TRANSFORMATIVE GOVERNANCE FOR A BLUE TRANSITION IN FINLAND (TRAGORA)

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Executive summary

Despite all efforts, not all lakes, rivers, coastal waters, and marine waters have yet achieved good ecological and environmental status. The overall status of inland waters has not improved during the recent years. Climate change already significantly threatens the achievement of good ecological status through various mechanisms, including increased precipitation and runoff. Aquatic and marine biodiversity are particularly hit by various human activities, such as hydropower generation and prospected large-scale offshore wind power developments. Moreover, economic activities (particularly food and energy production) operating in fresh or marine waters, or directly affecting them, have an important role in climate change mitigation.

While Finland and the EU are committed to promoting a transition of the blue economy by renewing the structure of the economy towards more sustainable and innovative production and consumptions patterns, these aspirations are yet to materialise. Innovations and policy reforms play key roles in the renewal of the blue economy so that it can contribute to the environmental targets while creating economic value and social wellbeing. The problem is that in many blue economic sectors current innovation and growth policies are met with significant challenges, such as profitability, social acceptability, and lack a clear vision for the future to guide and encourage investment and the renewal of businesses to ecological, social, and economic ends. Finally, aspirations to considerably upscale economic activity for tackling one planetary crisis (e.g., climate change mitigation) may not be coherent with tackling the other crises (ecological status of waters and biodiversity loss).

BlueAdapt project (funded by the Strategic Research Council of the Academy of Finland, 2018–2023) focuses on supporting the blue transition through high-level academic research and continuous stakeholder interaction. As part of the project, the consortium has developed a Transformative Governance Framework for a Blue Transition (TRAGORA). TRAGORA aims to help Finnish policy makers to navigate the complexity of policies related to the blue transition. TRAGORA provides a critical discussion of the current state and potential of both key innovations and policy developments of the blue economy in Finland, with the aim of developing forward-looking policy recommendations and support mechanisms for overcoming deadlocks, deficiencies and unsustainable practices in innovation and policy.

The normative backdrop of TRAGORA work is that economic activity must limit itself to ecological limits concerning the ecological status of waters and aquatic biodiversity. Moreover, the blue economic sectors need to assume their societal share of climate mitigation efforts. TRAGORA focuses on the key economic sectors directly reliant on waters or affecting the status of waters: 1) offshore wind power generation; 2) commercial fishing with a focus on selected species; 3) agriculture; 4) aquaculture; 5) forestry; 6) hydropower, and 7) peat production. All these sectors generate blue economic value, but they also have a considerable impact on aquatic and marine ecological status and biodiversity. We have left emergent sectors (e.g., seabed mining, harvesting of algae and blue biotechnology) out of scope as their development is still in their infancy and the economic potentials in Finland are unclear. Also, the increasingly important groundwaters are not specifically considered, as the BlueAdapt project's focus was on sectors impacting the ecological quality of surface waters. Moreover, not all economic sectors (e.g., mining and the forest industry) are included in our explicit analysis, but the analysis on the Water Framework Directive and the Marine Strategy Framework Directive and the planning systems contained therein, are also applicable to these sectors.

In TRAGORA, we divide **the above seven economic sectors in three pathways depending on their capacity to create economic benefits and social welfare, as well as on their contribution to tackling the triple environmental crises, aquatic and marine ecological status, biodiversity and climate change.** The three categories are the following:

- **Sectors with underutilised blue economy potentials**: the materialisation of blue economic potentials has not fully taken place despite social-ecological opportunities. This category includes offshore wind power generation and utilisation of selected, currently under-utilised fish stocks. The economic use of the under-utilised resources could be sustainably increased.

- **Sectors in need of decoupling** of economic value generation and deterioration of waters. These include economic sectors that serve key societal functions, such as food and energy production, but that should over time aspire toward zero-impact on the environment by way of technological, social and governance innovation. The category includes agriculture, aquaculture, forestry, and (large-scale) hydropower generation. The growth of these sectors is contingent on the decoupling between production and the negative impact on the status of waters.

- **Sectors in need of controlled phase out**. For these sectors, the ecological harm outweighs the socio-economic benefit that they produce. This category contains peat production and small scale (less than 2 MW) hydropower operations. The harmful aquatic and climate impacts of such activities need to be minimised in the short term and they should be out-phased altogether in the near future. These sectors and activities have no or very little growth opportunities, and their overall benefit to the society is negative.

After analysing the three categories of blue economic sectors, we discuss cross-cutting policies, particularly the policy aspiration to reach the good status of marine and inland waters as it plays a major role in the governance of all or most of the blue economic activities.

Our main finding is that economic sectors in different categories (underutilised blue potentials; decoupling; phase-out) require differentiated policies to achieve a blue transition. Underutilised resources require clear public goals and support for developing and upscaling innovations and economic activity in the sectors with clear environmental boundaries and safeguards. Our analysis of the decoupled sectors embarks from the recognition that societies cannot do without these sectors and the goods that they produce (e.g., energy, food, and industrial raw materials) but the sectors require policies pushing and incentivising economic renewal for decreasing and ultimately eliminating much of the negative environmental impact of these activities. Controlled phase-out sectors are detrimental to climate, biodiversity, and/or water quality, and their capacity to generate social wellbeing and economic benefit at scale are poor. These sectors call for phase-out plans with regulatory and economic steering instruments to match.

1. Introduction

Motivation and aims

Despite all efforts, not all lakes, rivers, coastal waters, and marine waters are yet to achieve good ecological and environmental status. The status of inland waters has not improved during the recent years, but some 80% of the lakes and 65% of the rivers are in good or excellent ecological status, while coastal waters are most affected (Finnish Environment Institute 2023). Climate change already undermines the achievement of good ecological status through various mechanisms, such as increasing precipitation and runoff (Huttunen et al. 2015). Also, aquatic and marine biodiversity are particularly hit by various human activities, such as hydropower generation and prospected large-scale offshore wind power developments (e.g., Iho et al. 2022). Moreover, economic activities (particularly food and energy production) operating in fresh or marine waters, or directly affecting them, have an important role in climate change mitigation. Ideally, economic sectors operating in or drawing from waters would play a key role in helping societies to tackle the triple planetary crises (ecological status of waters, biodiversity loss, climate change) while allowing the sectors to innovate, renew their business models, and create economic returns and social wellbeing (Ministry of Agriculture and Forestry 2016; European Commission 2021).

Meeting the challenges requires a sustainable blue transition in all the blue economic sectors. Yet, in many of these sectors current innovation and growth policies are met with significant challenges, such as low profitability, poor social acceptability, and a lack of clear vision for the future to guide and encourage investment and the renewal of businesses. This results in business-as-usual operations in which the sectors are not renewing and not positioned to help tackle the climate change, biodiversity, and water status challenges. Furthermore, without a clear vision, aspirations to considerably upscale economic activity for tackling one planetary crisis, such as climate change, may not be coherent with tackling the other crises, like ecological status of waters and biodiversity loss.

Our definition of blue economy contains on the one hand the aspiration to maintain or reach good ecological or environmental status of both marine and freshwaters (while also contributing to climate change and biodiversity loss mitigation where possible), and on the other hand supporting blue economic activity utilising aquatic ecosystem services provided by them (UN 2017; FAO 2018; Eikeset et al. 2018; European Commission 2021). This perspective requires the consideration of multiple environmental, economic, and social co-benefits simultaneously. Our understanding of blue economy contains all the key economic sectors directly reliant on waters or affecting the status of waters: 1) offshore wind power generation; 2) commercial fishing of selected species; 3) agriculture; 4) aquaculture; 5) forestry; 6) hydropower, and 7) peat production. The normative backdrop of TRAGORA, which stands for Transformative governance for a blue transition in Finland, is that economic activity in these sectors must limit itself to the ecological limits concerning the ecological status of waters and aquatic biodiversity. Moreover, the blue economic sectors need to assume their societal share of climate mitigation efforts. TRAGORA focuses on policy pathways to help blue economic activities support the achievement ecological status of waters, climate change mitigation, and biodiversity loss mitigation goals.

The need to provide clarity to the complexity of blue economic and environmental policies has motivated the work behind this publication. The aim of TRAGORA is to help Finnish policy makers to navigate this complexity and provide science-based knowledge on how the policies in respective sectors of the blue economy could be developed to meet multiple environmental and societal goals simultaneously. We shed light on where the key policy lock-ins are jamming development, and how they could be managed.

Scientific groundings, methodology and structure

TRAGORA is based on transdisciplinary research of the BlueAdapt project, funded by the Academy of Finland Strategic Research Council 2018–2023. It is a result of a co-productive process within the BlueAdapt consortium and with stakeholders to create solutions to meet the multiple environmental and societal aspirations related to the different sectors of the blue economy (see e.g., Valve et al. 2023). The BlueAdapt consortium has analysed local questions and processes, such as the permitting and ecological compensations related to a planned major pulp mill operation in Northern Savo, as well as fish farming operations in the Finnish Archipelago Sea. Simultaneously, the consortium has explored and evaluated the functionality of current EU and Finnish blue economic and environmental policies. The process has been open ended involving academics from Finnish universities and research institutes (Finnish Environment Institute; Natural Resources Institute Finland; University of Helsinki; University of Eastern Finland; University of Lapland), ministries (Ministry of the Environment and Ministry of Agriculture and Forestry), as well as companies from several blue economy sectors. In TRAGORA, different research streams of the BlueAdapt project meet. This means that TRAGORA brings together findings from:

- two regional transition arena processes,
- scientific analyses,
- literature reviews,
- legal doctrinal analyses,
- development of integrated ecological and water quality modelling platform, and
- co-creation events organised within the consortium.

The BlueAdapt project and TRAGORA have not been linear processes and we have sought to respond to societal needs as they rise. We have also followed new research avenues that have opened through mutual learning within the consortium and between the consortium and our stakeholders. We have learnt in the process that blue economy is a particularly tricky subject to analyse as it covers so many sectors, activities, and societal functions, and invites We have learnt in the process that blue economy is a particularly tricky subject to analyse as it covers so many sectors, activities, and societal functions, and invites difficult questions of policy scope and content. For this reason, we have had to make some omissions (e.g., not discussing all blue economic sectors) and TRAGORA as result of our work is necessarily an imperfect snapshot of the blue economy and its policies.

Despite its breadth of sectoral activities, TRAGORA is not an attempt to provide an all-inclusive analysis of water-related activities, pressures, or dilemmas, but to generate an understanding of the dominant challenges and policy pathways to manage them. We have left emergent sectors (e.g., seabed mining, harvesting of algae and blue biotechnology) out of scope as the development is still in their infancy, and the economic potentials in Finland are unclear. Also, groundwaters are left out due to the BlueAdapt project's focus on surface waters. These limitations notwithstanding, we are confident that TRAGORA is a step forward in the understanding and governance of the blue economy. Our contributions are mainly synthetical and conceptual, which allow taking an analytical birds-eye view of the blue economy and its policies in Finland to help decision-makers navigate the difficult terrain.

A key output of TRAGORA is that we categorize the seven blue economic sectors mentioned earlier in three groups based on their capacity to contribute to tackling the triple environmental challenges (status of waters, biodiversity, and climate change) and in creating economic benefits and social wellbeing. The three categories are the following:

- **Sectors with underutilised blue potentials:** in this category, the materialisation of blue economy potentials has not fully taken place despite social-ecological opportunities. The category includes offshore wind power generation, and the transformation of underutilized fish stocks, such as cyprinids, for human consumption. Both sectors have ample possibilities for sustainable growth if there is sufficient policy support for this, and the foreseeable environmental trade-offs particularly to the marine biodiversity are carefully considered.

- **Sectors in need of decoupling of economic value generation and deterioration of waters:** This category includes economic domains that serve key societal functions (e.g., food and energy production) but that should over time aspire toward zero-impact on the environment by way of technological, social, and governance innovation. The category includes agriculture, aquaculture, forestry, and large-scale hydropower. The growth of these sectors is contingent on the decoupling between production and the negative impact on the status of waters.

- **Sectors in need of a controlled phase out.** This category contains peat production and small-scale hydropower generation (less than 2 MW capacity). In the phase-out category, the ecological harm (ecological status of waters, biodiversity, and climate change) of the activity outweighs the socio-economic benefit that the sector produces. The harmful aquatic impacts of such activities need to be minimised in the short term and may face termination altogether over the long term. They have no or very little growth opportunities in the current policy setting.

Structurally, TRAGORA begins in Chapter 2 by laying out the analytical framework that guides our exploration of policy lock-ins and how to cope with them. In chapters 3–5, we focus on the policy lock-ins and their management options in the three categories of blue (economic) sectors, namely sectors with underutilised potentials (chapter 3), sectors in need of decoupling (chapter 4), and sectors to be phased out (chapter 5). In chapter 6, we focus on policies steering the good ecological/environmental status of waters that cut across economic sectors. In chapter 7, we synthesise the analysis and discuss key policy initiatives to help manage the triple environmental challenges in the blue economic sectors.

2. Analytical framework

Curbing the negative environmental and economic trends into opportunities for a transition in blue economy lays high expectations on governance. The governance of blue economy transition should be simultaneously agile in shifting policy lock-ins and economic path-dependencies, predictable in supporting investments and economic renewal, legitimate in sharing the burden of environmental efforts between sectors, and coherent with the existing water and marine, biodiversity, as well as climate policies. A key question here is how public policies and instruments, including law, can facilitate and support private economic and social activity to advance the blue economy and to reach the set environmental goals.

