The macro-economic effects of increasing seaweed production in the North Sea Region

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This project was carried out by Wageningen Economic Research and funding was provided by the Ministry of Agriculture, Nature, and Food Quality through the Knowledgebase Program 34: Circular and Climate Neutral; BAPS KB-34-007-004.

Wageningen Economic Research
Wageningen, May 2023

REPORT
2023-073
ISBN 978-94-6447-687-3

Monika van den Bos Verma, Sophie Koch, Heleen Bartelings, Sander van den Burg, 2023. *The macro-economic effects of increasing seaweed production in the North Sea Region.* Wageningen, Wageningen Economic Research, Report 2023-073. 20 pp.; 13 fig.; 0 tab.; 21 ref.

There is considerable interest in the Netherlands and Europe in the potential of seaweed as source of food, feed and biomass for a biobased economy. The aim of this study is to evaluate the macro-economic effects of increasing seaweed production in the North Sea. The explorative analysis showed that the seaweed sector in NSR is in its nascent stages. Despite an modelled 10% annual growth over next 30 years, production in the North Sea Region remains too small to have any visible impact on global markets for seaweed. The size of the seaweed sector remains too small to function as alternative source of protein in consumer diets. The Modular Applied GeNeral Equilibrium Tool (MAGNET) was used in this study. MAGNET is a recursive dynamic, multi-regional, multi-commodity CGE model, covering the entire global economy. The best available data from FAO and information from scientific literature were used. We emphasise that results are indicative and should be used as such. More reliable data collection and improved insights in the different cost structures in various North Sea region countries can improve the accuracy of the simulations

Key words: seaweed, MAGNET, North Sea, economy, human diet

This report can be downloaded for free at https://doi.org/10.18174/629904 or at www.wur.eu/economic-research (under Wageningen Economic Research publications).

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Wageningen Economic Research Report 2023-073 | Project code 2282700545

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Preface

Concerns about food security, the needed development of biobased economy and the protein transition have, among others, fuelled interest in the further development of seaweed production and use. Wageningen University and Research is involved in numerous research projects on seaweeds, ranging from Horizon Europe projects, Public Private Partnerships and contract research to knowledgebase research funded by the Ministry of Agriculture, Nature and Food Quality. This report presents the results of a study conducted under the Knowledgebase Program 34: Circular and Climate Neutral. It addresses an issue underexplored in other research topics: the expected macro-economic impacts of upscaling seaweed cultivation in the North Sea.

This issue is relevant as various as interest groups make claims about the potential contribution of seaweed production to the economy. The study is the first in its kind to apply the MAGNET model to seaweed cultivation. Results show that, on a global scale, production in the North Sea region is small and even with 10% annual growth remains small. The expected contribution to the economy remains small as well. This is a reality check, not an argument against upscaling seaweed cultivation. Benefits of upscaling seaweed cultivation can include much needed positive local impacts on the ecosystem and the local economy.

Wageningen Economic Research thanks the Ministry of Agriculture, Nature and Food Quality for funding this research.

Ir. O. (Olaf) Hietbrink
Business Unit Manager Wageningen Economic Research
Wageningen University & Research

1 Introduction

There is considerable interest in the Netherlands and Europe in the potential of seaweed as source of food, feed and biomass for a biobased economy (Buschmann et al., 2017; Duarte et al., 2021; Hasselström et al., 2020). Various research programmes study the potential applications of seaweed, numerous small and larger companies venture into the production and processing of seaweeds (Araújo et al., 2021) and policies to stimulate growth of the seaweed sector are developed.[1] Among the foreseen applications of seaweed is use as food product (FAO and WHO, 2022; Slegers et al., 2021) although no specific targets on seaweed consumption have been formulated.

Within seaweed research, much attention goes out to the biology of seaweed and the technologies for farming and processing. Economically oriented studies have focused on expected and/or experienced cost of production, the potential revenues, business models, value chains and consumer acceptance (Hasselström et al., 2020; Selnes et al., 2021; Zhang et al., 2022). An analysis of the expected macro-economic impacts of upscaling seaweed farming in Europe is lacking.

So far the European algae market represents a marginal portion of global seaweed production, while Asian suppliers account for around 87% of global market (Ferdouse et al., 2018). Much is expected: according to the Seaweed for Europe report, the European seaweed market in 2030 could be worth up to €9.3bn (Seaweed for Europe, 2020). Furthermore, under the right market conditions, producers in Europe could reach about one third of this market representing a value of €2.7bn, generating about 85,000 new jobs (Seaweed for Europe, 2020). An analysis of the expected macro-economic impacts of upscaling seaweed farming in Europe is lacking.

The aim of this study is to evaluate the economic effects of increasing seaweed production in the North Sea, using the Modular Applied GeNeral Equilibrium Tool (MAGNET). This model has a long history of use within Wageningen University & Research for assessing the global impacts of policies in agriculture. MAGNET is a recursive dynamic multi-sector, multi-region Computable General Equilibrium (CGE) economic model that covers the global economy (Woltjer et al., 2014). MAGNET is based on the Global Trade Analysis Project (GTAP) database (Aguiar et al., 2019) and is a model that has been developed at Purdue University in the United States (Hertel and Tsigas, 1997). MAGNET has been extended and updated with several modules, including additional sectors such as 'seaweed sector' for this work. We use the adapted MAGNET model to undertake a few experiments to raise seaweed production (tonnes) in North Sea regions (NSR) (France, Portugal, Great Britain, the Netherlands, Ireland, Denmark, Norway).

In Chapter 2 we describe the method to include seaweed in MAGNET and in Chapter 3 we present results from the scenario analysis about the potential (macro) economic impacts of increasing production of the Seaweed sector in the NSR. Chapter 4 concludes that under the scenarios studied, the production in the NSR region remains small to have any visible impact on global markets for seaweed.

[1] See for example https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12780-Blue-bioeconomy-towards-a-strong-and-sustainable-EU-algae-sector_en

2 Model adaptation

The Modular Applied GeNeral Equilibrium Tool (MAGNET) is a recursive dynamic, multi-regional, multi-commodity CGE model, covering the entire global economy. As with other CGE models, MAGNET explicitly represents the economic linkages across the sectors of each regional economy. This is particularly important when analysing policy effects in sectors that are vertically linked with each other, such as fertilisers, agriculture and biofuels. It is built upon the GTAP model (Hertel, 1997) and is the successor of the LEITAP model which has been widely used for policy analysis (Banse et al., 2008; van Meijl et al., 2006; Nowicki et al., 2009, Woltjer, 2011). The MAGNET model is modular in nature and extends the GTAP model through the addition of a number of policy-relevant modules. For this study MAGNET has been extended with a seaweed sector by splitting the original GTAP sector fisheries 'fsh' into seaweed and fisheries.

