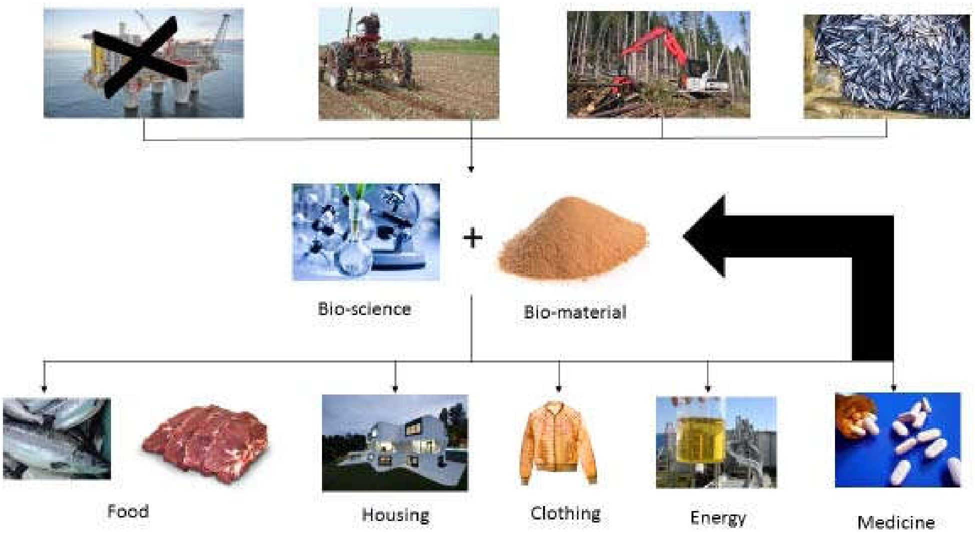
REPORT

12/2017
ISBN 978-82-7492-358-4
ISSN 2535-3004

CURRENT INDUSTRIAL USES OF BIOLOGICAL RESOURCES AND PRODUCTS IN NORWAY

A cross-sectoral view on the bio economy



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PROJECT NAME: BIOSMART	Project No.: 4739
CONTRACTING: The Research Council of Norway via Ruralis	Contracting ref.: 244608

Document No.: 12/2017	Document Type: Report	Status: Open
ISBN: **978-82-7492-358-4**	ISSN: **2535-3004**	No. Of Pages: 39
Project leader: Jannike Falk-Andersson		Date: 31.12.2017

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TITLE: Current industrial uses of biological resources and products in Norway. A cross-sectoral view on the bio economy

Summary:
The bio economy is a wide phenomenon encompassing a broad resource base on land and in the oceans. The possibilities for future developments are huge. Traditionally each sector in the bio economy (forestry, agriculture, fisheries, aquaculture and related industries) operates separately and there have been few cross-sectoral studies. This report contributes to remedy this shortcoming by offering a “wide-angle” view on the bio economy studying industries in all the major sectors in parallell. The study concerns bio economy in Norway. The report answers these questions: 1) What types of products are produced in the different (industrial) sectors when it comes to main products and by-products? 2) What are the capacities and types of businesses in the various sectors? 3) What kind of connections can be observed between different industrial sectors in the bio economy? The report builds on a previous report on resources in the primary sectors of the bio economy (Falk-Andersson et al., 2016). The report starts with a definition of central terms, such as main product, by-product and waste and a discussion of the value pyramid. For each sector, we provide a description of main products and by-products. The sectors differ hugely in character, from agriculture and reindeer herding as predominantly domestic industries, to forestry, fisheries and aquaculture, which are aimed at export. We combine different types of secondary data for the descriptions: public statistics, especially business statistics from Statistics Norway, and various reports, public documents and web information. By-products represents an increasingly important product category because of the need to focus simultaneously on sustainability and economy in society. Another major issue is the balance between specialization and integration. Much of the development of products and processes in the bio economy occurs in the form of specialization in the sectors. However, integration is necessary to avoid a total atomistic bio economy. In recent years we observe interesting examples of developments across sectors in the bio economy, such as production of biogas from by-products from aquaculture and forest industry. Another example is the combination of food products from agriculture and seafood to enhance the service product in the tourism and hospitality industry. The bio economy has a large potential to fill societal needs in the future, when it comes to food, feed, and fiber, as well as energy, new materials, health and recreation.

Keywords: Bio economy; resources; industrial uses; main products; by-products; cross-sectoral connections

Notes: Biosmart home page: http://biosmart.no/

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FOREWORD

Development of the bio economy and exploitation of linkages across sectors and value chains requires knowledge about resources and resource use in the different sectors of the bio economy. Building on an earlier report in Work Package 6 of the Biosmart project (Falk-Andersson et al. 2016) mapping resources and production in the primary sectors of forestry, agriculture, fisheries and aquaculture, this report provides data and analysis of the industrial processing and products in these sectors of the bio economy in Norway, also including industry based on reindeer herding. The report covers both main products and by-products and has separate descriptions on each sector and a common discussion of findings and implications. We thank the program BIONÆR of the Research Council of Norway via the Biosmart project (Contract No. 244608) for funding the research behind this report. We thank Heidi Rapp Nilsen for correcting and giving comments to the report. Finally, we acknowledge colleagues in the Biosmart project for valuable discussions on various aspects of the phenomenon of bio economy and use of resources in the different sectors.

Tromsø, 31.12.2017

The authors

1 GLOSSARY AND DEFINITIONS

The sustainable conversion of renewable biological resources and handling of waste streams is an integral part of the bio economy (European Commission, 2014). There are several concepts in use for the various outputs from these processes. Moreover, the concepts in Norwegian may not easily translate into English and vice versa. Therefore, before we start presenting the substance of the report we need to clarify some concepts. Such a clarification is all the more important because we in this report compare different sectors in the bio economy and there is lack of uniform use of some of the concepts. A general framework for definitions is provided through the EU waste legislation (European Commission, 2012). This general framework is to some extent applied in the regulation of specific sectors, such as the food sector. Of special interest for this report is that Norwegian authorities adopted the EU regulations on animal by-products in 2016.[1]

Raw material (also referred to as raw product): Any object or material intended for further processing. In the bio economy the actual raw material (raw product) is biological.

Main product (also referred to as primary product): Object or material that is the deliberate purpose of a production process. Can be further specified, for example "fish and shellfish from aquaculture and harvesting based on quotas in Norwegian waters and/or landings in Norway" (Richardsen et al., 2015). When we look along a value chain there are gliding transitions between a raw material and a main product. For example, for a farmer, grain is a main product, while a mill will see it as a raw material (for further processing).

Co-product: Product manufactured along with a different product, in a process in which both are required in the production of another product.[2] All co-products in the same process have equal importance.

Rest product: The terms by-product and rest product are sometimes used interchangeably. Principally, in this report we understand 'rest product' to be the most comprehensive of these terms, including both by-product and waste. This view is also applied in a recent report on rest products in the Norwegian food sector (Lindberg et al., 2016). Sometimes the concept "production residue" is used synonymous with rest product (European Commission, 2012). On this basis, a rest product is any product resulting from, but not the main (deliberate) purpose of a production process. There are two categories of rest products: waste and by-products. In this report, we are mostly addressing the by-product category of rest-products, while we to little extent describe the use of waste in the different sectors.

[1] Source: http://europalov.no/rettsakt/biproduktforordningen-om-produkter-som-ikke-er-beregnet-for-humant-konsum-revisjon/id-1250

[2] Source: www.businessdictionary.com/definition/coproduct.html

Rest raw material: In the food sector in Norway the term "restråstoff" is used (Lindberg et al., 2016). English translations used are "rest raw material", "rest raw product" and "residue". This indicates that "rest raw material" corresponds to the term "rest product" as it is explained above. However, the term rest raw material is sometimes used in a narrower way similar to 'by-product' and its eventual sub-categories (see below).

Waste: Rest product that has no value and must be scrapped. Hence, EU defines waste as "any substance or object which the holder discards or intends or is required to discard" (European Commission, 2012, p. 9).

By-product: A product that is not the main purpose of a production process, but has potential value provided that it can be applied in a way that does not violate health and/or the environment.[3] Another way to put it is that by-products are rest products with value. Within the sectors, by-products are further specified. For example, the food authorities define animal by-products as products that cannot be used for human consumption and has detailed regulations concerning by-products.[4] For example, animal by-products are divided in three categories:

Category I by-products: Represents the greatest risk. By-products in this category must normally be destructed through incineration. Hence, in practice this category can be regarded as waste.

Category II by-products: Represents a somewhat lower risk than category 1 and can among other things be used for biogas, compost and feed for fur-bearing animals. When it comes to aquatic animals, category II by-products come almost solely from aquaculture and includes mainly dead fish and fish that show signs of disease (Richardsen et al., 2015).

Category III by-products: Represents least risk and can be used as feed to production animals, technical and medical products, fertilizer, biogas and compost. For example, category III materials from aquaculture consists of parts of slaughtered fish suitable for consumption, but that for commercial reasons are not used for consumption (Richardsen et al., 2015).

When it comes to rest products, this report does not analyse the waste fraction, only the by-product fraction. The headings in the respective chapters on the bio economy sectors in section 4 reflect this in that we use 'by-products', and not 'rest products'.