TRAGORA-work draws from the transition theory which analyses policy conditions for fostering and upscaling technological, social, and governance innovation (Geels and Schot 2007; Upham et al. 2014; Kivimaa and Kern 2016; Marques et al. 2018; Ghosh et al. 2021). Innovations are often disruptive with the potential to stretch and transform the existing regimes (Smith and Raven 2012). Thus, innovations and forerunner companies gain a central role in the transformation of the blue economy. Scholarship around sustainability transition has evolved to understand how path-breaking innovations evolve into niche solutions that contribute to changes in sociotechnical regimes (Lazarevic and Valve 2020). Research in the field built on historical cases show how niche solutions develop, grow, and eventually topple an incumbent regime (Geels and Schot 2007). For instance, technical advances in manure processing have created still widely underutilized opportunities to increase nutrient-use efficiency (Valve et al. 2020). Vertical farming and cellular agriculture hold promise for decoupling much of the environmental impact of food production. In the context of all these innovations and the wider socio-technological transition, the big question is how can we offer fertile policy and institutional ground for economic renewal for the different sectors of the blue economy to help tackle the triple planetary challenges?

At present, policies and institutional setups create considerable hurdles for strengthening the environmental, social, and economic capacity of the blue economy. As an example, the EU and Finnish legal systems contain forces both accelerating and braking transitions in the blue economic sectors (Soininen et al. 2021). We also acknowledge that such braking forces cannot typically be overcome by any flick-of-the-switch policy changes as the policies have coevolved on certain material, practical, and economic trajectories building lock-ins. However, at the same time the strengthening of sustainable blue economy calls for new measures to support market (re)formation.

Based on transition theory and our analysis, changes needed in the operation of markets and value creation possibilities vary considerably from one sector to another. The changes in different sectors may require changes in consumer and raw material markets, market change so that a competitive edge cannot be gained by creating significant negative environmental externalities, new economic opportunities arising from the improvement of the water status and the aquatic resources, or how public services support value creation. In addition to these market-mediated pathways, change may be driven by non-market arrangements. However, blue economy does not necessarily follow a linear pathway because of its multi-scalar governance dynamics, strong ecological feedback mechanisms, and the fragmentation of land-based and water-based policy and legislative frameworks. Bearing these lessons from the transition theory and research in mind, we move next to analyse the policy lock-ins and ways to manage them in our seven economic sectors.

3. Sectors in need of materialising blue economic potentials

3.1 Offshore wind power generation: realising an untapped potential with ecological safeguards

Context

The demand for renewable electricity is rapidly growing, and this growth will likely continue in the future due to strengthening climate change mitigation efforts, the disruption of the energy markets due to the Ukraine war and the shift towards hydrogen economy (IEA 2018; Koljonen et al. 2020; AFRY 2020; Keramidas et al. 2020). Wind-energy is the fastest growing electricity generation technology in the OECD countries, Finland included (IEA 2020; Lund et al. 2021). In Finland, the growth of the wind power sector has mostly taken place on land, and currently there is only one offshore wind farm in operation. This will likely change in the future as Finland boasts considerable potential for offshore wind power generation (Granskog et al. 2018). Still, also offshore wind power generation brings about adverse environmental impacts, e.g., for birds and bats, migratory fish stocks and flora on the sea floor, but these impacts could be largely mitigated with careful spatial planning.

Offshore wind power generation has important advantages in comparison to its onshore counterpart. Offshore wind farms tend to cause fewer social conflicts than onshore farms because they are further away from residential areas and consequently cause less harm in terms of altered landscapes and noise (Ladenburg 2008). The fact that the Finnish marine waters – excluding coastal waters – are not in private ownership also reduces conflict. Moreover, an offshore wind turbine produces roughly 30% more power than a similar onshore turbine due to larger turbine sizes and economies of scale (Levitt 2011). While this advantage does not yet make offshore wind power generation more cost-effective than onshore generation, this is likely to change in the future. In addition, offshore power generation has features which reduce systemic costs (Granskog et al. 2018; IEA 2019). It provides a more stable power output than onshore windmills because of steadier wind conditions at sea. This, in turn, reduces the problem that intermittent power sources frequently need to be balanced out by the rest of the power producers in the grid. Finally, the electricity grid close to the coastline uses high-voltage lines and is not far away from energy-consuming cities and industries, which translates into less pressure for re-building the existing electricity grid and reduced loss of power thanks to shorter transmission lines.

Currently, the potential of offshore wind power to produce renewable energy is underutilized. Despite the share of renewable energy sources in the production of electricity in Finland has already become significant, there is a considerable need to increase the renewable electricity generation due to the predicted increase of total and renewable electricity demand. This calls for changes in the generation of renewable energy and on how to provide a level playing field between competing electricity generation technologies.

The high cost of offshore wind power generation has been – and still is – a key factor affecting the current lack of development in the sector. The general subsidy scheme for renewable energy, which is based on the technology neutrality principle, has been changed several times and currently contains a combination of two of the most common subsidy systems: a feed-in-tariff system and an auction system. Onshore wind power operators have won the only competitive biddings organized under the most recent statute. Currently, new wind power operations on land are profitable without any financial support. Hence, it is likely that no new competitive tendering will be organized, and Finland is not planning to establish new offshore wind energy specific support scheme, although EU law (RED II) would allow this, if certain requirements are met. The only offshore wind power facility in place in Finland to date has earned project specific investment support as new techniques were developed. (Similä et al. 2022).

Despite lack of offshore wind energy specific national support scheme, the policy context relevant for offshore wind energy has significantly changed in the last 3–4 years. Technological development has reduced costs and a certain policy lock-ins affecting offshore wind energy have been or are about to be solved. Moreover, the EU provides a variety of support programmes, which are also relevant for offshore wind energy. This development has opened a new outlook for offshore wind energy in Finland as well as more broadly in the EU, and there are currently investment plants for large offshore wind power parks. Some policy lock-ins still remain, however.

Policy lock-ins and solutions

We have recognized six specific policy lock-ins, most of which have since been addressed by policymakers, and some are being considered in ongoing policy processes. These are:

1. **Reserving marine areas for wind energy production.** Planning decisions have traditionally been made only after a concrete wind farm plan is envisioned by an operator, although plans could be prepared in advance. This has changed since the introduction of maritime spatial plans (MSP), which have been accepted for the Finnish marine waters in 2020. In the MSPs, certain areas are reserved for offshore wind power generation. The non-legally binding MSPs inform other planning and permit authorities of the most suitable locations for wind power generation, although a legally binding planning decision (typically the general plan) is still required if operations are planned in the territorial waters of Finland.[1] Maritime spatial plans are to be updated at least once in a decade. The MSPs and the general plan are both regulated by the Land-use and Building Act (132/1999, from 1.1.2025 onwards the Land Use Act)). The general plan covers the territorial waters, whereas the maritime spatial plans cover both the territorial waters and the exclusive economic zone. In the exclusive economic zone, both exploration and constructing of wind power operations require a permit from the Council of State under the Finnish Exclusive Economic Zone Act (1058/2004). In 2022, the Council of State gave first three such exploration permissions. In addition, environmental impacts assessment and water permit are required before construction. The MSP is a considerable improvement in reconciling the potential sea-use conflicts between wind power and other interests (e.g., biodiversity) and in offering wind power operators predictability to plan investments ahead. Yet, it remains to be seen whether the MSPs are updated at pace with the rapidly developing offshore wind power sector, and whether their lack of legal bindingness will prove challenging in permitting the operations.

[1] Land Use and Building Act (132/1992) ch 8a as amended by the Act 482/2016 (Finland 2016).

2. **Considering the ecological impact of offshore wind power operations**, both the Water Framework Directive and the Marine Strategy Framework Directive are based on the idea that their objectives should be taken into account in the implementation of sectoral water use policies in a way that ensures that these water uses are made compatible with achieving the objectives of water management and marine strategies. With regards to the WFD, an offshore wind power project may be situated in coastal waters in the scope of application of the WFD (see more chapter 6). If the wind power project is deemed to cause negative impacts on the status of the coastal water bodies, it requires an exemption from the WFD's objectives. Finnish legislation does not currently contain mechanisms for granting exemptions from the water management objectives during a river basin management planning cycle in connection to the permit processes, which may create a significant legal hurdle for several blue economic activities, offshore wind power included. Currently, Ministry of the Environment is, however, preparing legislative changes concerning this. Furthermore, offshore wind power development may affect the implementation of the MSFD's good marine environmental status goal, that includes wide array of marine environmental aspects like biodiversity, seafloor integrity and seafloor habitats, and underwater noise (Puharinen et al. 2021). While an individual offshore wind power operation can hardly make a significant difference in terms of whether the overall Good Environmental Status in a large marine area is reached or not, the cumulative impacts of several large wind power operations affecting a significant percentage of the seafloor can constitute a pressure on the seafloor integrity, marine biodiversity, and noise levels. Currently the biggest cumulative impacts on i.e., seafloor bottom are observed in the inner coastal waters and inner archipelago of the Bothnian Bay, Archipelago Sea and the Gulf of Finland(Korpinen et al. 2019). In the current legal setting, the marine management or the GES objectives do not have a binding legal implication on permitting of wind power parks (Puharinen et al. 2021; Similä et al. 2022). Furthermore, particularly permitting under the Finnish Water Act focuses on assessing each individual development's environmental impacts in its pin-point location, which does not allow taking into consideration the cumulative impacts of these operations on the wider state of the marine waters (Pappila – Puharinen 2022). Although it has been proposed that legislative changes would be required to increase the legal weight of the GES objective and the operational environmental targets, no progress has been made so far. This may leave marine environmental status vulnerable to rapid, large-scale offshore wind-power developments. Currently, the environmental impact assessment of offshore wind-power is still under development (Galparsoro et al. 2022).

3. **Accelerating decision-making.** A temporary legislative package (Acts 1144/2022, 1145/2022, 1146/2022 and 1147/2022) aiming to speed up decision-making concerning investments on green transition was accepted in late 2022. The permit authorities handling environmental, or water permits must give priority to those permits, which concern projects fostering green transition, e.g. offshore wind power projects. Moreover, appeals concerning planning decisions relevant for renewable energy production shall be heard by administrative courts as a matter of urgency in relation to other appeals concerning spatial planning and building permit matters. Based on provisional political agreement on the renewable energy directive (Interinstitutional File 2021/0218(COD), the forthcoming renewable energy directive will impose strict time limits for the permit-granting processes of offshore wind energy, which is 2 years in renewables acceleration areas and 3 years outside these areas.

4. **Using state-owned marine areas for wind energy production.** Another recent development concerns the use of state-owned marine areas for wind energy projects. In 2021, the Government adopted an auction model to be applied in the leasing of state marine areas to companies for the project development and construction of offshore wind power. The auction model does not apply to the province of Åland, nor to offshore wind power projects located outside territorial waters in Finland's exclusive economic zone. The auction model aims to accelerate the market-based development of offshore wind power. Metsähallitus, which is the state authority governing state-owned land and water areas, will initially carry out preliminary studies of marine areas and select the areas to be auctioned based the overall benefit of society. Vattenfall Ltd. was selected through auction in 2022 as the operator for first offshore wind energy project, the size of which is at least 1.300 MW.

5. **Making property tax neutral in relation to the amount of electricity generated.** Property tax of wind farms is based on the investment costs according to the law in force. In relation to the electricity generated, the taxation of an offshore wind turbine is higher than that of an onshore one, because of higher costs. The Governmental Programme of Prime Minister Sanna Marin (2019) aimed to change that. However, there have been several twists and turns on this matter without concrete legislative development. Now the Governmental Programme of Prime Minister Petteri Orpo (2023) again indicates that a change is coming. Hence, technically speaking, the matter is a work in progress, but politically widely accepted.

6. **Co-operation with neighboring Member States.** The recent development of the EU law is strengthening cooperation on offshore energy between member states. The cooperation concerns both offshore grid planning (regulation (EU) 2022/869) and permit-granting for joint offshore renewable energy projects (provisional political agreement on renewable energy directive, Interinstitutional File 2021/0218(COD)). This development is also encouraging Finland to cooperate more closely with its neighbors.

Conclusions

The policy developments described above show that many previous policy lock-ins hindering the development of the offshore wind power sector are solved or are about to be solved. The EU strategy to harness the potential of offshore renewable energy (COM(2020)741 final) and the Governmental Programme of former Prime Minister Sanna Marin (2019) symbolize the policy shift towards stronger support for offshore wind power generation. Although it would not be possible to claim that all policy lock-ins have now been solved or are soon to be solved, the policy development has been significant.

Remaining policy lock-ins concern reconciling wind power generation with military radar surveillance as current radar technologies are easily interrupted by the wind power stations and consequently opposed by the Finnish armed forces. There is no technical solution to this presently and the needs of radar surveillance limit significantly the number of marine areas available for offshore wind power particularly in the Gulf of Finland. Moreover, offshore wind power remains more expensive than onshore wind energy at least some years onwards. Still, it looks that policy developments have opened a path for significant development of offshore wind energy.

