



Involving the Hydropower Sector
in strategic barrier removal:
Applying an NbS approach

Imprint

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Disclaimer: the contents of this strategy are the responsibility of the authors. The Strategy does not necessarily represent the views of their organisations, nor those of the organisations asked for feedback.

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MERLIN Key Messages

1. Removing barriers is essential to restoring river connectivity and ecological health, requiring collaboration across all affected sectors, including hydropower.
2. Many European rivers are fragmented by obsolete barriers once used for horticulture, water supply, and flood protection. This Strategy focuses on removing these, not hydropower dams.
3. Strategic assessment is needed to prioritize the removal of economically unviable barriers, requiring a broader definition of "obsolete."
4. Not all NbS (Nature-based Solutions) involve barrier removal, but when applied, they can support nature-positive outcomes and multiple benefits for the Hydropower Sector.
5. A strategic, outcome-focused NbS approach should replace ad hoc removals, integrating hydropower sector objectives into catchment-scale programs.
6. NbS-driven barrier removal benefits the sector by improving operations, enhancing reputations, and aligning with natural processes.
7. Institutional change must accommodate diverse hydropower operators, ensuring both small and large companies benefit while contributing to freshwater restoration.
8. Public and private actors play key roles in leading change. Hydropower companies can implement sector-led programs, with collaboration being crucial.
9. While this Strategy focuses on barrier removal, some in the sector preferred a broader emphasis on nature-positive actions.

MERLIN Executive Summary

This Strategy considers the potential role for the Hydropower Sector in the removal of barriers (such as dams, sluices and weirs) from European rivers to improve connectivity. It takes an NbS approach, which is driven by multiple socio-economic benefits that may arise, and thus is premised on strategic assessments and designing programmes at the landscape or catchment scale to deliver such benefits.

This Strategy proposes five strategic actions to better support the involvement of the Hydropower Sector in appropriate barrier removal to help support freshwater restoration.

The focus is primarily on transversal barriers, which are artificial structures that cross river channels to hold back water (e.g. dams, weirs and sluices). Hydropower is one of several sectors linked to barriers that cross river channels. Other relevant sectors include horticulture, inland navigation and water supply.

There are some transversal barriers that are still needed by society – including many producing hydropower – and thus cannot be removed. The focus of this Strategy includes the removal of any barrier that may have been constructed for a range of different reasons (not necessarily hydropower) and are no longer required. This will include, but should not be limited to, small, abandoned barriers.

EU nature policy applies the term ‘obsolete’, however this ambiguous term is potentially problematic. There is an understandable focus in the Sector on retaining barriers that could be used in the future for hydropower. The focus of action in the Sector therefore should be on **removing barriers that are not economically viable now, or in the foreseeable future.**

Strategic holistic assessments are needed to identify appropriate barriers that could be removed and the multiple and diverse benefits that could arise for the Sector, for example managing operation challenges for strategically important hydropower facilities. Without a common understanding that strategic assessments are necessary to identify barriers that could be removed, some opportunities to remove barriers may be missed. The Strategy is focussed on how the Hydropower Sector can be involved in such strategic assessments and programmes.

Barrier removal can be undertaken in the Sector as a mitigation measure. The removal of barriers can help the sector comply with legal and regulatory frameworks, such as the EU Sustainable Finance

Taxonomy and Environmental Impact Assessment Directive. These could include the need to offset the unavoidable ecological impacts of new and upgraded hydropower facilities.

An NbS approach encompasses an alternative way of thinking about and acting with ecosystem processes. It frames actions to sustain and restore ecosystem processes as an opportunity for the Sector. The design of such NbS programmes needs the involvement of the Hydropower Sector as a key partner to carefully plan catchment-scale programmes, as the types and combinations of management measures will vary with the type of challenge and desired benefits deemed relevant. However, meaningful and measurable action is required to avoid claims of ‘greenwashing’.

An NbS lens is important as it focuses on how barrier removal – planned at the landscape or catchment scale – can help the Sector address challenges and deliver multiple benefits for business. These Sector challenges may be linked to shifting social and political expectations, or be operational, arising from interactions with the freshwater ecosystems within which hydropower plants are situated. A rapidly changing climate amplifies such ecosystem-related operational challenges, for example water scarcity and poor water quality in arid and semi-arid catchments. Strategic approaches to barrier removal could help the Sector identify barriers that if removed could help them to better manage environmental conditions within catchments to enhance the resilience of hydropower operations. Other benefits may also arise, for example relational benefits for companies and reputational benefits for the Sector.

The five strategic actions identified in this Strategy aim to create institutional arrangements to enable mainstreaming of barrier removal through taking an NbS approach.

Strategic Action (A) focuses on increasing understanding across the Hydropower Sector on what taking an NbS approach to barrier removal entails. Understanding of NbS in the Sector varies and, more specifically, what NbS involving barrier removal could and should entail. The success of subsequent actions hinges on this first strategic action. Not all NbS programmes will involve barrier removal and not all barriers are or will be removed using an NbS approach. Bringing together these two domains – NbS programmes and barrier removal – is potentially useful, but also potentially confusing. Using examples, evidence and building on existing Sector guidelines with an explicit NbS framing – that

emphasises the diverse benefits that can arise for the Sector – is needed and can also help dispel assumptions that may be hindering action. Successfully increasing understanding however ultimately requires key strategic actors to work together to promote such understanding through existing networks and Sector specific forums.

