Great Britain, Spain and Belgium, but USA and Germany are also an important markets (Statistics Iceland, 2014).

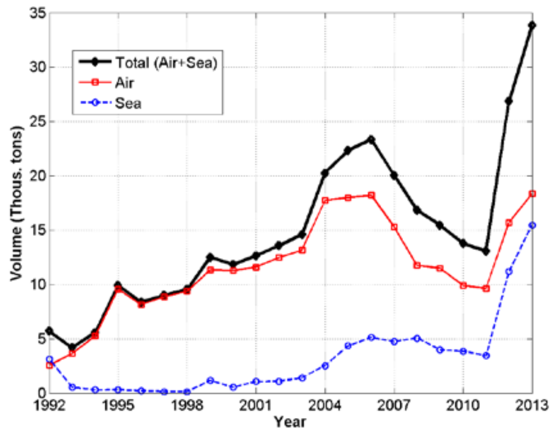


Figure 21. Volume of exported fresh fish portions from Iceland 1992 – 2012 (Statistics Iceland, 2014)

There is an increasing demand for high quality fresh fish on the European markets. Considering Iceland exporting almost 25,000 tons in 2012 as shown in Figure 21, it would be beneficial to extended self-life of products resulting in the possibility to use ship instead of airfreight. Temperature is the most important factor in storage of fresh fish and without precise control, quality will be lost, for example shelf-life of fresh fish is halved by raising the temperature from 0 to 4°C as biochemical processes taking place post mortem, such as blood coagulation and rigor, are highly temperature dependent. At higher temperature these processes are accelerated resulting in less blood removal, gaping, drip loss etc. Therefore, fresh fish exporters are forced to choose airfreight with high cost, large amounts of ice etc. as maintaining cold-chain from harvesting to market is critical for end-product quality and value.

The main advantage of the superchilling technology is to extend/prolong the shelf life compared to traditional chilling and maintain high quality of foods (Kaale, Eikevik, Rustad, & Kolsaker, 2011).

Super chilling and quality

One new idea to maintain quality for fish product, particularly fresh fish, is superchilling. This idea has mostly been practised in laboratories but could be commercialized on a large scale. The superchilling process preserves food by partly freezing its water. Through scientific research on superchilling, the beneficial effect of the method has been proven with decreased drip loss, reduced microbiological growth and extended shelf life of fresh products. Superchilling of white fish and salmon has been tested by the Icelandic applicants on a larger scale and results have shown that the quality of superchilled foods is mainly related to the properties of ice

No fish product exported from Iceland has delivered more value adding than fresh fish portions, or more than 100% since 2006 (Knutsson, 2012).

High value in fresh fish export from Iceland crystals. Recently, several studies on superchilling technology for salmon have been published indicating that optimum properties of ice crystals are achieved by high rate of superchilling. Processing and transportation of fresh fish is currently a great challenge and finding solutions to implement superchilling would lead to a more compatible status for West Nordic countries fresh fish products, e.g. through higher quality, longer shelf life and more economical logistics.

4.8.4. Future opportunities for fisheries production in West Nordic countries Bioeconomy

The economy of the Faroe Islands, Greenland and Iceland is built on resource-based industries, which is the cornerstone of the living standard in these countries. In Greenland, fisheries export is 93% of the merchandise export, in Faroe Islands it is 91% of the total export and in Iceland it is 37% of the total export. The biggest challenge for future prosperity for these nations is relying on renewable resources like fisheries and aquaculture. Fish resources are sustainable and have natural restrains to supply raw material, however, increasing value contribution of the fishing industry must come from strengthening fish stocks. Increased opportunities are highly dependent on robust fish stocks and additionally, investment in innovation and technology to improve yield and increase in product value along with high quality, return the highest prices for the product which will maximize value creation in the fisheries industry.

> Opportunities in fisheries of the West Nordic Region depend on robust fish stocks and investment in innovation and technology to improve yield and increase quality of the products. Combining strong industry, such as the fishing industry, with research, development and innovation within the biotechnology sector will benefit the economy of the West Nordic countries.
>
> *Opportunities in combining fisheries and biotech*

Iceland could share the knowledge with the other two countries of the West Nordic countries when it comes to productivity and value creation in fisheries, especially concerning demersal fishing and processing (Figure 22). The EBITA in the Icelandic fishing industry in 2012 was 30% (Statistics Iceland, 2014), mostly due to effective fisheries management and control of its fisheries value chain as well as how to manage access to high end markets for its product and quality of product and yield in production (McKinsey & Company, 2012). Iceland is leading when it comes to utilising its raw material and is exporting side products in the demersal fishing for more than 477 million DKK annually, products that were discharged not such a long time ago.

> The knowledge available in the West Nordic fishing industry has increased in the last decade and knowledge and technological transfer between the countries and increased cooperation would strengthen the West Nordic countries.
>
> *Cooperation in fisheries between the West Nordic Countries*

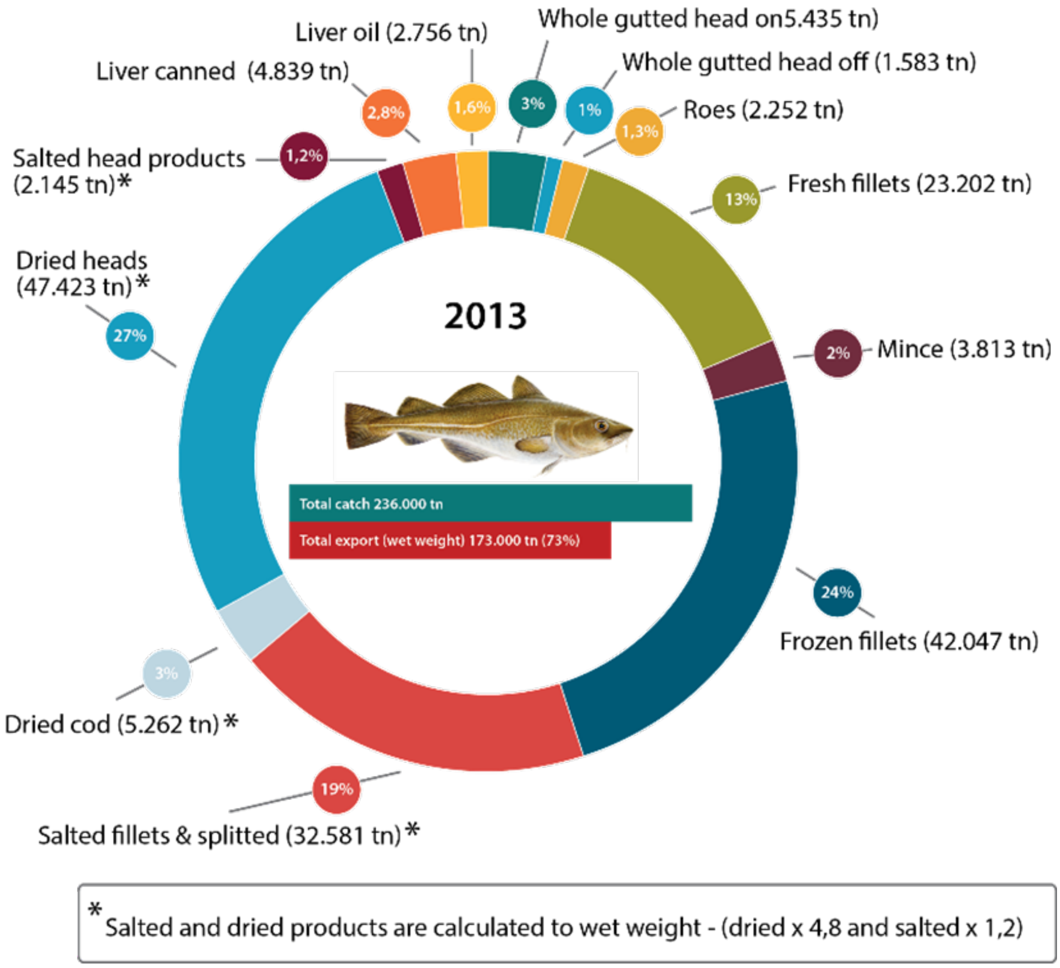


Figure 22. Utilization of Icelandic cod in 2013 (Statistics Iceland, 2014).

4.9. Aquaculture

Aquaculture is an ascendant industry globally in connection with the ever-growing world population. Fish farming both occurs on land and in sea, depending on the species bred and the climate at the farming site. The most appropriative measure of this resource would be weight of slaughtered fish annually. The global possibilities for aquaculture are restricted by access to fresh water and sea area. The West Nordic countries with their vast access to ocean around them give extensive opportunities in this respect.

It is debated whether aquaculture is a resource industry or a pure production industry. At the one hand, farmed fish is not a natural resource itself and would not exist naturally without human activity. A share of the productivity is dependent on non-reviewable input like fingerlings and other equipment. On the other hand, the industry needs access to both land and ocean, which are in fact renewable natural resources and the costliest input of aquaculture, the feed, is from renewable resources.

Therefore, products from aquaculture can be classified as renewable biological resources (Johannessen, 2014).

Coastal aquaculture farms are ubiquitous in some European countries. Sea-cages hold over one million tons of fish while hundreds of thousands of tons of mussels, oysters and clams are grown on suspended ropes, racks or trays (FAO 2006). Offshore aquaculture, also known as open ocean aquaculture, is an emerging approach to marine farming where fish farms are moved some distance offshore. The farms are positioned in deeper and less sheltered waters, where ocean currents are stronger than they are inshore. As oceans industrialize, conflicts are increasing among the users of marine space. This competition for marine space is developing in a context where natural resources can be seen as publicly owned. In both cases, there can be interactions with the tourism industry, recreational fishers, and wild harvest fisheries. The problems can be aggravated by the remoteness of many marine areas, and difficulties with monitoring and enforcement. Remote sites can be chosen that avoid conflicts with other users, and allow large scale operations with resulting economies of scale. Sites for inland aquaculture using traditional flow-through systems are exhausted.

Spatial planning for aquaculture

As the wild catch of most species is stagnating, the general supply of seafood in the world will be from aquaculture. Farmed salmon has overtaken wild catch of salmonids and is still increasing with total supply of around two million tons in 2013, and at the same time the total catch was less than half million tons (Marine Harvest, 2014).

Production of Atlantic salmon has increased by 428% in twenty years, with an annual growth of 9%. The growth from 2013 to 2020 is expected to be around 3% annually with limiting biological boundaries being pushed in farming and resulting in expected diminishing future growth (Kontali Analyse AS, 2014). Future growth will relay on progress in technology, development of improved pharmaceutical products, implementation of non-pharmaceutical techniques, improved industry regulations and intercompany cooperation.

Energy use in fish farming is optimal from the feed usage viewpoint as the fish does not have to use energy reserves for body temperature regulation as the fish has the same temperature as its environment. Further, the density of the fish body is similar as the water it is living in, resulting in the minimum energy usage for movement and physical support. Due to these facts, the fish only needs around 1.2 kg of dry feed to produce 1 kg of product. For comparison, chicken farming needs two kg of feed to produce 1 kg, pork around 3 kg and the

According to Agriculture and Environmental Service Department of the World Bank the: "*Aquaculture in the world has grown substantially for the past decades and is increasingly important protein provider as well as to keep price of fish down overall. It is the department's view that there will be a great need for investment in this industry with safer technologies and adaptation to local conditions and appropriate settings*" (Voegele, 2014).

Future need for aquaculture in the world

cattle/sheep production needs 8 kg of feed to produce 1 kg of meat (Marine Harvest, 2014). In this sense, the salmon farming is environmentally friendly and discard only around one third of the waste compared to pig industry. Only vegetable industry has less discharge than salmon farming (Rúnarsson, 2014). However, feed production for fish farming will increase the demand on fish-meal and oil, where around 20 – 30% of fish feed origins from wild fish products as fish-meal or oil and the rest comes from vegetarian products. With steady increase in price of fish oil, producers have moved to rapeseed oil but soy meal and wheat have traditionally been the most important vegetable protein sources in fish feed production (Marine Harvest, 2014).