The growth of offshore wind energy is not without problems. The construction costs of an offshore wind farm are lower in shallow marine areas and often the same areas are important for fish population, fisheries, biodiversity, and landscape. Technological development, including floating turbines, might lower the construction costs of offshore wind farms on the open seas in the future, but the tension between different uses of marine areas will remain. The critical issue for mitigation is location and key instruments for that purpose are maritime spatial plans, general land use plans and water permits. These instruments are in place, so the success of governance depends on their effective use and implementation. There is also a dire need for strengthening the water and marine management considerations and objectives, particularly when it comes to managing the cumulative pressures in the permitting of offshore wind parks to make sure that the development in the sector does not result in environmental degradation and biodiversity loss.

Finally, maritime spatial plans are renewed on a slow pace and hence they are not necessarily updated when permission for the construction of wind farm is under consideration. The coordination of the uses of marine areas could be strengthened with increasing the current speed of MSPs or adopting new non-binding spatial management plan and a clear science-based approach to weighing up the needs of marine diversity and different uses. Interests protected by law, such as protected areas for biodiversity, must be prioritized over wind power, and no exceptions should be granted. This is particularly important for the construction of wind farms in the exclusive economic zone, which is not covered by general land use plan. Moreover, the legislation does not provide solutions in the exclusive economic zone for a situation where several operators are interested in the same sea area. This is a challenge because preparing an application for gaining a water permit is costly. In the territorial sea, the auction model solves this issue. According to the Governmental Programme of Prime Minister Petteri Orpo, a legislative project will be carried out with the aim to coordinate permit processes, compensation and tax matters concerning offshore wind energy projects in the exclusive economic zone with those of wind energy projects in territorial waters and land areas.

3.2 Commercial fishing: transforming underutilized or undervalued fish stocks into blue resources

Context

In Finland, the structure of fish consumption has changed in recent decades. Although Baltic herring (Clupea harengus), together with the European sprat (Sprattus sprattus), is the most abundant commercial catch species in the Baltic Sea, it may be considered as undervalued fish as the consumption of Baltic herring as human food has significantly declined (Ignatius and Haapasaari 2016; Pihlajamäki et al. 2018; Pihlajamäki et al. 2019; Haapasaari et al. 2019; Haapasaari et al. 2021). Instead, imported salmon has gained a dominating role in the consumer market. Currently, only approximately three percent of the Baltic herring caught in Finland ends up in human consumption whereas most of the herring catches are exported or used in Finland as raw material for fish oil and fish meal industry or sold to fur farms to be used as a fur animal feed. This keeps the monetary value of herring catches lower compared to the price of herring sold for human consumption (Pihlajamäki et al. 2018; Haapasaari et al. 2021). At the same time, a sustainable source of animal protein for human remains underutilised.

About 96% of the total Baltic herring catch in 2017 was caught by the trawl fleet (Hanstén et al. 2021). Fishing herring for food differs somewhat from feed-directed fishing due to the higher quality requirements for food fish storage and processing methods. Most of Baltic herring is caught with large trawler vessels, which seek to minimise the need to land their catch to save fuel. Due to quality requirements, only the last trawl catch caught during a trip tends to qualify for human consumption (Pihlajamäki et al. 2018). A structural change from feed to food-directed fishing would call for investments in large trawler vessels (including e.g., on-board freezing equipment) and, alternatively or simultaneously, an increased use of and support for small vessels which would be able to bring the catch to shore more regularly (Pihlajamäki et al. 2018). If the supply of food-quality fish is to be increased, the profitability of trawl fishing the good quality fish should be increased. There are some indications that the recent increase of fuel costs, together with increased food prices and expected reduction in fur farming, may support such a shift in Baltic herring, sprat and bleak (Alburnus alburnus) fishing.

Commercial fishing and the processing of the catch for human consumption generates value from the blue resources. In addition, fishing should be seen as water quality management (removing phosphorus) and population control measure. While fish catches need to remain within sustainable annual yield limits, emergence of underutilized fish stocks can also cause problems. For example, the increase of cyprinids (Cyprinidae) is part of the eutrophication cycle that needs to be cut off. Cyprinids cause turbidity and release of nutrients while feeding on the bottom. However, cyprinids catch seldom generates revenues for fishers as no market for fresh cyprinids exists and only few food manufactures are specialised in the processing of cyprinids. Moreover, the consistent warming of the Baltic Sea is favouring warm water freshwater species, like percids and cyprinids. Thus, the coastal fishing might need to adapt to this changing species composition, while the potential fishery yields of percids and cyprinids are predicted to increase in wide areas (Peltonen and Weigel 2022).

In lakes, increasing vendace (Coregonus albula) fishing is one way to increase the generation of blue value in a sustainable manner. The annual vendace yield from Finnish lakes is 8–13 million kilos, while the total catch by professional fishing was 2.8 million kilos in 2014 (Marjomäki et al. 2016). Fishing of vendace removes nutrients and protects from zooplankton losses (Nürnberg et al. 2019). Vendace is largely consumed as human food without processing. In the North Savo transition arena, a need for new modes of investment support for vendace fishery were identified (Valve et al. 2019).

For commercial fishing, the key policy instruments include the quota system, fishing permits and the European Maritime, Fisheries and Aquaculture Fund (EMFAF) which aims to enhance the operational conditions of sustainable fisheries over the long term by providing funding for development and innovation projects. In Finland, 71.8 million euros EMFAF funding have been allocated for the 2021–2027 period. The EMFAF has four priorities:

- Fostering sustainable fisheries and the restoration and conservation of aquatic biological resources.
- Fostering sustainable aquaculture activities and processing and marketing of fishery and aquaculture products, thus contributing to food security in the EU.
- Enabling a sustainable blue economy in coastal, island and inland areas, and fostering the development of fishing and aquaculture communities.
- Strengthening international ocean governance and enabling seas and oceans to be safe, secure, clean, and sustainably managed.

Over the last two government periods in Finland, the development of the fisheries sector has become an important policy area with six government strategies and programs in place to set targets for sustainable fisheries development. These policy goals reflect the renewed centrality of blue resources in the EU policies to provide sustainable food protein production under climate change. A key question is whether the subsidies and subsidised measures have the potential to reorganise fishing and the production of fish protein in an environmentally, economically, and socially sustainable way.

Policy lock-ins

There are problems that require disentangling if the fisheries are to have an important role in sustainable blue economy. This can be approached from three complementary directions, as the policy lock-ins touch fishing activities at sea as well as consumer practices and value-chains on land. In fisheries policy, it has been stated that without specified targets for food use or proactive management of catch, the dominance of feed use of Baltic herring will persist, which applies also to other fish species (Pihlajamäki et al. 2018). An increase in the value of Baltic herring catch, and more efficient fishing and consumption of underutilized fish such as cyprinids, smelt – and to some extent, vendace – requires coordination and development of actions throughout the value-chain that includes fishers (different types of fishing techniques and investments), logistics (ports, sorting, and transportation), processing (new product innovations and processing techniques) and retail (novel consumer products and marketing).

In consumer markets, there are behavioural biases towards domestic fish, as there are no unified certification labels or measures to guarantee availability (Pihlajamäki et al. 2019). Finally, in technical development, the actors have been successful in introducing new process innovations, such as fragmenting technologies and chemical processing that could lead to emergence of novel value-added products. However, it may take a long time for technical innovations, such as new processing technologies to turn fish biomass into chemical, pharmaceutical or cosmetics industry materials or fragmenting the protein component of fish to be utilised in other products, to materialise as actual consumer products.

Solutions to lock-ins

Blue economy could benefit from a stronger coupling of the commercial fishing of Baltic herring, sprat, and cyprinids, with the food system. This calls for changes in consumer and raw material markets. Along with market changes, measures are needed to improve the operational conditions of professional fisheries.

For the markets to evolve, regulatory and policy changes are needed:

- EMFAF support needs to be seen increasingly as means to enhance a blue economy transformation. This means that EMFAF support should be allocated in a strategic way to strengthen the supply of e.g., Baltic herring and cyprinids for human consumption. In the current programme period, investments in the development of the value chain of underutilised fish are allocated 10 % higher subsidy share than other investments. This is a welcomed measure that needs to be strengthened further if impact evaluations indicate needs for that.
- Clear criteria are needed for strategically important investment and development projects. Projects with links to value chains that develop the use of underutilised fish or generate more value from Baltic herring and sprat catches, could be granted an extended amount of support. Competitive bidding provides an efficient means to enhancing such projects and investments.
- Support for the modernisation of both fishing and fish processing infrastructures continues to be critical although EU regulations limit the subsidisation of fishing fleets. The new types of financing mechanisms, such as guarantee or (subsidised) leasing schemes, are a welcomed addition to the support instruments. Support schemes should also treat different processing operators in the same way, because currently the support is determined depending on whether the processed fish is from the catch of the processor or bought from other fishers.
- Potentials and benefits of an interdisciplinary research programme (Academy of Finland and Business Finland) should be examined. This programme could focus on the role of Baltic herring and sprat fisheries (as well as cyprinids) and the consumption potentials of those fish species at the time when food safety concerns are gaining more attention, fuel prices are on the rise and fur farming is expected to decline and warming of the Baltic Sea in increasing the potential fishery yield of cyprinids.

In addition to new measures, a continued effort is needed to support professional fisheries:

- Fishing rights as regulators of freshwater fisheries: There is a need to lighten the acquisition of fishing rights (Valve et al. 2019). Merging of small water cooperatives should be enhanced, and allocation of fishing rights publicly facilitated in regions in which the fragmentation of water cooperatives complicates the sustainable fishery of vendace, for example.
- The maintenance and strengthening of the general conditions of professional fisheries is important in a situation in which the profession declines, and its representatives are aging (see Kotimaisen kalan edistämisohjelma). EMFAF funding is directed to immediate development challenges of fisheries through 10 Leader groups that e.g., enhance collaboration between fisheries, support local business and product development and help to remove administrative burden in co-managed water bodies. These networking and coordination activities have proven regionally important and such support should be available also in the future.
- Public procurements are important in advancing the demand for underutilised fish. Positive examples can be found for example in Kiuruvesi and Sodankylä, where municipalities have successfully re-organised practices in their institutional kitchens in collaboration with local fishers.

- Profiling fishing as an ecologically feasible business is important and proven successful in rejuvenating regional networks to support new product innovations (e.g., Apetit, Pielisen kala, Leikkala).
- Education policies and curricula are central in providing new workforce and developing the skills and practices of the existing professional fishers.

4. Sectors in need of decoupling of economic value generation and their negative impact on waters

4.1 Agriculture: increasing ambition and effectiveness in existing policies

Context

In Finland, agriculture is the main source of external nutrient loading to marine and inland waters. Agriculture comprises more than 60% of the overall loading of phosphorus and more than 50% of nitrogen loading to the Baltic Sea (Rankinen et al. 2016). Despite efforts over several decades, this loading has not decreased in accordance with the policy targets (Räike et al. 2020). There are some signs of positive development, the phosphorus reserves of agricultural soils are decreasing (Lemola et al. 2023). This indicates that phosphorus runoff may over time decrease. However, mineral or manure fertilization that exceeds the crop uptake and causes risk for eutrophication is still a considerable problem particularly in localities in which animal manure production and application exceeds the need for fertilising nutrients (Huttunen et al. 2021). Recent study developed scenarios by applying the modelling framework and expert evaluations on nutrient load ceilings (maximum allowable loads) to reach good ecological status in coastal waters. The results indicated that extensive reductions would be needed in nutrient loading from several sectors, especially from agriculture to improve the status of coastal waters. Nevertheless, the scenarios implied that even with most stringent measures to reduce nutrient loading (e.g., limit livestock and crop production to minimum), it would not be possible to reach good environmental status in the coastal waters within the next 30 years, as loading is enforced by climate change increased nutrient leaching from agriculture (Fleming et al. 2023).

The persistence of nutrient loading and difficulties to reduce it has its roots in the Finland's agricultural policy frame. When joining the EU in 1995, Finland abandoned production-based subsidies and customs taxes whilst adopting the Common Agricultural Policy and allowing the free trade of agricultural products. With the CAP framework, area-based subsidies became the main source of income to farmers. As implemented in Finland, the CAP framework led to low input use and extensive farming practices (Lankoski and Ollikainen 2013). As a part of the 1995 policy reform, a voluntary agri-environmental support scheme was introduced. While its aim was to promote environmentally friendly practices, it was, nevertheless, designed as overcompensation to provide another revenue source to farms. The 1995 adopted policy frame has remained rather similar over time despite reforms made to the overall CAP frame over time. The framework has increased arable land area, and it keeps low-productivity fields in production and favours quasi-cultivation.

Out of the 43.600 farms in Finland, two thirds grow crops and one third raises also domestic animals. In monetary terms, about 60% of the agricultural output is generated by animal husbandry (Natural Resources Institute Finland 2021). In Finland, the share of direct income support in farm incomes is highest in the EU (Niemi and Väre 2019). The number of farms has decreased over time and is expected to be in the range of 32.000–40.800 farms by 2030 (Niemi and Väre 2019, Taloustohtori). In contrast, the cultivated area has remained unchanged due to reasons mentioned above. Farms and regions have become differentiated in terms of input intensities and main production lines.