Strategic Action (B) focuses on highlighting potential synergies between hydropower dimensions of renewable energy policies and nature restoration policy objectives to set out a clearer NbS pathway for action by hydropower companies. This is needed as policy (and policy actors) can influence how actions are seen as relevant by the Sector. The current mix of EU policy objectives, instruments and perspectives can be confusing for the Sector to navigate. Nature-related policy needs a clearer orientation towards economic sectors (including the Hydropower Sector). Renewable energy policy needs to highlight barrier removal as a mitigation measure for hydropower expansion and the role of NbS measures to strengthen the resilience of strategically important hydropower barriers. Synergies also need to be set out at the Member State (MS) level in both energy and climate change plans, and nature restoration plans. The development of bespoke national hydropower and barrier removal strategies could help strengthen understanding about where synergies could be found. Adding barrier removal conditions to hydropower licences could also be a lever that could help remediate the ecological and hydro-morphological impact of barriers on river ecosystems.

Strategic Action (C) focuses on creating clearer finance pathways to involve the Sector in planning, designing and delivering NbS and barrier programmes. This is important as barrier removal may not be simple, can be costly and business decisions are strongly guided by an understanding of costs and benefits. Finance pathways need to be designed to provide financial incentives to support action by those in the Sector with resources – such as large corporations – and to enable those with fewer resources – such as single hydropower barrier operators – to also act and benefit. **Of particular importance for larger hydropower operators is the need to align finance to an NbS approach** and with clear links to policy requirements, for example the EU Taxonomy (2020) and to support collaborative approaches, for example between the public and private sector. Creating effective financial pathways entails many considerations. Three existing finance models already in use are presented: 1. cost recovery, 2. Sector organised; and 3. a blended finance model. The key implications of each are highlighted to inform these pathways.

Strategic Action (D) focuses on the need for leadership in, and collaboration between, the public and private Sectors at different stages of programme development and delivery. A strategic approach planned at the catchment scale is often necessary to effectively address Sector challenges and deliver diverse benefits, but also adds complexity to planning, designing and in delivery. Alongside the other actions in this Strategy, a key process in developing leadership is having clear roles and responsibilities that help foster a collaborative, learning ethos. Delegating these roles and responsibilities however also requires knowledge and expertise. This collaborative leadership is essential to overcome obstacles and to ensure that NbS approaches and barrier removal measures are applied efficiently and effectively. While collaboration across economic sectors is needed, the primary concern is first and foremost ensuring collaboration across levels of governance between the public sector and the private sector, for example hydropower companies and their representative organisations.

Finally, **Strategic Action (E) focuses on providing tools to strategically identify appropriate barriers to be removed to help guide investment decisions in the Sector.** This includes the need to collaboratively develop tools with large hydropower companies and Sector representatives to design NbS programmes with barrier removal as a core measure. This type of tool needs to be strongly orientated towards Sector challenges – particularly in the context of climate change – to help companies better understand future scenarios to identify win-win opportunities that an NbS approach seeks to uncover. Such a tool needs to be adaptable to fit the different business settings found across the Sector. This type of tool is necessary to avoid an ad hoc, site-by-site approach dominating sector action and to stimulate more ambitious action beyond barriers that could be seen as ‘low hanging fruit’, for example through only removing abandoned barriers that are easy to access. In so doing it will help the Sector focus on removing barriers that have limited future economic viability for retrofitting hydropower. A different tool is also needed to inform investment decisions by small hydropower operators to understand when small barriers may not be economically viable for continued hydropower production in the future.

For all strategic actions, attention is needed to consider if large and small hydropower operators can benefit from the institutional changes proposed in this Strategy.

Finally, **these Strategic Actions should be viewed as a starting point for further involvement of, and dialogue with, the Sector to explore and refine ideas further and to build stronger relationships.**

Currently, trust between different actors is lacking in part due to traditionally adversarial positions between some hydropower and nature restoration actors. For example, there was strong opposition towards the focus of this Strategy on the removal of barriers from some hydropower representative organisations involved in the process. A practical and focused entry point is important. However, a key learning outcome from the process of developing the Strategy is that **while the focus on an NbS approach is helpful, the focus on the removal of barriers is largely unhelpful for involving the Sector in activities aimed at enhancing river connectivity.**

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Acronyms and Abbreviations

→	CoP	Community of Practice
→	CS	Case Study
→	DGs	Directorate General (of the European Commission)
→	EC	European Commission
→	eNGO	Environmental Non-Government Organisation
→	EU	European Union
→	FFR	Free-flowing Rivers
→	MS	Member State
→	NbS	Nature-based Solutions
→	RT	Round Table
→	WFD	Water Framework Directive

1 Introduction

The H2020 project [‘MERLIN’- Mainstreaming Ecological Restoration of freshwater-related ecosystems in a Landscape context: INnovation, upscaling, and transformation](#) aims to contribute to the implementation of the European Union’s (EU) Green Deal goals by learning about how to deliver more freshwater ecosystem restoration measures across Europe for the benefit of nature, people and business. To better understand how to achieve this, the project has worked with 18 case studies that encompass a range of contexts since 2021. This includes regional and national programmes within large river systems, such as ‘Room for the River’ in the Netherlands, and initiatives focused on restoring peatlands and smaller river systems.

Various measures can be applied to help deliver a diversity of benefits from freshwater ecosystems for both people and nature, for example benefits from reducing the risks from extreme fluctuations in water levels. Such measures include action to restore natural river channels (i.e. re-meandering artificially canalised river channels), restoring connections between floodplains and rivers, rewetting land to restore peatlands and removing barriers to restore natural flows (MERLIN, 2024). The application of such measures may be motivated by biodiversity goals. Alternatively, the purpose of such measures can be driven by the need to resolve different societal challenges, such as climate adaptation, by working with ecosystem processes. This is the essence of a Nature-based Solutions (NbS) approach. Such an approach often hinges on adopting a catchment scale perspective to design strategic programmes that may involve multiple measures. At the same time this creates more potential to deliver multiple benefits for people and nature than *ad hoc* site level action (Cohen-Shacham et al., 2019). For example, strategic barrier removal can lead to socio-economic benefits by improving hydro morphological processes (Lutter et al., 2024, Leisher et al., 2022). This focus on addressing challenges to benefit people and nature expands the relevance of nature-positive initiatives beyond traditional ecosystem restoration actors.