To implement seaweed in MAGNET, data was collected from the FAO about production and export value of seaweeds in million euros. The FAO data about production and trade did not match very well. For several countries, the FAO data reported more seaweed exports than production, see Figure 1. In these cases we assumed that the production data of FAO is incorrect and we adjusted the total production in a country to match the export.

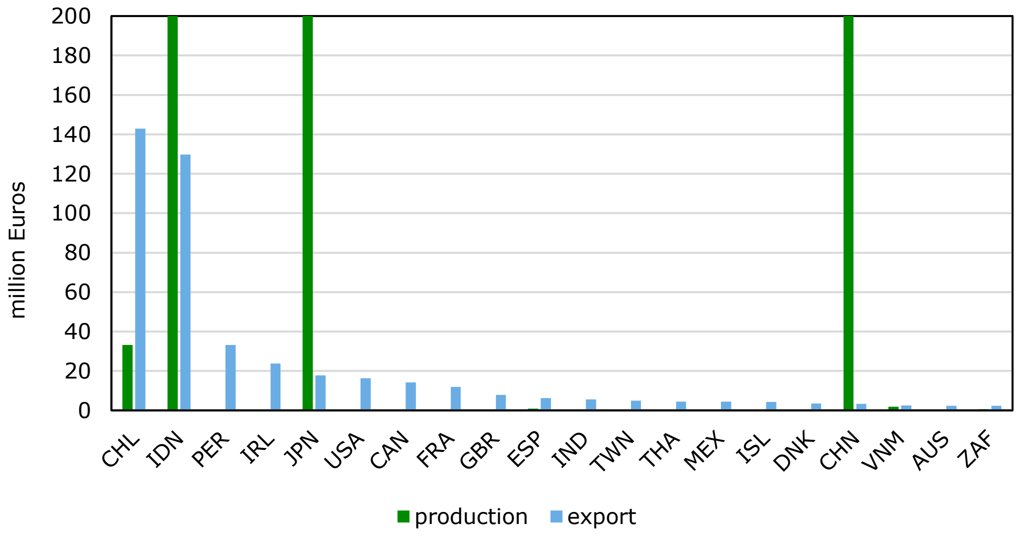

Figure 1 *Production versus export of seaweed, 2014, USD million*
Source: https://www.fao.org/fishery/statistics-query/en/aquaculture

The cost structure for the new seaweed sector is based on Zhang et al. (2022), which provides cost data on Danish seaweed farms. The data is used to calculate shares of different types of inputs used in seaweed farming. Sectors in MAGNET demand primary (land, labour, capital, natural resources) and secondary inputs (all other material inputs) to produce output. Not all sectors use all inputs, though. For example, the seaweed sector does not use agricultural land as an input. In absence of comparable data for all countries in the NSR regions, Danish data is applied to all NSR countries. The average cost structure of seaweed production is shown in Figure 2. Almost 57% of the costs are labour costs. Capital and seed costs account for 35% of the production costs. The rest is maintenance, harvest and various other costs.

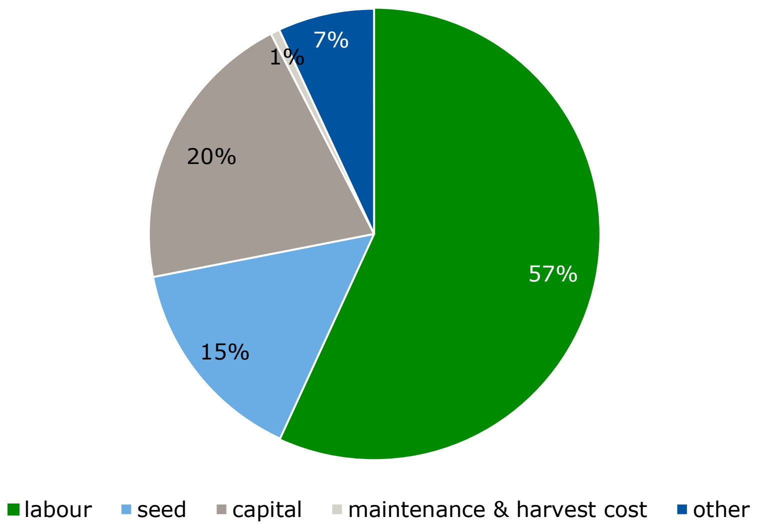

Figure 2 *Production cost structure of seaweed*
Source: Adapted from Zhang et al. (2022).

The data on seaweed production in MAGNET comes from FAO (Food and Agriculture Organization) Food Balance Sheets 2014. FAO does not, however, provide seaweed production data for the Netherlands and Great Britain (two of our focus countries) and data for these had to be imputed. The status of seaweed production in the NSR in 2020 is shown in Figure 3. In terms of share in NSR production, Norway is the biggest producer, followed by France, Denmark and Ireland. Production in the Netherlands is the lowest in the group.

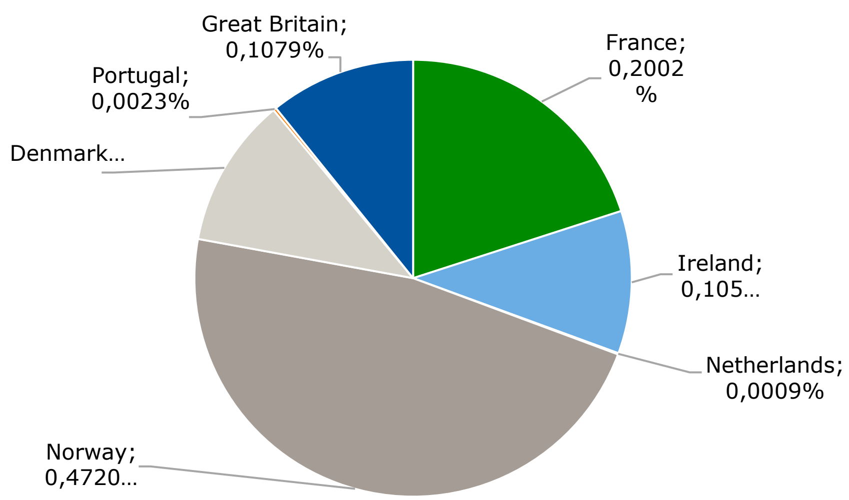

Figure 3 *Share of selected NSR countries in seaweed output (% of world production)*

The output thus produced is demanded by domestic consumers, consumers abroad (by trade channel) and also as a secondary input by other sectors. Figure 4 below shows the demand structure used in MAGNET. The demand structure used is based on expert opinion. Most of the seaweed produced is demanded by consumers (78%). Other uses are in processed food (14%) or biofuels (8%).