EU's new CAP policy for 2023–2027 will modify the working conditions of Finnish farms. With the reform, EU aims to strengthen the contribution of agriculture to climate change mitigation and biodiversity conservation. Despite the stated aims, the reform is not especially radical. It keeps Pillars I (direct income support) and II (rural development) as they were but adds to them some new features. Perhaps the most important change is that CAP area payments are now linked to an enhanced conditionality that imposes a stronger set of mandatory environmental compliance conditions for farmers. A new Eco-scheme is introduced to promote adoption of voluntary practices in farms, while also the previous agri-environmental support system continues to be available although its relative share is smaller than before: From the 200 million euros allocated to it almost a half is to support organic farming and animal welfare.

Following the new policy, each member state needs to make a strategic plan for agriculture with a SWOT analysis, and the Commission follows more closely how member states achieve their targets. The Finnish CAP plan was submitted to the EU Commission for scrutiny. The Commission provided very critical comments on the plan, especially concerning the low-level environmental policy ambition, absence of numerical targets and weak implementation. Previously the Commission had noted that Finland should consider strengthening the regulation of diffuse pollutant loads from agriculture. Finland's national CAP plan was accepted by 31 August 2022. The enhanced conditions include among others mandatory buffer strips, and fertilizer regulation. The Rural Development Programme continues to define the nation-wide terms and measures for agri-environmental subsidies in 2023–2027. The new Eco-scheme, funded by Pillar I, promotes mostly biodiversity but includes measures, such as wintertime vegetation that may also promote water protection.

By our estimate, the new national CAP does not resolve the main policy lock-ins that have been present in the national CAP policy frame. Therefore, there are no reasons to expect that it would bring any success in reducing nutrient loads. We identify four distinct sources of policy lock-ins concerning incentives for agricultural production, regulation of livestock production, design of the EU common agricultural policy, and lack of integration between support systems and eutrophication damage.

Policy lock-ins concerning incentives for nutrient load reduction

The environmental regulation of agriculture has evolved over time to a complex mix of economic and command-and-control instruments (Kauppila et al. 2017). Finland's environmental policy towards agriculture in 2023–2027 consists mainly of the agri-environmental support scheme, Eco-scheme, environmental permitting of livestock farms, and CAP area payments with an enhanced conditionality that links payments to a larger set of mandatory compliance conditions including the Finnish Nitrates Decree (1250/2014), which implements the EU Nitrates Directive (91/676/EEC) (Kauppila et al. 2017) and the new Phosphorus Degree defining binding maximum levels of phosphorus application for all farms as a function of the soil P status of the fields. The previous crop-based upper limits for nitrogen application are abandoned and currently only Nitrate directive imposes an upper limit of 170 kg/ha for all fields.

Changes in phosphorus and nitrogen legislation may or may not promote reduction of nutrient loads. For phosphorus, the outcome will depend on how farmers adapt to the tightening phosphorus legislation: clearing more land increases loads, selling manure out reduces loads. Establishment of a digital nutrient resource could enhance the viability of regulatory control (Valve et al. 2022). In the presence of the new phosphorus legislation, placing emphasis on manure processing and prevention of land clearing in peatlands is vital for promoting in phosphorus loads reductions. For nitrogen, high prices of nitrogen fertilizers currently moderate the expected increase in nitrogen fertilization. In fertile soils, the increase in nitrogen fertilization has only minor effect on loading, as plants will efficiently use it for growth. Most risks relate to low productivity soils, where low yields increase excess nitrogen and its loading.

The structure of the Finnish agri-environmental subsidy policy remains unchanged, and it contains a large set of practices for the farmers to choose from. Among others, wetlands, buffer zones, catch crops and runoff management will be promoted. As a new target, subsidies are given to nature-based two-stage channels that provide several ecosystem services, such as flood protection, nutrient retention, and enrichment of biodiversity in the riparian zones. Circular economy solutions, such as nutrient recycling are promoted by specific measures. The new Eco-scheme replaces the previous greening requirements and supports farmers' voluntary choice of wintertime vegetation, green manure fields, landscape and game fields, as well as plants promoting biodiversity. Making buffer strips mandatary for all farmers is a welcome reform. The strips tend to reduce especially erosion, particulate phosphorus and nitrogen losses.

At the moment, it is difficult to assess the environmental performance of the new policy design. The Ministry of Agriculture and Forestry assessed that the national CAP program will reduce 17 % of nitrogen loads and 8 % of phosphorus loads but one should approach this optimistic assessment with caution as the methods used in the assessment are not presented. Moreover, despite some new features, the main design of the previous policy does not change much, implying that the nutrient load reduction estimates seem unfounded. The policy challenges in reducing nutrient loading and promoting efficient agricultural production are as follows:

- First, the voluntary support scheme consisting of agri-environmental support and Eco-schemes with practice selection continues to be inefficient, expensive, and provides low incentives towards innovation. Furthermore, it does not allow for regional targeting of agri-environmental policies to the most polluted water areas.
- Second, there is inefficiency in governing nutrient loading and the sharing of costs and benefits within the current program. Finland's program has typically over-compensated conservations costs, thus providing an implicit income support to farmers. This shows up in high participation rates in the program relative to other EU member states (Ollikainen et al. 2019). The program has provided water quality benefits, but research suggests the net benefits are close to zero (Laukkanen and Nauges 2014) or even negative due to increased nitrogen loading (Lankoski and Ollikainen 2013). Further, during period 2008–2020, water protection measures in agricultural areas have been insufficient (Vilmi et al. 2021).
- Third, Finland's program represents "pay the polluter principle" approach instead of relying on "polluter pays principle". Equally importantly, it pays for management practices instead of paying for performance in reducing nutrient loading. The weaknesses of this approach are well-known. It is more costly, more complicated, and backward-looking than paying for performance (Shortle et al. 2021). In the Finnish case, the aim has been to enrol as many farmers as possible to the program, but this is possible only with low requirements (and costs) and high compensations.

Money could be spent in a better way. For instance, extending the enhanced conditionality to cover animal welfare would increase the effectiveness of the policy,

- reduce participation costs, and allow redirecting the saved funds to innovative pioneering practices.
- Fourth, to improve water protection policy, agriculture should be treated applying the same policy principles as other sectors where the polluter pays principle is applied. Polluter pays principle would shift the focus of actions on performance. Polluter pays principle could be rooted to the expected loading and quantified impacts of practices reducing it (Lötjönen and Ollikainen 2019). This approach would promote new efficient technologies and improve knowledge base on factors affecting loading (Shortle et al. 2021).

Policy lock-ins concerning the EU Common Agricultural Policy and national subsidies

The adopted Common Agricultural Policy frame in Finland has created production structures that prevent reducing, or even increase, nutrient loading. The most important structural challenge is that there is a higher level of animal support payments to dairy farms in the C-support areas relative to A and B areas, established when Finland joined the EU. The support system provides incentives to shift dairy farming from Uusimaa, and South-West regions to the Bothnia region. The subsequent intensified clearing of peatlands for fields increases especially nitrogen loading, GHG emissions and concurrently also the costs of the food processing industry. Agricultural production has thus become regionally specialized. Moreover, the differentiation of livestock and crop production to different regions has led to nutrient imbalance so that some sub-regions with intensive animal husbandry encounter problems from high manure phosphorus surpluses, while the regions dominated by crop production suffer from a deficiency of organic fertilizers (Lemola et al. 2023).

Second, the current area payments tend to increase arable land and nutrient loading. Decoupled area payments provide an important source of revenue in boreal agriculture without distorting the choice of crops for production. Area payments have, nevertheless two distorting implications. First, they maintain low productive fields in production reducing profitability of agriculture. Second, they invite more land to cultivation, as they provide a secure and considerable source of revenue (Lichtenberg 2002; Lankoski and Ollikainen 2013). The arable land area was in 1995 less than 2 million ha and has risen to more than 2,3 million ha since then. The increase in the field area inevitably leads to higher nutrient loading, which may even outperform the load reductions per hectare obtained from agri-environmental policies. Finland's agricultural policy promotes extensive production in large field areas containing high share of low production fields. Intensifying production to smaller but higher productive areas would provide the same output but with much lower nutrient loading and higher revenue for agriculture. A recent study shows that 10 % of farms receiving CAP support payments has not sold any agricultural products during the previous CAP program (Niskanen et al. 2022).

In addition, the water management practises of agricultural fields require revision as water scarcity may become more frequent also in Finland with climate change affecting the intensity and periodicity of droughts in the northern latitudes (Ahopelto et al. 2019). This calls for resource-efficient and combined management of nutrient and water balances in the fields, and preparing also for water scarcity, like storing water in wetlands and ensuring good soil structure (Winland-project 2018). Conventional drainage systems can be replaced by nature-based two-stage channels that provide several ecosystem services, such as flood protection, nutrient retention, and enrichment of biodiversity in the riparian zone. Based on a recent study (Västilä et al. 2021), the additional value of phosphorus retention and conservation of protected species was 2.4 times higher than the total costs of constructing the 2-stage channel.

Solutions to lock-ins in the Finnish CAP policy frames

Decoupling emissions from production is a widely used target in many policies, especially in climate policy. For industrial point sources with technologically controlled constant returns to scale production, new technologies allow for increasing production with lower emissions or even total elimination of emissions. For agriculture, decoupling of nutrient loads from production is a more complicated task. Nutrient loading depends on uncontrolled stochastic weather conditions, soils differ with respect to productivity and propensity to loading, and arable land exhibits decreasing returns to scale. In an idealized form, total agricultural nutrient loading can be estimated as a product of loading per hectare in each soil type, times the amount of land in cultivation in each soil type. This is a simplification, however. Loading between fields in each soil type differs depending on their productivity, fertilization history, and the adopted management practices. Furthermore, some practices that reduce nitrogen and total phosphorus loading may increase load of dissolvent phosphorus (Evenson et al. 2022; Iho et al. 2023).

Agricultural policy processes also operate on different time spans and in terms of different jurisdictional scopes. Therefore, decoupling of agricultural production and harmful environmental impacts requires actions at different time spans.

A short run solution for agriculture is a cost-efficient reduction of nutrient loading taking place via two channels: reduction of loads per hectare (1) and phasing out the least fertile arable lands from cultivation (2). Achievement of the former requires policies ensuring that the competitive edge in farming cannot be gained at the price of harmful environmental externalities, and that the farmers use more sustainable production inputs such as organic fertilisers in production, and consumer demand is created for environmentally friendly products. Meanwhile, the latter provokes a call for a far more efficient and incentives-creating policy than Finland has employed so far. A cost-efficient solution reducing loading per hectare may not be enough to reduce the loading sufficiently to the level that would not cause harmful effects in aquatic environments, because of the large land areas remaining in cultivation.

A deeper longer-term reform fostering efficient decoupling would step out from the subsidy system that maintains large areas in cultivation without generating incentives for effective production of food. The required reform would redesign agri-environmental support system to favour innovative and forward-looking farming, promoting new food production solutions, such as vertical farming and cell-cultured proteins, and facilitate a change towards sustainable and healthy plant and blue product-based diets to provide supply for the growing demand for more sustainable agricultural, food and feed, products.

The critical dimensions of transformation in the short run are the following:

- Determined actions to reduce phosphorus loads from legacy phosphorus, the biggest challenge for agriculture in the South-western parts of Finland, in particular. The use of soil amendments, such as gypsum and structure lime from recycled material to reduce phosphorus loads considerably in the short run. More efficient monitoring of phosphorus application should be planned and set in motion.

- Promoting nutrient recycling in agriculture to provide multiple benefits and a structural step towards a more balanced use of nutrients in manure, improvement in the domestic supply of organic fertilizers, and reduction of greenhouse gas emissions associated with manufacturing of mineral fertilizers. Nutrient separation from manure provides a crucial step in achieving a balanced phosphorus use on the fields, in addition to providing organic material improving soil quality.
- Favouring sustainable management practices, such as crop rotation, use of legumes and perennials, to improve soil productivity, nitrogen fixation, and reduction of soil erosion.
- Renewal and strengthening of water management in farmlands. Climate change adaptation requires increased efforts to both flood and drought control. However, water management should no longer be conceived merely as a flood protection measure, but increasingly as means to revitalise ecosystems, provide nutrient retention, prevent CO2 emissions, and enrich biodiversity in farmlands. Conventional drainage systems may potentially disturb material cycles and water flow and to impoverish riverine habitats. Those can be replaced by two-stage-channels and made eligible for the EU agri-environmental subsidy scheme (Västilä et al. 2021). Strengthening incentives in the agri-environmental support program to adopt nutrient load reducing practices by strengthening river-basing management with differentiated and targeted instruments.
- Finally, there should be targeted research and development and investment (RDI) policies to support new modes of protein production and productification. There are many directions to increase productivity of agriculture without increasing its environmental footprint. Precision farming, vertical farming, and new possibilities of applying digitalization provide examples. Another potentially very important future direction relates to cell-culturing food. This notion refers to cultivation of plant, animal, or microbial -based proteins in bioreactors with the help of renewable electricity, thereby decoupling food production from agricultural land and weather conditions. Cell culturing represents a radical transformation of agriculture to an industrial food processing technology that liberates much land and nature from food production. Cell-food may create new business opportunities and at the same time help reduce environmental emissions from traditional agricultural production to the atmosphere and waterways. Finland hosts pioneering companies on this field and the society should create favourable innovation environment for the development.