Alongside learning through the implementation of different ecosystem restoration measures, the MERLIN project has also adopted an NbS framing to work with six economic Sectors with the aim of understanding how to support the widespread uptake (i.e. mainstream) of such measures to support economic activities. For the Agriculture, Insurance, Water Supply and Sanitation, and Navigation Sectors, a broad approach has been applied that encompasses multiple NbS measures, for example floodplain reconnection, channel re-meandering, wetland and riverbank restoration and barrier removal. For engagement with the Hydropower Sector the removal of transversal barriers no longer required for hydropower or other economic activities was selected as a focal NbS measure that can support improvements to river connectivity. We explain this more in section 1.4. The removal of such barriers however one of several measures the Hydropower Sector could integrate into the design of NbS programmes to support future business activities. Other relevant measures may include installing naturalised by-pass channels, restoring in-channel features upstream, reconnecting floodplains, and riparian planting (see Annex 3). Furthermore, the Hydropower Sector is one of several economic Sectors with links to barriers and that could potentially benefit from barrier removal and/ or NbS programmes that entail enhancing river connectivity.

Based on multi-stakeholder dialogue and other sources of data, this Strategy proposes strategic actions to involve the Hydropower Sector in planning and delivering NbS programmes that consider and deploy barrier removal.

Target audience for this Strategy:

- Hydropower Sector representative organisations and hydropower operators – particularly those who already recognise the benefits of barrier removal beyond compliance with laws and regulations and/ or those already adopting an NbS approach
- European (EU) and Member State (MS) policy actors from renewable energy/ climate mitigation and from nature restoration policy domains
- Proponents of barrier removal and of an NbS approach from the third Sector (Environmental NGO’s)
- Solutions-orientated scientific researchers working on the interface between energy/ climate change mitigation and nature restoration action domains

1.1 Purpose of this Strategy

An NbS approach has continued to gain traction as a useful approach within policy, research and environmental NGO communities with the focus on working with nature to support, not hinder, economic activities, particularly in the context of a rapidly changing climate (Calliari et al., 2022). However, achieving this in practice will require both working with economic Sectors and adopting holistic perspectives (i.e. that consider multiple objectives and influencing factors) to create the necessary institutional conditions to enable action by the Sector. A specific focus, such as barrier removal, can be useful for strategic planning aimed at accelerating the uptake of alternative ways of thinking and acting that an NbS approach represents, particularly in large systems (Waddock, 2022). Selecting an entry point that aligns with political priorities can also help support collective action (Xie et al., 2022).

Many barriers that transverse river channels (dams, weirs and sluices that control water levels within river channels) have socio-economic functions, including some utilised by the Hydropower Sector to produce electricity. However, attention is also increasingly turning to the need to reduce the number and impact of barriers to increase river connectivity across catchments, for example with the EU 2030 Biodiversity Strategy and the new EU Nature Restoration Law (2024). This focus on barrier removal for enhancing river connectivity provides a practical entry point for strengthening uptake of an NbS approach. However, to date the overlap between these two ideas (barrier removal and NbS) has remained under explored. Bringing together barrier removal and an NbS approach represents an innovative Strategy, offering a shift in perspective. The focus is on the Hydropower Sector as a key group of actors needing to contribute to planning, designing and delivering strategic assessments and programmes.

NbS can deliver multiple socio-economic benefits but achieving this in practice requires deliberate efforts for mainstreaming an NbS approach, involving different ways of thinking and acting. Mainstreaming can be understood as where ideas and practices common in one Sector are normalised within other Sectors of society, by developing shared understandings and concerted actions (Scott et al., 2022). This may involve deliberate efforts to transform institutional arrangements to provide clearer pathways for more ambitious planning and action (Carmen et al., 2024).

The overall aim of this Strategy is to support the Hydropower Sector's contribution to the removal of transversal barriers (dams, weirs and sluices that control water levels within river channels) that are no longer required for economic activities (for example see Figure 1). The focus is not on removing barriers required for hydropower production. The main focus is on supporting the uptake of an NbS approach to barrier removal within the Hydropower Sector, identifying barriers that if removed, could help address sector challenges and create multiple, diverse benefits for the Sector and for society (see **Fehler! Verweisquelle konnte nicht gefunden werden.** below).



Figure 1: The removal of a barrier on the River Almond, Scotland. Undertaken by the Forth Rivers Trust, 2022. This is the type of barrier removal that could form part of a strategic approach to connectivity, including the Hydropower Sector in identifying, planning and delivery.