Pre-feasibility studies by Matis have shown that the black soldier fly (*Hermetia illucens*) (BSF) represents a promising option for the production of feed protein, with growing interest in its use. The aim of the project was to answer questions related to optimal raw material use for the Black soldier fly larvae as ingredient for fish feed and potential raw material reduction. Results so far have shown that the larvae can be grown on different substrates but with variable efficiency. By taking advantage of available nutrients and water, the larvae can reduce the amount of feedstuff by 50-95%, making the benefits of their use substantial in relation to resource utilization and environmental impacts.

Opportunities in feed production for Aquaculture

Fish farming is the fastest-growing sector of world food production. Aquaculture feed is strongly dependent on fish meal and fish oil to meet the critical protein requirements. Increasing use of fish for human consumption, along with a decline in availability and increasing costs has created a need for alternative sources for protein. However, fish meal and fish oil are still are the main ingredients in modern fish feeds. Increased consumer and environmental awareness have resulted in development in other directions, as substantial amount of worldwide wild fish catches is processed into fishmeal and fish oil for feed production, raising concerns regarding the sustainability of this arrangement. With regards to both resource utilization and environmental issues, it is therefore important to look at other biological streams as raw material sources for fish feed. Significant amounts of raw materials are underutilized in the West Nordic countries, including waste from agriculture, fish processing, households and manure from livestock production. Due to the low protein content of most waste streams mentioned, this raw material is not suitable for direct use in fish feed. However, with low expenditure, these raw materials can be utilized for the cultivation of invertebrates which in turn transforms them into high quality protein and oil ingredients for feed. In addition, this would reduce the enormous amount of waste generated.

Increased demand for fish and fish products has led to increased research of protein resources for fish feed. Fish meal has been one of the main sources but is expected to fall short of demand in the near future. To meet this shortage protein-rich microorganisms (i.e. Single cell protein) have been used to produce protein from wood. Microbial biomass from cultivated residual streams from wood-based biorefineries in Sweden were collected and used for production of fish feed in feed trials for Tilapia. Fishes fed with such feed where fishmeal had been substituted with single cell protein, shoved similar or better growth than fishes fed with control feed containing fishmeal (Alriksson et al., 2014).

Fish feed from wood

FAO estimates that food production in the world needs to be doubled before 2050, which is difficult to vision due to already high pressure on natural resources. Agricultural land is scarce, overfishing is common and climate change with its associated complications can have serious consequences for food production. New ways of procuring protein and sustenance are needed. Insects have been part of humanity's nutrient source through the ages. Today, it is believed that insects are part of the diet of two billion people while hostility regarding their consumption, and even existence, is evident in many societies, especially in the developed world. While the majority of edible insects are caught in their natural habitat, innovation in large-scale cultivation has been emerging. It is uncertain how majority of the western population will react to this development, but the starting point could be to utilise insects as a source of nutrition for the growing of traditional protein like fish.

Table 19. Aquaculture in the Nordic countries in million DKK.

Aquaculture 2012	Faroe Islands	Iceland	Greenland
Slaughtered tonnes	62,783	7,849	0
Export Value (FOB)	1,823	216	0
Farming contribution to GNP	2.77%	n.a.	0
Processing contribution to GNP	1.97%	n.a.	0
Total contribution to GNP	4.73	0.14%	0
Workforce	750	250	0
Workforce (percentage)	2.8%	0.14%	0
	(Statistics Faroe Islands, 2014)	(Statistics Iceland 2014)	

4.9.1. Aquaculture in Faroe Islands

The clean ocean surrounding the Faroe Islands is an advantage for the fish farming industry that has increased substantially the recent years. Currently, three companies produce and export farmed Atlantic salmon in the Faroe Islands. These companies use both land-based farms and cage aquaculture. The juvenile fish is commonly raised in land-based tanks, using recycling water system. The recycling system has solved the problem related to water scarcity. Salmon for the market is then farmed in seawater cages.

The North Atlantic drift surrounds the Faroe Islands and mingles with the cool Arctic currents cascading from the north. This unique current system, combined with the remote location of the Faroe Islands, maintains a cool and steady sea temperature around the islands. Research has shown that cool and steady sea temperatures are essential for the overall welfare and thereby also the quality of salmon.
Remotely located, in pristine waters in the middle of the North Atlantic Ocean, the Faroese fjords and sounds are perfect for premium aquaculture production, as they provide exceptional biological conditions and excellent circulation of fresh pristine sea water (Salmon from the Faroe Islands, 2014).

Ideal location for salmon farming

The slaughtered weight of salmon produced in 2010 was 37,221 tonnes but increased substantially up to 62,783 tonnes in 2012 (Table 19) and is foreseen to exceed 80,000 tons in 2014. Trout has not been farmed on the Faroe Islands since 2010, when the production was 1,791 tonnes (Johannessen, 2014). Figure 23 shows the salmon production during the period from 1996 to 2013. The production dropped in 2000 due to a salmon outbreak, resulting almost in a total collapse of the salmon farming in the islands.

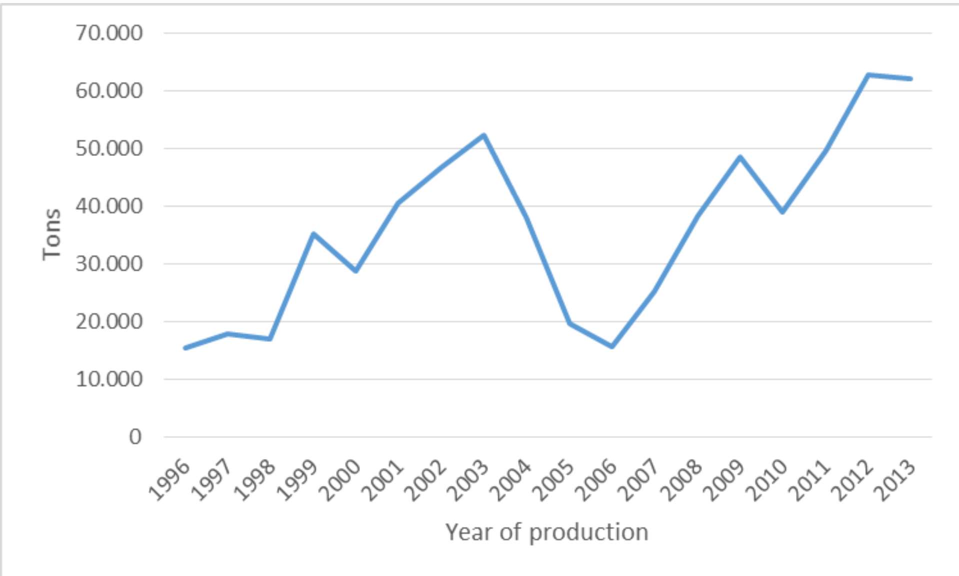


Figure 23. Salmon production in the Faroe Islands 1996 to 2013 (tonnes - gutted weight) (Hagstova Föroya 2014)

The export value of salmon was DKK 1.8 billion in 2012. The direct contribution of the aquaculture, farming and processing, sector to Faroese GDP was 4.7% in 2012. This amount includes the processing of the salmon. The direct contribution of farming only, excluding processing, was 2.78% as the value of processing alone was 1.97%. The aquaculture industry usage large amount of raw and help material such as feed. This material is partially imported, while some is produced locally. The production of the raw and help materials for the aquaculture creates jobs for and adds value to the economy. This part of the value chain is important for Faroese economy, producing feed for local production as well as an alternative export value. If the provision of all raw and help material for the aquaculture would have been imported, and processing would have been done abroad, then the contribution from aquaculture to the Faroese economy would be less significant.

> In 2003, the Faroe Islands implemented one of the world's most stringent and comprehensive aquaculture veterinarian legislations. A total of 83 detailed paragraphs created one of the world's most sustainable and predictable aquaculture environments. The legislation ensures continuous welfare management and responsible care of the environment. This enabling legislation and the subsequent regulatory framework put into place have been so successful that salmon from the Faroe Islands are completely free of antibiotic (Salmon from the Faroe Islands, 2014).
>
> *Sustainable and predictable aquaculture*

The salmon farming is a profitable business in Faroe Islands with more than 70% of the countries' annual profit in the primary sector (Johannessen, 2014). Salmon farming had an annual profit of almost one billion DKK in 2013, compared to a loss of 41 million in demersal fisheries and 293 million profit in pelagic fisheries the same year (Table 19) (Johannessen, 2014). The cost of producing gutted and packed salmon in Faroese in 2012 (Fob) was 23.20 DKK/kg, in line with the cost in Norway but lower compared to the cost in Chile, UK and Canada (from 27.40-29.20 DKK/kg) (Havbúnaðarfelagið (The Faroese Fish Farmers Association), 2014). The average yield per fingerling is an important indicator of production efficiency and in Faroe Islands it is estimated to be around 4.6 kg. In UK and North America, the fingerling yield it is estimated to be little more than three kg showing the competitiveness of the Faroese aquaculture (Marine Harvest, 2014).

4.9.2. Aquaculture in Greenland

Aquaculture of Arctic char in Greenland has not been successful and currently there is no aquaculture in Greenland. Possibilities of halibut fish farming are being considered along with cultivating macro algae but no results have yet been reached (Wegeberg, Mols-Mortensen, & Engell-Sörensen, 2013). However, few private companies have applied for permission to collect seaweed for test collection in order to start commercial production in near future. Arctic seaweed production is an unique opportunity that can be developed in Greenland as a supplement for commercial fisheries and hunting and also for local cuisine in restaurants.

4.9.3. Aquaculture in Iceland

Aquaculture is a growing industry in Iceland, even though the cod farming is declining, the salmon and arctic char farming is evolving. This applies especially to the Westfjords and East Iceland, which have naturally protected areas from deep sea waves and turbulent weather conditions, with long deep fjords giving a good protection.

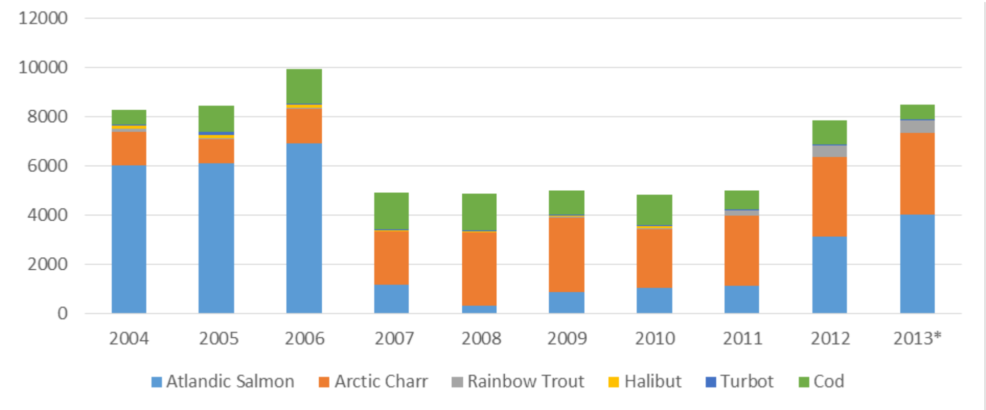


Figure 24. Slaughtered fish by tons from aquaculture in Iceland from 2004 to 2013 (Hagstofa Íslands (Statistics Iceland), 2014).

Figure 24 shows amount of farmed fish produced in Iceland during the period 2004 - 2013, with estimated production in 2013. Since the peak in 2006 and with the decrease in production between 2007 and 2011, aquaculture seems to be growing again in Iceland, with almost 8,000 tons slaughtered in 2012. The value of exported aquaculture fish in 2010 was DKK 128 million.