In the mid-term, CAP pillar II subsidies in Finland should be re-designed:

- In Finland, a reform is needed to promote efficient agriculture with much lower environmental footprint per hectare. This reform should change the agri-environmental support requirements and incentives so that the requirements for incentives match performance in water protection, better coping with changes in consumer preferences towards healthier diets and increasing needs to strengthen efforts towards climate and biodiversity benefits. Furthermore, a greater share of funds reserved for environmental goals should serve promoting new and innovative environmental investments in agriculture.
- The reform should be tailored to make full use of synergies between climate, water and biodiversity policy, for instance, by strengthening the role of buffer zones and nature-based drainage systems as green infrastructure with trees, bushes and other “agro-forestry” solutions as a buffer for nutrients and a shade for the aquatic environments to provide cooling. It is also important that EU policies promote integration of biodiversity and water protection goals. Reducing arable land area by gradually out-phasing peatlands and marginal and low productivity lands provides the main step in Finland for promoting the synergies. EU’s becoming regulation may require that even 50% of cultivated peatlands will be phased out of cultivation, and better targeting of support would take marginal lands from production.

- Steering of water management in farmlands must consider the challenges posed by different soil types. On clay soils, the water holding capacity of soils in crucial. While good infrastructure (drainage) is necessary to get water out from soil in autumn and spring, water holding capacity (depending on soil structure) is important during the growing season. To prevent CO2 emissions from peatlands requires in turn an elevated water table, wetting and cultivation of crop suited to wetted fields. An increasing challenge on both soil types relates to flooding that increases with climate change. Adaptation requires increased efforts to control flood and to adapt on more frequent droughts, while drainage is to be based on multifunctional two-stage channels.
- Targeted subsidies for the cultivation of legumes and manure transportation. Finding ways of balancing the trade-off between different phosphorus fractions and nitrogen when promoting no till, wintertime vegetation and other erosion reducing measures.

In the long term, also CAP pillar I subsidies should be rethought. Income policy of the CAP pillar one should be re-evaluated and redesigned to phasing out low quality lands from agriculture and providing new possibilities for more efficient production in the remaining lands. Quasi-cultivation should be eliminated as a farming activity by requiring farmers to harvest and sell of agricultural products if they accept area payments and other subsidies (provided no failure of crops). This requirement would help excluding poor arable land from the support system, and the reallocation of support payments should promote sustainable and efficient production on reduced land areas. As World Bank's recent report asserts, current support to agriculture provides everywhere very low return and suggests that a part of current support should annually be allocated to research and development, finding more efficient practices, and spread information on new solutions widely to farmers. A revision of support payments of CAP pillar one would also facilitate required steps to adapting to climate change and extreme weather conditions agriculture faces.

How to start reforming of agricultural policy?

Above analysis suggests a profound reform for agriculture. Introducing polluter pays principle as Pigouvian policy would provide the environmentally sound and motivated step towards the reform in agriculture in a way that would not cause rapid reduction is farm income. Most natural and urgent would be to use both climate policy and water policy instruments. Our suggestion to promoting the reform are as follows:

First, triple environmental benefits would be created by climate policy motivated tax-subsidy scheme levied on GHG emissions from peatlands. Taxing emissions but subsidizing wetting and restoration of these lands would reduce both GHG emissions and reduce nitrogen loads and lead some fields to be excluded over time from production promoting biodiversity conservation. Furthermore, it would create incentives to really wet the fields and not just abandoning them in which case decay of peat would continue.
Second, a river basin pilot in the catchment of the Archipelago Sea on the reduction of nutrient loading should be organized using tendering system and nutrient load indexes for phosphorus and nitrogen. The pilot would gather information on farmers' ability to assess additional reduction in nutrients, its costs, and the most typical nutrient reduction practices available for farmers. An analysis of the information would then provide grounds for the next CAP reform.

These suggestions would mean that market-based incentives to promote environmental goods in agriculture provide for most farms improving incentives and increasing revenue. They would at the same time correct some of the negative side-effects of area payments.

4.2 Aquaculture: harmonising environmental and economic aspirations in fish farming

Context

The contribution of aquaculture to the Finnish economy overall is quite small. The living resources sector (fishing, aquaculture, food processing, wholesale, and retail sale), employs roughly 2596 people, produces a yearly turnover of slightly under 1 billion euros, and creates value added for approximately 155 million euros (Heikkinen 2019). There is no data regarding the exports of the aquaculture industry alone (fisheries contribute around 18 million euros). In 2018, roughly 14.4 million kg of fish was cultivated for human consumption in Finland (a 0.7 million kg decrease from year 2020) (Natural Resources Institute Finland 2022). Even though the demand for aquaculture products is growing, production has decreased, or is at least not growing. Fish farming accounts for, depending on the marine area in question, between 0 to 4 % of the total phosphorus load on water bodies and 0 to 2% of the total nitrogen load on water bodies, although in certain water bodies the shares can be considerably higher[2] (Marine Strategy of Finland 2021; Fleming et al. 2023).

The aquaculture sector in Finland consists mostly of farming rainbow trout and the production of roe. Other species are minor compared to rainbow trout, but include trout, charr, sturgeon, and crayfish. Most operations use open pens that are in coastal waters close to the shore, each producing between 30 to 1.000 tons of fish annually (Soininen and Belinskij 2023). Some companies have established pens farther into the sea or operate recirculation plants on land to mitigate nutrient emissions to waters and to meet the tightening environmental requirements for the sector (Soininen et al. 2019). Conventional open pen rearing units release by design nutrient and other discharges to the water body in which they are located (Read and Fernandes 2003). These discharges can better be controlled in closed loop or recirculation aquaculture operations, but these technologies are yet to take off on a large scale mostly due to profitability (Soininen et al. 2019).

The policy setting of the aquaculture sector is constructed so that the Marine Strategy Framework Directive (MSFD, 2008/56/EC) and the Baltic Sea Action Plan (BSAP) devised under the Helsinki Convention[3] steer the overall, cumulative nutrient levels in the Baltic Sea. Particularly the MSFD is binding on Finland as an EU member state but at present the overall nutrient targets are not operationalised to steer the development of individual fish farming projects. At the project level, the operations require permits according to the Environmental Protection Act (527/2014) and Water Act (587/2011) of Finland. Both Acts seek to mitigate the harm caused by aquaculture operations to adjacent property owners and the environment, and the permit systems are also used to implement and enforce the environmental requirements of the Water Framework Directive (WFD, 2000/60/EC). In practice, the permits control the aquaculture operation's emissions and their ecological impact to the adjacent water body and permit is denied in cases where the operation would cause considerable harm to other water uses, deteriorate the ecological status of the water body, or considerably hinder the achievement of the good status objective. It is rarely the case, however, that a single

[2] These mentioned figures do not include the Åland island marine waters.
[3] Convention on the Protection of the Marine Environment of the Baltic Sea, in force 17 January 2000

installation (even a large-scale open pen operation) would single-handedly deteriorate the status or considerably hinder the achievement of the good status objective. For this reason, aquaculture permits are typically allowed but with limitations on production levels (Soininen and Belinskij 2023).

Policy lock-ins

The policy lock-ins in the aquaculture sector can be categorized at four levels. First, at the level of policy goals, the lock-in is that the current EU and national policy goals for the sector are incoherent. On the one hand, the EU Commission set a goal already in 2012 for increasing aquaculture production significantly (Blue Growth Agenda, EU Commission 2012). In the 2021 Finnish Domestic Fish Promotion Program (Government decision in principle 8 June 2021) established that the desired increase of aquaculture production in Finland is 260 % from 14 million kg/a (2017) to 50 million kg/a in 2037. On the other hand, the water and marine environmental policies are aiming at significant improvements in the status of coastal and marine waters, and the subsequent decreases in cumulative nutrient loads from different sectors, including aquaculture. The EU Water Framework Directive sets a binding legal obligation not to deteriorate the ecological quality of coastal waters, and to reach Good Ecological status by 2027 the latest. Similarly, the Marine Strategy Framework Directive aims at Good Environmental Status of marine waters. Moreover, and implementing the goal set in the MSFD, the Baltic Sea Action Plan aims at Good Ecological Status of the Baltic marine environment by 2021. In the aggregate, these ecological goals present significant legal challenges for maintaining existing and especially increasing future nutrient loads into the Baltic Sea. Such incoherence of policy goals does not offer clear pathways for the future development of the sector (Soininen et al. 2019). This challenges especially open-pen fish farms considering that the national growth target for the aquaculture industry is 260 % from the current level of production.

Second, the aquaculture sector lacks a clear strategy for renewal considering the environmental and regulatory pressures. Considering the EU and HELCOM environmental policies, further growth in the aquaculture sector should take place without major increases in nutrient outputs. This places considerable pressure on decoupling the fish production and nutrient emissions to waters. At present, most of the policy discussion in the sector revolves around how to maintain existing operations and technologies in use rather than aiming at decoupling the nutrient emissions from production, however (Ministry of Agriculture and Forestry and Ministry of the Environment 2014; Finnish Government 2022). On balance, the growth planned for in the EU and Finnish blue growth policies is difficult to achieve by resorting to the open-pen technology without legally infringing the WFD and MSFD goals and obligations at the level of individual water bodies (small-scale), and especially at the level of entire marine regions and the Baltic Sea as a whole.

Third, at the level of implementation policies, the policy lock-in is the lack of effective measures to manage the cumulative nutrient loads to the Baltic Sea (Soininen et al. 2019; Puharinen 2021). The Water Framework Directive and the Marine Strategy Framework Directive establish monitoring and planning frameworks to help achieve the environmental status goals but offer little help for curbing the cumulative nutrient loads to waters. These loads originate from several sectors, out of which diffuse loads stemming agriculture, and runoff nutrients from ditched forest lands lead the pack. The aquaculture industry and other point-sources of nutrient emissions, such as municipal wastewater treatment operations may have significant emissions and impact on the status of waters locally but play a smaller role in the overall nutrient levels in coastal and marine waters of the Baltic Sea. If there is no willingness to take effective measures to curb diffuse nutrient emissions stemming from agriculture and forestry, it will be difficult to reach the EU ecological and environmental status goals. This in turn reflects negatively on the aquaculture sector as the regulatory requirements of reaching the ecological and environmental goals are not based on sector-by-sector nutrient quotas but on the ecological quality of the receiving water body or marine area (Soininen et al. 2023). In such a setting, if agriculture and forestry produce nutrients runoff to an extent that maintains coastal water bodies and marine areas below good ecological status, the regulatory pressure for discontinuing existing permits and rejecting new permits will increase, despite aquaculture industry's efforts to reduce their nutrient output per operation, or per a unit of fish produced (Soininen and Belinskij 2023).

Fourth, at the level of individual projects and their environmental permitting, the aquaculture sector may be facing tightening legal requirements for obtaining environmental permits and increasing governance uncertainty. The current regulatory setting leads to legal uncertainties as to whether and on which terms it is possible obtain a permit due to the less-than-good status of coastal and marine waters; the limited duration of permits (e.g., for 5 to 8 years), which is detrimental to predictably planning ahead the development of the industry and the individual operations; and finally, to more stringent requirements on the reliability of environmental impact assessments, which lead to the use of costly prediction models that are not yet fully equipped to establish the connection between nutrient emissions from single aquaculture operations and their impact on ecological/environmental status (Valve et al 2019a; Soininen and Belinskij 2023).

Ultimately, the incoherence of policy goals concerning aquaculture, the lack of effective measures to management the cumulative nutrient loads to waters, the tightening legal and permitting requirements, and the lack of clear strategy for the renewal of the aquaculture operators lead to a deadlock within the entire aquaculture sector (Valve et al 2019a).

Solutions to lock-ins

The key factors for transformation are that competitive edge should not be gained by producing negative environmental externalities. At present, however, the Finnish aquaculture producers are struggling to compete in the food market as they are competing against producers from other countries with less governmental oversight or that are operating in marine areas where nutrient outputs do not contribute to eutrophication to a similar degree as in the Baltic Sea (e.g., in Norway, on the coast of the Atlantic). Consequently, efforts to include more of the negative externalities into the price of production will likely lead to Finnish companies exiting the market, unless major innovation to production and nutrient abatement technologies are made.

There are two policy pathways to manage the lock-ins. First pathway is to recognise the key production technologies that have capacity for decoupling production and nutrient emissions. At present, the most promising innovation for such change is recirculation aquaculture. Recirculation aquaculture is essentially a technology for farming fish or other aquatic organisms by reusing water in production. The technology is based on the use of mechanical and biological filters. Recirculation can be carried out at different intensities depending on how much water is recirculated or re-used (Bregnballe 2015). In Finland, only a handful of recirculating aquaculture facilities are in operation. Those have not been profitable so far, but technological development is fast promising increasing profitability (Laine et al. 2023). In Finnish installations the wastewater is either directed to another industrial or municipal wastewater treatment plant or treated locally (Soininen et al. 2019). The co-operation of such facilities should be supported for instance by integrating aquaculture permits with the permit renewal of existing industrial and municipal wastewater treatment operations that would have capacity for the treatment of emissions in these and RAS activities. Another technological option is to couple open aquaculture operations with algae or other nutrient up taking species, but currently a key limitation here is that matching the scale of nutrient emissions and absorption has proven difficult.