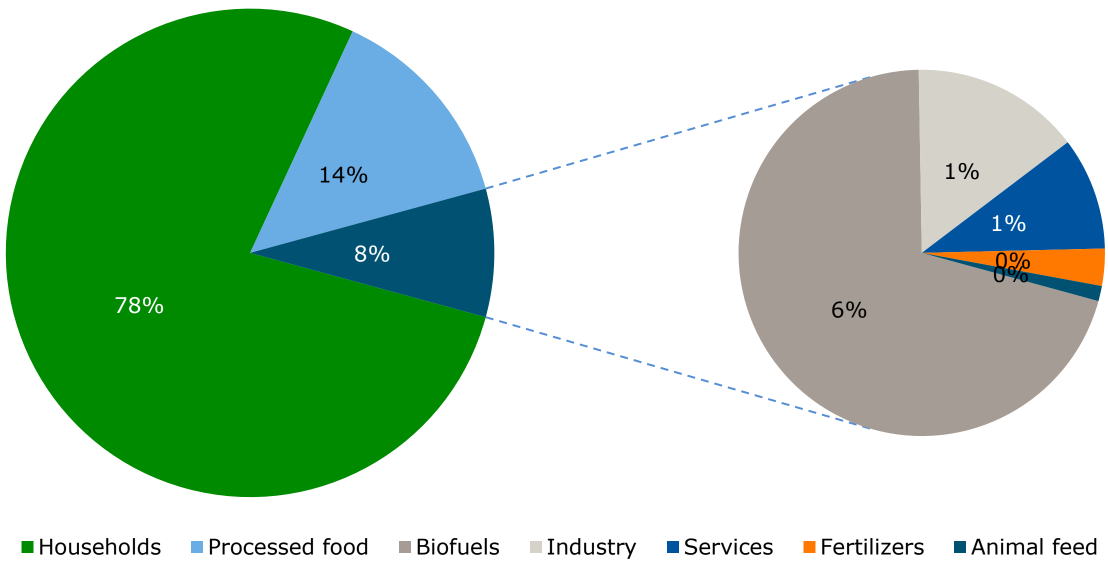

Figure 4 *Demand structure of seaweed*

MAGNET calculates household nutrition indicators, using the flow of primary agri-food commodities through the global economy from farm to fork. It has been incorporated as a nutrition module in MAGNET. The method of tracing nutrients through the food system allows for making agriculture, the food supply chain and the economy as a whole nutrition-sensitive in scenario analyses. In this study the nutritional values of seaweed are added to the model. As we have only one seaweed sector in MAGNET we use average nutritional values of several types of seaweed (category aquatic plants in FAO, 2014). We assume the following values: on calorie (0.00054), protein (0.000028), fat (0.000006) and carbs (0.0000935) per kilo of physical quantity. By combining these values with FAO Food Balance Sheet data on physical production in tonnes of aquatic plants (FAO, 2014) we can calculate the total nutritional value of seaweed consumption.

Due to missing data for the Netherlands (NL) and Great Britain (GBR) in the FAO Food Balance Sheet data, we had to make certain assumptions to calculate physical production units associated with the value of production (dollar terms) in the model. This was done in three steps as follows:

- Step 1: For the countries that do have FAO data on physical production units, we calculate price (dollars/tonne of seaweed).
- Step 2: Next, we use price data from these countries as proxy for price in the countries with missing physical production data. Based on type of seaweed produced in the country we used the Portuguese price for the Netherlands and the average of prices in France, Ireland, Norway and Denmark to calculate the price in Great Britain.
- Step 3: The calculated prices along with the value of production in the country are used to calculate the physical quantity of seaweed production in the Netherlands and Great Britain. This quantity is used to replace the missing data.

The nutritional value of seaweed production in different regions is later used by the model to determine the nutritional value of seaweed consumption for both domestically produced seaweed and imported seaweed.

3 Results

3.1 Introduction

We used the model to undertake a few experiments to raise seaweed production (tonnes) in North Sea regions (NSR) (France, Portugal, Britain, the Netherlands, Ireland, Denmark, Norway). The first set of scenarios shows production increased by 10% every year over the period 2020-2050. Two alternative manners of achieving this increase in seaweed farm production in the countries are evaluated: a) an increase in technical efficiency in the sector (doubOP) and b) subsidising production in the seaweed sector to give it a boost (doubDS). In both scenarios it is assumed that demand will follow increased production of seaweed based on market mechanisms.

These two scenarios are evaluated in contrast with a baseline scenario without any assumptions on seaweed production or demand growth being made. All scenarios (baseline, doubOP and doubDS) follow a GDP and population growth path dictated by SSP2 (Figure 5). SSP2 is one the five Shared Socioeconomic Pathways developed for the sixth IPCC report (O'Neill et al., 2016) and is seen as a 'middle of the road' scenario extrapolating the current and past developments into the future, leading to divergent income paths across countries and a moderate population growth. The expected growth in GDP and population is shown in the graph below.