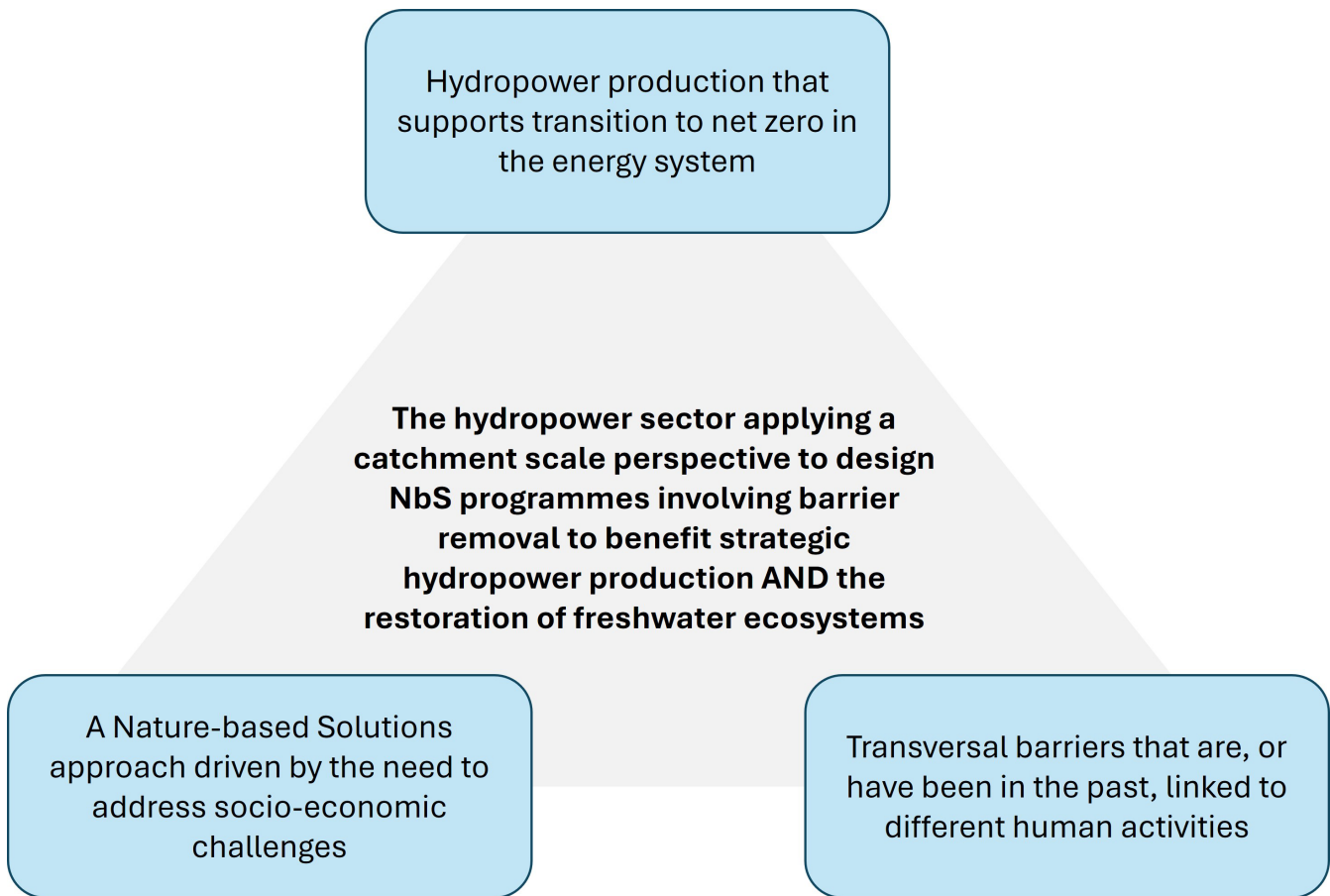


Figure 2: The focus of this Strategy

In the following sections we explain what is meant by the Hydropower Sector (Section 1.2), Nature-based Solutions (Section 1.3) and transversal barriers (Section 1.4). Section 2 then sets out the current situation in terms of some key Hydropower Sector challenges and potential benefits that could be delivered for the Sector through an NbS approach to barrier removal. Following this, the process for developing this Strategy is explained (Section 3 - methodology). Section 4 then presents the strategic vision, followed by each of the five strategic actions in Section 5. Section 6 discusses the strengths of this Strategy and gaps that still need to be addressed. Finally, Section 7 concludes, emphasising the importance of an iterative approach to better involve and support the Sector to contribute to enhancing river connectivity.

1.2 The European hydropower Sector

The Hydropower Sector is a sub-Sector of the larger renewable energy Sector. Hydropower both provides base load energy generation (16% of the global electricity generation comes from hydropower), and helps balance the volatility of other renewable energy sources (mainly wind and photovoltaics), providing ancillary and stability services to the grid (Quaranta et al., 2024a).

Hydropower is generated in different ways. Hydropower plants can involve building bespoke artificial barriers transversal to the river channel but can also exploit existing barriers (built for other purposes), hydraulic structures and pipes. Barriers used for hydropower production may store water for controlled release through turbines. These barriers with storage capacity are often referred to as dams. Hydropower plants that have the capacity to store large volumes of water (that may or may not transverse and thus structurally encroach on river channels) are called reservoir-hydropower within the Hydropower Sector, or storage-hydropower (IRENA, 2023, Gasparatos et al., 2017) and may support other secondary functions, such as irrigation. Hydropower plants with smaller transversal barriers, that have limited storage capacity (i.e. not beyond the mean daily inflow, in general), are usually defined in the Sector as run-of-river hydropower schemes (Quaranta et al., 2024a). Hydropower also includes pumped storage hydropower, when two or more reservoirs are connected and have a pumping capacity. These can be open-loop systems, or closed-loop systems, the latter having no dependence

on the replenishment of water from nearby river systems (IRENA, 2023, Gasparatos et al., 2017, Quaranta et al., 2024b). This categorisation terminology can be confusing for actors not familiar with the Sector. For this strategy it is important to understand that hydropower is produced in multiple ways, including but not limited to the use of in-river transversal barriers (see Figure 3).