Second and more complicated policy pathway is to establish national and legally binding nutrient loading levels for all water bodies and marine regions, and to fully implement the current BSAP nutrient limits and operationalise the MSFD goals. This would translate into a total cap on nitrogen and phosphorus for the water bodies and marine regions of Finland and shares under the cap of nutrient emission would be allocated or sold out via tendering across different sectors, such as agriculture, aquaculture, and forestry. In such a system, also open pen fish farming operations could be ecologically viable, but this would mean that nutrient emissions from the current levels in other sectors would need to be cut. Such a system would require establishing the emissions emanating from the different sectors and comprehensive monitoring to match.

It has also been proposed that strengthening the EU MSFD's implementation in Finland could resolve some of the problems related to translating the overall marine ecosystem status objectives into concrete norms on individual sectors and activities (Puharinen et al. 2021). This necessitates, first, that the marine management's operational environmental targets are developed; currently, the targets miss a lot of their potential as they are formulated on a very general level, rather than being specifically targeted and refined into operational targets for economic sectors or specific areas, which would be needed to translate the overall marine environmental ambitions into concrete legal obligations (Puharinen 2023). Second, the Finnish legislation currently does not provide any binding legal implications for the marine management objectives, the Good Ecological Status objectives, or the environmental targets. Thus, for the marine management regimes to steer the economic sectors and their activities in line with reaching GES, the GES objective and the environmental targets should be included as binding preconditions in the permitting conditions in the Environmental Protection Act as well as the Water Act (Puharinen et al. 2021).

4.3 Forestry: introducing policies for governing water emissions

Context

Forestry is an important source of industrial raw materials in Finland. At the same time, forestry releases nutrients to waterways and is a source of considerable sediment loading. The sources of loading differ between mineral lands and peatlands. For both forest land types, clear-cutting opens the forest soil to erosion and increases nutrient and sediment loading. Ditched peatlands produce higher loads than mineral lands (Finér et al. 2021). Large areas of wetlands were ditched between 1960s and 1980s for forestry (Finér et al. 2021). To maintain forest growth potential, regular ditch cleaning is needed in these lands during the rotation and after clear-cutting. The most common water protection measures in forestry are buffer zones, sedimentation ponds and overland flow fields. Forestry is responsible for 7300 tonnes of nitrogen and 444 tonnes of phosphorus loading, which counts for 12 % of anthropogenic nitrogen loading and 14 % of phosphorus loading (Finér et al. 2021).

Policy lock-ins

The forestry sector is currently faced with the following lock-ins. First, the knowledge base of the impact of forestry on waters is changing (Nieminen et al. 2017; 2018b; 2021). While it was earlier believed that drainage results only in short-term changes in nutrient exports, recent studies indicate permanently deteriorated water quality due to drainage of peatland soils. Furthermore, by emphasizing the need to prevent carbon release from peat, climate policy provides new impetus for the management of peatland forests. The browning of surface waters is a phenomenon that can be observed everywhere in Finland and elsewhere in the northern hemisphere (Skerlep 2021; Albrecht et al. 2023) and is now entering the policy agenda. Recent studies indicate that forest management may have a much greater role in surface water browning than was thought earlier (Skerlep 2021; Vuorio 2020).

Second, efforts to prevent sediment and nutrient loading require changes in forest management. Traditional view has been that nutrient loading per hectare is very small from forestry, and that old ditches play only minor role in nutrient and sediment loading. This understanding has changed dramatically: recent studies show that old ditches may be source of nutrients and sediments decades (Finér et a. 2021) and nutrient concentrations from drained peatland forests may even increase over time since drainage (Nieminen et al. 2017; 2018b). This research challenges the old forest management regime relying on clear-cutting and regular ditch cleanings (Ahtikoski et al. 2012; Nieminen et al. 2018c) and emphasizes the need for catchment-based approach (Häggblom et al. 2020). Furthermore, recent studies also show that ditch cleaning, made annually on average 60.000–70.000 hectares during 2000s, is in many cases not the optimal choice for the society because of the negative effects caused by nutrient and sediment load damage in headwater streams (Miettinen et al. 2020). The amount of sediments released to waterways from ditching are large and they are especially harmful in sensitive small rivulets, headwaters of rivers and lakes, which are important spawning areas for many aquatic species. Sediment loading can be reduced using sedimentation ponds and overland flow fields, but the need for restoration of head waters is rather high (Nieminen et al. 2018a; Miettinen 2020). One closely related problem is that the current legislation lags behind requiring that ditches should be kept open and water flowing (Halonen and Similä 2020). Section 8 in Chapter 5 of Water Act of Finland sets an obligation to the beneficiaries of the ditching to maintain the ditch. Reducing or giving up the ditch maintenance to promote environmental protection is only possible when all stakeholders agree in accordance with Section 7(2) in Chapter 5 of the Water Act.

Third, efforts to restore once ditched peatlands have so far failed. Finland has ditched about 5.7 million hectares peatlands and wetlands for forestry, mostly between the 1960s and 1980s, and currently 25 % of forest growth of all the Finnish forests comes from peatland forests. Out of this area about 0.8–1 million hectares have turned out to be unprofitable for forestry and now remain idle (Häggblom et al. 2020). How much of this nearly one million hectares of peatland forests where initial ditching failed contribute to nutrient and sediment loading is still open. Restoration of peatlands would benefit biodiversity, water quality, and climate change mitigation over time. There is a need to improve our knowledge on sediment and nutrient loading as well as to develop emission coefficients for alternative measures in forest management (Finér et al. 2020).

Fourth, surface water browning challenges current management practices. Streams, rivers, and lakes have been subject to changes in water colour over the last decades. This increase is a result of rising dissolved organic matter and iron concentrations in the water. Browning affects the quality of freshwater ecosystems and drinking water production (Albrecht et al. 2023). Alternative hypotheses have been proposed to explain what causes browning. The first hypothesis was climate change and increased decay of organic material, another is recovery from atmospheric S deposition (acid rain). A recent hypothesis is that land cover changes, specifically increase in coniferous forest cover (spruce), which promote accumulation of organic soils, is an important factor behind browning (Skerlep 2021). However, it is evident that current forest management practises with intense harvesting, soil preparation, ditch maintenance and inefficient water protection measures promote organic carbon leaching and discharge. Moving to more natural forest management practices and reducing ditch connectivity would counteract freshwater browning in the future (Härkönen et al. 2023).

The current water protection measures (buffer zones, sedimentation pools, overland flow fields) do not work against browning. Changes in forest management are needed, including the shift to continuous cover forestry, and favouring hardwoods and perhaps also inventing new measures to directly improve water quality. Only few experiments have been carried out this far. For instance, adding large wood to forest ditches and sedimentation ponds has been very recently studied as a means of reducing sediments and dissolved organic carbon exports (PuuMaVesi 2021).

Solutions to lock-ins

The primary cause of nutrient emissions is the ditching of peatlands to improve forest growth. Ditches have proven to be a source of considerable nutrient emissions and sediments over long timespans. Therefore, strengthening regulation of ditching and promoting implementation of related water protection measures is needed, but also actions toward the restoration of previously drained forest lands not currently under forest management are needed (Ministry of the Environment 2020). Continuous cover forestry and strip harvesting would provide alternatives to current management of peatland forests by regular ditch cleanings and large-scale clear-cutting. Strip harvesting is based on clear-cutting of small strips in the forest land area. Both management regimes can be optimized to maintain water table at levels that support economically feasible tree growth, and still prevent nutrient loading and release of carbon from peat (Miettinen et al. 2022). More natural and diverse peatland forest management with mixed forest cover and improved catchment retention by peatland restoration could also diminish water quality impacts (Härkönen et al. 2023). Furthermore, the increasing use of GIS data and integrated modelling helps to plan water protection more efficiently and to identify high risk areas (Tattari and Leinonen 2017). Spatial differentiation of measures and policy would help to target the most important sites and regions.

The first policy solution would be to levy a ban on ditching pristine wetlands. This would effectively rule out even the slightest attempts to increase ditched forest land areas. This could be made by introducing new legislation to this effect.

Secondly, anticipating the becoming EU nature restoration regulation, Finland should make a national plan for restoring those forest peatlands where ditching has not increased sufficient forest growth. Setting priorities and schedule on the restoration of sites, such as unfertile wetlands, would help the implementation of the new regulation and at least slightly reduce nutrient loading from the ditched sites. Overflow fields would provide an efficient and permanent structure for water protection in these lands (Miettinen et al. 2020).

Third, on managed peatlands under active management, the first task would be to abandon subsidies for ditch network maintenance. Instead, forest owners should be given more support for planning how to manage previously drained peatland forests in a way that decreases harmful environmental impacts. Ditch network maintenance should be controlled by a permit (Lång et al. 2022). The permitting process should assess the eligibility and need for ditch network maintenance against alternative forest management practices for ditch network maintenance including not only water both also climate and biodiversity impacts. These alternatives include continuous cover forestry, where the amount harvested trees is selected so the remaining trees maintain the groundwater table at a level, which minimizes harmful environmental impacts, or strip harvesting, where the size of strips and the age of trees is chosen so that the water table remains at the target level. If a permit is given, it should set maximum limits for the width and depths for ditches, and instructions for using carefully planned water protection measures. Finally, fertilization to increase forest growth could promote evaporation and help to replace ditch network maintenance needs (Miettinen et al. 2020).

Fourth, on managed mineral lands, final harvesting and the following soil preparation is the main source of nutrients. In even-aged forest-management leaving buffer strips between harvested area and adjacent waters decreases nutrient loads to watercourses. For both water quality and especially biodiversity reasons, sufficiently wide buffers should be left along creeks and streams (Tolkkinen et al. 2020). Avoiding clear-cutting, for instance by shifting from even-aged management to continuous cover forestry also decreases negative impacts on water quality and could be considered especially in forest sites where continuous cover forestry is a financially profitable option compared to even-aged management.

4.4 Hydropower: Removing small-scale operations and introducing environmental flows to mid-sized and large operations

Context

Most of the Finnish rivers have been dammed for hydropower generation during the 20th century and the remaining rivers are protected by law (Soininen et al. 2018; Iho et al. 2022). Consequently, there are slim opportunities for developing hydropower further despite the economic (IEA 2020a) and climate change mitigation (IEA 2020a) benefits of such generation (Iho et al. 2022). Rather, the hydropower sector has been frequently called to mitigate its negative impact on riverine ecosystems, migratory fish, recreation, and tourism. At present, the EU biodiversity strategy for 2030 and the EU Water Framework Directive (arts. 4 and 11) put significant pressure on preventing the further deterioration and restoration of freshwater biodiversity (COM (2020) 380 final). As a concrete target, the biodiversity strategy calls for restoration of roughly 25.000 kilometres of rivers as free flowing (COM (2020) 380 final). To make the objectives of the EU biodiversity strategy and the Water Framework Directive a reality, a shift in the hydropower sector, and existing hydropower permits, is required.

In Finland, hydropower accounts, depending on the year, 10–20 % of the total electricity consumption (Energy Finland 2018). The Finnish hydropower operations are part of the Nordic electricity markets (Nordpool) in which electricity flows between Sweden, Norway, Denmark, Finland, and central European countries, but the flow from country to country is limited by the capacity of transboundary transmission cables. The price of electricity is determined by production and consumption at the market. A key factor of the electricity markets is that production and consumption need to be balanced daily from seconds to minutes and hours to days to prevent the electricity grid from collapsing (Iho et al. 2022). Hydropower contributes to this balancing. Also, hydropower is typically one of the most affordable means of generating electricity as most of the investment costs have been sunk. Consequently, most hydropower operators are reluctant to forfeit their operations.

Another characteristic of the electricity market is that much of the demand is typically inelastic as many societal operations from industrial production to households need a certain amount of electricity regardless of the price of electricity. Subsequently, changes in electricity markets are mostly driven by changes in electricity generation technologies and by public policies internalizing climate externalities. The key policy question concerning the future of hydropower in Finland is how the incumbent regime producing negative environmental externalities especially in built rivers could be reduced to balance the societal benefits (affordable electricity, stable electricity grid, climate change mitigation) and harms (esp. riverine ecosystems) of hydropower. (Iho et al. 2022)

Policy lock-ins

The key policy lock-ins are connected to reconciling hydropower generation and river biodiversity. This is due to three sets of policy lock-ins. First, the goals of EU and Finnish hydropower policy are incoherent. On the one hand, hydropower is a key sector in providing energy security by allowing electricity grid operators to balance intermittent production and consumption of electricity thus stabilizing electricity prices (Iho et al. 2022). Moreover, hydropower is seen as renewable energy that has a role in climate change mitigation. On the other hand, hydropower is one of the key culprits behind the less-than-good ecological status of rivers in Finland as required by the EU Water Framework Directive art. 4 (Soininen et al. 2018). The status of biological elements, such as migratory fish stocks, is a key criterion in evaluating the good status (WFD Annex V). At present, there is no clear understanding of what kind of specific measures WFD arts. 4 and 11 require from existing hydropower operations. Legal proceedings to clarify the situation are ongoing (e.g., ELY-Center 2017), and the EU Commission has also inquired the from the Finnish government, how the country will seek to realize the WFD goals. There is no clear strategy or policy pathways to tackle this question at the moment.