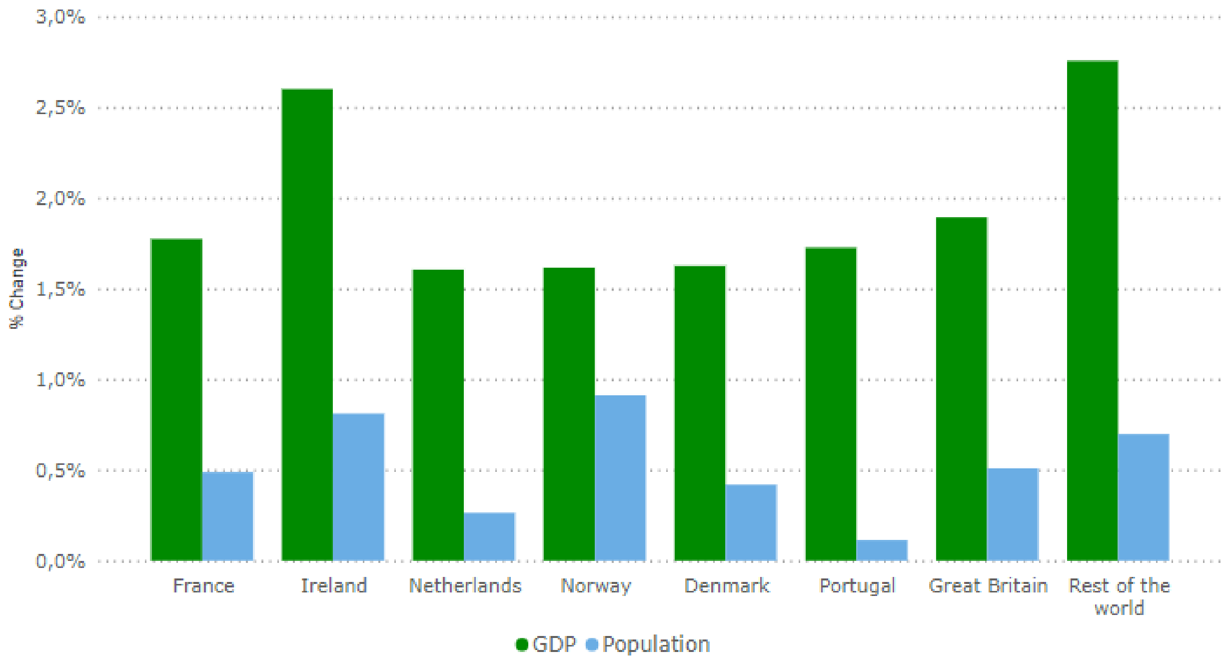

Figure 5 *GDP and population annual growth rates over 2020-2050*

The impacts of the targeted increase in production or demand of seaweed in the scenarios are evaluated in terms of the macro indicators (sectoral trade and production); prices changes, GHG emissions and impacts on nutrition. We also look at the impact of increased seaweed production on the main sources of demand for seaweed in the model - the consumption of seaweed by people. The results are presented along those of the baseline scenario.

3.2 Seaweed production and prices under different scenarios

Figure 6 shows implications of the SSP2 assumption on the production of seaweed in some of the NSR countries over the period 2020-2050 for the Baseline scenario. Figure 7 compares the baseline seaweed production in 2050 to the other scenarios. Both the figures are based on tonnes of total (farmed/cultivated as well as wild) seaweed output.

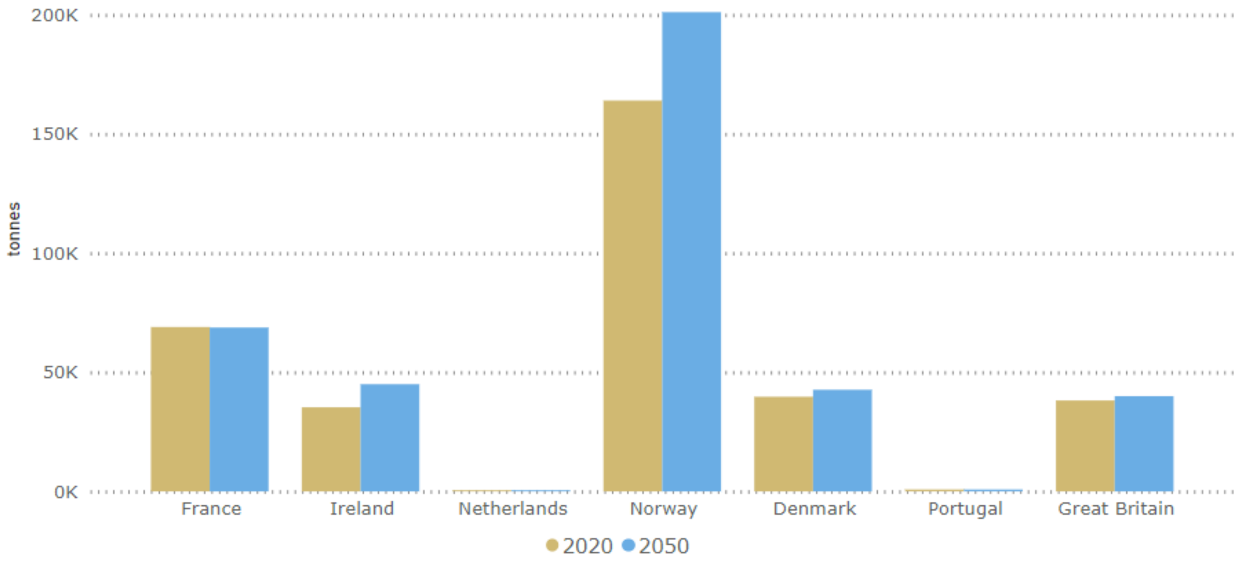

Figure 6 *Seaweed production in 2020 and 2050 in Baseline scenario (following SSP2)*

As seen from Figure 6, the SSP2 developments result in a modest increase in seaweed output in most NSR countries. A scenario comparison with Baseline (Figure 7) shows that production is highest in scenarios where supply/output is doubled.