It is an important fact that the optimal conditions for fish farming in Iceland are in Westfjords and East Iceland, the two regions in Iceland with the best natural environment condition for aquaculture, but which are suffering a negative regional development in the country. The fish farming is expected to contribute to turning that development around and could be the foundation for future prosperity for these regions. Even though fish farming has been growing in Iceland since 2007, it is still a comparatively small section within the fish industry. However, there are optimistic plans within the industry and

When looking at the Faroes prosperity in salmon farming, there is no doubt that Iceland could learn from its neighbour and partly build its future wellbeing on aquaculture. The Faroe Islands have managed to build a successful industry which is already contributing more to the economy and export than catch fisheries and is more profitable. For Iceland, the fish farming is not only an expectation for future economic growth but it could also be extremely important for strengthening regions in the North West and East of Iceland, regions that are currently suffering economic and social problems with reduced population. Iceland could look to the Faroe Iceland´s success in salmon farming considering value creation, job creation and rural development.

Opportunities in Aquaculture in Iceland expected production in 2014 will be 13,000 tons and the production is expected to grow to 40 - 50,000 tons within the next 15 - 20 years. The value of such a production is estimated around DKK 1.4 billion.

4.10. Algae Production

Macroalgae are abundant in coastal areas of the North Atlantic and can be cultivated and produced in bulk, off shore. Their growth rates and productivities far exceed those of terrestrial plants and they accumulate high levels of carbohydrates (up to 60%). The abundance and the high carbohydrate content make macroalgae an attractive source of biomass for biorefineries. However, they are also challenging as bio refinery feedstock because of structural complexity of polysaccharides, heterogeneous sugar composition, and sulfatation.

Macroalgal polysaccharides have various uses today but mainly as a high volume and low value gelling agents. Macroalgal bulk added value derivatives envisaged include (i) mono-sugars for fermentation and subsequent fermentative production of platform and specialty chemical chemicals and energy carriers (ii) mono sugar substrates for enzymatic synthesis of platform and speciality chemicals and (iii) oligosaccharides as (prebiotic) food/feed supplements. Many complex polysaccharides including complex sulphated complex polysaccharides such as ulvan and fucoidan are not exploited to any extent today but are potential sources of bulk quantities of enzymatically-derived potent bioactive oligosaccharides for feed, food and skin health, as prebiotics for functional food and as sources of rare monosugars for the synthesis of platform- and specialty chemicals.

> Cultivation, harvesting and bulk processing technologies of macroalgae are being established in various Nordic projects, but processing of marine polysaccharides to high added value products has not been developed to industrial bulk state. This provides unique while challenging commercial opportunities for the Nordic countries, especially the West Nordic countries. The utilization of macroalgal biomass has been limited by lack of appropriate cost-effective pre-processing technologies including bio refinery processing enzymes and fermentative bio refinery organisms.
>
> *Challenges and opportunities in macroalgae*

Another value stream that can be exploited from macroalgae are proteins and protein derivatives. Previous research has demonstrated that blue light stimulates the protein synthesis in red algae. By improving the knowledge and insight in macro algae response to red and blue light it may be able to optimize the protein content, and thereby make more economical, environmental friendly and sustainable feed for aquaculture (Gruwier, Kloster, Rasmussen, Olesen, & Bruhn, 2014).

The Nordic Algae Network has 21 partners in Iceland, Norway, Denmark and Sweden with the main goal to help the partners to a leading position in the Algae field for commercial utilization of high value products and energy from algae products. To increase the synergy and facilitate collaboration between the partners, news and innovative value with focus on different applications of algae: Chemicals, pharmaceuticals, ingredients for food and feed energy carriers. Industrial scale utilization of algae requires intensive development of growth harvest and conditioning systems in the coming decade and up scaling of algae production is a long innovative process.

In addition to the potential of deriving high value added products from macro-algae, the cultivation of macro-algae also has clear environmental benefits. Macroalgae absorbs excess nutrients, such as nitrate and phosphate - caused by aqua- and agriculture, from the ocean. Thereby it cleans the coast line. Macroalgae also acts as a carbon sink, thus contributing to the mitigation of climate change (Chung, Beardall, Mehta, & Sahii, 2011).

4.10.1. Faroe Islands

In the Faroe Islands, the company Ocean Rainforest engages with the cultivation of macroalgae on the open ocean. The company has designed a Macro-Algae Cultivation Rig. The cultivation rig has been deployed since 2010 and it has proven itself very capable to withstand the harsh weather conditions in the North Atlantic. Although several challenges remain in making the cultivation of macroalgae commercially viable, the cultivation rig is demonstrating excellent growth rates. Moreover, the company has received very good feedback from its customers concerning the quality of product. It is clear that conditions for the cultivation of macroalgae in Faroese waters are excellent, partially due to the stable all-year round ocean temperature between the isles. Through the Nora funded MacroBiotech project, Ocean Rainforest and the project partners are currently in the process of analysing the content of bioactive compounds and the seasonal variation of these in order to optimise a bio-refinery process.

4.10.2. Iceland

Iceland has been dubbed as a premier location for algae biomass production at the recent European Algae Biomass Conference 2013 due to the country’s green renewable energy and logistic possibilities. Algae production is a growing industry with huge future development potentials. Iceland’s green renewable energy, with its compatible rates, will offer the industry big advantages as a future micro algae production centre. Iceland can make long-term energy contracts offering a much-needed stability in production costs. This also results in stable grid connections and reliable delivery rates.

5. Biotech and bioenergy

One highly interesting aspect of the bioeconomy is the application of biotechnology to increase value and produce high value products from biomass, including waste streams and underutilized biomass. The bio-recourses in the West Nordic are, from a biological aspect, very interesting as conditions are extreme such as cold temperatures and lack of sunlight. These conditions and other unique aspects of the region make the West Nordic countries an extremely interesting source of valuable biomolecules, enzymes and organisms. An example of unutilised waste streams are streams from fisheries where e.g. valuable proteins and peptides can be recovered, as well as polysaccharides such as chitin and chondroitin sulfate (polysaccharide in cartilage and in tunicates).

> A mapping and opportunity analysis focusing on biotech opportunities in the West Nordic bioeconomy will be a highly important addition to the conclusive mapping and opportunity analysis of biorecourses and the utilization in the West Nordic conducted within the project reported herein.
>
> *Biotech opportunities in the West Nordic countries*

Underutilized biomasses of macro-algae are of special interest in biotechnology as they are abundant in the coastal areas of the North Atlantic and can be cultivated and produced off shore in bulk. Their growth rates and productivity exceed by far those of terrestrial plants and they can accumulate high levels of carbohydrates as a feedstock resource for biorefineries. Furthermore, as they are marine, macro-algae will not compete for agricultural space and water on land.

Bioprospecting opportunities are plentiful in the West Nordic countries. The bio-recourses in the West Nordic countries include extremophiles, such as psychrophilic marine microbes, invertebrates, slow growing plants, lichens as well as submarine and terrestrial thermophiles in Iceland and Greenland. These extremophiles are highly unique and have been shown to be an abundant source of enzymes and microbes for processing feed and food components (proteins, lipids, and polysaccharides) as well as for applications in chemical and pharmaceutical synthesis or in molecular biology. These organisms are also a potential rich source of small bioactive molecules and polysaccharide derivatives, which can be used as health promoting ingredients in food, feed and skin care, including cosmetics or as novel sources of antibiotics.

5.1. Biotech in the Faroe Islands

The Faroese economy rests heavily on primary production and the biotech sector on the Faroe Islands are mostly limited to quality control of the production industry. The recent opening of the Research Park iNOVA, which is equipped with modern equipment such as RT-PCR, Next Generation gene sequencers and mass spectrometry, provides affordable, rent-based access to biotech infrastructure for startup companies or foreign companies wanting to establish themselves on the Faroe Islands. The first companies to take advantage of the new opportunities are P/F Fiskaaling, which used iNOVA equipment to develop a genetic sex determination test for smolt (juvenile salmon) and Amplexa Genetics A/S, a Faroese owned contract laboratory located in Odense, Denmark, who will perform genetic tests for the National Hospital of the Faroe Islands.

5.2. Biotech in Iceland

Icelandic biotechnological research and development can be traced back to the early eighties of the last century. Prospects and potentials in biotechnology in Iceland were then mapped and early opportunities were recognized, especially in relation to the fish industry, in genetic resources of unique geothermal regions of Iceland and similarly in many diverse marine and other cold-adapted biotopes. However, receptive industrial environment is limited and development has mostly been within research institutes and universities. The potential in the field for Iceland is high, education and research infrastructure is at a high level and abundant underexploited and even unique genetic and other bio-resources are present in the country. Promising general R&D directions have been marked and followed, some which can be traced back to the early pioneering steps.

5.2.1. Enzyme bioprospecting and developments

The biotechnological potential of extremophilic organisms in Iceland was recognized early, but the main R&D emphasis has been on thermophilic bacteria. Iceland is one of the most interesting geothermal regions in the world in the number and diversity of geothermal biotopes which is almost unmatched elsewhere. Iceland can be considered an important high diversity region in terms of the Convention of Biological Diversity as regards potential exploitation, benefit sharing and conservation. From the early start, the R&D focus has on been enzyme bioprospecting and development and later, also on metabolic engineering of thermophilic bacteria for production of energy carriers (e.g. ethanol) and platform chemicals (e.g. diols). Bioprospecting of enzymes from cold adapted biotopes is also increasing, especially from marine microbes harbouring coastal areas. Matis has invested major effort in this field especially targeting enzymatic activities for processing and developing marine polysaccharides and derivatives as novel substrates and products for industry, and as bulk feedstock biomass for emerging marine biorefineries. Cold active of enzymes have also high potential in food industries where high temperature is detrimental. The Icelandic company Penzyme has explored various possibilities for such applications focusing on proteases from cod.

5.2.2. Fish industry related biotech

R&D in developing novel enzymes, enzyme aided processes and products for the fish industry started also in the late eighties in the University of Iceland, the Fishery Research Institute and IceTech. This involved, amongst other things, R&D in cold active processing enzymes for generation of food flavorants from fishery wastes and oligosaccharides from shrimp shell waste. Two companies exist today based on this pioneering work, Zymetech producing cold active proteases from cod for medical uses and Genis, enzymatically producing chitin oligosaccharides also for medical applications. Currently, there is a surge in research activities in this particular field in Iceland. This is to a large extent industry driven and aims at increasing resource efficiency in the fish industry. Matis is to a large extent leading the R&D with important contributions from universities and independent small local research stations. Various projects are ongoing aiming at complete utilization of particular resources, creating added value from waste streams and underexploited raw materials, as well as development of enzymatic processes to increase efficiency, improve quality and generate new added value products. The novel processes or process aids are usually incorporated into existing technology chains of the fisheries or into associated independent product lines. Companies have also been established around specific products, such as Kerecis that processes and markets fish-skin for tissue regeneration, Iceprotein and Codland that produces bioactive peptides from proteins in fisheries' byproducts, and MPF Iceland which produces fish protein isolates from byproducts. Many of these companies are associated with larger companies that harvest and process fish, which is an important factor for them to be successful.

> The same research group has been working in this field from the beginning, from the late eighties, first at the Technological Institute of Iceland (IceTech), then in the biotech company PROKARIA which merged with The Fishery Research Institute to form Matis. This has ensured important continuity of the R&D work in the field. Enzymes have been developed and commercialized by the Matis group for molecular biology applications and for the chemical and the food industries.
>
> Initially commercialization was aimed at foreign markets, mostly through R&D contracts made with large industrial companies (e.g. Nestle and Roquette Frères), but also directly through the Icelandic companies, first PROKARIA and now PROKAZYME. Besides Matis and University of Iceland, biotechnological R&D work is carried out in the University of Akureyri (development of fermentative thermophilic biorefinery organisms) and in the companies Blue lagoon (cosmetics), Prokatin (biorefinery organisms utilizing geothermal gasses, H_2S, CO_2 and H_2) and Prokazyme (marketing thermophilic enzymes).
>
> *Long history of research*

5.2.3. Bioactive or health promoting biomolecules

From early on, the unique flora and fauna of the North has been seen as a possible underexploited source of potent bioactive molecules. Earliest research stem from the eighties, and early nineties. The research has been led by the University of Iceland, the Faculty of Pharmaceutical Sciences and has recently become major research focus of Matis, with bioactivity screening and analysis facilities at Saudarkrokur in the North of Iceland. Important bio-resources include invertebrates, lichens, seaweeds, slow growing artic plants and extremophilic microbes. Possible products are of a wide variety and for different consumer markets. In many cases important supportive analytical evidence has been found for various health promoting effects such as immunostimulating, antioxidant, antidiabetic and anticarcinogenic activities of extracts or specific compounds or biomolecules from the target organism. This is a promising field in Iceland. The route to consumer market is relatively short. A number of small companies have been established around these bio-resources, in cosmetics, folk medicine and food supplements. However, supportive research into health promoting effects needs to be strengthened in support of claims of beneficial effects of the products.