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[3] Source: https://www.sp.se/sv/index/services/restprodukter/Sidor/default.aspx

[4] Source: https://www.mattilsynet.no/fisk_og_akvakultur/animalske_biprodukter/fakta_om_animalske_biprodukter_og_regelverket_som_gjelder.3552

2 INTRODUCTION

The bio economy is a very wide phenomenon encompassing a broad resource base on land as well as in the oceans with a myriad of small and large value chains. The possibilities for future developments are huge. Traditionally each sector in the bio economy (forestry, agriculture, fisheries, aquaculture and related industries) operates separately and there have been few cross-sectoral studies. This report tries to remedy this shortcoming by offering a “wide-angle” view on the bio economy studying industries in all the major sectors. The study concerns bio economy in Norway. We answer these questions: 1) What types of products are produced in the different (industrial) sectors when it comes to main products and by-products? 2) What are the capacities and types of businesses in the various sectors? 3) What kind of connections can be observed between different industrial sectors in the bio economy?

The report builds on and extends a previous report on resources in the primary sectors of the bio economy (Falk-Andersson et al., 2016). While that report very much reviewed the current status in the *primary* sectors of the bio economy (forestry, agriculture, fisheries and aquaculture), and hence highlighted the (biological) raw materials (and products), this report focuses on the next step in the value chain, *industrial* processing. Such processing is located all over Norway and takes place in a number of different small, medium sized and large companies. Some of the companies processes main products from extracted biological resources or products produced in the primary sectors, while others handle by-products and waste. The companies “themselves” produce main products and by-products, and may handle the by-products internally or deliver them to specialized companies “further down” the value chain. In some cases, primary production and industrial processing take place within the same company, such as in farm dairies and in integrated companies in the aquaculture sector. Other companies may be highly specialized.

The structure of the report is as follows: In the remainder of the Introduction (section 2) we give a brief account of the value pyramid as a way of structuring the various industrial uses of biological resources and primary products. In section 3, we give a general account of data, sources and application of the data. Section 4 contains descriptions of the various sectors, divided in main products and by-products. The introduction in the sector chapters includes a further specification of data and sources of data. Section 5 is a discussion of implications of the sector studies focusing on the possibilities for fruitful connections across sectors at the same time as businesses in the bio economy specialize into new products and markets.

2.1 THE VALUE PYRAMID

In section 1 (Glossary and definitions) we introduced a taxonomy of uses of bio resources. An important divide is between main products and rest products, where by-products are the valuable parts of the rest product. This divide does not necessarily correspond to differences in value. In some cases, the by-product may even be more valuable than the main product (or can be made more valuable through research and development). There have been various attempts at conceptualising the different uses of bio resources in terms of value. A rather common model is the "value pyramid" which places low value at the bottom and high value at the top. For example, Werkgroep Businessplan Biobased Economy (2011) introduced a model where 'energy' is regarded the least valuable use, with successive increase in value with 'chemicals and materials', then 'nutrition', and 'healthcare and lifestyle' on top. Hence, to produce energy products from a certain biological material is the least valuable and should be the last "resort". The first choice to consider should be products aimed at health and lifestyle, for example medicine and furniture. The model has later on been adjusted and specified for various contexts (see for example Antikainen et al., 2017; Bosman and Rotmans, 2016). For example, Figure 1 shows the model applied by Antikainen et al. (2017), which has an emphasis on forest products. In both these contributions volume is connected to value, in that the model assumes that lower value corresponds to increased volume and vice versa. However, as other authors have pointed out, this type of model cannot be used rigorously, as the circumstances (e.g. resources, market, location, policy etc.) are very different across companies and branches (Jónsson and Viðarsson, 2016). So, in this report, the value of various versions of the value pyramid lays first and foremost in the identification and listing of various uses of biological resources and primary products rather than in ranking different uses. Moreover, given the supra sectoral scope of the report including both main and by-products, we limit the detail of the descriptions of the many various uses in the different sectors.

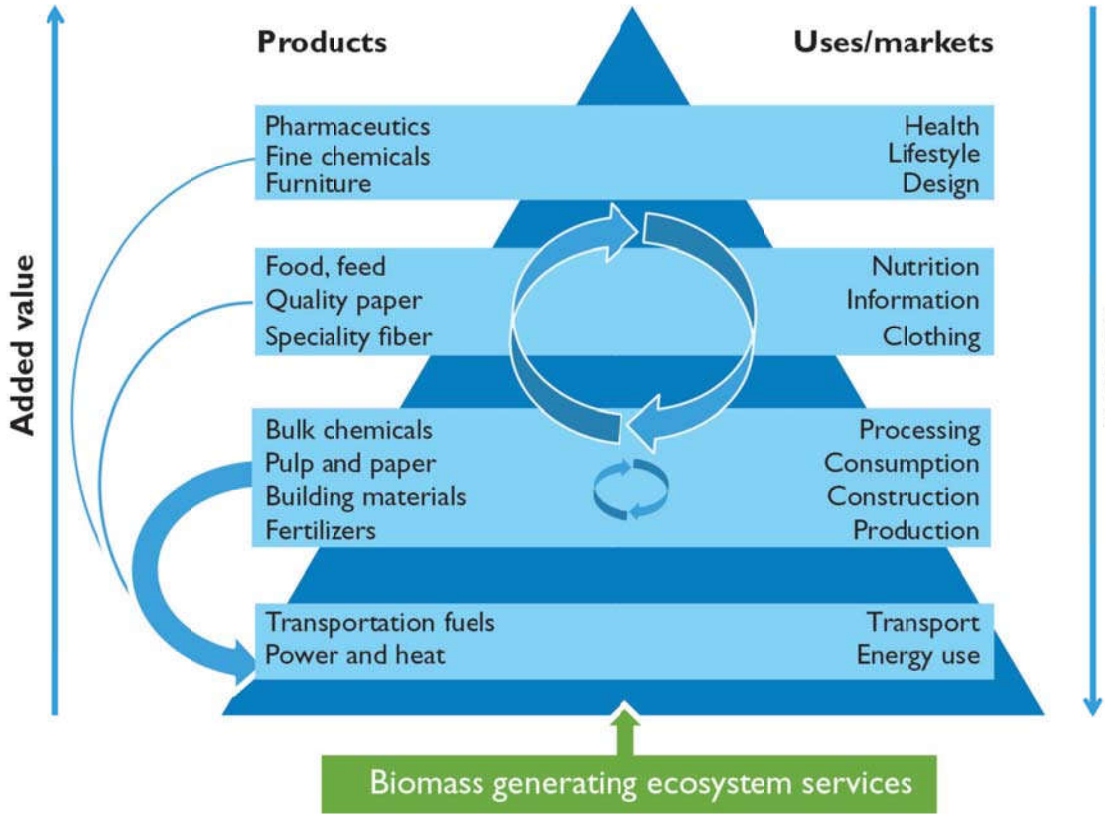

Figure 1: Biomass value pyramid for a circular bio economy (source: Antikainen et al. 2017)

3 DATA AND METHOD

The basis for the descriptions of the various sectors is a mix of public statistics and various written sources (research reports, articles, books, legal rules, and web pages). Most of the statistical data were derived from Statistics Norway, where the statistical theme "Agriculture, forestry, hunting and fishing" with sub-categories covers many of the relevant uses.[5] Moreover, the statistical theme "Energy and manufacturing" contains data on the use of biomass in district heating.[6] The statistical theme "Nature and the environment" has data on treatment of waste in terms of e.g. composting and biogas production.[7] In some cases, such as agro-food, we have utilized adapted data based on statistics from Statistics Norway (NIBIO, 2017). In categorizing different products, we have also applied the standard categories used in public business statistics (NACE).[8] Concerning written sources, most of these are specific for each sector, even though some sources, such as legal rules, have a cross-sector aim. In chapter 4 we have applied the various data and sources in order to provide coherent descriptions for each sector concerning the industrial uses of biological resources sorted in main products and by-products. However, beyond the basic topics "main products" and "by-products" the format varies somewhat for each sector due to substantial differences in the sectors and differences when it comes to available sources of information. Therefore, specific details about data and sources are provided in the beginning of each of the sector descriptions.

[5] Source: www.ssb.no/en/jord-skog-jakt-og-fiskeri
[6] Source : www.ssb.no/en/energi-og-industri
[7] Source: www.ssb.no/en/natur-og-miljo
[8] Source: www.ssb.no/klass/klassifikasjoner/6

4 INDUSTRIAL USES

This section gives in words and numbers an overview of the current industrial uses of biological material from the various bio economy sectors in Norway (forestry, agriculture, reindeer husbandry, fisheries and aquaculture). We describe uses in terms of main products and by-products, which both provide a potential basis for the future bio economy. However, in many cases there is a gliding transition between main products and by-products.

4.1 FORESTRY

4.1.1 INTRODUCTION

The main aims of Norwegian forest policy are to promote resilience and long-term stability of resources. More specifically, policies for Norwegian forest management aim to promote sustainability and to meet cultural, social, ecological and economic needs in the present and the future (Nordic Timber, 2012). In 2005, Norway's Forest Act ("Skogbrukslova") was brought up to date to promote sustainable forest management. The aim was to balance the need for economic development at a national and local level and ecological concerns such as securing biodiversity (Nordic Timber, 2012; Skogbrukslova, 2005). The Forest Act applies to all forest land and forests. The term "forest land" refers to land that is either under forest production or is suitable for forest production according to an overall assessment, and is not under use for any other purpose (Nordic Timber, 2012).

Forestry in Norway is one of the country's largest export commodities. Several studies imply that there is a huge potential for increased utilization and value added from the forestry sector (Pöyry Management Consulting AB, 2014; Sjølie et al., 2015; SKOG22, 2015). The wood industry manufactures many products. These are usually split into two categories, 1) lumber production producing sawn timbers and solid wood products, and 2) the pulp and paper industry, which make use of the wood fiber. This industry produces items such as paper, cardboard etc. In addition bioenergy constitutes a third type of main product from forestry. However, in some cases bioenergy is a by-product rather than a main product, making it difficult to give exact figures on the two types of uses of forest raw materials.