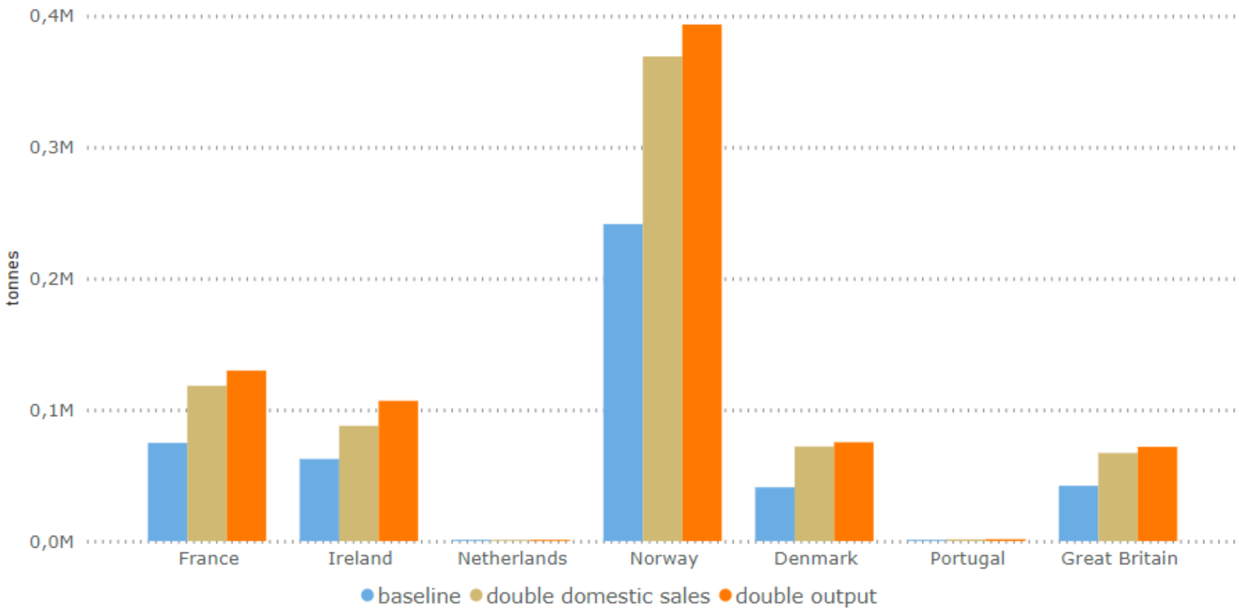

Figure 7 *Seaweed production in 2050 in Baseline and alternative scenarios*

The impact of this increased seaweed production on prices is shown in Figure 8. In most NSR countries (except Ireland) prices in Baseline in 2050 are higher than those in 2020. Prices in the alternative scenarios are however lower than their levels in 2020 as well as in Baseline on account of increased production. Not surprisingly, prices under the scenario where production gets a bigger boost by targeting output instead of demand show a lower price. Finally, prices in the rest of the world hardly show any impact of increased NSR output, given the very low share (1-2%) of NSR region in world output of seaweed.

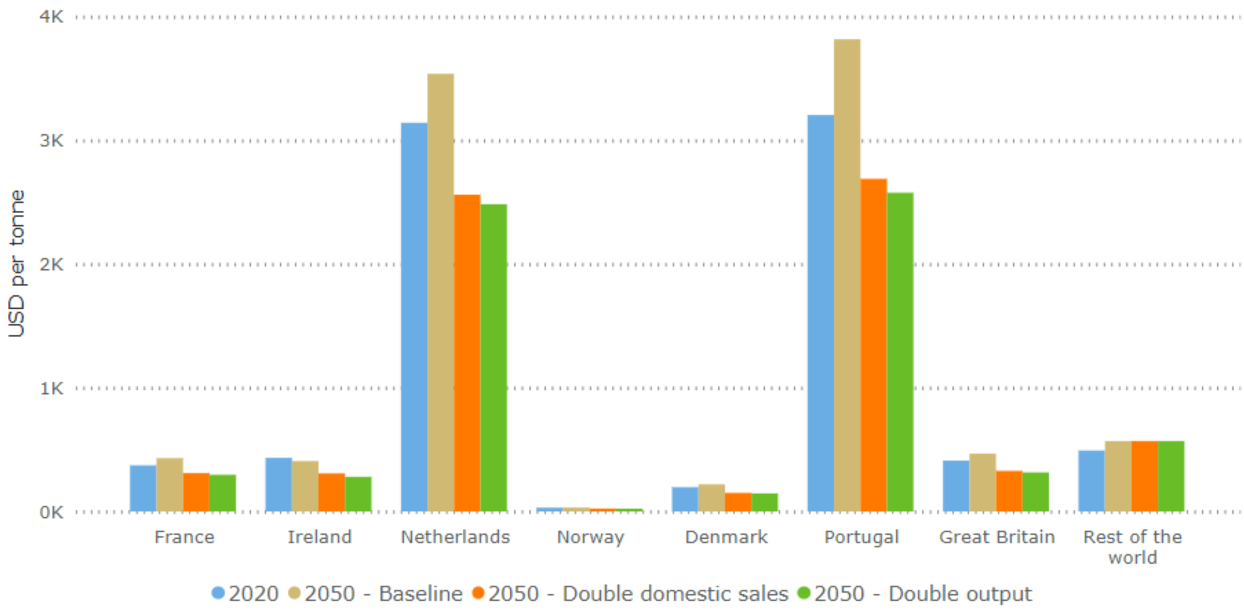

Figure 8 *Seaweed price (USD/tonne) in 2020 and 2050*

3.3 Trade

Figure 9 shows the starting status and evolution of seaweed trade. In 2020, NSR countries' exports of seaweed amounted to USD 41m (=15+26), which accounts for less than 20% of total global exports i.e. USD 212m (=15+26+9+172) of seaweed. About 37% of NSR exports go to countries within NSR, while 63% head out to regions outside NSR. These shares remain more or less the same in 2050 in Baseline. In scenarios where NSR production or domestic sales are given a boost, the trade profile changes a bit with exports within NSR declining to 32 instead of 37% of seaweed exports going to NSR countries. In absolute terms, it is about USD 18-22m worth of extra exports to non-NSR countries in comparison to Baseline. Note that in absolute terms, intra-NSR trade is still higher than in Baseline (USD 25-27m compared to USD 20m in the baseline scenario).