5.2.4. Sustainable biomass and biorefineries

Seaweed

There is an immediate interest in Iceland in the vast seaweed biomass resources available in coastal areas and the possibility of extensive off shore cultivation. Seaweeds can be cultivated and produced in high abundance surpassing other biomass of comparable bulk and ease of cultivation. They accumulate high levels of carbohydrates, the component that is a potential bulk feedstock for chemical, enzymatic and microbial bioconversion to added value products, including biofuels and platform chemicals. Conditions for establishing an economic seaweed biorefinery platform in Iceland are favourable, e.g. energy cost is relatively low and use of available geothermal heat and steam enables efficient pre-processing of the biomass facilitating subsequent fractionation and enzymatic access to polysaccharides. Harvesting and pre-processing technologies have already been established in Iceland. The company Thorverk harvests coastal seaweeds in the fjord Breidafjordur for production of dry seaweed meal and uses geothermal heat in its drying processes. Until very recently, no processing of high value compounds form seaweeds has been realised, the company Marinox has been a pioneer in processing and utilization of high value compounds from microalgae.

Until very recently, no processing of high value compounds form seaweeds has been realised. The company Marinox, founded in 2011 based on years of extensive work done in collaboration with Matís, is a pioneer in Iceland in the processing and utilization of high value compounds from macroalgae. Marinox has developed several proprietary processes to extract highly active polyphenols and sugars from Icelandic seaweed, and already has commercialized several skincare products (UNA skincare) containing these extracts. Great opportunities are in this area for the West Nordic countries.

Marinox – pioneer in value creation from microalgae

The unusual recalcitrant polysaccharides are the main threshold for bulk utilization of seaweeds in biorefineries. The main constituent polysaccharides are often polyuronates or complex, heterogeneous polymers containing different, often sulphated, sugars, including deoxy sugars and sugar acids (uronates). It is difficult to degrade these polysaccharides into monosugars by physicochemical methods and fermentative organisms are also lacking to convert the monosugars further to added valuable products. Important work is ongoing at Matis in utilizing unique Icelandic microbial resources for solving these problems for brown algae polysaccharides. Matis has developed specific thermophilic enzymes for complete degradation of these polysaccharides and is working on developing an efficient thermophilic bioconversion organism by metabolic engineering.

Macroalgae as a potential industrial resource has been recognized in Iceland. Numerous projects are ongoing, from cultivation to development of very specific value added products. The potential of macroalgae is high. It is a source of new sugars for industry e.g. appreciable amounts of so called rare sugars. It is also a source of highly bioactive small molecules, including oligosaccharides, polyphenols, flavorants and colorants. The greatest potential is, however, bulk utilization in multi-value stream biorefineries, but dependent on progress in enzymatic and fermentation technologies.

Using thermophiles in biorefineries has many advantages. They are robust by nature, living in the harsh, high temperature environments of geothermal habitats. Many lineages are also adapted to conditions of extreme pH and to the presence of toxic sulphuric compounds and poisonous metal ions and complexes, - conditions that reign in high density raw biomass slurries fed to bioreactors. Fermentation at elevated temperatures may also ease the extraction of volatile products either by distillation or gas stripping. This alleviates the potential problem of product inhibition or intolerance and should prolong the fermenting life of cultures. The ability to grow at high temperatures in bioreactors further reduces costs of cooling, distillation and extraction and prevents contamination of spoilage bacteria. High temperature increases solubility of polysaccharides, leads to reduced viscosity of fermentation broths, enables higher feedstock loads and facilitates enzymatic access to polysaccharides. This subsequently mitigates fermentation scale up problems of mixing and aeration and enables greater feedstock loads.

Thermophiles in biorefineries

Other biomass resources

In contrast to Scandinavia, access to lignocellulosic biomass (wood and terrestrial plants) is limited in Iceland as a sustainable feedstock for biorefineries. There is, however, ongoing national effort in forestry and substantial land is available for fast growing special feedstock plants. Biomass from waste streams in the food industry are also a potential resource for biorefineries. An example of a successful use of such biomass in Iceland is the utilization of waste shells from shrimp factories. Primex, a company located in Siglufjordur in North of Iceland, manufactures pure chitin and chitosan derivatives from these resources for different applications. On the other hand, another company, Genis (also in Siglufjordur), produces bioactive oligosaccharides for medical applications enzymatically from chitin feedstock.

Numerous possibilities for Iceland lie in more complete utilization of waste from the food industry such as cartilage from fish for production of chondroitin sulfate, bioactive peptides from fishery waste water and different products can be envisaged from various waste streams in the agricultural sector.

5.2.5. General about biotech companies in Iceland

In 2009, the number of biotechnology companies in Iceland (categorized as high tech industry) active in R&D were about 27. Many of these were in the health sector and therefore outside the scope of this report, of which Decode is best known, a global leader on human disease related genetic research. Other companies are associated with utilization of abundant and/or unique genetic and bio-resources and aim at developing and marketing biobased products and processes. Besides the companies mentioned above, ORF ltd, is an important Icelandic biotech company. It is a pioneer in the manufacturing of growth factors and other recombinant proteins in barley. The recombinant barley is then cultivated in geothermally heated greenhouses, bypassing the use of bacterial or animal cell system. Another recent growth area is micro-algae utilization for production of biomolecules for food application, such as astaxanthin or omega fatty acids. A few companies have been founded in this field including AlgaLif, Vistvæn Orka and KeyNatura. Also, substantial opportunities exists in utilizing macroalgae for their unique compounds, and one company has pioneered that field in Iceland, Marinox Ltd, with its cutting edge research done in collaboration with Matis for the past few years.

The level of education among employees, scientific infrastructure and R&D competence in Icelandic biotech is high. Within the biotech, Matis plays a central and important role in applied biotech research, with its roots in food science and resource management as well as having traditionally a strong connection to the industry. Matis provides research facilities for small companies and has state of the art laboratories for R&B biotech research. The staff is versatile, highly skilled and experienced which is reflected in large number of successful international project participation and peer reviewed scientific papers. Important work is also done in the Icelandic universities of more basic research character, in pharmaceutical bioprospecting and enzymology at the University of Iceland and in applied microbiology at the University of Akureyri.

5.3. Bio-energy production

Most of the demand for energy in Iceland is met by harnessing geothermal or hydrothermal power, of which there is and abundance in the country. Only transport relies solely on imported fossil fuels. Today about 47% of the total fuel consumption in transport in Iceland is petroleum and approximately 53% diesel. Today it is estimated that less than 1% originates from renewable sources. In 2049 it is estimated that alternative energy use in transport will only have reached about 50% (Orkuspárnefnd

(National Energy Authority), 2008). In the last decade increased emphasis has been put in research in alternative energy carriers which can replace the traditional fossil fuel, mainly bio-ethanol, methane and bio-diesel.

Economic production of biofuels depends on availability and abundance of sustainable biomass. Two classes of biomass feedstock dominate research: First and second generation. First generation products are manufactured from edible biomass such as starch rich or oily plants. Second generation processes utilize biomass consisting of agriculture residues i.e. the non-food parts of crops, or other non-food sources, such as perennial grasses, wood or algae and municipal and industrial waste. Second generation biomass is widely seen as possessing a significantly higher potential to replace fossil based products.

In Iceland sustainable and abundant biomass resources for high volume biofuel production are scarce compared to many other countries. However, it has been calculated that the potential biofuel production in Iceland, and comparing this to total energy usage for transport, that there is more than enough of biomass and production capacities in Iceland to produce the energy needed. It follows that biofuels of different kinds will be derived from more than one source, from municipal and agricultural waste, farm manure and sewage, from cultivated energy plants and macro- and micro-algae.

5.3.1. Biogas

Methane formation is a natural biological process in anaerobic waste and biomass and the gas can be harvested relatively easily. Methane is currently processed at Alfsnes municipal waste landfill site in Reykjavik by Metan hf. approximately 80% of the gas produced at Alfsnes is collected and used as energy source. Utilization of municipal waste biomass for energy production is an economic feasible process and its utilization is important for environmental reasons. However, the biogas production only meets a fraction of total energy demand for transport in Iceland. SORPA bs, the waste management company in Reykjavik, has recently established a biogas research facility to study the biological processes in biogas production. The ongoing is research aims at more efficient production of methane from municipal waste where parameters including type of organic materials, pre-treatment methods, temperatures range, etc., are studied.

The feasibility of production of biogas from livestock manure as alternative-sustainable and economic energy source for farms has been recognised in Iceland and initial steps have been taken in developing small biogas production plants using manure.

5.3.2. Biodiesel

Various oil and/or fat containing biomass resources can be used for production of biodiesel. This includes oil producing specific microalgae and cyanobacteria, slaughterhouse fat wastes and used frying oils from restaurants. Potentials also lie in producing oil rich plants especially for biodiesel production. The company Orkey in Akureyri already uses the above resources and the biodiesel is blended with diesel and used to power Akureyri's public transport system. The capacity of the company is only limited by resource abundance.

To realize the transition from petroleum refineries to biorefineries new refining and conversion technologies are needed due to the vast differences in the composition and properties of petroleum and lignocellulose. Second generation biomass contains large quantities of recalcitrant polysaccharides, e.g. cellulose in plants and alginate in seaweeds. For a versatile multi value stream biorefineries fermentative organisms capable of producing a variety of added value chemicals including biofuels need to be developed as traditional organism do not suffice. For complete degradation to fermentable monosugars efficient enzymes need also to be developed as well as cost effective enzyme production organisms.

New technologies needed

Biorefinery is analogous to a fossil fuel based refinery that can produce energy carriers (biofuels) and platform chemicals and specialty chemicals from carbohydrate rich biomass. Carbohydrate rich feedstock for biorefineries can be derived from many different sources, including forestry waste (e.g. wood chips), agricultural waste (e.g. straw, corn stover), paper waste and dedicated energy crop as well as from seaweeds. In Iceland natural plant or wood based resources are scarce. However, recently the potential area available for combining cultivation of energy crops and re-vegetation was estimated from available geographical data to be around 4,000 km^2 (Brink & Gudmundsson, 2010). The possible harvest of several potential energy crops that can be cultivated in Iceland has also been evaluated (Sveinsson & Hermannsson, 2010). These include the cereal barley, hemp and perennial plants and could also include short rotation forests. The drawback is that cultivation of energy plants may compete with agricultural usage for land and considerable quantities of fertiliser may be needed for sufficient bulk production. Forestry is now increasing in Iceland and wood derived biomass may become a future resource for biorefineries, but may also compete with other more profitable utilization. The second generation seaweed biomass may be one of the most promising biorefinery feedstock biomass in Iceland because of potential high bulk production with carbohydrates up to 60% of dry weight. Macro algae are abundant in coastal areas of Iceland and can be cultivated and produced in bulk, off shore.

An alternative or complementary to a fermentation biorefinery is thermochemical processing or production of syngas providing a different range of products. A two platform biorefinery would consist of sugar platform whereby fermentable sugars are pre-treated and converted to bioethanol and other added value fermentation products. The second platform is a syngas platform that takes the fermentable feedstock and produces a gas which can then be used for chemical synthesis including biodiesel.