4.1.2 MAIN PRODUCTS

Annual cutting of timber is 10 million m3 pr. year in Norway. About fifty-two percent of the Norwegian round wood logs harvested is processed by sawmills. Approximately two hundred and twenty sawmills are operating in Norway on an industrial scale. However, ninety of these stand for 90% of the volume of production.

Wood processing industry has a long history in Norway. Many paper mills have been established on the basis of available raw materials, not because there was an obvious market for the products. This was also the case for Norske Skog: There were large amounts of poorly exploited timber in Central Norway, in the sense that there was little local processing capacity for the thin top of the log, which could not be used for lumber. Forest owners in the region had therefore for quite some time been considering various processing industry alternatives. Norske Skog's predecessor Nordenfjelske Treforedling was established 1st of March 1962. The investors were mainly forest owner associations in Norway, supported by agricultural associations. Long before that several wood mills had been established, such as Saugbrugs in Halden in 1859, and Follum fabrikker in Hønefoss and Union in Skien in 1873. In 1989, these and other wood mills consolidated through Norske Skog. Among other things, Norske Skog merged with Follum Fabrikker and acquired 50 per cent of the shares in Union. Saugbrugsforeningen was acquired the same year. As a result, at the end of 1989, Norske Skog had 24 production units in Norway.[9]

Forest industries worldwide are facing a range of challenges, such as declining demand for newsprint paper, fluctuating sawn-wood prices, and society's concern of forestry's negative environmental impacts (Sjølie et al., 2015). Today Norske Skog has closed down much of its capacity, resulting in increased export of Norwegian timber. For example, in 2015 approximately 4 million m3 (40 %) of harvested timber was exported, mainly to Sweden and Germany.[10] Most of the volume of Norwegian timber is supplied to sawmills making construction wood and wood processing industries producing pulp and paper. Table 1 gives an overview of main types of products in the various forest industry branches and approximate annual processing capacity.

[9] Source: Norske Skog www.norskeskog.com

[10] Source: Statistics Norway https://www.ssb.no/en/jord-skog-jakt-og-fiskeri

Table 1: Main types of products, indication of capacity and companies in forest based industries in Norway.

NACE code	Branch	Types of main products	Approximate annual processing capacity	Company examples
16.1.	Sawmill	Sawn wood	Sawn wood: 2.5 mill m3	Moelven, Bergene Holm, Kjeldstad + a number of SMEs
16.2.	Production of sawn wood products	Gluebeams, impregnation planing boards etc.	Planing board: 1.4 mill m3 Impregnation: 0.4 mill m3	
17.1.	Pulpmill	Pulp and paper	Pulp: 1 mill ton Paper: 1.1 mill ton	Norske Skog, MM Karton FollaCell
17.2.	Production of products based on paper and pulp	Fiberboard	Fiberboard: 180,000 m3	Forestia

Source: Statistics Norway https://www.ssb.no/en/jord-skog-jakt-og-fiskeri

Concerning bioenergy, 150 years ago and before, wood was the dominant source of energy in Norway. After the industrial revolution, the pulp and paper industries became by far the largest producers of bio-energy within Norway. Electricity shortages and CO2 taxes on the use of oil have in recent years led to renewed interest in the use of bio-energy. In 2015 we assume that 2 million m3 of timber were used for chopped firewood. 2/3 of this came from broadleaves.[11]

4.1.3 BY-PRODUCTS

Production of main products in the forestry processing industries results in various by-products. Most common is sawdust from sawmills and bark from sawmills and paper mills. The sawmilling industry produces several co-products (Tellnes et al., 2011). Another by-product is bark, which results from debarking of the timber before it is processed. Approximately 500,000 m3 of bark is produced annually. 80 % of this is used in heating for drying the sawn wood. In the sawmilling industry, 2/3 of energy use comes from bioenergy. 20 % of the bark goes to soil improvement for gardening (Treforedlingsindustriens Bransjeforening, 2016). When sawing the timber, sawdust and wood chips are produced. 1.3 million m3 is delivered to mills for production of pulp and paper. 700,000 m3 goes to industrial building solutions in floors, walls and roofs.

In the pulp and paper industry, paperboard and fiberboard are produced. Total pulp production sums up to 1 million tons; 850,000 tons of mechanical pulp and 150,000 tons of sulphite pulp (Treindustrien, 2016). In Norway, half a million tons of newspaper

[11] Source: Statistics Norway https://www.ssb.no/en/jord-skog-jakt-og-fiskeri

and half a million tons of uncoated mechanical paper are produced. Paper for wrapping and packaging sums up to nearly 100,000 tons. Nearly all the production of pulp and paper is exported. Only 15 % is used in the domestic market (Treindustrien, 2016). The production of fiberboard amounted to 180,000 m3 in 2016.

The production of paper is an energy intensive process. Energy is used mainly for two purposes:

- To separate, process and transport fiber and water (electrical energy)
- To provide process heat and to dry the paper (thermal energy)

The major use of electrical energy in mills, which process fresh fiber, is the process that mechanically converts wood chips into fibers. This process is called the thermomechanical pulping (TMP) process. Paper production based on recovered paper consumes less energy because the fibers from recovered paper are more easily separated than those within wood.[12]

Over the last 20-30 years, various new uses of timber have been developed. Lignin is used in concrete, asphalt, paint and ice cream. Vanillin, which adds flavor to vanilla ice cream and vanilla sugar, is also extracted from lignin. Furthermore, fabrics such as viscose and carbonic acid can be fabricated into cellulosic soda.[13] The Norwegian company Borregaard is a world leading biorefinery. This company manufactures lignin, specialty cellulose, vanillin and bioethanol for a variety of applications in agriculture and fisheries, construction, pharmaceutical and cosmetics, food, batteries and biofuels by utilizing various components of the timber.[14]

4.2 AGRICULTURE

4.2.1 INTRODUCTION

Agriculture means any type of biological production that is produced wholly or partly on agricultural land. On global level, agriculture produces a vast range of products. Whereas food and feed is most important, there are also beverages, natural stimulants and non-food products such as fiber and energy.[15] Nevertheless, the main products from agriculture and the basis for most agriculture based industry has to do with food or feed. In Norway, with some exceptions (e.g. sugar and chocolate) most food processing is based on the produce from the country's around 40,000 farmers

[12] Source: www.norskeskog.com
[13] Source: https://no.wikipedia.org/wiki/Skogbruk
[14] Source: http://www.borregaard.no/
[15] On a list derived in 2013 of the 52 most valuable crops and livestock products on world basis, 50 of the products were food products and two (cotton and rubber) were non-food products. Source: https://en.wikipedia.org/wiki/List_of_most_valuable_crops_and_livestock_products List based on statistics from FAO: https://web.archive.org/web/20110713020710/http://faostat.fao.org/site/339/default.aspx

(Storstad and Rønning, 2014). Important processing industries are slaughter, dairy, and processing of grain, oils and fatty substances, and fruits and vegetables. When it comes to grain, oils and fatty substances processing results to large extent in feed (concentrates) in addition to food. To some extent, production of beverages uses inputs from Norwegian farmers (e.g. local cider, beer and malt). Concerning structure and organization, most of the food processing is undertaken by specialized companies and factories. Most of the produce from primary agriculture is transformed into new products, such as cheese and bread, while some produce (e.g. fruits, vegetables and potatoes) are sorted and packed for direct consumption.[16] In both cases these can be referred to as main products.

Production and processing of food is the largest industry sector in Norway, encompassing around 19 per cent of all industrial employment (44,300 persons in 2012) and 17 percent of the value added (Berg and Krøtø, 2015). Of this, processing of fish and seafood constituted around 20 per cent of the value added, while the rest (nearly 80%) was connected to agriculture, amounting to about 25 billion Norwegian kroner (around 3 billion Euro). The proportions of the value creation indicate the relative *capacity* in the various food industry subsectors (branches). In order of magnitude the sectors are: Meat and meat products (22%), dairy products (16%), bakery and pasta (12%), other food articles (11%), feed products (10%), fruits and vegetables (4%), grain products (2%) and oils and fatty substances (2%). Almost all of these agricultural based products are sold domestically. However, the proportion of domestic *inputs* to the products vary, from almost all within meat, dairy, potatoes and vegetables to lower proportions when it comes to fruits, bakery, grain and feed, to nothing when it comes to food articles such as coffee, tea and sugar (Himle, 2016). Both primary production and processing results in by-products. Important by-products on the *farms* are straw, which can be used as feed, and manure used as fertilizer or in some cases biogas. The agriculture based processing *industry* also results in a number of different by-products.

In recent years, the tendency in the sector has been to invest in fewer and bigger plants, for example in the dairy sector (Almås and Vik, 2015). This has led to a restructuration of food processing in Norway and increased centralization (Kårstad, 2015). On the other hand, over the last 15-20 years a flora of small scale food processing has been developing, for example farm dairies (Forbord, 2005) and small, specialized meat processing and micro-breweries (Berg and Krøtø, 2015; Borch et al., 2005; Stræte, 2015).

To get a closer and more systematic overview of uses of the "raw" products from Norwegian agriculture, we turn to selected public statistics and literature. In Table 2 we give an overview of *main products* based on agriculture in Norway. The overview is based on the standard business categories (NACE), second level (Mikkelsen, 2017). An important source of statistics here has been NIBIO (2017) supplemented with

[16] The main markets for food products in Norway are the grocery market (70%), service market (kiosks and petrol stations) (5%), and institutional households (25%) (Kårstad, 2015).

information from Kårstad (2015) and Himle (2016). Concerning *by-products*, we provide a summary of results from a report by Lindberg et al. (2016).