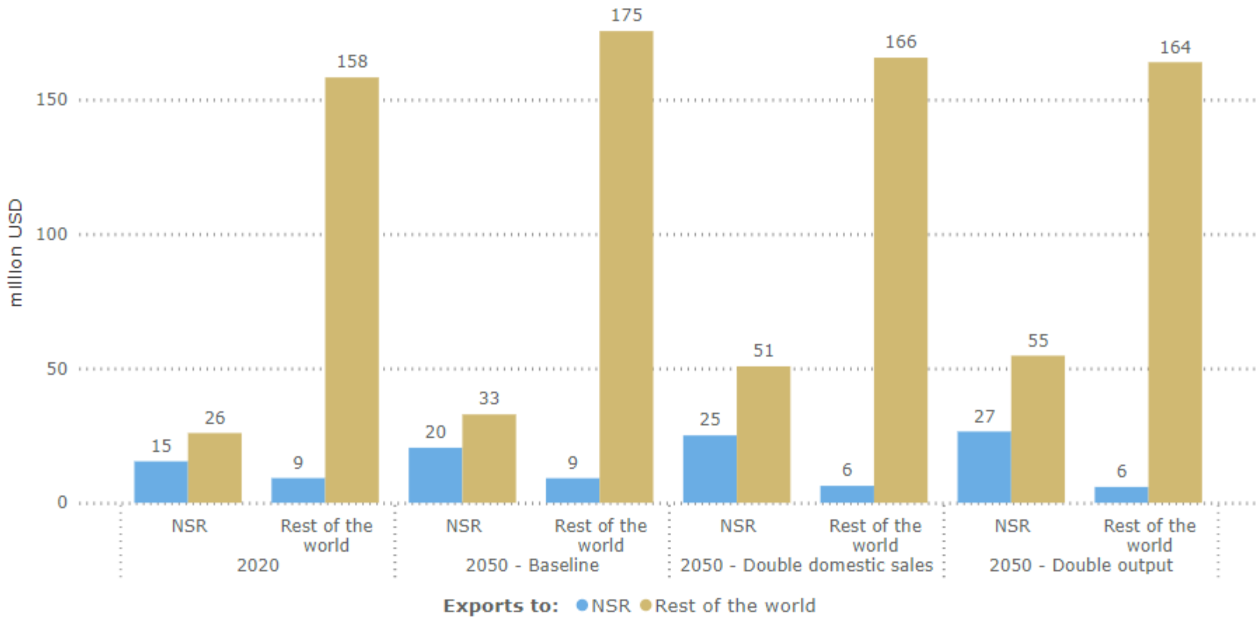

Figure 9 *Value of NSR seaweed exports in 2020, USD million*

Figure 10 shows similar information at a disaggregated NSR country level. From Figure 10, we can conclude the following:

- French, Portuguese and Norwegian exports are more geared towards non-NSR regions while Ireland sees most of its exports going to other NSR countries.
- Exports in all regions increase, and value of exports under alternative scenarios exceeds those under baseline.
- While Norway is the largest producer in the region in terms of quantity, the value of exports is not the highest owing to lower value of Norwegian seaweed coming from a dominant share of wild harvested seaweed, which has lower prices than farmed seaweed (Figure 8).

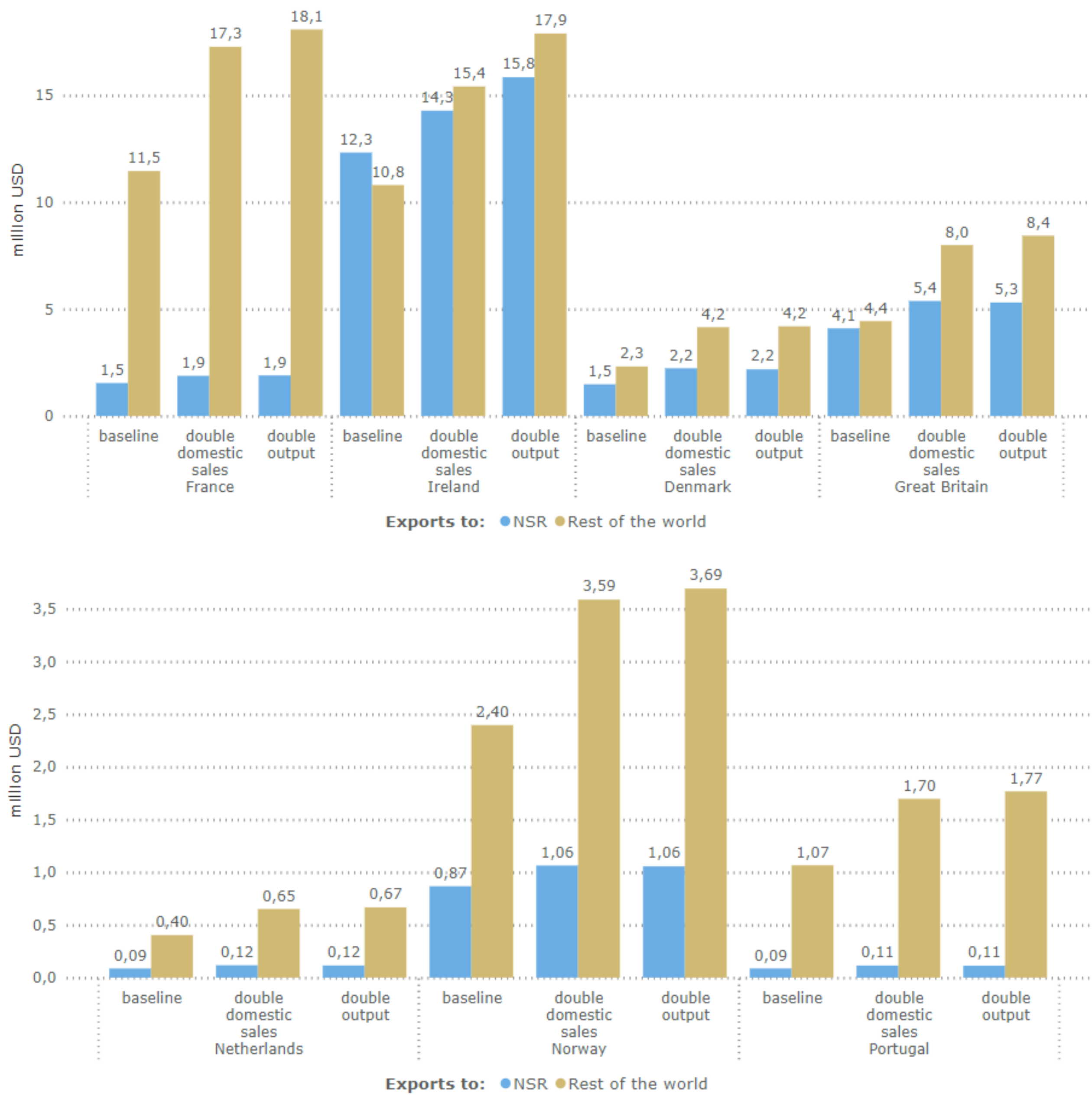

Figure 10 *Value of seaweed exports from selected NSR countries in 2050 under Baseline and alternative scenarios, USD million*

3.4 Impact on seaweed consumption

Before looking at how seaweed consumption changes over time we take a snapshot of consumption and calories in 2020. Figure 11 (top panel) shows the share of consumption (consumer expenditure) in each of the selected NSR countries that is met through domestic production of seaweed as against the share met through imports of seaweed. The bottom panel of Figure 11 shows the same shares for calories from seaweed consumption. A trend emerges showing that except for Ireland, demand for seaweed in value terms (top panel) is met mostly by imports, ranging from 21% of demand being met through imports in Denmark and Norway to 89% in the Netherlands.