In Iceland state of the art research in this field is being carried out by the University of Akureyri in investigating potential biorefinery organisms and by Matis on biorefinery enzymes and organisms. The biotech group at Matis has collaborated in a number of Nordic and EU projects in developing robust carbohydrate processing enzymes and engineering fermentative organisms for production of biofuel (ethanol) and added value chemicals from lignocellulose and macro algal biomass.

6. Nature based tourism in the West Nordic countries

Tourism in Faroe Island and Greenland is considered as a complementary and competitive destinations to Iceland, but according to tour operators interviewed, these two countries are thought to lack tourist infrastructure (Islandsstofa (Icelandic Tourist Board), 2013). Greenland was visited by 37,000 people in 2012, of which 50% came from Denmark. In addition approximately 30,000 tourists arrived with cruise ships. By international standards, relatively few tourists visit Greenland despite the country's unique nature, culture and geography (Rambøll Management Consulting, 2014), however, this number of annual tourists exceeds the number of inhabitants in Greenland.

> *"The West Nordic region is one of the world's most inspiring destinations, offering three astonishing countries: Greenland, Iceland and the Faroe Islands. Each country has its own character, culture and history, but they share incredible nature, a warm welcome and an unlimited range of things to see and do.*
> *The West Nordic region is something special. Situated in the North Atlantic, the area's geographical remoteness has preserved an authentic world of wonderful cultural traditions and natural phenomena.*
> *It's a region full of things to discover."*
> http://www.vestnorden.com/vntm-region.html
>
> *The West Nordic Region*

Cultural tourism is expected to account for around 40% of all European tourism in its broadest sense, according to EU (EU, 2014). These tourists are looking for authentic experiences and are interested in other countries cultures such as food and gastronomy and to experience unique elements of overall travelling experiences. This food experiences is a vital part of the tourist supply chain linking local food products and suppliers with cultural and tourism entrepreneurs. This is often part of cultural activities including local food of high quality. Food is believed to comprise for up to 30% of total expenditure which is spent directly to local businesses. This results in significant potential for tourism in the West Nordic countries encouraging product development within the travel industry and potentially linking travelling with good health and wellness (Islandsstofa (Icelandic Tourist Board), 2013).

> By combining the unique nature, wildlife, fisheries, local food production and activities such as horse riding, hunting tours, recreational sea angling, salmon fishing etc., and tourism can add considerably to the income of the people in rural areas as well as in bigger towns and cities.
>
> *Tourism in the West Nordic countries can provide opportunities and jobs*

The West Nordic countries are the future destination for the adventure tourism industry, attracting tourists curious of new remote areas and experiencing cultural stories, local food and nature. The business of adventure tourism is estimated to turn around US$ 263 billion worldwide indicating a great potential for the West

Nordic countries. Adventure tourism could also be a driver for rural economic and strengthen small communities using cultural resources (West Norden, 2014).

6.1. Development of tourism in the Faroe Islands

About 100,000 tourists visited the Faroe Islands in 2013 with an economical turnover of DKK 400 million and employed around 400 – 500 people full time (Visit Faroe Islands, 2013). Part of that number are over 44 thousand passengers and 21 thousand staff visiting the islands by 49 cruise ships (Visit Faroe Islands, 2013). The vast majority of ships arrive to the capital of Torshavn, but an increasing number sailed to the second largest city, Klaksvik, in 2012 and 2013. However, these guests only spend a few hours on the islands and, therefore, their contribution to the local economy is limited since most of the services are provided on board.

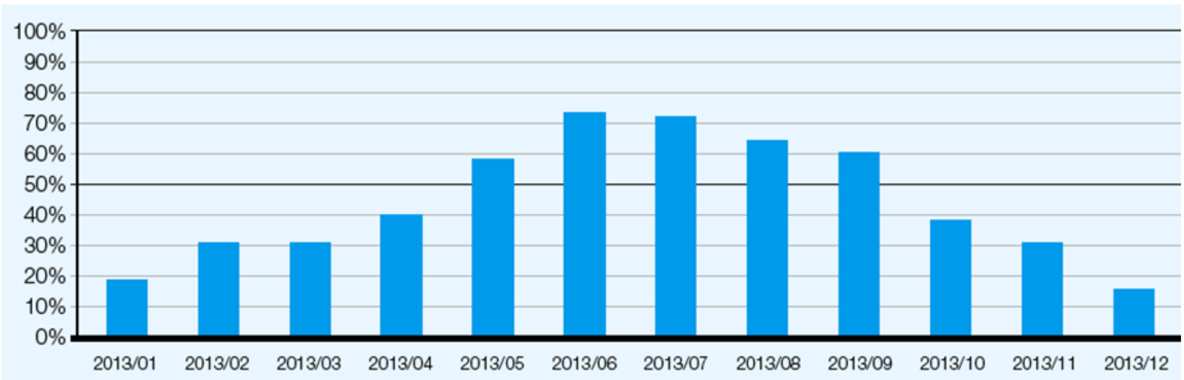


Figure 25. Percentage of rooms occupied at hotels and guesthouses by month in 2013 (VFI 2014).

There is generally lack of statistical information concerning the tourist industry in the Faroe Islands. Only in 2013, the Office of National Statistics started slowly to gather some information regarding the industry. In the coming years, more information will be compiled. One indicator of the size of tourism is the amount of overnight stays in the country and in 2013 there were 130,771 overnight stays in the Faroe Islands. In 2012, there were approximately 100,000 overnight stays, however, this number should be taken with caution and is not directly comparable to the one from 2013, since it is not collected by the Office of National Statistics and is based on volunteered self-reporting by the accommodation providers. Almost three quarters of these overnight stays were in hotels and 6% of guests stayed on the largest island, Sudurstreymoy, where the capital is located. More than 50% of visitors staying overnight are from Denmark, followed by Norway, Germany and Iceland (Visit Faroe Islands, 2013). The seasonality of tourism in the Faroe Islands can be seen in the availability of accommodation during the year. Figure 25 shows that the accommodation is substantially filled during the summer months, especially June and July, while less than 20% of rooms are occupied during December and January.

There has been a growing focus in recent years on developing the tourism industry in the Faroe Islands. This increased focus is also evident in the decision to double the budget of the Tourist Board in 2013 to DKK 14 million (Visit Faroe Islands, 2013), of which 73% has been used in direct marketing activities of the Faroe Islands abroad in 2013 (Visit Faroe Islands, 2013). The rationale behind this is that one of the key challenges facing tourism in the Faroe Islands is that the country is simply unknown to large proportion of potential tourists.

Figure 26. The new branding strategy uses "un" in front of adjectives to differentiate the Faroe Islands from other places (VFI, 2014).

In 2012, a new tourism branding strategy was developed for the Faroe Islands and was presented in 2013 (Visit Faroe Islands, 2013). Using the slogan ‘Unspoiled, Unexplored, Unbelievable’, the strategy involves uses this ‘un’ in front of adjectives in all marketing material (Figure 26), emphasising that Faroe Islands are something unique that has not been experienced before (Visit Faroe Islands). The idea behind this is to unite the industry behind a common message that should be used in all the marketing of the Faroe Islands, therefore creating a strong and more visible brand from which all communication strategies should depart (Visit Faroe Islands, 2013).

The overarching target of Visit Faroe Islands is to increase the turnover of the tourism industry to DKK one billion in 2020. The number of overnight stays should increase from 90,000 in 2011 to 200,000, and the number of employees should increase with 450 persons (Visit Faroe Islands, 2013).

“It is encouraging that Faroese tourism industry seems to have found a sense of direction and that the conditions have been created for the industry to flourish. It is clear that the industry has been revitalized. However, the new brand has only been used to market the Faroe Islands in 2014, so it is still too early to determine its influence. Nevertheless, it will be interesting to view the statistics for 2014 and beyond. Only then will it be possible to gauge whether Faroese Tourism really has ‘taken off’” (Faroese Employers Association 2014).

Faroese Employers Association statement

The Faroese tourist infrastructure is somewhat underdeveloped. For instance, in many places public transport options are very limited. Moreover, there are very few restaurants and cafes outside the largest cities. This can present a limitation and challenge for many guests on their travels. At the same time, it is exactly this underdevelopment of tourism that has been considered an asset of the Faroe Islands as a tourist destination.

In recent years, New Nordic Cuisine has received increasing attention across the world. There is currently a considerable amount of innovation within the Faroese Cuisine, and this has been reflected in the offers that are available for tourists. There has been an increasing number of excursions and niche tourist packages to the Faroe Islands, such as a tailor-made as well as package gourmet holidays, see (Solea, 2014).

In 2007 a National Geographic panel of 522 experienced experts voted the Faroe islands the world's best islands using the words "*authentic, unspoilt and likely to remain so*" it highlighted one of the reasons behind the rationale "*Quite rightly, tourists are expected to be like the Faroese, such as taking choppy ferries and hiking through any weather*" *(http://www.visitfaroeislands.com/en/be-inspired/national-geographic-traveler/)*

National Geographic experts

One of the niche possibilities is the option to visit local families to allow visitors to get closer to the Faroese culture and traditions and allows tourists to try Faroese specialities in a homely and friendly atmosphere. Faroese traditional food can also be sampled at specially Faroese Cultural Events, which are organised in a small traditional village 'Gjógv', where guests can also join in the traditional chain dance and listen to performances by Faroese artists.

One of the more popular types of excursions for visitors is boat trips. Many of these tours are excellent for bird watching, where the boats sail directly under bird cliffs and into grottos. Deep sea fishing excursions, where visitors can go on day long excursions and fish for species such as cod, haddock, ling, coalfish, halibut are also available with several trip providers. Special angling package holidays are also an option. Finally, there are a range of hiking and horse riding excursions available for tourists visiting the islands.

There is generally optimism concerning the tourism industry in the Faroe Islands. The indications are that visitor numbers and overnight stays are growing, as are the range of offers available to visitors.

6.2. Development of tourism in Greenland

The direct turnover of the tourism industry in Greenland in 2012 was DDK 334 million with foreign visitors of only 37,000 people staying overnight, of whom 50% came from Denmark.

In addition, about 30,000 tourists disembarked from cruise ships but this group is giving limited income, with most of the service supplied on board the cruise ships. However, the direct turnover is complemented by sales in other sectors, such as transport and retailing. Iceland, for instance, receives over 800 thousand foreign visitors a year but Icelanders are only more than five times the number of Greenlanders.

Tourism is expected to have considerable potential for further development. Tourism is an important sector bringing foreign capital to Greenland's economy and the number of employees is expected to rise with further development of the industry. However, the tourism industry has to grow considerably to play a significant socioeconomic role in the future. The tourist sector is estimated to employ around 400 – 500 people around the year, but the business is suffering an enormous seasonal variation with little business in low season but multiple numbers during spring and summer.

Meat from marine mammals, game, birds and fish has been the main ingredient in Greenlandic food for generations. The high meat content in the diet provides energy and nourishment all year round for a physically demanding existence where the harsh Arctic winter could seriously tax one's reserves of energy.
The Greenlandic culinary culture is also closely tied to the old hunting community's strong social solidarity, where vital necessities depended on the catch being shared. Today, food and mealtimes remain a central part of Greenlanders' characteristic hospitality (Greenland, 2014).

Food in Greenland

There are many challenges facing the Greenland tourism industry, like a short tourist season (spring and summer), lack of infrastructure and limited capacity in human capital. The industry has a reputation of insufficient service level by international standards and a lack of focus on how to deliver various services to make up a tourist experience. In general, the sector is considered to be lacking maturity.

The current global spotlight on the Arctic and on Greenland should be able to foster a positive trend as regards the number of tourists in Greenland in the coming years, not least when compared to the current low number of guests from abroad staying overnight (37,160 in 2012). By comparison, Iceland had 800 thousands visitors in the same year, i.e. 22 times as many, even though Iceland's number of inhabitants is only about 5.6 times higher and the country's geography is significantly smaller (Rambøll Management Consulting, 2014).