4.2.2 MAIN PRODUCTS

Table 2 shows the various agriculture based industries according to categories used in public statistics (NACE) and lists *typical products* produced in each branch. Most categories concern produce for human nutrition and/or enjoyment with a couple of exceptions. Code 10.1. (Meat, egg, etc.) also includes non-food products such as wool and hides. Code 10.9. concerns feed entirely. We notice a wide range of products in all branches. Consequently, it is challenging to find a unitary expression for *processing capacity*. However, we have been able to find figures for the annual volumes (in tons) of "raw material" delivered to the biggest branches in terms of volume. For example, the dairy sector handles around 1.5 million tons of milk each year, and the meat industry processes 350,000 tons of meat annually. The grain industry takes in an average year care of 350,000 tons of food grain. 350,000 tons of potatoes are processed each year. The feed industry produces nearly 2 million tons of feed every year, but note that this also include feed to aquaculture. The *number and types* of companies ("virksomheter")[17] varies between the branches. Farmer owned corporative[18] cooperatives dominate in the three largest food industries; meat, dairy and grain. A corporative farmer cooperative (Felleskjøpet Agri) also leads in feed production. The *size distribution* also differs with a few big and many small and medium sized firms (SMEs) in the meat sector and the bakery sector, and few and large companies in the dairy sector and when it comes to "oils and fatty substances".

[17] Note that the NACE statistics builds on locally delimited enterprises (in Norwegian "virksomheter", before 2014 "bedrifter"). This means that corporations such as Tine and Nortura are not units in the statistics, rather all the companies that are part of the corporations. For more information see: http://www.ssb.no/virksomheter-foretak-og-regnskap/artikler-og-publikasjoner/fra-bedrift-til-virksomhet

[18] With corporative we mean companies that consists of many enterprises, such as the dairy company Tine.

Table 2: Main types of products, indication of capacity and companies in agriculture based industries in Norway.

NACE code	Branch	Types of main products*	Approximate annual processing capacity**	Number of enterprises (2014)***	Company examples*
10.1.	Meat, egg etc.	Various meat products from cattle, lamb, pigs, poultry, reindeer Egg	Meat: 350,000 tons Egg: 60,000 tons	304	Nortura, Grilstad, Nordfjord Kjøtt, Prima Gruppen, Norsk Kylling, Fatland, Stensaas + a range of SMEs
10.5.	Dairy	Liquid milk products, cheese, butter, yoghurt, ice-cream, milk powder	Milk: 1,550,000 tons	113	Tine, Synnøve Finden, Q-meieriene, Diplom-Is, Hennig Olsen + several farm dairies
10.7.	Bakery products	Bread, biscuits, pastry, other bakery products and pasta	N.a.	608	Gomanbakeren, Mesterbakeren, Bakers + a range of SMEs
10.6.	Grain products	Flour, cereals, starch	Food grain: 350,000 tons	49	Norgesmøllene, Lantmännen Cerealia
10.4.	Oils and fatty substances	Vegetable and animal oils. Margarine, cooking fat	N.a.	34	Mills, Denofa, Norsk Protein, Norsk Matraps
10.3.	Fruits, vegetables and potatoes	Cannery products (jam, juice, vegetables), frozen products (vegetables, fruits), potato products (mashed, flour, chips) + direct consumption	Total produce for processing and direct consumption: Potatoes: 350,000 tons Vegetables, fruits, and berries: 200,000 tons	76	Hoff, Tine, Bama Industri, Røra Fabrikker, Lerum, Findus
10.8	Sugar, coffee, processed food etc.	Sugar products, chocolate products. Processed products (soups, sauces, tea, coffee, flavors, processed food)	N.a.	184	Nidar, Brynhild, Orkla, Mondelez + many SMEs
11.	Beverages	Liquor, wine, beer, cider, malt, mineral water, soft drinks	N.a.	112	Ringnes, Arcus + many local breweries
10.9.	Feed products#	Feed concentrates, mineral feed	Feed concentrates produced: 1,950,000 tons	104	Felleskjøpet Agri, Norgesfôr, Fiskå Mølle

Sources: *) Kårstad ed. (2015). **) Himle (2016). ***) NIBIO (2017)
#) NB! Feed products include feed to aquaculture and agriculture, as well as pets.

4.2.3 BY-PRODUCTS

Production of main products in the agricultural processing industries results in various by-products. There is very little waste in the sector. How much volume the by-products represents and the potential for value were mapped in 2016 (Lindberg et al., 2016). This publication provides an overview of annual volume, composition, quality, application and potential uses of by-products from processing of various agricultural foods, such as a) meat, b) cereals, c) vegetable oils, d) vegetables and potatoes, and e) fruits and berries.[19] This means that by-products from the production of feed is not included. Neither does the report cover the handling of by-products, e.g. food losses, in the grocery sector and the hotel, restaurant and catering sectors.

The report shows that by-products from meat production constitutes the largest volume. Here, by-products are defined as everything of the animal that is not meat, such as bones, hides and guts that have a potential value. The annual volume constitutes 264,000 tons of residues of various sorts. Of these 27,300 tons are animal fat, which is a resource that has potential for higher value. Milling of grain into food results in 69,800 tons of hull and bran ("skall" og "kli") annually. Of this, wheat bran constitutes the most, 61,000 tons. In addition, Norwegian breweries produce 17,000 tons of brew spent grain ("mask"). Manufacturing of vegetable oils is modest and gives 800 tons of pomace ("pressrest"). Manufacturing based on vegetables and especially potatoes results in 64,150 tons of by-products, that is, slightly less than for cereals. Processing of fruits and berries results in 1585 tons of pomace, of these 1300 tons come from processing of apples. All in all, the aforementioned agricultural based food productions result in 415,000 tons of biological by-products each year. Much of these by-products are used as animal feed. But there are examples of more valuable uses. The report provides a number of examples. One example is the company Norilia which makes products from hides, guts, wool and offal, to significant degree for export. E.g. hides from Norwegian cattle are used in luxury automotive seating.[20] Another company is Norsk Protein, which makes feed, fertilizer and energy from animal by-products such as offal.[21] Norsk Protein also regains much of the fat from animal by-products. The feed branch uses by-products from other agricultural and bio economic branches, e.g. pomace from production of vegetable oils, animal fat, fishmeal, fish ensilage and urea in the manufacturing of various feed and feed concentrates.[22] Valuable uses of by-products from processing of potatoes are potato spirits, potato flour and mashed potatoes. By-products from fruits and berries are for the most part used as animal feed, compost and soil improvement.

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[19] These types correspond to the NACE branches 10.1., 10.6., 10.4., and 10.3 respectively, see Table 2.
[20] Source: http://www.norilia.no/
[21] Source: http://www.norskprotein.no/
[22] Source: https://www.landbruksdirektoratet.no/

4.3 REINDEER HUSBANDRY

4.3.1 INTRODUCTION

Reindeer husbandry is the ancient and culturally based utilization of the reindeer (*Rangifer tarandus tarandus L.*) by the Sámi of the North and Middle Norway, but also adopted by local groups mountain farmers of Central South Norway (Bitustøyl, 2013). Traditionally the animals were used as means of transportation and practically all parts of slaughtered animals have been utilized either as food or raw materials for handicrafts and tools, as part of as good as a fully natural resource based economy (Kjellström, 2000; Ruong, 1982 [1969]; Vorren and Manker, 1976). In wide parts of the Sámi areas reindeer milk was a staple food item. In some regions milking practice were sustained up towards the 1960s (Falkenberg, 1985; Fjellheim, 1995).

Finnmark, Norway's northernmost county, is the stronghold of reindeer husbandry in Norway. A picture of the times up to four decades ago is provided by this quotation:

"In Finnmark the reindeer was the main meat producer and were staple food for the population. Still the production of reindeer meat is more than doubles the provision of cattle and sheep. Reindeer fur was important for clothing, and the reindeer was necessary for traffic and transportation (Sara, 1979).

During the 20th century reindeer husbandry gradually has changed towards meat production for external markets. While direct sale of animals or meat to private merchants have a long history establishment of modern slaughterhouses for reindeer started in the 1950s and 1960s (Riseth 2009). From 1968 Norges Kjøtt- og Fleskesentral established cooperation with the two largest of these and during a few decades developed a quasi-monopoly of the marketing of reindeer meat (Norges Kjøtt- og Fleskesentral, 1981; Reinert, 2006). During the latest couple of decades an increasing number of small to medium, mainly family-based companies in addition to having established slaughter companies also perform value-added activities realizing much more of the surplus value by refining and marketing luxury products.

During modernization and integration into the wider society many self-produced items also have been replaced by bought market goods, though parts of the traditional self-production persist as household and family practices. Further some art and handicraft production have been partly commercialized for a long time. This provides a basis for extending local ventures by using culturally based knowledge to offer combined food and adventure products reaching both tourists and local/regional markets (Ween and Riseth, 2017).

4.3.2 MAIN PRODUCTS

Meat is the dominating product. Reindeer meat has a number of clear advantages: It contains higher concentrations of vitamin B12, iron, zinc and selenium than any other meat. Further, it contains the essential lipid acids humans are dependent on in concentrations comparable to recommended seafood items. Moreover, it contains only 2 per cent fat, which is at the level of chicken. Thus, health recommendations for consumption of reindeer meat are well founded. The challenge is that the total production is very limited (Hassan, 2012).