The bottom panel however paints a slightly different picture – for example while Norwegians spend more on imported seaweed their calorie dependency on imports is quite low (3% of calories total calories from seaweed consumption are coming from imported seaweed). This is due to the fact that seaweed production in Norway is dominated by wild and not farmed seaweed and the former is a lower value product. Similarly for Ireland, while the share of consumer spending on domestic seaweed (70%) dominates the total consumer expenditure on seaweed, only 66% of total calories from seaweed are attributable to domestically produced seaweed. Given these price differences across countries we will look at both consumer expenditure and calories to look at consumer demand.

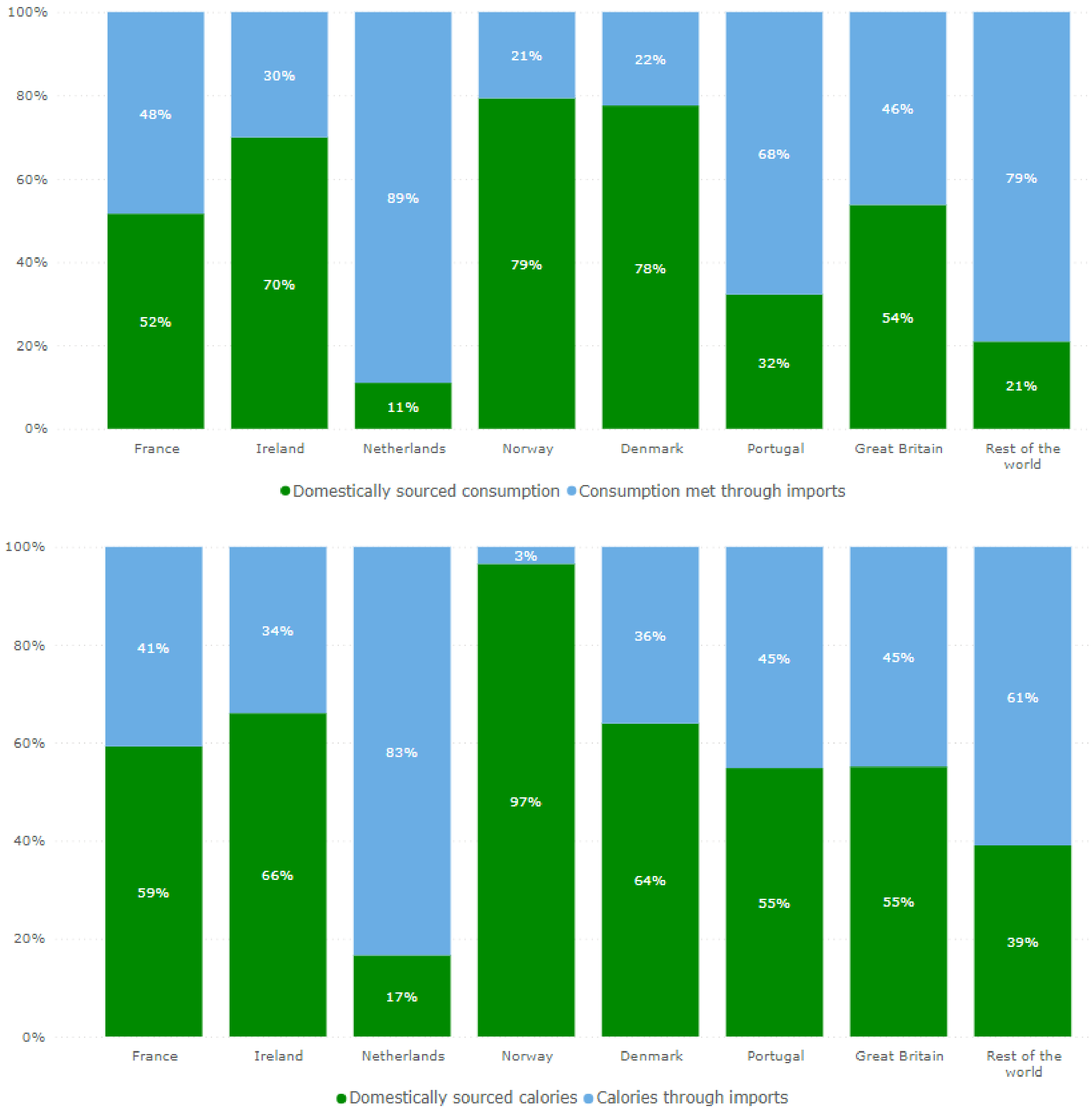

Figure 11 *Share of seaweed consumption value (top) and calories (bottom) by sources in 2020*

Figure 12 shows the consumer expenditure on domestic and imported seaweed in the NSR countries. While consumer expenditures in all scenarios are higher than those in 2020, expenditure scenarios with increased production are lower than Baseline, which seems to suggest a declining consumption of seaweed. However, Figure 13 shows that calories from seaweed available to consumers are higher under the scenarios with higher production than under Baseline. This suggests that the consumer expenditure must be lower on account of lower prices rather than on account of lower absolute consumption.