Opportunities in Greenland's tourism

According to Statistics Greenland, the income from tourism in the period from 2003 to 2011 has been slowly growing, around 3.6% a year and with high fluctuation. Foreign visitors in Greenland spend only around DKK 1,100 a day on accommodation, food, excursions, souvenirs and other minor shopping, with average time of four days per trip (Rambøll Management Consulting, 2014). This is a low number on international standards and contradiction if kept in mind that Greenland is not a cheap travelling destination, with rather high prices for most goods.

According to Greenland Tourism Statistic (GTS, 2014), 25% of tourists visiting Greenland are globetrotters. Travellers seeking new knowledge and exploring unknown regions where few tourists have been, experiencing local nature and culture and observing new things and listen to new stories. A globetrotter doesn't mind to find his own way around, engaging in interactive activities and appreciates good quality guide service. *"I travel to meet new experiences, new people, new countries." (*Swedish tourist, on board Sarfaq Ittuk, August 2012*).*

Overland transport in Greenland is solely local, since the infrastructure (roads and trails) is highly limited. This is primarily due to the Arctic weather conditions and the vast distances between towns. For the same reasons, the potential for developing public transport is minimal (Rambøll Management Consulting, 2014).

Transport in Greenland

There seems to be great opportunities in Greenland tourism and the Governments´ objective regarding the sector is: *"To secure economically, socially and environmentally sustainable growth in the tourism and adventure sectors so that these account for an important share of Greenland's export earnings by 2020"* (Rambøll Management Consulting, 2014). It is estimated that the tourist sector could reach a size of DKK 600 - 800 million in 2025 and it could provide greater revenue to the Greenland economy compared to the current status (Rambøll Management Consulting, 2014). This size of the sector is equivalent to 4 – 6% annual growth in the sector, considerable increase from current 3.6% growth.

6.3. Development of tourism in Iceland

Travellers to Iceland have almost tripled since 2000, from 302 thousand to 807 thousand foreign visitors in 2013. In 2013, turnover of tourism was 12.7 billion DKK and its share of export of goods and services was 26.8%, and had been growing from 19.6% in 2009. The industry currently accounts for more in total export than the fisheries (Ferðamálastofa (Icelandic Tourist Board), 2014). In 2009, the tourist sector employed around 8,500 workers, equivalent to 5.2% of the total workforce in Iceland (Statistics Iceland, 2014). These numbers are in line with world statistics where the total turnover of tourism with over 1.03 trillion US$ (3.4 billion US$ a day), which is around 30% of total export of service in the

The volcano Eyjafjallajökull erupted in 2010 with tremendous consequences. Neighbouring areas were covered with ash. Just below the volcano is the farm Thorvaldseyri which is a dairy farm with considerable cereal cultivation. The farm was hit hard by ash and flooding from the melting glacier. The situation was very difficult but the people decided not to give up but rather make the best possible out of this. The land recovered during a two year period. A museum was built which shows the history of the farm and the recovery after the eruption. The number of tourists visiting the farm in 2013 was about 62 thousand. Now the sustainability of the farm is under development.

From destruction to prosperity

world and around 6% of total export of service and goods. Tourism input to the world GNP is around 5% and share of employment is around 6-7%, or around one of every 12 jobs in the world. In developed countries this is around 2.5% but in developing countries the number is as high as 10% (UNWTO, 2014).

Nature based tourism is important for the Icelandic economy and its future growth. Over one million travellers are expected to visit Iceland by 2020, more than three times the population (OECD, 2014). However, Iceland´s strategy for tourism is to ensure environmental sustainability. The infrastructure and policy making must be strengthened and an adequate environmental performance of tourist operators must be ensured (OECD, 2014). Iceland would benefit from developing a comprehensive action plan for sustainable tourism but sufficient revenue source is needed to finance tourism related infrastructures (OECD, 2014).

After the Eyjafjallajökull volcano eruption in 2010, the government, Reykjavik City and over 100 Icelandic companies in tourism worked together under the umbrella brand Inspired by Iceland. Today, this cooperation is still active under this brand. Islandsstofa (Promote Iceland) is the executer and the developer of the campaign and the marketing for Iceland as a destination abroad. The main objectives of the campaign in the beginning was to turn the negative side of the volcanic eruption to a positive story by raising interest on Iceland as a tourist destination

Eyjafjallajökull eruption 2010

Today, the focus of the marketing is to increase the main markets awareness of the season between September and May in Iceland. New branding strategy for Iceland in tourism has been developed. The main message and stories about Iceland, include that Iceland is pure, sustainable, adventurous, cultural, creative and mysterious. One of the key messages is also that Iceland is not that far away from Europe or USA. Several different marketing activities have been developed and executed with the focus on a specific target group, enlightened traveller and included e.g. public relations, social media, media visits, publications and advertisements in selected markets (Pálsdóttir, 2014).

An successful marketing campaign, Inspired by Iceland, increased the number of visitors as well as resulting in Iceland being ranked as top destination by many leading travel counsellors like National Geographic and Lonely Planet (OECD, 2014). In 2013 about 100.000 tourists traveling on cruise ships visited Iceland making stops in several places around Iceland, both the number of ships and passengers have been increasing steadily in recent years. Tourists in Iceland are mostly prosperous and well employed individuals who are interested in nature, but cultural interest is on a rise (Ferðamálastofa (Icelandic Tourist Board), 2014). The tourism is built on unique combination of environmental values such as wilderness, natural hot springs, geothermal activity, lava fields, glaciers and northern lights. Iceland is one of the most popular destinations for whale watching in Europe. Around 150 thousand foreign visitors take a whale watching trip to enjoy these large animals including species such as mink

- and humpback whales as well as harbour porpoises and dolphins (OECD, 2014). Ten whale watching companies were operated in 2009 with estimated total value creation of around DKK 19 million (Agnarsson, 2010). The interplay between cultural matters like local and regional food could be beneficial for the tourism industry. The company Fisherman is promoting Sudureyri in Westfjords as a fishing village, with emphases on small village heritage and locals seafood. Travellers are introduced to the village were most of the workers are employed by the fish factory Icelandic Saga, followed by a walkthrough in the production facility. *"With plenty of knowledge and passion for delicious fishmeal´s and love passing them on. Our chef will happily help you cook your own four-course meal"* (Fisherman, 2014). Visitors will cook their specially selected fish with a cook's assistance and in two hours they have experienced something special to take back home as a souvenir as well as the knowledge to cook and enjoy Icelandic fish.

"When it comes to food tourism, it is important to examine both local and regional food systems because tourists that choose local food often assume that they are buying an authentic product that originates from a local producer. In that respect the traceability and visibility of a product is an increasing concern of consumers. It has become important for the travel industry, especially with regard to sustainable tourism, to increase the availability of local food. The interplay between local food production and tourism can be beneficial for the economy, social justice, health, welfare and the environment as well as the sustainability of regions. Marketing opportunities in sustainable tourism are on the rise and they offer avenues for producers of local food. There is an ongoing development of local food and tourism in Iceland and in addition, restaurants and grocery stores increasingly offer a selection of locally produced food." (Eidsdottir, 2012).

Local food and tourism in Iceland

Fresh water fishing is also important in Icelandic tourism such as rod fishing of salmon and trout. Iceland is considered to have some of the most interesting rivers and streams for rod fishing in the world with crystal-clear, well-managed rivers and breath-taking scenery attracting anglers from all over the world. In 2013, rod fishing gave over 68 thousand salmons and 56 thousand trout's, over 30% of this catch was released back to the river (Gudjonsson, 2014). Rod fishing in Iceland is a base for important industry with a turnover of around DKK one billion a year, direct revenue to The Federation of River Owners are almost DKK 50 million a year (Gudjonsson, 2014). This industry is creating

Fisheries related tourism

Fisheries related tourist industry in Iceland has increased over the last years, giving maritime regions grate opportunities. Enterprises in Westfjords have been leading in this business with two massive companies operating fleets of leisure vessels, Hvildarklettur and Iceland Sea Angling. These companies are operating 20 leisure boats each as well as full service for fishermen, including travelling and accommodation. There are also companies offering whale/seal and bird watching, often including angling in there service. There are also businesses offering sea angling on smaller boats with captain supervision, taking around 2 - 6 hours each trip.

considerable foreign currency for the Icelandic economy and value creation from each fish is probably a world record, as well as attracting almost third of the Icelandic nation enjoying rod fishing as a hobby (Gudjonsson, 2014). This tourism has been followed by growing interest in bird hunting like geese, ptarmigans, ducks, cormorants, shags, guillemots, and many other species of birds. Reindeer hunting is also an opportunity to connect sport with nature experience in Iceland.

One of the successful tourist attractions is the Icelandic horse which is famous for its unique abilities both in Europe and USA. Every two years the Icelandic horse tournament is in Iceland and 2,500 – 3,000 foreign visitors attended the tournament in 2012. Horse renting is very popular and about 18% of tourists travelling to Iceland visit the country to experience the Icelandic horse (Möller et al., 2009). The numbers of companies renting the Icelandic horse are growing. The companies offer both short rides and longer tours, often across the highlands in the middle of Iceland and the estimated revenue of horse renting is 48 – 75 million DKK (Möller et al., 2009).

Dare to go small and taste Iceland's most important export!
Sudureyri is a small and environmentally friendly village where everything is about fish. This is a chance to hear about live at the edge of the Arctic Circle! See how a thriving community processes Iceland’s finest fish and get a fresh taste of it whilst listening to local stories. Learn why Iceland's first class export product can be on a domestic dinner plate just 36 hours after leaving the ice-cold Atlantic Ocean water, and just how unbelievably sustainable we operate.

Fisherman – Fishing village in Sudureyri

7. Discussions and conclusions

Regional policy and strategy setting

The bioeconomy in the West Nordic countries is a large part of the GDP compared to the other Nordic countries. Their production and export is mainly limited to primary production. However, this also opens up possibilities for growth and added value creation for the economy of the West Nordic countries by strengthening secondary industries and service sectors. The common interests of the West Nordic countries are apparent. They call for close cooperation of the countries in putting their common interests on the agenda both in Nordic and other international collaboration and strategy settings. A clear and focused strategy for the West Nordic region with specific priorities is vital for effective participation in international forums on bioeconomy. Therefore, a West Nordic Bioeconomy panel would be a forum for realizing such a strategy as well as a platform for promoting common policy, to identify opportunities, advice industry, governments and the public as well as set a common strategy for the West Nordic region with policy- research-, commerce, NGO´s and industry partners alike. This would help maintain and strengthen the bioeconomy in the region, as well as opening up new opportunities for research and innovation in the region. Focus should be on wide cooperation with existing networks and infrastructures as well as representatives of the proposed Nordic Bioeconomy panel, other national European Bioeconomy panels and the European Bioeconomy panel. Current forums such as NORA and the Arctic Circle have a good infrastructure and could be used to raise the topic of bioeconomy with theme specific meetings. A key action would be to establish stakeholder platforms, complementing the advisory activities of the West Nordic Bioeconomy panel, to discuss industrial opportunities, infrastructure and support system to enhance value creation from bioresources as well as to discuss the balance between use and protection of bioresources and how to secure biodiversity.

The environment in the West Nordic is very vulnerable to pollution and effects of climate change, both due to its cold climate and rapid warming. Therefore, an extra care has to be taken when resources are utilized in order to prevent adverse effects. The unique circumstances in the West Nordic, the vast open areas, the wildlife and the harsh environment, are both strengths and weaknesses when the opportunities in the West Nordic are discussed. Unspoiled and unmatched nature and biological diversity, unique to the region, are clear attractions in addition to the rich natural resources. Green growth is vital for value creation established on efficient and sustainable use of resource, therefore, policy making in the West Nordic region focusing on green growth is highly important and must be transparent and co-operation oriented.

Environmental weaknesses on the other hand lie in the vulnerability and threat from human activities, both global and local. Therefore, the sustainable use of resources and protection of the environment are key issues in the West Nordic countries. It is important to establish stakeholder platforms to discuss industrial opportunities, infrastructure and support system to enhance value creation from bioresources as well as to discuss the balance between use and protection of bioresources and how to secure biodiversity.