The second lock-in is that the legal status of hydropower operators is well protected against changes in environmental or social circumstances. This protection comprises private ownership of the river flows and a legal right to compensation if the economic value of the operation considerably decreases due to anthropogenic reasons (Soininen et al. 2018; Iho et al. 2022). This incurs potentially major economic losses to public authorities seeking to shift existing permits as the hydropower losses will need to be compensated to the hydropower operators. Moreover, the once granted administrative water permits enjoy strict protection meaning that the permits cannot be entirely revoked against the hydropower operators will, and there are strict legal criteria for adding new and changing existing permit requirements (Soininen et al. 2018; Iho et al. 2022). Permit conditions concerning fisheries damage can be changed if there are some conditions in the original permit, but these need to be done operations by operation which puts a heavy administrative burden on public authorities. Overall, the private ownership of river flows, the legal right to compensation for the loss of hydropower, and the strong legal protection of existing permits all translate into challenges for re-evaluating hydropower policy in one fell swoop. Consequently, the policy developments are likely to be incremental and piece-meal.

The third lock-in is connected to the lack of enforcement of existing legal and permit obligations set for hydropower operators. Dozens of smaller hydropower operations in Finland still either lack an administrative water permit altogether or are not complying with their legal obligations to build fishways or otherwise mitigate and minimize the harm caused by the damming of the river to migratory fish stocks (Soininen et al. 2018;

Iho et al. 2022). The Finnish enforcement authorities have been mostly passive and reluctant to enforce legal requirements, despite some efforts to reconcile the situation (e.g., ELY-Center 2017). This is due to much of the obligations for producing assessments about the status of the environment and the need for fisheries measures resting on the shoulders of public authorities instead of industrial actors as per the polluter pays principle.

Solutions to lock-ins

In evaluating the future directions of the hydropower sector in Finland, and policy changes to achieve this, there is a need to differentiate between different size hydropower operations (small, medium, and large). Large operations are generating more than 10MW each and contribute significantly to both electricity generation and balancing the electricity grid. These operations cannot be forfeit without considerable harmful implications to the functioning of the electricity markets and energy security. Measures to mitigate the biodiversity harm of the operations is still feasible, however, by constructing fishways and natural by-passes, restoring spawning grounds for migratory fish and so on (Iho et al. 2022). The smallest category (below 2MW) operations contribute, on balance, very little to the Finnish hydropower generation (less than 1 %) and do not take part in balancing the electricity grid. Such operations could be seized, and rivers restored to help achieve the objectives of the EU biodiversity strategy and the Water Framework Directive (Iho et al. 2022). In medium-sized operations (between 2MW and 10MW), the balance between maintaining the operations with biodiversity mitigation measures and seizing operations to restore the rivers is more difficult and needs to be based on case-by-case (Iho et al. 2022).

Bearing in mind the need to separate hydropower policy based on the size of the operation, the Finnish Water Act should be changed to require a periodical review of existing hydropower permits in which the governmental permit authority would review whether the permit conditions are in line with the EU Water Framework Directive art. 4 and other environmental requirements. The permit holder should apply for such renewal in the light of the polluter pays principle and allocate most of the cost of relicensing to actors reaping the benefits of electricity generation. Such system is already in operation in Sweden after legislative changes in 2019 (upcoming Puharinen et al. 2023). In small hydropower operations, such an obligation for periodical permit review would provide an opportunity to consider dam removals and the expropriation of the operations against a case-specific full compensation as required in the Finnish Constitution. In large operations, these processes would likely lead to more stringent environmental conditions and requirements to build natural by-passes for migratory fish, to restore spawning grounds and other measures to mitigate the harm of the operations to riverine ecosystems. The operations would come to include more of the negative externalities of electricity generation into their operative costs. In medium-sized operations there would be cases in which economically feasible operation would seize making those rivers eligible for restoration. In other locations, the operations that could withstand the cost of mitigation measures would continue operations into foreseeable future.

5. Sectors in need of phase-out: peat production

Context

Peat extraction is a controversial activity from a water quality perspective as production of peat releases Dissolved Organic Carbon (DOC), humic substances, and nutrients to waters when the peatlands are drained for extraction. At the EU level, the aquatic impact of peat extraction is in the scope of application of the Water Framework Directive. In Finland, the Environmental Protection Act is the main regulatory instrument for managing the environmental impacts of peat extraction. Moreover, several other Acts regulate the different aspects of peat extraction, such as the Nature Protection Act (9/2023), the Environmental Impact Assessment Act (252/2017), and the Land Use and Building Act (132/1999).

Policy lock-ins

In the past, policy lock-ins related to the insufficient regulation of DOC and humic substances at the EU level, and questions of scientific uncertainty regarding the aquatic impact of peat extraction, especially considering similar emissions stemming from diffuse sources, such as ditching of peatland forests to boost the growth of wood (Belinskij 2015; Albrecht et al. 2023). At present, peat extraction for energy purposes is a declining activity in Finland. The main driver for this development is the EU's emission trading system, which is driving up the price of carbon emissions of energy production. This decreases the market demand for peat. New peat production permits are still issued, however, for the use of peat in animal husbandry and horticulture. This means that even though the energy demand for peat is decreasing with beneficial impact on climate change mitigation and water quality, alternative sources of market demand are developing and continue to support peat production. At present, peat production licenses do not set sufficiently stringent water quality requirements for peat operations and do not contain considerable restoration requirements for the permit holders after the operation.

Solutions to lock-ins

Despite the market demand for energy peat is decreasing, there is a trend for increasing peat production for other purposes. There is a need to develop more stringent measures to regulate both the licensing of peat production operations in the Environmental Protection Act and in terms of restoring once ditched and exploited sites after the lifespan of the operations. To this end, the water quality requirements in the Environmental Protection Act should pay increasing attention to DOC and humic substances, and the permits should contain obligations to restore peatlands by rewetting where biophysically feasible (see also Albrecht et al. 2023). A target year for the phase-out of peat land extraction should be established. The Finnish Climate Change Panel has suggested phasing out peat by 2030. By this time horizon it is also possible to develop substitutes for peat in animal husbandry and horticulture.

6. Cross-cutting policies: improving the bite of water and marine planning and management

Context

The EU Water Framework Directive requires all the EU member states to reach Good Ecological Status of inland surface waters, transitional waters, and coastal waters by 2015, or if postponed, by 2021, or 2027 the latest (WFD art. 4.1; Squintani and van Rijswick 2016; Puharinen 2021). Simultaneously, these waters are regulated by the non-deterioration clause, which requires EU member states to implement all necessary measures to prevent further deterioration of water bodies in their territory (WFD Article 4.1(a)(i); 4.1(b)(i)). The main instruments for implementing these goals are River-Basin Management Plans and Programmes of Measures, in which water bodies are analysed and classified by water body type and status, the main ecological trends and human pressures are recognized, and key measures to reach or maintain good status are stated.

In the marine domain, similar goals to the WFD are set by the Marine Strategy Framework Directive which states that marine waters must be in good environmental status by 2020. A key instrument under the directive are marine strategies that are produced in collaboration with the regional seas organisations, in the context of the Baltic Sea, with the Helsinki Commission (HELCOM).

Currently, Finland is not on path to reach the set good ecological/environmental status requirements in all marine and freshwater ecosystems, in the set timescales. The key reasons for this are related to 1) the waterbodies' naturally slow and varying response to management actions, 2) the incomplete and changing knowledge base that hinders making informed decisions and 3) the issues in policy and legal regulation.

Lock-ins concerning ecological boundaries and nature's slow response time

Despite many efforts already, the good status is yet to be reached in many water bodies (particularly in coastal waters), and the progress has been slow. One reason for this is the slow recovery time of the ecosystems in the receiving waterbodies and the internal loading that persists the eutrophication development even when the external loading can be reduced (Carvalho et al. 2019; Heiskanen et al. 2019; Viitasalo and Bonsdorff, 2022, Hyytiäinen et al. 2023, in revision). Dimensioning and targeting of the measures need careful spatio-temporal consideration and understanding the sensitivity and resilience of the receiving waterbody. In addition, climate change increases water temperature and the more regular heavy rainfalls make it difficult to achieve the good status goals (see references in Puharinen 2021 for overview).

Lock-ins concerning insufficient and changing knowledge base

The status classification that is based on the surface water monitoring data, is the cornerstone of successful planning of water management. So far, the collected data has provided a massive amount of new knowledge on the status of Finnish waters. The implementation of the surface water monitoring has been, however, a challenging task especially in countries with a considerable number of waterbodies, such as Finland. Monitoring all waterbodies and all status class indicators with sufficient certainty has been and continues to be an overwhelming endeavour in Finland. WFD's requirements coupled with the environmental administration's limited and diminishing monitoring resources has led to insufficient monitoring, high uncertainty in the status classification and poorly known effects of human pressures on the ecosystems.

Implementing the needed expensive, large-scale, and integrated management measures requires careful planning that can rely on reliable biophysical knowledge base. This means also assessing the ecosystem function and structure, not only the physico-chemical impacts, to better understand the mechanisms of the non-attainment and the status deterioration (Carvalho et al. 2019; Weigel et al. 2023). Not knowing the most sensitive or the most resilient waterbodies also impedes blue economic activities as the ecological potential and boundaries are unclear.

The uncertainty over impact assessments increases when the size of the project is large and duration long. An illustrative example of this is Supreme Administrative Court decision on Sokli mining project (KHO 2022:38). The environmental and water permit applications were rejected because of uncertainties of impact assessment and inadequate water protection measures. Generally speaking, the environmental impacts of mining projects are particularly context specific. The natural conditions of the location and the river basin, the minerals extracted, the technology used for extraction, as well as the enrichment and refining processes used all affect environmental impacts and vary from project to project. Moreover, the site of a mining project is determined by the location of the mineral deposit, which decreases possibilities to reduce environmental impacts by zoning, or other land-use planning measures. Environmental risks caused by mining are likely to increase in the future as the demand for minerals is increasing globally due to green and digital transitions. To reduce geopolitical risks on critical raw materials, the EU aims to enlarge extraction of minerals in European mineral rich countries like Finland. This puts increasing pressure on the biophysical knowledge base of river-basin management planning.

Lock-ins concerning policy and legal regulation

First, the WFD's ecological status goals are binding, especially in the licensing of new projects, but this is not sufficiently reflected in Finnish legislation, but only in legal practice. Deficiencies in the legislation make it difficult for different actors to assess what the law obliges them to do. This uncertainty, in turn, makes it difficult to translate obligations into concrete measures (Belinskij et al. 2018). On the MSFD's part, there is still significant ambiguity on whether the marine environmental status objectives are binding on Member States' marine policies in total and on the authorisation of specific projects. While meeting the aspirations of good marine environmental status and proper implementation of the Directive advocate for establishing binding legal implications and operational mechanism for the objectives at the level of national law, the Finnish legislation does not currently establish any binding obligations deriving from the marine management objectives (Puharinen et al. 2021; Puharinen 2023). The same is more or less true for the targets set under the Helsinki Agreement and under HELCOM: the goals may be binding on Finland as a state, but the country currently lacks legal implementation mechanisms to translate these state obligations to specific obligations for planning and permitting at the project development level.

Second, the concrete parts of the goals that obligate authorities and private operators are mainly operationalised through environmental and water permits. These goals do not extend to land use, which is key especially in the management of diffuse water pollution. With the help of individual water management measures, it is not possible to bring about extensive changes in practices and business models in various sectors if the legal system does not overall support this.

Third, the interpretation and implementation of the ecological status goals is always influenced by a bunch of other rights and legitimate societal expectations (Belinskij et al. 2018). For example, property rights of old operations, such as hydroelectric plants, protect property owners against significant changes to permits, at least not without compensation (Soininen et al. 2018). Even if the property rights do not altogether prevent taking effective water management measures, it means that, for example, the implementation of fish ways and the dismantling of dams can easily lead to a situation where the operator must be compensated for the harm caused by the changes (Hepola et al. 2023).

Fourth, environmental impact assessments of various projects often contain significant uncertainty (Paloniitty and Kotamäki 2021; Thorén et al. 2021). In this setting, the environmental impact assessment, often done with mathematical models and empirical data, plays an increasingly important role and the inevitable uncertainty of the assessment results can become a decisive issue. To receive the permit, the applicant must show with sufficient certainty that the WFD non-deterioration demand would not be violated within the timespan of the proposed project (40–50 years). At present, it is legally unclear in whose favour that uncertainty must be interpreted. The key question is whether the uncertainties of the environmental effects support the granting of a permit or the denial of a permit. It is also unclear what kind of information production and modelling methods can be used to assess the environmental impact of projects. In addition to high uncertainties, it is not well-established when models should be used or which models or what type of models are those to use. This leads to versatile ways of choosing and using the models which in turn leads to difficulties in assessing the reliability of the modelling process and model outputs.

Fifth, the impacts on water bodies of all key sectors are not legally regulated at all or are only loosely regulated. Good examples are drainage and ditching of peatland forests, which, in the light of recent research, has a key impact on the state of the waters.