The average registered slaughter quantum through thirteen years is 1800 tons (Landbruksdirektoratet, 2015, 2016a, b; Statens Reindriftsforvaltning, 2014). As a an effect of the limited amount of marketed reindeer meat there probably is an overlap with NACE-code 10.1 from agriculture as reindeer husbandry is included in publications from Statistics Norway under the label of Agriculture only with numbers of reindeer without any production quanta registered there.[23] In a normal year about 1100 tons are marketed as products with different degree of processing (Markedsutvalget for reinkjøtt, n.d.). In 2017 there were altogether 26 registered companies in the trade of reindeer slaughter, refinement of reindeer and outfield production, and marketing and sale.[24]

4.3.3 BY-PRODUCTS

Reindeer fur is the main by-product. Furs are dried and prepared and can also be tanned. Around 80,000 animals are slaughtered per year. No statistics are available, so how much of this potential that is utilized is unknown. Simple web search reveal sales prices from a few hundred up to between one and two thousand kroner. [25]. I.e. the potential value may be around 80 million NOK.

Reindeer antlers are another rest product. In some East Asian cultures antlers are considered as an aphrodisiac. Whether this potential market is utilized in Norway is unknown. Traditional medical reports and clinical observations on deer antlers show that antlers are biologically active to cure various diseases and that there is a potential for nutraceuticals and functional foods, but chemical and biological properties need to be determined (Kawtikwar et al., 2010). The potential for reindeer antlers also is unresearched.

Moreover, other parts of reindeer are still used as raw material for handicrafts. Current value and potential are unknown.

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23 http://www.ssb.no/jord-skog-jakt-og-fiskeri/artikler-og-publikasjoner/landbruket-i-norge-2015

24 Landbruksdirektoratet, unpublished file

25 https://grillhyttespesialisten.no/reinsdyrskinn/
https://coop.no/sortiment/obs-sortiment/hjem-og-interior/stue/skinn/andre-merkevarer-10004
https://www.xxl.no/nordic-reindeer-sitteplate-av-reinskinn/p/1068069_1_style

4.4 MARINE BIO RESOURCES AND PRODUCTS

The seafood industry can be defined as the part of the seafood sector that receives and processes fish and shellfish (Nyrud and Bendiksen, 2017). In terms of volume, this constitutes the largest part of commercial marine biomass use. In addition to these animal products, products are also made from marine plants such as seaweed and kelp. This constitutes so far a small volume. A significant amount of marine primary products, such as wild fish and farmed fish, is exported and processed abroad. In this report we focus on domestic industrial processing of fish, shellfish and marine plants.[26] It comprises of a range of main products and different by-products.

4.4.1 MAIN PRODUCTS

Based on NACE code 10.2 Table 3 gives an overview of productions in the seafood industry (processing and preservation of fish, shellfish and molluscs). The code contains four sub categories: 1) production of salted fish, dried fish and clipfish, also called conventional products (Nyrud and Bendiksen, 2017), 2) frozen fish, fish filets, shellfish and molluscs, 3) canned fish, and 4) slaughtering, processing and conservation of other fish.[27] The first three categories regard wild fish, while the last category includes all types of processing of farmed fish. To estimate the capacity in the seafood industry is a complex task. Firstly, it is a question of where in the value chain we measure (Dreyer and Bendiksen, undated). We can measure the capacity to receive and store raw product and/or we can measure production capacity. Moreover, we can choose to measure the work force, the capital input and/or technical equipment. We could also take departure in the annual catch of wild fish and production of farmed fish in Norway, but then we have to subtract the proportion that is exported and add imported raw material. Another challenge concerns aquaculture, where the proportion of vertically integrated firms increases, making it difficult to separate industrial processing from primary production (fish farming) (Nyrud and Bendiksen, 2017).

Nevertheless, one method is to count the number of employees in the sector, which was slightly above 10,000 in 2014 (Table 3). The share of employees gives an indication of capacity in the sub-sectors. Measured as work force, 80% of the capacity was in the two sectors freezing and filet (code 10.202) and processing and conservation of farmed fish (code 10.209). Since the 1990s, the number of companies in the seafood industry has steadily decreased, while the size has increased (Nyrud and Bendiksen, 2017). This applies both when it comes to harvested (wild) species (white fish, pelagic fish and shellfish) and farmed fish (salmon and trout). Nevertheless, the industry is still relatively spread geographically with many small- and medium sized enterprises. The

[26] Our review does not include wholesalers, retailers and exporters.

[27] Note that production of fishmeal and fish oil is described in the section "By-products" below. The same is the case for industrial uses of marine plants.

total value of the production in the 421 companies was about 53 billion NOK in 2014, while the costs in terms of intermediate consumption[28] were around 43 billion NOK.

Table 3: Main types of products, indication of capacity and companies in industries based on fisheries and aquaculture in Norway.

NACE code*	Branch*	Types of main products*	Approximate annual processing capacity (2014)**	Number of enterprises (2014):**	Company examples
10.2	Processing and preservation of fish, shellfish and molluscs		Number of employees: 10,309 Production value: 53,159 Mill. NOK Intermediate consumption: 43,260 mill. NOK	421	
Of this:			Share of employees***:		
10.201	Production of salted fish, dried fish and clipfish	Salted fish Dried fish Clipfish	19%		Tørrfisk fra Lofoten
10.202	Freezing of fish, fish filets, shellfish and molluscs	Frozen fish Fish filets Shellfish Molluscs	36%		Findus, Norway Seafoods
10.203	Production of canned fish	Canned fish	1%		Vesteraalens
10.209	Slaughtering, processing and conservation of other fish and fish products.	Other fish products	44%		Salmar, Marine Harvest, Lerøy, Vegalaks

Sources: *) Statistics Norway https://www.ssb.no/en/jord-skog-jakt-og-fiskeri ; **) NIBIO (2017): ***) Berg and Krøtø (2015)

4.4.2 BY-PRODUCTS

By-products from aquaculture and fisheries are used as raw products for animal food, and as ingredients and consumption products. In 2014, 628,000 tons of by-products was utilised, while the remaining 259 tons (0.04%) was not utilized. The latter is mainly due to by-products not being brought to shore in the white-fish sector (Richardsen et al., 2015). Better utilisation of these by-products as well as harvesting at lower trophic levels, such as krill and other zooplankton, has been suggested as a potential source of feed to the growing aquaculture industry (Thomassen et al., 2003). The zooplankton *Calanus finmarchicus* is used to produce food supplements and feed for fry and pet-food, as well as flavouring in different types of food articles (calanus.no,

[28] Intermediate consumption includes all costs except depreciation. Source: http://www.ssb.no/a/metadata/conceptvariable/vardok/1787/en

2015). From 2003 to 2014 there has been an experimental fishery on *Calanus*, and management authorities have called for more knowledge on the carrying capacity of both the *Calanus* population itself, but also other components in the ecosystem, before increasing the quota available for commercial harvesting (Broms, 2005). Macro algae are mainly harvested for alginate and seaweed meal (Fiskeridirektoratet, 2015) and has the potential to be used for human consumption, feed, materials, chemicals, fuels and pharmaceuticals (Skjermo et al., 2014). Deep, cold waters surround Norway. This makes up rather hostile environments that organisms have adapted to. It is believed that these adaptations provide a pool of bioactive marine compounds that could be the basis for future marine bioprospecting industries. Arctic Biodiscovery Centre (previous Mab Cent), based in Tromsø, is a centre for research based innovation that focuses on studying the biochemistry of Arctic marine organisms with the aim of finding and developing high-value bioactive compounds (Svenson, 2013). Since fish harvesting and aquaculture are the main sources of marine by-products in Norway today, we focus on these two sectors.

Any food processing will produce by-products, but in the fisheries sector this utilization is more important for the economic viability of the industry than in most sectors. This is because by-products normally make up a significant part of the catch and, if treated properly, may be more valuable than the main product (Gilberg, 2002). Traditionally, the whole fish was used for food or feed, but since the industrialisation of the fisheries the volume of wasted by-products increased substantially (Gilberg, 2002). In the 1970s the problem of waste and other by-products that were discarded, grew so large that the industry took the initiative to establish a project to find out how these fish by-products could be utilized industrially (Olsen, 2001). The by-product of fish, for example cod, is skin, bones, heads, collar bone, cut off, backbones, shells, liver, roe, milt, tongues, stomachs, intestines, gall bladder and swim bladder. While liver, roe and tongues from cod to some extent is consumed, almost 60% of the cod catches can be considered to be by-product of filet production (Jónsson and Viðarsson, 2016). Furthermore, unwanted species caught as by-catch and farmed fish that die or get slaughtered due to disease are also by-products (Olsen, 2001). Since the 1990s, the fishing industry has become more aware of the potential value in by products (Rubin 2004, as in Søvik 2005).

There are four major groups of fishery by-products: 1) raw material used for energy and fertilisers, 2) raw material used for feed, 3) raw material used for food and 4) speciality products. The major use of by-products has been for feed production, which has a low profitability. Processing into food and food ingredients normally gives a much higher profit, while extracting and purifying high-value biochemicals from specific fractions of the by-product generally yields the highest profit (Gilberg, 2002). The latter will still generate a significant amount of unutilised mass. Figure 2 is a value pyramid illustrating increasing value of the by-products depending on the final products produced, with pharmaceutical products at the top (Jónsson and Viðarsson, 2016).