Rural development and infrastructure to support innovation, centre of excellence

Opportunities within the bioeconomy are likely to have an impact on the inhabitants of rural areas and help to reverse the trend of young people, especially women, moving from the areas to the larger towns, cities and other countries. People seek education away from the rural areas and often do not return due to lack of job opportunities, isolation and other problems that small communities are facing in the West Nordic countries. This results in brain-drain from these areas, social disruption in age and gender and fewer productive members in the societies. By increasing the number of jobs for educated people in the secondary sector with innovation, research and further processing of raw materials from the primary sectors, there is a possibility of altering this trend and creating more value in the economy. A possible solution to increase opportunities for highly educated people in the West Nordic Region is to gather a strong group to create an interdisciplinary Centre of Excellence (CoE) focusing on issues related to the region such as bioeconomy, environmental issues, social issues, rural development, energy production and on solutions that lead to added value of production from the region through the entire value chain. The CoE would be located in the West Nordic Region, however in order to fully benefit this vast geographical area the CoE would apply information technology (IT) solutions to link different experts and local/national knowledge centres together through a virtual knowledge network/consortium. The CoE should include stakeholders from all sectors and would cooperate with experts from the other Nordic Countries as well as other countries involved in the bioeconomy and Arctic research. The partners in the CoE would also share infrastructure e.g. pilot plants and laboratory instruments, which in turn would lead to faster transfer of knowledge and implementation of new techniques in the region. To maximise the impact of the CoE, it´s partners will act as local "ambassador" that will involve local stakeholders (e.g. industry, farmers) in order to overcome barriers regarding the acceptance of this new methodology and way of thinking e.g. by increasing the level of understanding and create incentives to attract primary industries in their region.

The CoE would therefore have multiple impacts and would turn the region into an attractive area for highly educated people as well as support and promote the economy of the area with research and innovation, create derivate jobs and increase the possibilities available in the area.

The Blue Bioeconomy

Marine bioresources are the most important biological resources of the West Nordic countries, as fisheries contribute extensively to the GDP in all three countries. In order to have a positive impact on value creation in the West Nordic countries, investment in innovation and technology along with strengthening the fish stocks is needed. The knowledge available in the West Nordic fishing industry has increased greatly in the last decade. Increased knowledge and technological transfer between the countries and increased cooperation is highly recommended and would strengthen the West Nordic countries in the field. New technology is constantly being implemented in the fishing industry and while the Icelandic fishing industry is a frontrunner when it comes to utilisation and value creation, there is a room for improvement. New technology developments in the blue bioeconomy should take into account effects on rural development. Obstacles need to be identified and overcome and effort needs to be invested to increase the growth of the industry in the region at large. An action plan should be formulated to create a blueprint on how to make the most out of the opportunities in the Blue bioeconomy in the West Nordic countries. Institutes working on research and development in the area should receive more support to be able to better support the industry and anticipate future opportunities and developments. Cross-national collaboration between institutes and industry in the area should be increased.

It is important to increase processing yields within the fisheries. However, substantial increase in value addition and creation of new innovative products is likely to occur in synergy between fisheries and the biotechnology. This applies to the agricultural sector as well. Furthermore, utilizing bioresources for e.g. protein production, isolation of bioactive compounds and produce ingredients and products for the pharmaceutical, health industry and cosmetics could multiply the value creation from raw materials. A clear strategy for R&D and commercialization of high value marine products via biotechnology should be established to increase the likelihood of success and make the most out of available marine bioresources. Combining strong industry, such as the fishing industry, with research, development and innovation within the biotechnology sector will benefit the economy of the West Nordic countries as well as turn the region into an attractive area for young educated people. Priority should be put on establishing a central marine raw materials biorefinery and demonstration plant to speed up commercialization efforts in the region.

Along with the fishing industry, the aquaculture is growing in Faroe Islands and Iceland and sharing knowledge and experiences is highly encouraged as it can only benefit both parties. The strong aquaculture industry in northern Norway is also an important partner for Iceland and Faroe Islands in further developing the aquaculture industries in the North West Region. Knowledge transfer to Greenland will be important to establish an aquaculture industry there. Aquaculture is an ascending industry globally and with accessibility to the vast ocean in the West Nordic Region, the countries have extensive opportunities within this industry. The unique features of each country should be exploited to maximize and diversify aquaculture opportunities (e.g. geothermal heat in Iceland can open up opportunities for new species). Significant focus should be put on research into future feed sources for aquaculture, for example utilizing new raw materials (macroalgae, insects, plants etc), as well as disease control. Spatial planning should also be given special attention to harmonize the needs of the industry, environment and citizens.

Underutilized resources and new opportunities

The West Nordic region has a variety biological resources for sustainable and responsible utilization. The major resources include waste streams, such as those found in the fish industry, wood, grasses and crop residues. Production of micro-algae is also a feasible option. However, macro-algae may be the resource which has the highest potential for utilization. Macro-algae grow in abundance in coastal waters of the West Nordic countries and their high carbohydrate content make macroalgae an attractive source of sustainable biomass. Macro-algae can be used as biorefinery feedstock and the proteins and protein derivatives funnelled into in various value streams. Macro-algae are cultivated off shore in the Faroe Islands and Iceland has promising prospects for algal biomass production, as geothermal energy can be used in the production at relatively low costs. Production of bioenergy and valuable chemicals from macro-algae, along with other sources of biomass, is an important direction of research for the West Nordic countries. An important aspect of focusing on biorefineries is that they can aid in reducing the use of fossil resources. Fossil resources are only partially used as fuel and for combustion where large part is used in the chemical industry as raw material for producing vital and commonly used products, such as plastic, solvents, pharmaceuticals, etc. Chemicals from biorefineries could substitute this to a large extent or even completely in the future. In order for production of valuable chemicals to become realistic, new refining and conversion technologies are needed along with development of effective processing enzymes. Iceland has established a good reputation in the field enzyme biotechnology and metabolic engineering of potential biorefinery microorganism for processing and further bioconversion of macroalgal polysaccharides into added value products.

Research on better utilization of feed and new possibilities in feed production should also be given greater attention. It is important to explore opportunities across different sectors of the bioeconomy as well as new innovative sources of biomass for feed, such as using the black soldier fly to produce protein or to grow fungus, rich in single sell protein from wood waste streams.

The economies in the West Nordic countries can be reinforced by further developing industries based on sustainable and responsible utilization of available resources. The aim should be to create multiple value streams from each resource, to improve processes and to apply new technology with the goal of minimising waste and maximising value.

Opportunities within and across sectors

Linking different pillars of the bioeconomy presents great opportunities where industry and research can benefit from knowledge and advances across sectors. It is impossible to address sustainability without including the bioeconomy on a brought scale, which makes it a key factor in R&D as well as in running a successful business in all sectors.

The West Nordic bioeconomy is, and will continue to be, resourced based rather than processed based. It does not mean that there are no opportunities in processed based economy in the region, but the big opportunities in the near future are in resource utilisation. The region have huge opportunities in marine biomass, access to clean and relatively inexpensive energy and water, which can to a point provide opportunities in various sectors.

However, a number of issues need to be considered carefully when dealing with the resource based bioeconomy. Socio-economic sustainability is one of three pillars of sustainability but is often neglected, for example the widespread use of subsidies in fisheries and agriculture.

Many of the bio-economic resources in the Nordic countries are highly vulnerable to change, e.g. due to climate change and to natural fluctuations. This has serious consequences for the economies that rely on these resources. De-risking and identification of potential obstacles with a systemic approach is needed. Such work requires interdisciplinary expertise with the broadest possible scope. An interdisciplinary centre of excellence (CoE) is therefore needed to bring together as much knowledge as possible. This CoE should work across sectors and look at all opportunities as well as associated risks.

There are some sectors in the West Nordic bioeconomy that present obvious opportunities where the region has some advantages over other regions in the world. There are for example enormous opportunities in algae, which can be seen as agriculture of the oceans. There are definite opportunities in using experience from land-based agriculture when dealing with some of the issues that will arise when harvesting and cultivation of algae will commence on large scale in the area. This applies for issues such as property rights which will become a controversial issue.

Agriculture in the West Nordic countries is challenging due to harsh weather conditions, at least compared to agriculture in warmer climate. The West Nordic countries on the other hand benefit from having to use less amounts of pesticides, as pest infestation in the agriculture is limited because of colder climate and therefore residues are less likely to be present in the production. More emphasis should be put on maintaining and claiming this benefit of Nordic agriculture and food production, especially in the West Nordic countries. Another advantage of the West Nordic agriculture is the short supply chain from producer to customers. This characteristic is also valuable and should be supported and combined with increased tourism in the region. If farmers are able to provide food and other supplies in their nearest environment, carbon footprints are reduced, contributing to the protection of the environment as well as the strengthening the region´s image and its food production.

More emphasis should be on research on new crop variants, such as grain or berries and their adaption to the West Nordic environment. There are also unexploited possibilities in using greenhouses to produce locally grown vegetables for domestic use in Greenland and the Faroe Islands. Along with research on new crop variants, further research on re-vegetation, soil conservation and grazing pressure in the West Nordic countries is needed along with research on effects of climate change on the Arctic and the living conditions there.

Tourism in the West Nordic countries can provide opportunities and jobs for the inhabitants if the sector is managed in a sustainable way by a supporting infrastructure. However, the environment is vulnerable and an appropriate infrastructure to tourism would be of great value to the societies in the West Nordic countries. An increase in tourism, as Iceland has experienced in recent years, can have a negative effect on the nature if the infrastructure is lacking, such as transportation, trails and access points in the nature, sanitary facilities, hotels, restaurants, and other servicing facilities. By combining the unique nature, wildlife, fisheries and agriculture and activities such as horseback riding, hunting tours, salmon fishing etc. with the hospitality of the local people, tourism can add considerably to the income of the people in rural areas as well as in bigger towns and cities. Further, tourism can help to create world wide net of consumers looking for clean high value food products exported from the region as well as ambassadors motivated to preserve the Arctic for the future. The key is a sustainable approach to all activities in the West Nordic countries, whether it is food production, transportation, bio-technology or tourism.

There are opportunities within the different sectors in the West Nordic countries. However, when each sector is operating separately in “its own silo”, the growth potential might be limited. If interdisciplinary cooperation between different sectors is enhanced, the growth potential of the economy is far greater. This interdisciplinary cooperation could include transfer of knowledge and best practices, between sectors. An example is the high utilization yield of raw material accomplished within cod fishing in the Icelandic fishing sector where knowledge of production of by-products could be transferred to other sectors. Further, research and development in combining e.g. aquaculture and horticulture, forming a semi-closed system where waste/by-products from one production are used as feed/fertilizer in the other production. Research and development are essential in pushing the entire bioeconomy further and should be supported across sectors, e.g. by governmental support, industrial investment and/or competitive research funds. Innovation, supported by strong infrastructure, is another key element in enhancing the bioeconomy, exploring underutilized possibilities and the economic benefits and growth opportunities within the West Nordic countries.

How to create synergy between (West) Nordic and EU H2020 funding

The initiatives supporting bioeconomy in the West Nordic countries whether local, regional or Nordic will have most impact if they can be aligned with European and other international research and innovation programs. It is important for the West Nordic countries to promote common interests, create synergies, provide inputs and influence agendas in international research and Pan-European innovation programs. The West Nordic countries should therefore put emphasis on active participation in preparing research agendas in H2020 through their national representatives in program committees, Standing Committee on Agricultural Research (SCAR) and other pathways open to the West Nordic countries. The West Nordic countries should encourage and assist the Nordic funding bodies in aligning their research policy with European policies in order to create synergies. The West Nordic countries should also find ways within the Nordic- and European cooperation to enforce regional programmes such as the Nordic Atlantic Cooperation (NORA) and the Northern Periphery and Arctic Programme (NPA). It is also very important for the West Nordic countries to participate actively in the European Bioeconomy Panel as well as the proposed Nordic Bioeconomy Panel and suggested West Nordic Bioeconomy Panel. This will ensure that the common interests of the West Nordic countries are clear and on the agenda in global and regional context.