There are approximately 25,000 hydropower plants within the EU (Quaranta et al., 2024b). 4,500 of these are large dams (storage-hydropower plants involving barriers of a height of 15 meters or greater from the lowest foundation to crest or a barrier between 5 metres and 15 metres with a storage capacity of more than 3 million cubic metres) (ICOLD, n.d., Quaranta et al., 2024b). The size, storage capacity, and complementary functions of barriers utilised by the Hydropower Sector therefore varies.

In 2022 the installed capacity of hydropower (excluding pumped storage) was 248,526 megawatts (MW) of electricity and production was 686360 gigawatt hours (GWh) (IRENA, 2024). In 2022 production declined compared to levels in 2020, 2021 and 2023 due to a prolonged drought that lasted for the first three quarters of that year (IHA, 2022).

Hydropower production is considered strategically important for balancing the supply of renewable energy to meet demand in some Member States (MS), and thus critical in achieving some MS renewable energy policy objectives. In recognition of this strategic role, hydropower is identified within EU Renewable Energy Directive and some Member State (MS) energy and climate mitigation policies. Furthermore, hydropower is also considered important to help manage the impacts of volatile global energy costs (Quaranta et al., 2024b). This includes locally produced energy from small scale hydropower operations (EREF, 2021). For some Member States (MS) maintaining the role of hydropower in the renewable energy mix entails a focus on increasing hydropower production through retrofitting and upgrading existing plants, for example in France and Croatia (IHA, 2021). In other MS there is a greater focus on building new hydropower dams (IHA, 2023), for example within the Balkans region (Carolli et al., 2023). Therefore, the type of activities undertaken to maintain and/ or develop hydropower capacity by the Sector varies across MS.

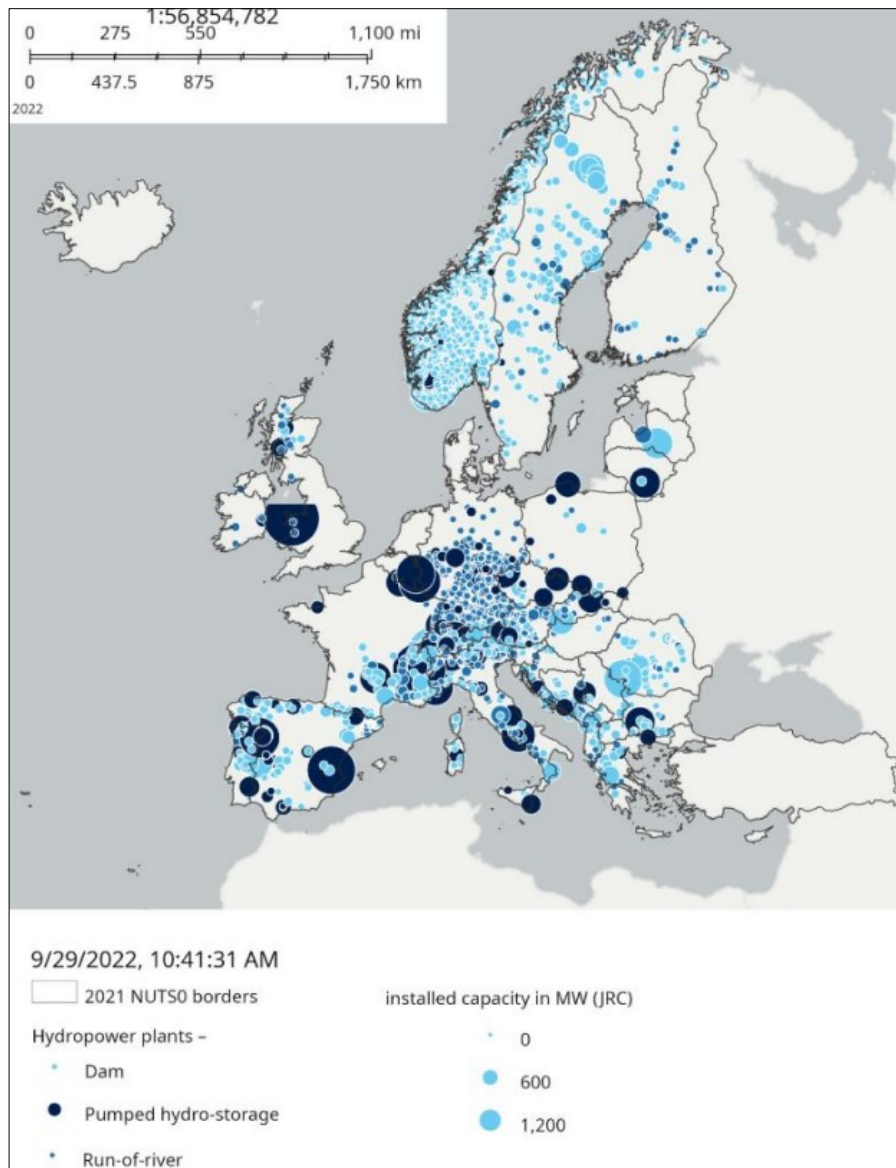


Figure 3: Types of hydropower distribution in Europe (2022) Quaranta et al. (2024b - Data source: JRC hydropower database)

A shift towards greater focus on environmental sustainability within the Hydropower Sector is already underway (IRENA, 2023), for example the [Hydropower Sustainability Standard](#) and Certification Scheme established to outline key (social and environmental) sustainability criteria and promotes the use of NbS in upper catchment management, especially for addressing sedimentation and erosion challenges (Hydropower Sustainability Secretariat, 2021). The need to deliver benefits to local communities by supporting and creating additional socio-economic outcomes is a recognised dimension of sustainability within the Sector (IHA, 2019). The resilience of current hydropower assets to climate change is also important consideration.