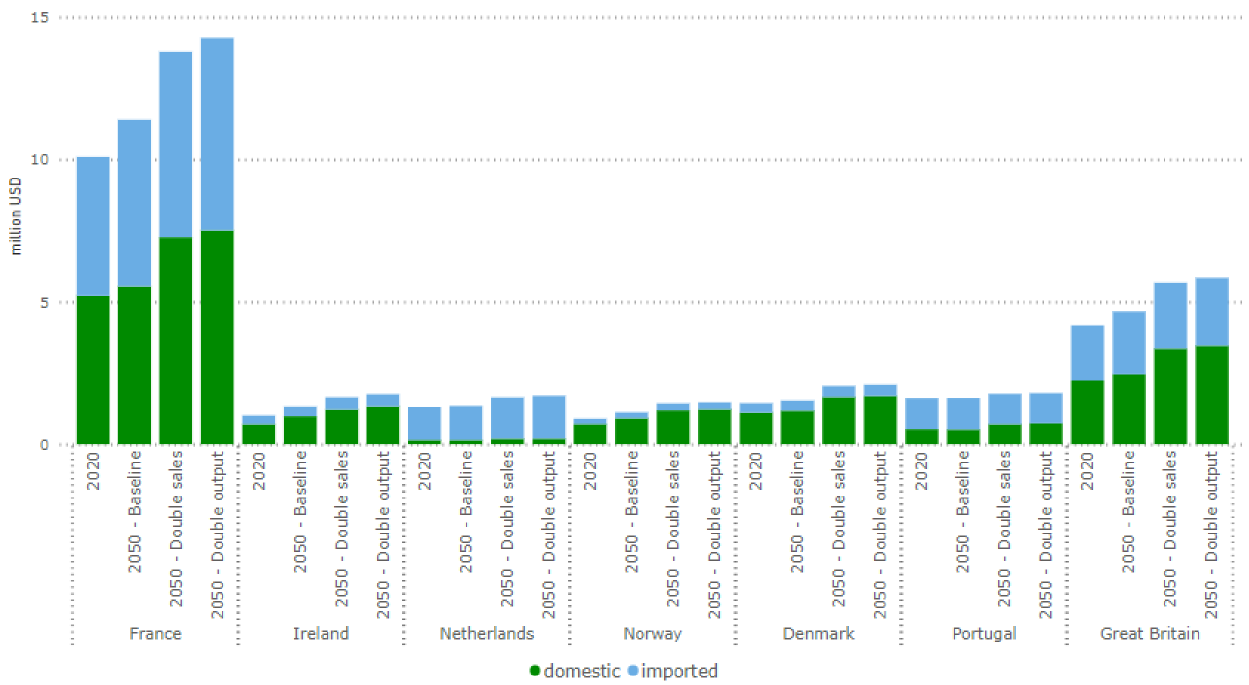

Figure 12 *Consumer expenditure on seaweed by source (domestic and imported), for selected NSR countries, USD million*

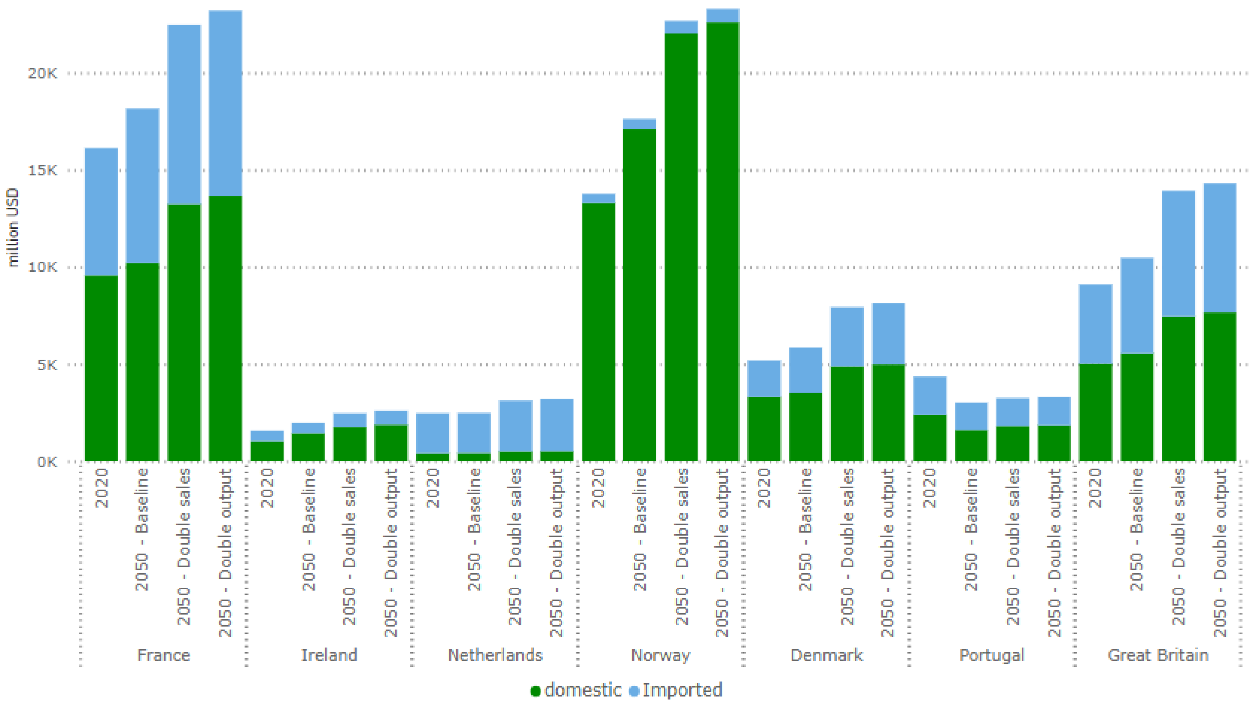

Figure 13 *Calories available to consumers from seaweed consumption by source for selected NSR countries*

4 Conclusions

The explorative analysis showed that the seaweed sector in NSR is in its nascent stages and despite an envisioned 10% annual growth over next 30 years, the size of the seaweed sector remains too small to function as alternative source of protein in consumer diets. An approach more targeted towards increasing seaweed consumption might yield better results on this second front. Furthermore, other applications of seaweed might increase demand but these are not studied in this study.

From a global perspective, production in the NSR remains too small to have any visible impact on global markets for seaweed. While the individual countries show differences, the NSR as a whole remains focused on exports, with most exports going to other NSR countries. When it comes to national seaweed import, countries from the NSR and non-NSR regions are equally important. For global markets the volumes produced and traded remain modest.

The work presented should be seen as a first exploration of macro-economic effects of expanding seaweed production in the North Sea region. The best available data from FAO and information from scientific literature were used. We emphasise that results are indicative and should be used as such. More reliable data collection and improved insights in the different cost structures in various North Sea region countries can improve the accuracy of the simulations presented in this report.

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REPORT 2023-073

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Report 2023-073
ISBN 978-94-6447-687-3

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,200 employees (6,400 fte) and 13,200 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.