Further, it is important to monitor calls e.g. SC2 and SC5 under the H2020 and identify collaboration opportunities for innovation in the region. It is also important to use the West Nordic funding bodies to strengthen and promote projects of West Nordic regional interest that will lead to synergic effects with European and pan-European funding bodies. Cooperation on research topics will e.g. increase the competitiveness and economic benefits for the West Nordic Region as well as European research area in general. Opportunities provided with the Galway statement should be utilized for initiating a wider Arctic collaboration which can be of great importance for the Arctic bioeconomy. In addition, the West Nordic countries need to collaborate on other issues of common interest such as the utilization of abundant and unique bioresources in accordance with the United Nations' Convention of Biological Diversity. This includes genetic resources unique for the region such as terrestrial and marine extremophiles and invertebrates of various marine habitats. Laws and regulations regarding access and benefit sharing of geothermal biotopes in Iceland have been in place since 1999. Protection on benefits from biodiversity research should be expanded to cover the many different and unique biotopes for the region and put into legislation in Greenland, Iceland and Faroe Islands.

7.1. Overview of opportunities presented in blue boxes

West Nordic Bioeconomy panel, p. 11

The common interests of the West Nordic countries are apparent as they distinguish themselves from the other Nordic countries when it comes to economic dimensions concerned with evaluation of the bioeconomy. West Nordic bioeconomy panel could have the mission to identify opportunities and to suggest a sound strategy for the West Nordic region in order to maintain and strengthen the bioeconomy in the region, as well as to communicate that strategy. It could serve as consultation venue and strategy forum, put common interest of the West Nordic countries more explicitly on the agenda of the Nordic Bioeconomy Panel, to be further feed into the European Bioeconomy Panel, setting EU strategy in the field. Furthermore, it could open up new opportunities for research and innovation in the region.

Arctic Centre of Excellence, p. 14

An interdisciplinary Centre of Excellence (CoE) focusing on issues related to the region such as bioeconomy, environmental issues, social issues, energy production and on solutions to increase added value of production of the region would benefit the rural development of the region. The CoE wold increase cooperation between the Nordic countries as well as with experts from other countries involved in Arctic research. The CoE would have multiple impacts, as it would turn the region into an attractive area for highly educated people as well as support and promote the economy of the area with research and innovation, create derivate jobs and increase the possibilities available in the area.

Organic waste as a resource for innovation, p. 30

The project *Organic waste as a resource for innovation* is an ongoing cooperation project between Umhverfisstofnun (The Environment Agency of Iceland) and Matis, funded by the Nordic Council of

Ministers. In the first part of the project, mapping of organic waste in Iceland, Greenland and the Faroe Islands will be carried out, focusing on by–products and waste from the fishing industry and slaughtering. Fishing industry is the largest industry in the three countries but agriculture is also important since it promotes sustainability in the countries. Iceland, Greenland and the Faroe Islands all have in common that they are remote islands where the nations are highly dependent on import of supplies. Mapping of organic waste and by–products is therefore important and can encourage innovation and sustainable economy of the nations.

Importance of fisheries for the West Nordic countries, p. 63

Wild fish stocks are by nature renewable resources, provided they are sustainably utilized. For nations like the West Nordic countries that depend heavily on fisheries there is a need to maximise the sustainable yield (MSY) of the fish stocks to boost the value creation as well as productivity throughout the value chain in the fish industry. This calls for new thinking, focusing on multiple value streams development and implementation of new processes and technology including biotechnology.
"Maximum sustainable yield is a broad conceptual objective aimed at achieving the highest possible yield over the long term (an infinitely long period of time)" (ICES, 2011)).

Cooperation in fisheries between the West Nordic Countries, p. 74

The knowledge available in the West Nordic fishing industry has increased in the last decade and knowledge and technological transfer between the countries and increased cooperation would strengthen the West Nordic countries.

Opportunities in combining fisheries and biotech, p. 74

Opportunities in fisheries of the West Nordic Region depend on robust fish stocks and investment in innovation and technology to improve yield and increase quality of the products. Combining strong industry, such as the fishing industry, with research, development and innovation within the biotechnology sector will benefit the economy of the West Nordic countries.

Future development in Greenland fisheries, p. 69

Altogether, fishing in recent years has been moderately growing in Greenland both in regards to production volumes and income. In general, however, there is a need for reform to combat overcapacity, low productivity in some parts of the sector and a strong need to modernise the fishing fleet, which is today in large parts composed of older and relatively small vessels. This calls for long-term, stable and attractive framework conditions for the Greenlandic fishing industry. Distribution of licenses is one tool. Another possible tool is to develop a taxation structure that supports a healthy economy and treasury and at the same time enables the sector to continue to develop.

Opportunities in aquaculture in Iceland, p. 81

When looking at the Faroes prosperity in salmon farming, there is no doubt that Iceland could learn from its neighbour and partly build its future wellbeing on aquaculture. The Faroe Islands have managed to build a successful industry which is already contributing more to the economy and export than catch fisheries and is more profitable. For Iceland, the fish farming is not only an expectation for future economic growth but it could also be extremely important for strengthening regions in the North West and East of Iceland, regions that are currently suffering economic and social problems with reduced population. Iceland could look to the Faroe Iceland´s success in salmon farming considering value creation, job creation and rural development.

Opportunities in feed production for Aquaculture, p. 77

Pre-feasibility studies by Matis have shown that the black soldier fly (*Hermetia illucens*) (BSF) represents a promising option for the production of feed protein, with growing interest in its use. The aim of the project was to answer questions related to optimal raw material use for the Black soldier fly larvae as ingredient for fish feed and potential raw material reduction. Results so far have shown that the larvae can be grown on different substrates but with variable efficiency. By taking advantage of available nutrients and water, the larvae can reduce the amount of feedstuff by 50-95%, making the benefits of their use substantial in relation to resource utilization and environmental impacts.

Fish feed from wood, p. 78

Increased demand for fish and fish products has led to increased research of protein resources for fish feed. Fish meal has been one of the main sources but is expected to fall short of demand in the near future. To meet this shortage protein-rich microorganisms (i.e. Single cell protein) have been used to produce protein from wood. Microbial biomass from cultivated residual streams from wood-based biorefineries in Sweden were collected and used for production of fish feed in feed trials for Tilapia. Fishes fed with such feed where fishmeal had been substituted with single cell protein, shoved similar or better growth than fishes fed with control feed containing fishmeal (Alriksson et al., 2014).

Biotech opportunities in the West Nordic countries, p. 83

A mapping and opportunity analysis focusing on biotech opportunities in the West Nordic bioeconomy will be a highly important addition to the conclusive mapping and opportunity analysis of biorecourses and the utilization in the West Nordic conducted within the project reported herein.

Challenges and opportunities in macroalgae, p. 81

Cultivation, harvesting and bulk processing technologies of macroalgae are being established in various Nordic projects, but processing of marine polysaccharides to high added value products has not been developed to industrial bulk state. This provides unique while challenging commercial opportunities for the Nordic countries, especially the West Nordic countries. The utilization of macroalgal biomass has been limited by lack of appropriate cost-effective pre-processing technologies including bio refinery processing enzymes and fermentative bio refinery organisms.

New technologies needed, p. 91

To realize the transition from petroleum refineries to biorefineries new refining and conversion technologies are needed due to the vast differences in the composition and properties of petroleum and lignocellulose. Second generation biomass contains large quantities of recalcitrant polysaccharides, e.g. cellulose in plants and alginate in seaweeds. For a versatile multi value stream biorefineries fermentative organisms capable of producing a variety of added value chemicals including biofuels need to be developed as traditional organism do not suffice. For complete degradation to fermentable monosugars efficient enzymes need also to be developed as well as cost effective enzyme production organisms.

Opportunities in West Nordic countries agriculture, p. 46

The most promising opportunities in agriculture in the West Nordic countries are to emphasise the clean air and water when growing vegetables and producing meat from sheep and reindeer, i.e. the clean and healthy production the farmers in the West Nordic countries can provide in a sustainable way.

Greenhouses in West Nordic countries agriculture, p. 46

The use of greenhouses in Greenland and Faroe Islands to produce vegetables for domestic use is a possibility in order to increase production of vegetables in areas not suited for outdoor cultivation. The early sowing in the greenhouses can positively affect the vegetables production and is worth further research.

Opportunities in vegetable production, p. 45

Large portion of consumed vegetables in Iceland are imported. About 45% of overall fresh vegetables were imported in 2010, 13,660 tons with value of over 93 million DKK. Consumers in Iceland prefer and opt for Icelandic vegetables over foreign. As such, the opportunity to increase domestic production is relatively large. There is a need to examine further use of vegetables in other food products such as tomatoes in salsa sauces, horticulture value chain and storage methods (Þorkelsson *et al*., 2012). The salad and berry production in Iceland has been increasing in recent years, and there is still a great opportunity for further increase. It has been publicly stated by the Icelandic Association of Horticulture Producers (Bjarni Jónsson, managing director), that a long term strategy is needed for the business framework of the horticulture sector, including electricity price strategy. A well-executed supportive strategy would result in a great increase in production, increased food security and self-sufficiency.

Opportunities in agriculture in Greenland, p. 39

Although residents of Greenland have historically not placed much importance on agriculture, the climatic conditions of the land for agriculture are improving in the southern region. This has allowed farmers to expand the production of existing crops. However some negative effects have been seen in relation to drought in most areas. Cattle ranging has also recently started in Greenland and there seems to be possibilities both in Nuuk area and South West Greenland, which could reduce and minimize import of beef and other products from cows.

Opportunities in sealing in Greenland, p. 54

With the right publicity and marketing effort, the sealing in Greenland could make good livelihood for the Inuit hunters and draw the attention of the fashion industry to the furs as a valuable material and sustainable living of the Inuit in harmony with the nature. The meat and other products from the seals can also ensure food security in underdeveloped countries as a protein supplement.

Hunting tours in the West Nordic countries, p. 58

Hunting tours in the West Nordic countries are already popular therefore combining the hunt with sustainable use and by protecting areas in the countries must be a focus point. Many species of seal, reindeer and musk-oxen in Greenland are currently underutilised and can be sustainably hunted to a larger extent. Hunting trips with tourists can provide the Inuit a living as guides and help the natives to utilise the wild species found in their surroundings. Birdlife in Greenland is also rich. Birding for tourists is also an unutilised area that needs to be focussed on in the coming future.

Tourism in the West Nordic countries can provide opportunities and jobs, p. 93

By combining the unique nature, wildlife, fisheries, local food production and activities such as horse riding, hunting tours, recreational sea angling, salmon fishing etc., tourism can add considerably to the income of the people in rural areas as well as in bigger towns and cities.

Opportunities in Greenland's tourism, p. 97

The current global spotlight on the Arctic and on Greenland should be able to foster a positive trend as regards the number of tourists in Greenland in the coming years, not least when compared to the current low number of guests from abroad staying overnight (37,160 in 2012). By comparison, Iceland had 800 thousands visitors in the same year, i.e. 22 times as many, even though Iceland's number of inhabitants is only about 5.6 times higher and the country's geography is significantly smaller (Rambøll Management Consulting, 2014).

Opportunities for reindeer husbandry, p. 60

Combining reindeer husbandry and tourism sustainably is a feasible way to increase value and raise society's awareness regarding the lifestyle of the reindeer herders.
Further utilisation of side products of the reindeer is also a good approach to increase the sustainability and income for the reindeer herders. The reindeer's fur is highly valuable if used in the fashion business with focus on the cultural and sustainable way of producing the skins.

Valuable data information for reindeer herders, p. 61

Information is important both up and down the value chain. Information to the herder/farmers is valuable for them to manage their resources. Information for the distributers and consumers can also be very valuable, for example traceability and/or origin information. Further work has to be put in gathering and distributing information for them to be useful and serve their purpose.

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