Furthermore, the Sector is already implementing NbS type measures and developing guidance to share good practice for working with nature. Increasingly attention has turned to creating naturalised by-pass channels around barriers in use. For example, the [fish bypass channel of the Ruppoldingen hydropower plant](#) on the River Aare in Switzerland was designed to resemble natural alpine small rivers. This entailed the creation of two side channels with large and deep pools, one of which was also designed to include gravel riffles and shallow water and a second deeper channel to aid the migration of different species of fish (ECRR, 2019). Naturalised by-pass channels can therefore help operators (including hydropower operators) comply with environmental regulations and licence conditions alongside other benefits and enhance river connectivity. This type of action utilises natural ecosystem processes, delivers a net gain in biodiversity beyond the immediate location of barriers and can also lead to more diverse socio-economic outcomes for local communities, but also may require additional land to deliver (Miller et al., 2024). [Sector guidance](#) has also recently been produced

by Eurelectric with a particular focus on naturalised fish bypass channels to increase connectivity around hydropower barriers.

Diverse actors are involved in the Hydropower Sector. The main Sector actors are private operators, both large corporations and small- and medium-sized companies. Large multinational and national corporations often use large barriers (i.e. hydropower dams) for electricity production and have business portfolios encompassing various energy production means and technologies (i.e. not only reservoir-hydropower produced with dams transversing rivers). On the other hand, some national energy companies within Europe are managed by the public Sector, e.g. in Austria. The Sector also includes medium and smaller sized businesses, for example who utilise smaller sized barriers to produce energy (termed run-of-river in the Sector) and private individuals utilising single barriers for hydropower primarily for their own use (EREF Small Hydropower Chapter, n.d.). Hydropower operators within the Sector therefore vary in their objectives and resources.

The Sector also includes various Hydropower Sector business networks and representative organisations (e.g. Eurelectric, the European Renewable Energy Federation (EREF), the International Hydropower Association (IHA) and the newly formed Hydropower Sustainability Alliance). These representative organisations seek to collectively support, inform and develop the Sector at the international, European and national levels, for example by developing shared guidance and standards and to shape wider institutional contexts to support the Sector.

Other types of actors also have a role in the Hydropower Sector, for example various Directorate Generals (DGs) within the European Commission, Non-Government and community organisations, for example those seeking barrier removal to help tackle the freshwater biodiversity crisis and/ or improve fish populations. Furthermore, scientific researchers from a range of disciplinary background are also involved in the Sector.

In summary, the Hydropower Sector is considered strategically important in some Member States (MS) to help reduce reliance on fossil fuels for energy production and thus help societies achieve net zero objectives. Some hydropower activities directly encroach structurally and functionally on riverine ecosystems. The Hydropower Sector is therefore a key strategic stakeholder in the management of catchments and has a key role (alongside other Sectors and actors) in shaping how freshwater ecosystems are managed in the future. There are considerable opportunities for collective action and to develop co-benefits for and led by the Sector, yet also possible trade-offs in how such benefits are realised and for who. It is important to note however that other Economic Sectors are also key in shaping the future management of rivers across Europe and therefore also need to be involved in the removal of barriers from Europe's rivers.

1.3 Nature-based Solutions (NbS)

We use the widely accepted definition of Nature based Solutions as “**actions to protect, sustainably manage, and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits**” (UNEP, 2022, IUCN, 2016). The core idea underpinning NbS is viewing and working with nature to sustain, not hinder, human activity through interventions inspired and powered by nature. Action is driven by a need to address societal challenges whilst also providing multiple socio-economic benefits alongside biodiversity gain (Sowińska-Świerkosz and García, 2022), for example delivering benefits for the Hydropower Sector.

To help guide understanding of what NbS entails (i.e. key components that distinguish NbS interventions from more traditional ecological or technological interventions) the IUCN has developed 8 principles (Box 1).

Box 1: The IUCN NbS principles

1. NbS effectively address societal challenges
2. Design of NbS is informed by scale.
3. NbS result in a net gain to biodiversity and ecosystem integrity
4. NbS are economically viable
5. NbS are based on inclusive, transparent and empowering governance processes
6. NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits
7. NbS are managed adaptively, based on evidence
8. NbS are sustainable and mainstreamed within an appropriate jurisdictional context

Source: IUCN (2020)

NbS interventions may involve the removal of transversal barriers, such as those structures with low storage capacity and where water normally overflows the crest of the structure (e.g. weirs and sluices). The focus on transversal barriers as a core focus in this strategy is explained in the following section. One example of the removal of transversal barriers is in the Deba River in the Basque Country ([MERLIN Case Study 2](#), Figure 4) where historic, small transversal barriers (weirs) have been removed. At one site this has reduced flood risk for local communities (Colls et al., 2024).



Figure 4: MERLIN Case Study 2 (Basque Country, Deba River) - removal of barriers with benefits for reducing flood risk (before and after implementation)



Source: Dr Turner, Yorkshire Water

Figure 5: A natural bypass channel created alongside a strategically important barrier (Rodley Weir, UK)

Traditional technological solutions can be necessary to help address specific Sector challenges. Often however technological solutions are prioritised and the potential role of NbS measures underplayed (Gu et al., 2022, Viers, 2017). This can lead to missed opportunities in strategic decision making to integrate nature into the design of interventions (i.e. an NbS approach). NbS are not however dichotomous with technological measures (i.e. hard engineering solutions). NbS can be dominated by natural design features (e.g. in the creation/restoration of wetlands and river channels), but NbS can also involve a mix of natural and more traditional engineered elements, for example a naturalised channel design with some use of reinforced banks to reduce erosion at key locations (Martin et al., 2021).