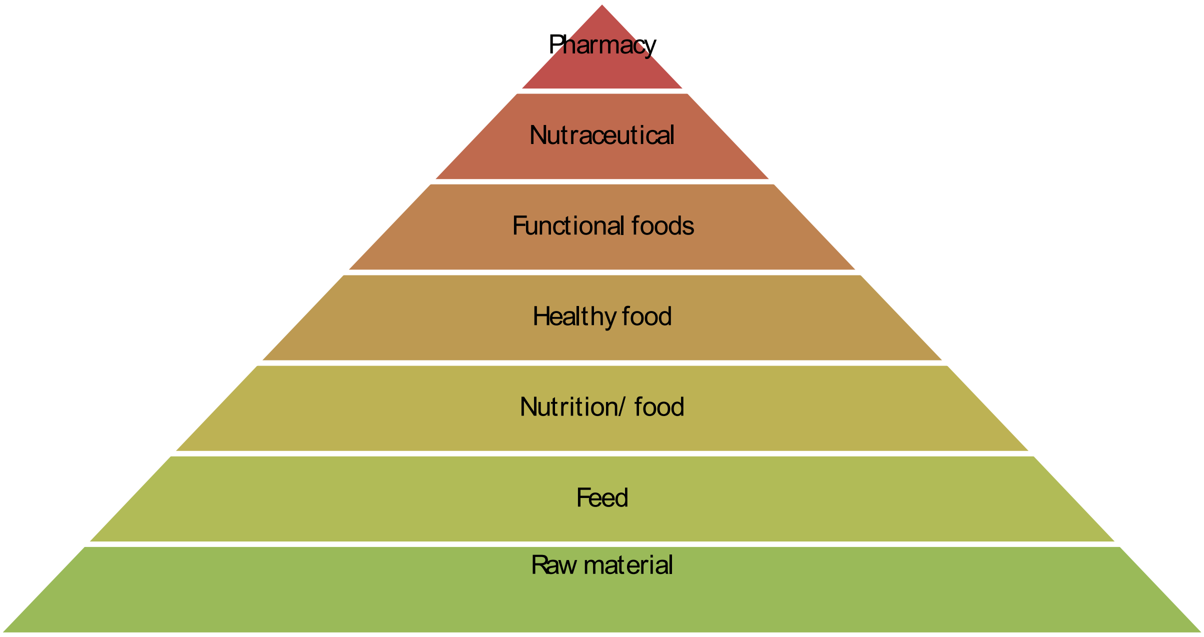

Figure 2: The value-pyramid for by-products from fish and seafood processing (from Jónsson and Viðarsson (2016))

Table 4: Examples of value added products from by-products from fish and seafood (from Arason (2002) as in Søvik (2005)).

Food ingredients	Health food ingredients	Fine chemicals
Flavour attributes	Ingredients with nutritional properties:	Bio compounds:
Proteins	- proteins	- enzymes
Collagen	- vitamins	- substrates
Fish oils	- minerals	- hormones
Ingredients with functional properties:	Nutraceuticals/ pharmaceuticals:	- gelatine
- gel forming	- speciality fish oils	- chitosan
- foaming	- hormones	- etc.
- water binding	- glucosamine	
- emulsifying	- chitosan	
	- other physiologically active extracts and compounds	

Utilization of by-products in the fishing industry on land is dependent on the quality of the fish, which can be affected by handling and temperature, and the production line (Akse et al., 2010). Mechanical gutting of the fish must be gentle to secure that the quality of the by-products is not compromised. The use of better gutting machines can increase utilisation of by-products of the ocean going fleet by securing more gentle handling, and thereby possibility to separate out valuable by-products (AS, 2013; Rustad, 2003). The material also needs to be kept at neutral pH and low temperature to preserve its quality. There is a need to develop systems for sorting and handling by-products on-board, and cost-effective preservation methods, as well as to improve the logistics from vessel to the processing plants (Rustad, 2003).

As also found for marine oils (Falch et al., 2003), Søvik (2005) found that quality and enzymatic activities in by-products from codfish differ between species, seasons and fishing grounds. Below is a description of major groups of by-products in the marine sector.

4.4.3 MAJOR PRODUCT GROUPS FROM MARINE REST RAW PRODUCTS

4.4.3.1 Marine oils

Marine lipids have found to have beneficial health effects, for example reducing the risk of cardiovascular- and inflammatory diseases (Rustad, 2003). Cod by-products are a source of marine oils, with the liver containing between 50-70% lipids, viscera 2-9% and cut-off 1% lipids. The lipid content varies between species of cod, season and fishing ground (Falch et al., 2003). Knowledge of all these factors is important to secure that the fish oil from by-products meets the specifications (Søvik 2005). Other sources of marine oils are the muscle of fatty fish, such as salmon, and blubber from marine mammals, such as seals. Fish oil is mainly used as a food supplement, but can also be used to enrich every day products such as margarine and egg. There are such products on the market today (Rustad, 2003).

4.4.3.2 Fish mince, surimi and surimi based products

Fish mince, surimi and surimi based products can be produced from cut-offs. Surimi is a myofibrillar protein concentrate used to produce seafood analogs, such as crab legs. It can also be used in novel products such as sausages and protein drinks. Surimi is produced by washing of the fish mince to remove water-soluble and odour bearing compounds (Venugopal et al., 1995).

4.4.3.3 Fermented products

Fermented fish products are classified in 1) fish and salt formulations, and 2) fish, slat and carbohydrates, and are used extensively in Southeast Asia for preparation of flavoured products (Venugopal et al., 1995). Fish sauce and paste are examples of the former products, and all kinds of fish material can be used for its production.

4.4.3.4 Fish protein concentrates (FPC) and hydrolystates (FPH)

FPC is used to recover fish protein from processing wastes. It is produced by removing water and oil from the substrate (Kristinsson and Rasco, 2000).

4.4.3.5 Extraction of enzymes and bioactive compounds

Enzymes are an important part of processes used in modern food industries due to their specific nature and high activity at low concentrations under mild conditions of pH and temperature. Fish have a high tissue concentration of enzymes, and cold water organisms are particularly interesting as their reactions are carried out at low temperatures. Combined with a better understanding of enzymes and commercial availability from marine sources, this has boosted research on the possibilities offered by enzymes that originate from fish and aquatic invertebrates (Shahidi and Janak Kamil, 2001). Marine enzymes can, among other things, be used for deskinning of fish and squid, ripening of fish and production of fish sauce and purification and cleaning of fish roe for caviar production (Shahidi and Janak Kamil, 2001; Vilhelmsson, 1997). Marine enzymes from Atlantic cod viscera have been found to be active at low temperatures and more heat labile than corresponding mammalian enzymes (Vilhelmsson, 1997). ArcticZymes is a Norwegian company selling enzymes based on Atlantic cod. Protamin is a bioactive peptide found in fish testicles. It is used as an antibacterial agent in food processing and preservation due to its ability to prevent Bacillus spores from growing (Rustad, 2003).

4.4.3.6 Fish silage

Fish silage is almost entirely used for feed and can be produced from all types of low-value fish and fish by-products (Rustad, 2003). It is usually made by mixing 2-3 % formic acid with raw material that has been minced, and allow the raw material associated enzymes dissolve the fish tissue. The silage may be processed further to a protein concentrate, or used directly in feed. The salmon aquaculture industry in Norway is a major silage producer (Rustad, 2003).

4.4.3.7 Collagen/ gelantine

Collagen is the main component in skin, and is used in a number of pharmaceutical and cosmetical products. Gelantine is the hydrolysed form of collagen. It is used in the food industry as a food additive to preserve texture, the water-holding capacity and stability of food. In addition to being derived from fish skins, collagen and gelantine is derived from fish bones (Rustad, 2003).

4.4.3.8 Energy

Dead fish and fish that show signs of disease (Category II by-products) from aquaculture can be used as raw material in the production of biogas. In Norway, the company Biokraft AS is building a large-scale plant for production of liquid biogas (methane) based on a mix of category II fish and waste water from pulp and paper production in Skogn in Trøndelag.[29] The factory will open in 2018. A by-product from the biogas production is organic fertilizer that can be used in agriculture.

4.4.4 AVAILABILITY AND UTILIZATION OF REST RAW PRODUCTS FROM FISHERIES AND AQUACULTURE

The Norwegian Seafood Research Fund is responsible for analysis of the availability and use of marine rest raw products[30] in Norway. SINTEF Fisheries and Aquaculture (now SINTEF Ocean) and Kontali Analysis are responsible for the analysis. This section is based on their report on availability and utilization of rest raw products from fisheries and aquaculture in 2014 (Richardsen et al., 2015). Figure 3 illustrates the production flow from harvesting/ aquaculture production to by-products.

[29] Source: http://www.biokraft.no/

[30] Rest raw product is a literal translation from the Norwegian term "restråstoff". To the extent that the rest raw product has value, it is a by-product, see definitions in section 1.