Solutions to lock-ins

Considering the transition mechanisms established for analysing the future policy pathways, the key question is how to integrate the ecological considerations of the WFD into the sectoral planning and management of the different sectors of blue economy so that the sectors would not deteriorate the water status, or considerably hinder the achievement of good status, and that they would pay for the cost of their activities to water quantity and quality. Moreover, the environmental assessment criteria of the WFD and its River-Basin Management Planning should be evaluated based on their likelihood to be achieved using the current understanding of coastal and freshwater ecosystem responses under combined human pressure and climate change impacts. The WFD implementation processes could also lead to new economic opportunities for improving the status of waters if the private benefits gained and public harm inflicted on waters would be more evenly distributed. Ecological offsetting within and between the different sectors of the blue economy is one example of this.

In concrete terms, there are several changes to the Finnish water management policies implementing the WFD and MSFD that would require legislative and policy changes:

- The binding nature of water management goals should be reflected in the Water and Marine Management Act and pass the legislation of different sectors such as the Water Act, the Environmental Protection Act, and the Forest Act. Legislative work to this end has already started at the Ministry of the Environment.
- The binding goals of water management should be aimed not only at point source polluters controlled by means of permits, but also at diffuse polluters, such as agriculture and forestry. To this end, possibilities to develop a national nutrient

trading scheme that would put a price on emitted nitrogen and phosphorus and allow actors to decrease emissions where it is the cheapest. This may also require a broader policy reform in agriculture and forestry in order to avoid a situation in which the same emissions are regulated by multiple instruments.

- Legislation for changing permits should be re-evaluated to implement the goals of water management. In particular, the permanence of permits granted under the Water Act is challenging from the point of view of water management. Legislative work to tackle some of the observed legal deficits has already started at the Ministry of Justice.
- In connection with the overall reform of the land-use legislation, it should be assessed in what way the land use law to be prepared could better support the realization of water management goals. For instance, industrial areas should be zoned considering river-basing management plans and best available knowledge about water status and trends so that operations would cause as little risk to water status as possible. As there are significant differences in the ecological settings between different locations and in how the pressures impact on nearby waters, it is important to be able to identify in advance which are the most vulnerable sites, where no additional pressures should be placed. This would also speed up the often-slow permit processes and would prevent making unnecessary impact assessment (that would anyway lead to high impact assessment uncertainties and permit rejection due to the project's initial misplacement).
- The data production and modelling methods used for environmental impact assessment should be regulated more precisely or at least given more detailed instructions. Fortunately, steps towards more coherent model assessments have already been taken by identifying the best modelling practice and model criteria in environmental impact assessments (Puntila-Dodd et al. 2022). In addition, a cooperative model guidance will be produced to assist environmental authorities and permit applicants to better understand the modelling process, model uncertainties and model output visualisations, and to help modellers produce more coherent and understandable modelling reports (Model Guidance project 2022).
- Resources should be put to systematically renew the traditional monitoring networks; new cost-efficient monitoring methods should be put in use, and the existing monitoring resources need to be allocated better (Kotamäki et al. 2019). The economic value of monitoring and improved status classification should be evaluated, and the knowledge base should be treated as an (economic) asset, not only as a cost (Koski et al. 2020). Efficient and coordinated use of new data measurement techniques (satellite data, automatic sensors, eDNA, citizen science etc.) for status classification should be promoted.The EU Commission should agree on how to continue after 2027, considering that ecological recovery times are long. The importance of monitoring and databases should be better acknowledged.

7. Synthesis

Synthesising our results, a societal transformation to sustainability requires a rethinking of economic activities so that value generation would not be in conflict, or would ideally support, international, European Union and Finnish policy aspirations to tackle deteriorating status of waters, loss of biodiversity, and climate change in tandem with their social and economic aspirations. This requires an increased focus on the couplings between policy sectors and a clear policy commitment to the environmental goals and economic renewal in the blue economic sectors. A key for successful policies to implement this is to search for co-benefits and to recognise potential trade-off between the economic sectors and the triple environmental goals, and to coin policies accordingly (Pascual et al. 2022).

To align the blue economic sectors with the triple environmental goals, we divided the sectors in three groups indicative of what the policies of these sectors would need to emphasise to support the co-benefits between the economic value generation and the triple environmental goals.

- **Sectors with underutilised blue potentials:** The category includes offshore wind power generation, and the transformation of underutilized fish stocks, such as cyprinids, for human consumption. Activities in this category can grow provided that the ecological trade-offs are managed.
- **Sectors in need of decoupling of economic value generation and deterioration of waters:** This category includes economic domains that serve key societal functions (e.g., food and energy production) but that should over time aspire toward zero-impact on the environment by way of technological, social, and governance innovation. The category includes agriculture, aquaculture, forestry, and large-scale hydropower. The growth of these sectors is contingent on the decoupling between production and the negative impact on the status of waters.
- **Sectors in need of a controlled phase out.** This category contains peat production and small-scale hydropower generation (less than 2 MW capacity). In the phase-out category, the ecological harm (ecological status of waters, biodiversity, and/or climate change) of the activity outweighs the socio-economic benefit that the sector produces. These activities should be phased out.

By utilising the three categories as a normative lens to blue economic policies, TRAGORA has sought to unpack the main types of policy lock-ins in each sector and offered both general and specific policy measures to manage the lock-ins. Effective policy measures are contingent on the type of policy lock-in as well as the social-ecological and policy circumstances of the sectors.

First, some sectoral policies contain gaps meaning that the economic sector in question is not sufficiently regulated to support its renewal towards the good ecological status of waters and other environmental and societal benefits. Examples include how the Finnish governance system regulates the aquatic impact of forest management (see section 4.3), and how Finland lacks policies to support the utilisation of underutilised fish-stocks for societal and environmental gains (see section 3.2).

Second, some of the policies analysed were conflicting leading to a situation where the businesses, governmental authorities, and civic actors are confused as to the future direction of the sector. This is clearly the case in the aquaculture sector which on the one hand is encouraged by EU and Finnish policy to grow considerably, but at the same time both the EU and Finland are committed to achieving ecological water status goals on a tight schedule (see section 4.2). This requires policy coordination across sectors coupled with technological development and support to drive a transition to novel technologies, such as recirculation operations. Moreover, this requires the integration of environmental considerations into the core of economic policies.

Third, still other policies contain unclear aspirations and requirements. For instance, it is quite unclear what kind of environmental impact assessment methods satisfy the requirements of the Environmental Protection Act and the Water Framework Directive in the context of permitting new operations, such as pulp mills and mining activities. The picture is even more unclear in relation to the Marine Strategy Framework Directive's objectives and how their overall aspiration for the status of the entire marine environment can be effectively operationalised in relation to managing different activities contributing to the cumulative pressure on the marine environment.

Finally, there are mal-adaptive policies that are out of sync with the current policy and societal realities. This is the case with the Finnish Water Act creating major hurdlhurdles for implementing the ecological status goals and restoring rivers to meet the requirements of the Water Framework Directive and the EU biodiversity strategy. Maladaptive policies require policy revision to bring past policies to date.

Despite policy lock-ins, all sectors in underutilised and decoupled categories contain promising societal and policy developments for increasing the co-benefits between the sector activities and the triple environmental goals.

Offshore wind power has great potential to grow in Finland's marine areas with considerable positive impact on climate change mitigation. After recent policy reforms, a key challenge concerns the specific location of these operations. In shallow sea areas, offshore wind power competes for space with biodiversity, including fish spawning or migration routes. In the exclusive economic zone the disadvantages of wind power generation to ship traffic, salmonid migration routes and marine biodiversity are highlighted. Strengthening the legal basis and updating the maritime spatial plans more frequently can offer a solution. Alternatively non-legally binding spatial plans specifically for the offshore wind power could be developed provided they have a clear linkage to water permitting of the operations. Also improving the implementation of the MSFD, particularly by strengthening the legal status in planning and permitting of specific activities (e.g., water management permitting of offshore wind power operations) could provide a mechanism to translate the general marine environmental protection aspirations into concrete legal norms in the development of the sector. The purpose of the plan would be to guide decision-makers in issuing binding water management permits for the operations.

Increasing use of sustainable, underutilised fish in human diets plays a part in the climate-friendly transformation of food systems. This is the case particularly if the fishing fleet can be modernised to use fossil-free fuel. Fishing can be also an important lake system and marine management and fish population control measure. For example, the increase of cyprinids as a part of the eutrophication and warming could allow targeting fishing practises and supporting their use as protein source for humans. Breaking eutrophication cycles also supports the achievement of biodiversity goals.

Agriculture changes natural environments to managed environments. Cultivation is based on planting of crops and fertilization to promote growth. Thus, agricultural production affects the water and carbon cycles of land as well as biodiversity. Many of current agricultural practices cause nutrient runoff decreases water quality, greenhouse gas emissions boosting climate change and decrease biodiversity through land-use change. The agriculture sector can be tuned to the triple planetary boundaries by three sets of measures. First, by switching to conservation practices agriculture can mitigate these impacts and provide positive solutions to the triple environmental challenges. Rewetting and paludiculture provides the single and most important practice in Finland that promotes all three goals. Increasing water level roughly to 30 cm from the soil surface reduces radically carbon release from peat, reduces nutrient loads and, depending on the choice of crops, may also promote wetland plants, such as cranberries. Second, shifting to innovative and more efficient cultivation solutions provides another solution to promote the triple goals. These innovative solutions comprise among others precision farming, vertical farming, and cellular cultivation. They directly reduce GHG emissions and nutrient loading and by decreasing land area needed for cultivation, they facilitate giving more land to nature thus helping biodiversity. A shift to climate-friendly diets and demand for sustainable food would promote the shift the new solutions. Third, agriculture, plays key role in saving the traditional biotopes, which belong to the rarest biodiversity hotspots. These habitats are highly valued by the society, and payments for ecosystem services from traditional biotopes are well-justified. Carbon farming in mineral soils reduces soil carbon release and may even increase soil carbon. Interestingly, it may also promote below surface biodiversity of microbes, which may increase crop yields. Thus, carbon farming enlarges the promotion of agricultural biodiversity to above and below soil biodiversity. Many traditional yet practices, such as conservation tillage, crop rotation, use of legumes and use of deep-root crops, if used at a larger scale improve soil health and contribute indirectly to all three targets.

Forestry has a large impact on the Finnish nature. Save nature conservation sites, practically all land in Finland is subject to forest management and its impacts. Forestry has changed forest structures, and decreased the amounts of wetlands, as large areas have been ditched for forestry. The biggest challenge in water protection lies in reducing nutrient and sediments loads from ditched peatland forests. The suggested shift to continuous cover forestry in peatlands promotes all three environmental goals. When continuous cover forestry eliminates the need for ditch network cleaning, nutrient and sediment loading decreases and at the same time peat release decreases. Continuous cover forestry is not as such a biodiversity solution even though forest remains as closed over time, but it can be included structural features promoting decaying wood and other required features.

The fish farming sector's impact on climate, biodiversity and environmental quality depends highly on the location of the operation and the technology used. In terms of climate change mitigation, the impact of fish protein production heavily depends on the types of protein it is compared against. Compared to red meat, farmed fish fares reasonably well, but the comparison is less conclusive otherwise. In terms of biodiversity, aquaculture can take some pressure away from overfished natural fish stocks but at the same time particularly open pen aquaculture's nutrient emissions to the Baltic Sea can negate this positive effect on biodiversity as eutrophication is the number one reason for biodiversity loss in the Baltic Sea. Increasing policy effort is needed to manage the overall nutrient emissions to the Baltic Sea (e.g., by sector specific nutrient quotas and strengthening the legal operationalisation of the MSFD's objectives and environmental targets), which would not only improve the ecological/environmental status of coastal and marine waters but also biodiversity.

Considering the hydropower sector, the key challenge is that river flows in Finland have been almost entirely allocated to hydropower generation. Consequently, river biodiversity and ecological status are struggling to meet the EU biodiversity and water quality targets despite hydropower playing a role for achieving the EU climate change mitigation targets. To help decouple some of the negative impact of the hydropower sector to river biodiversity and ecological status, one promising policy measure would be to coin a national plan for removing hydropower installations with less than 2 MW capacity. This would mean removing some 500 dams across the country. The estimated losses would be some 83 MW of hydropower generation capacity with 332 GWH annual electricity output. Some estimates suggest that this would mean that roughly 1–2 % of the Finnish hydropower generation capacity would be lost. Very few of these less than 2 MW operations have technical capabilities to participate in regulating the frequency in the electricity grid. If all the dam removals would be connected to habitat restoration measures, these removals and the national plan could have a significant ecological impact towards Finland meeting the EU biodiversity and water status goals without compromising the ability of the hydropower sector to cater for climate change mitigation objectives and balancing the frequency of the electricity grid.

Finally, peat production is detrimental to all the environmental goals in focus here. Burning of peat for energy is highly carbon intensive for which reason the EU Emission Trading System is putting significant pressure to out phase peat as a source of energy. Peat production is also detrimental to biodiversity as it typically transforms a wet peatland into a dry field completely changing the ecological makeup of the area. In terms of water quality, peat production produces DOC, humic substances, and nutrients, all of which deteriorate the ecological quality of waters. As all the environmental criteria are negative for peat production, Finland should develop a plan on how to close the industry and restore the ditched peatlands by rewetting and other measures where biophysically feasible.

New policies and changes to existing policies operating under these recommendations would make a marked improvement in the current blue economic policy setting both for people and nature. While some of our policy suggestions for the development of the blue economic sector policies will take time, some others are implementable already now, with ample support from research and practice.

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