Tackling such societal challenges such as the need to adapt to a rapidly changing climate and delivering diverse benefits for the Sector often requires landscape or catchment scale approaches, drawing on multiple measures with the intention of sustaining and restoring ecosystem processes whilst delivering other socio-ecological benefits (Cohen-Shacham et al., 2019). Multiple measures can also be used in parallel by the Hydropower Sector that enhance river connectivity across a catchment, for example barrier removal and creating naturalised bypass channels within a catchment to increase connectivity of transversal barriers that cannot be removed (e.g. strategically important barriers recognised as fulfilling an important function now and in the future) (Figure 5) (Turner, 2013). Furthermore, NbS programmes designed to tackle Sector challenges may will involve a range of measures (for example see Annex 3). Involvement of other actors (i.e. from other economic sectors, from the public sector) is important to help uncover new opportunities and enable better management of trade-offs, reducing the likelihood of conflict.

The IUCN principles are therefore useful. More broadly these principles are helpful as NbS interventions will contextually vary (i.e. different measures applied depending on the setting and nature of the challenge being experienced by the Sector). They also help distinguish an NbS approach from other types of interventions. For example, the difference between barrier removal driven by ecological benefits and taking an NbS approach to barrier removal (Table 1).

Table 1: Key distinctions and overlaps between Restoration and Nature-Based Solutions approaches to barrier removal Sector (adapted from Waylen et al. (2024)).

Key dimensions	Traditional restoration approach	NbS approach
What are the goals?	To restore ecosystem function, which entails removing or mitigating significant human impacts. Biodiversity and habitat conservation are usually prioritised. Defining the ideal natural state may be challenging, especially given climate and other human-induced changes.	To support more sustainable development by responding to societal and Sectoral challenges. These range from climate change mitigation and adaptation to manage extremes in water levels, water security, human health and wellbeing. Each process must define its own priorities.
What is the geographical scale and remit of work?	Interventions aim to restore functional ecosystem units, this could be whole catchments, though in practice restoration activities have often been confined to reach-scale initiatives and small rural sub-catchments.	Interventions are planned according to the scale of benefits required; this may entail working at catchment scales – or connecting work across catchments – or hydropower portfolios, but specific goals may also be achieved by targeting smaller scales.
How is work conceived and planned?	Usually a small group of partners with strong conservation interests.	Requires input from all the relevant stakeholder groups beyond conservation.
Who is involved?	Mainly public Sector (environmental statutory agencies), fisheries and related interest groups & eNGOs (environmental Non-Governmental Organisations). The expertise used focusses on ecosystem function and, especially for physical habitat restoration, hydro morphology.	Many groups from across Sectors: includes public Sector, not solely limited to environmental interests but also, for example extending to areas like planning; for-profit businesses through to community organisations. Expertise used includes ecosystem function and hydro morphology but extends to include expertise in wider economic and social issues.

What type of interventions and activities are involved?	Encompasses both passive interventions e.g. waiting for natural regeneration, and more proactive interventions e.g. engineering works to reconnect floodplains to river channels.	Potentially encompasses both passive and proactive interventions but may tend to emphasise more proactive designed interventions to ensure societal benefits will be delivered.
How are projects typically funded?	Public Sector grants, as well as 'in kind' resources such as staff time from eNGOs, fisheries interest groups and public Sector. eNGO resources are in turn provided by members and/ or donations.	Fixing societal challenges helps unlock more types of funding opportunities than for restoration alone. This includes additional resources provided by other stakeholder groups who are motivated to support & resource the work – ranging from crowd-funding and community volunteers, to public infrastructure funding and corporate investments.(See strategic action C, section 5.3)
How is the project monitored?	Monitoring, when it occurs, is often focused on assessing ecological, biophysical and hydrological parameters. This information should be used in adaptive management.	Monitoring should focus on achieving the societal goals; tracking intermediate steps, and assessing project processes. All this information should be used in adaptive management.

An NbS approach to barrier removal entails the Hydropower Sector co-instigating, designing and delivering catchment scale programmes involving barrier removal as one of multiple measures to address challenges to business activities, whilst also delivering wider benefits to people and nature. An NbS approach focuses attention in decision-making processes on the benefits of action for the Sector as well as society and nature. Thus, an NbS approach aims to reorient views of measures such as barrier removal within economic sectors as a potential opportunity for business.

1.4 Transversal barriers and their removal

For centuries there has been a strong reliance on managing and controlling water levels in Europe's rivers and surrounding land through the construction of barriers – a practice that continues (Angelakis et al., 2024). Such barriers, like most infrastructure, can have varying and multiple socio-economic functions (Schmutz and Moog, 2018). These functions include, but is not limited to, hydropower production. Other relevant sectors include horticulture, inland navigation and water supply.

Barriers also vary in their type (i.e. transversal is one category that includes multiple types of barrier) and distribution across Europe. Estimates suggest there are over 1.2 million barriers fragmenting rivers across Europe (Belletti et al., 2020). The AMBER Barrier Atlas has identified approximately 630,000 instream barriers across Europe (including but not limited to dams, weirs, sluices, culverts, fords, ramps) (AMBER Consortium, 2020). 68% the barriers identified so far are structures of less than 2m in height (Belletti et al., 2020). 450,000 of these are found within the European Union (Quaranta et al., 2024b).