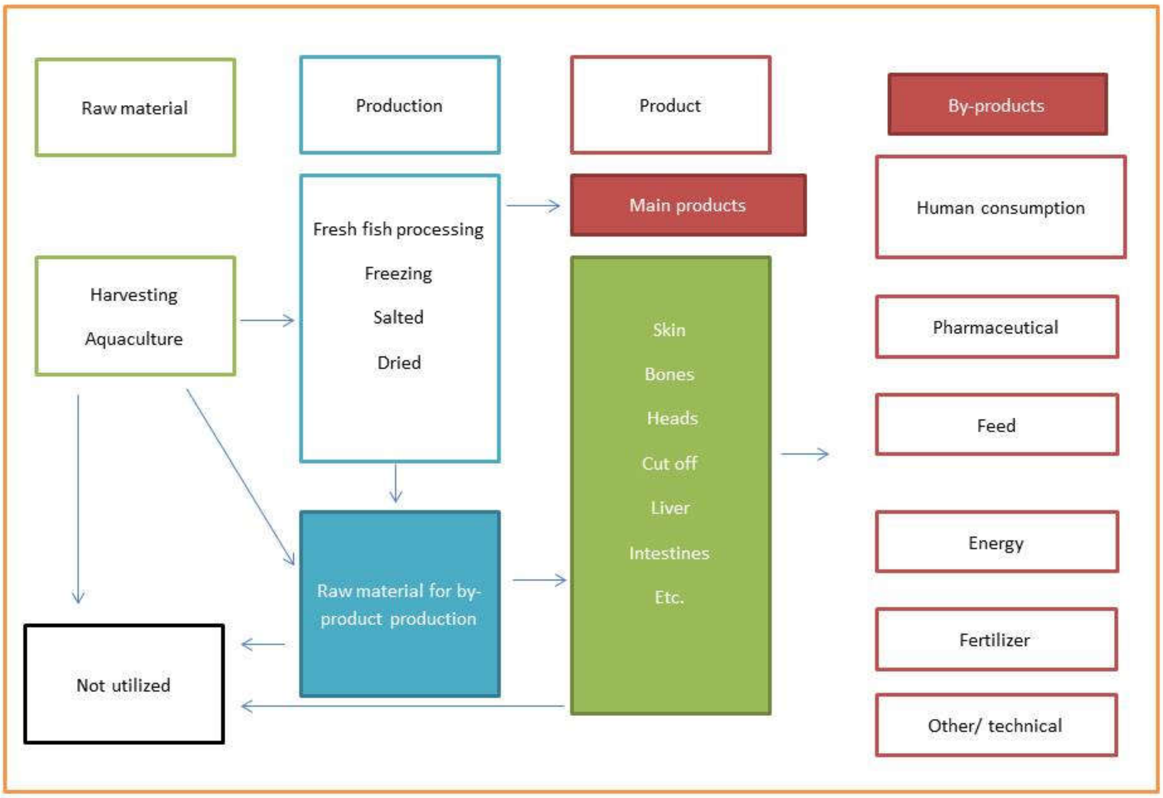

Figure 3: Illustration of utilization of rest-raw products from harvesting of fish and aquaculture (modified from Richardsen et al. (2015)).

From a raw material basis of 3.4 million ton fish and shellfish from the Norwegian fisheries- and aquaculture industry, about 885,000 ton (26%) is rest-raw products. Out of this, 628,000 ton was utilized. Table 55 shows that the groundfish (cod-fish) industry generates the largest amount of rest-raw product relative to the raw material, followed by shellfish, aquaculture and the pelagic fishery. However, the shellfish raw material base is relatively small compared to the other industries, and is therefore excluded from this report. The reasons why rest-raw materials from the groundfish industry are not utilized are a lack of good technological solutions on-board and economic incentives to bring the fish on-shore. What is brought to shore of rest-raw materials is largely utilized, and in the aquaculture industry it is only blood from the fish that is not utilized (Richardsen et al., 2015).

Table 5: Raw material and rest-raw product availability (in ton) from fisheries and aquaculture (numbers from Richardsen et al. (2015)).

	Groundfish	Pelagic fish	Aquaculture	Shellfish	Sum
Raw material basis	786,000	1,243,000	1,270,500	33,600	3,433,100
Rest-raw product availability	341,000	162,000	370,600	11,339	884,939
% rest-raw product available	43%	13%	27%	34%	26%

It is estimated that 37 % of rest raw products are utilized in the groundfish sector, 100% in the pelagic sector and 90% in the aquaculture sector (Richardsen et al., 2015). Figure 4 shows that Nordland, Møre & Romsdal and Troms have the largest volumes of rest-raw products available. The groundfish sector dominates in Finnmark, Troms, Nordland and Møre & Romsdal, while Trøndelag and Hordaland is dominated by rest-raw products from the aquaculture industry. Availability of rest-raw products from the pelagic sector is highest in Nordland, followed by Sogn & Fjordane, Møre & Romsdal and Troms (Richardsen et al., 2015).

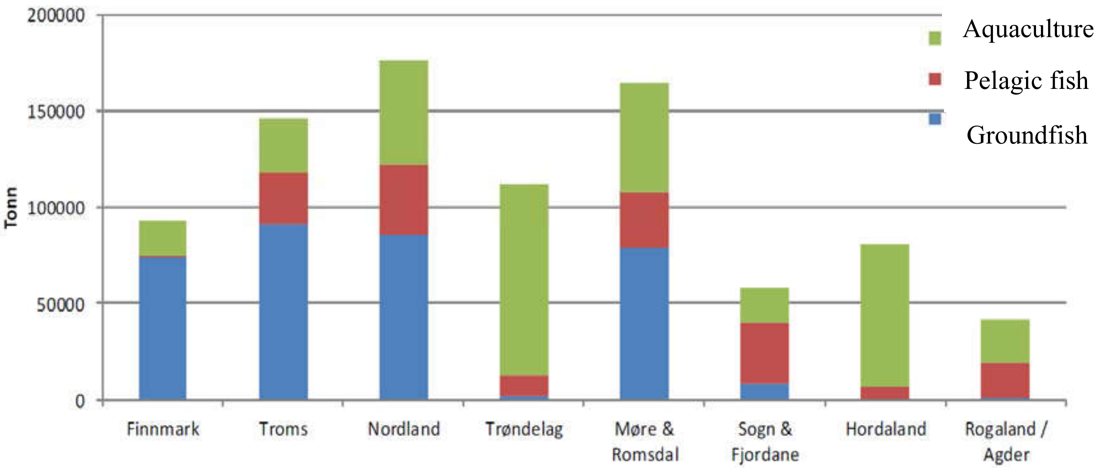

Figure 4: Availability of rest-raw products in Norwegian counties from aquaculture, and pelagic- and groundfish industry (tons). (Figure translated to English from Richardsen et al. (2015)).

Heads, guts and liver from groundfish make up the largest volume of rest raw products that are not utilized. Blood from both the whitefish- and aquaculture industry also represent a relatively high volume (

Figure 5). While the availability of rest raw products from the aquaculture sector is relatively stable throughout the year, with slightly lower production from October to December in 2014, the wild fisheries show larger fluctuations. Groundfish has a peak in availability from January to April, while pelagic fish peaked around January and

November in 2014. October and November and January to March have the highest supply of raw materials due to the seasonality of the fisheries.

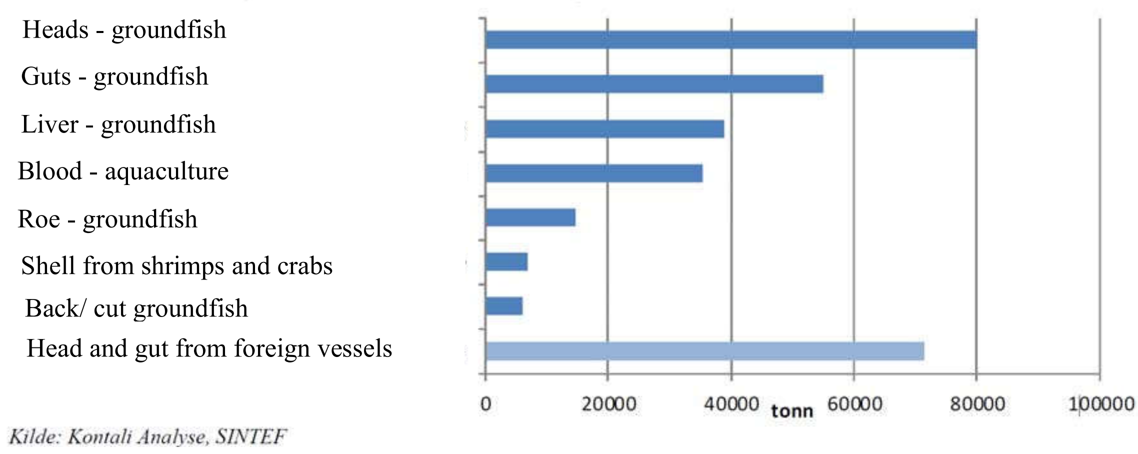

Figure 5: Not utilized rest raw products in 2014, ranked by weight (tons) (Figure translated to English from Richardsen et al. (2015))

Only a small part of the rest raw material is used to produce food for direct consumption, either as fresh or frozen seafood products. However, the majority of the rest raw material is processed in some form. About 40 % is used for production of silage, followed by fishmeal and animal feed production. Production of oil- and protein based on rest raw products from the aquaculture industry is the third largest category. Cod liver oil and protein extracts used for human consumption make up 4% of the rest raw product utilization (Figure 6).

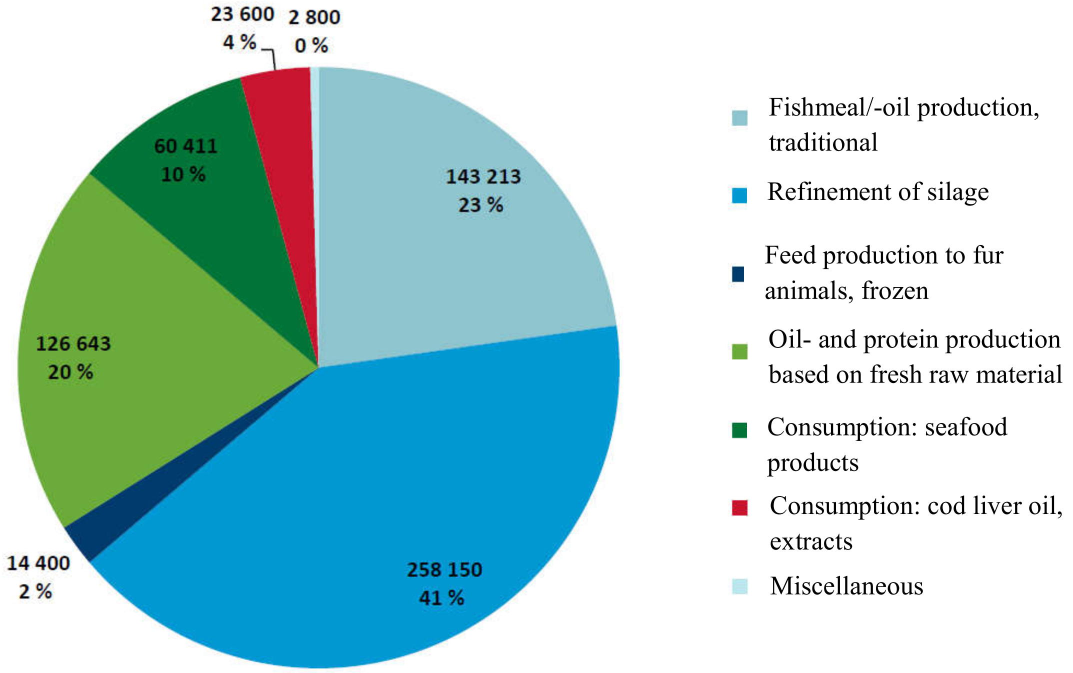

Figure 6: Utilization of rest raw products for different product types in 2014 (tons raw weight and share of total in %). (Figure translated to English from Richardsen et al. (2015))

In terms of the product groups produced from rest raw material, 75 % is used as components in feed, while 14 % is used directly for human consumption either as seafood, fish oil or protein extracts (Figure 7). Increased cod stocks and reduced herring stocks have affected the use of rest raw materials by increasing the amount used for consumption and decreasing feed production. The proportion of rest raw products used for bio-energy is relatively stable, with the source mainly being from aquaculture (Category II material). Salmon oil sold on the health food market makes up less than 1%.

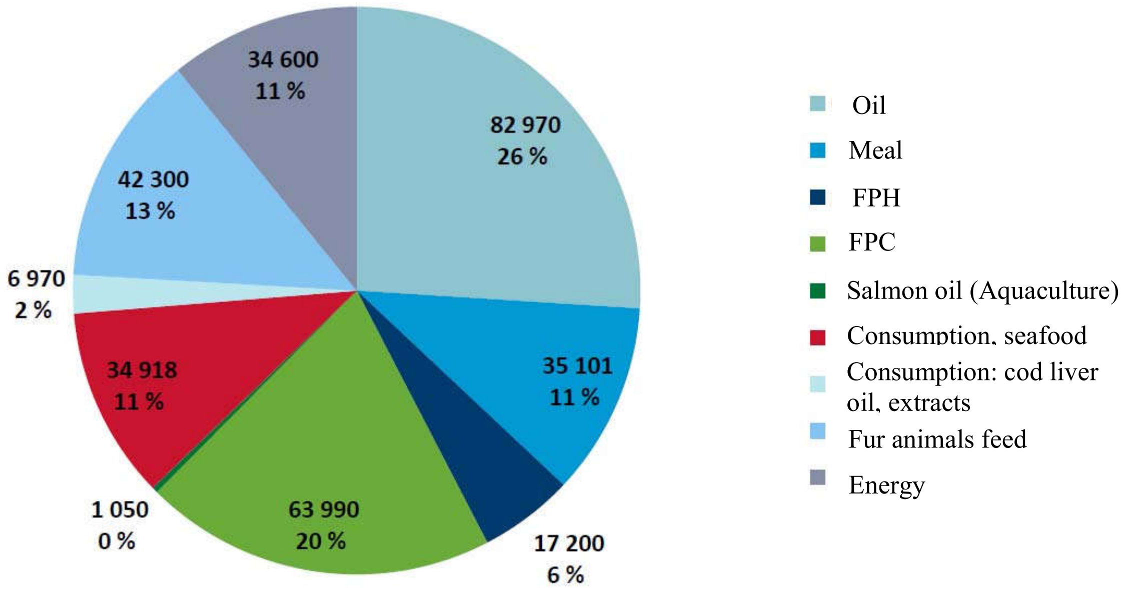

Figure 7: Product groups of marine rest raw products (tons and share of total in %). (Figure translated to English from Richardsen et al. (2015))

In terms of feed production, the majority (56 % in 2014) is used as fish feed, followed by farm animal feed (25%), fur animal feed (15 %), and pet feed (4%) (Richardsen et al., 2015)

5 DISCUSSION

This report explores the industrial utilization of bio resources and products across the major sectors of the bio economy – forestry, agriculture, reindeer herding, and the marine sectors (fisheries and aquaculture) in a certain country—Norway. Normally these sectors are studied separately, often linked to specific themes or challenges. Such narrow, specialized studies are needed, as the report demonstrates a huge difference in products, companies and markets between the sectors. Looking across the bio-industrial sectors, the products and the companies are founded on a very varied resource base stretching from "land to sea". Primary producers in the actual sectors, such as foresters, farmers, reindeer herders, fishers and fish farmers, contribute major inputs, such as timber, grain, milk, animals, fish and other seafood. In addition, there is industrial utilization based directly on natural (unprocessed) resources, such as seaweed and microorganisms.

One characteristic trait of the modern bio economy is heavy research to develop new, more or less specialized products that can meet new demands in the market or replace other products (e.g. fossil-based products) in meeting existing societal needs. Not at least the account of by-products in the marine sector in this report show how much effort that is put into exploring new biological resources and developing new potentially valuable and sustainable products based on these. Such exploration requires much specialized competence and work by scientists and firms, and specific support from authorities.

However, specialization is only one side of the "coin". Just as important is the other side – integration. In fact, Piore (1992, p. 443) claims that "the process of technological change…" can be understood "…in terms of the priorities of specialization and integration", see also Piore and Sabel (1984). The term "bio economy" may be diffuse and hard to understand, but interesting in the sense that it opens for looking at the possibilities for integration across sectors in the bio economy. Then it is necessary to have some sort of idea and comparable information about what is going on in each of the sectors. This report provides, to some extent, such information, especially what the typical products of each sector and subsectors are and the production capacities in the sub-sectors. As we have seen, in terms of volume, the capacities vary a lot between subsectors in each of the major sectors. However, as the value pyramid (Figure 1 in chapter 2, Introduction) illustrates, there is necessarily no connection between (increased) volume and value. It means that it may pay better off to produce small quantities of a rare product presupposed that the product fills a need in the market. In this case that would be some kind of niche, be it in the corporate market (industry, public institutions) or in the consumption market.

The type of technological trajectory corresponding to this kind of production is termed "flexible specialization" by Piore (1992). The examples of flexible specialization have increased considerably in all bio economic sectors since the economic crisis in the late 1980s. Among many examples are farm dairies and other types of specialized food processing on farms (Borch et al., 2005), small-scale firms in the bioenergy sector (Forbord et al., 2012; Nybakk et al., 2011), and specialty firms in the seafood sector (Forbord, 2016). The latter is also an example of how product inputs from *different* bio economic sectors, in this case specialty food products from agriculture and seafood, in combination with immaterial assets (Itami, 1991) can be used to enhance a service product (in this case, breakfast experience at a hotel).[31] Also important, flexible specialization includes as well the exploitation of by-products. One example is the company Marealis in Northern Norway, which has developed a blood pressure regulating health product made from prawn shell.[32]

Nevertheless, that there are obvious examples of value creation based on biological resources with special qualities does not eliminate the fact that volume and hence mass production (scale) will continue to have a huge role in the bio economy. However, mass production may not mean specialization within a narrow, specialized part of the bio economy. In fact, companies are developing that carry out mass production based on resources from many sectors of the bio economy. One example is the company Biokraft in Trøndelag building a factory in Skogn for producing liquid biogas for the transportation sector.[33] The resources that are put into the production is a mix of by-products (category 2) from the aquaculture sector and wastewater from a nearby pulp & paper production. Moreover, a by-product from this biogas production is organic fertilizer to be used in agriculture. When we also observe that flexible specialization in the bio economy also can be carried out in a large-scale company such as Borregaard,[34] we understand that there is no absolute correspondence between the form of organization and the type of technology (flexible specialization versus mass production).

So, what we think is well worth paying attention to for actors in the bioenergy in the future is to consider the balance between specialization and integration. This question concerns individual companies, branch organizations and authorities. A prioritized focus in innovation research programs in recent years, both in Norway and in the EU, has been integrated (transdisciplinary) research. One salient example is the program BIONÆR in the Research Council of Norway, which main purpose is to arrange for research and innovation that can create value creation in biobased businesses in Norway.[35]

In recent years, the program has had a focus on identifying valuable connections between sectors in the bio economy. At the same time, many of the projects, especially the technical-natural projects, are highly specialized, which also is important for building a valuable and sustainable bio economy. A question then is if specialization and integration shall take place within sectors or across sectors. Through this report we

[31] Cf. the concept experience economy (Pine and Gilmore, 2011)
[32] Source: https://nofima.no/nyhet/2016/03/rekeskall-senker-blodtrykket/
[33] Source: http://www.biokraft.no/
[34] Source: http://www.borregaard.no/
[35] Source: https://www.forskningsradet.no/prognett-bionaer/Forside/1253971968584

have painted a holistic portrait across sectors and given some examples of exploitation and cooperation across sectors. Given the huge diversity in resource base and markets there will no doubt be further specialization within the sectors, which also will open possibilities for cooperation and development across sectors.

A question will be how to manage and organize to derive the advantages in such a missed world. The view put forward by Piore (1992) is that neither a one-sided market solution (price signals) nor a pure hierarchy (top down approach) are apt. However, between these two organizational archetypes, there is a variety of possibilities for network forms of organizing securing some predictability as well as flexibility. In this way, we can pave way for a “smart” bio economy in Norway and meet the great societal challenges.

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