Over 260,000 transversal barriers (i.e. dams, sluices and weirs) have been identified across Europe (approximately 25% of all mapped instream barriers) (AMBER Consortium, 2020). The distribution of such transversal barriers varies across MS (Figure 6 below), for example in Finland and Austria most barriers are classified as dams, whereas in the England and Poland barriers also include many weirs and sluices (AMBER Consortium, 2020). This variation in the distribution of transversal barriers will influence opportunities for removal across Europe.

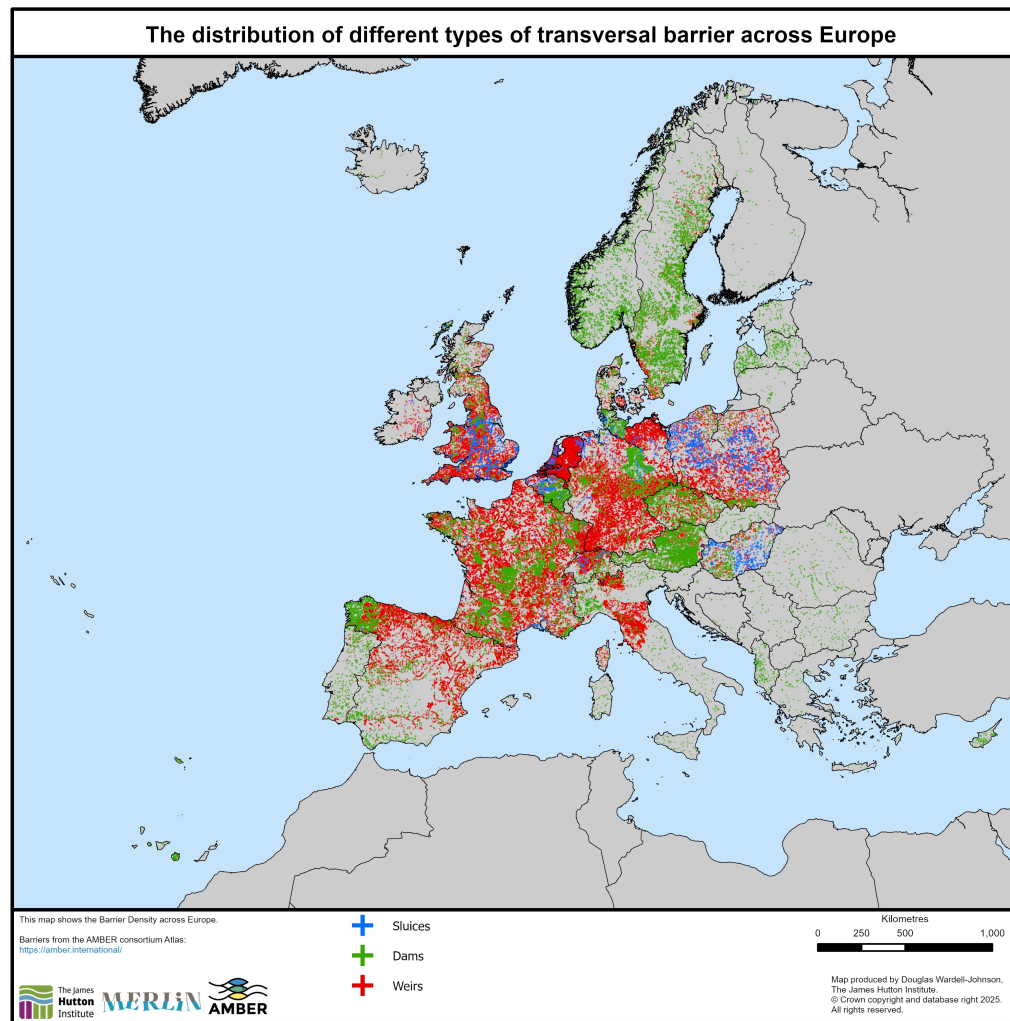


Figure 6: The different distribution of dams, sluices and weirs across Europe

By creating long sections of deeper, slow flowing water, transversal barriers alter ecological processes upstream and downstream. To date there has been strong focus on the impacts of barriers on migratory fish (e.g. Song et al., 2020). Barriers also alter riverine ecosystems in other ways. Ecological changes also arise as barriers hinder the movement of other (non-migratory) species of fish (Birnie-Gauvin et al., 2017, Jones et al., 2021) and can also alter the type and distribution of macrophytes (Jones et al., 2020). Barriers also create hydro-morphological changes in river ecosystems by altering the movement of sediment, nutrients and water (Schmitt et al., 2019). The presence of barriers in river ecosystems can increase GHG emissions, particularly methane, due to the stagnation of water and reduced oxygen level in impounded areas (Maavara et al., 2020). Barriers therefore alter riverine ecosystems upstream and downstream of barriers (Parasiewicz et al., 2023), however, the impacts and how these are perceived by different actors can vary (Gasparatos et al., 2017). While often the focus has been on the impact of large barriers that may still be supporting economic activities (i.e. hydropower production), cumulatively smaller barriers also have a large impact on ecosystem integrity of river ecosystems, even more so given their high abundance. However, smaller barriers have often in the past been overlooked in strategic planning (Belletti et al., 2020, Manders et al., 2016).

Mitigation action (to reduce the impact of barriers) has traditionally been orientated towards technological solutions, for example by installing fish ladders (Song et al., 2020). However, the effectiveness of such technological solutions is increasingly questioned, for example many are not effective for multiple species of fish, including non-migratory species (Noonan et al., 2012). In addition, there are ecosystem level impacts (Magilligan et al., 2016) with the homogenisation of riverine habitats, particularly where multiple barriers are found in close proximity (Belletti et al., 2020). Such changes can reduce socio-ecological resilience within catchments (van de Bund et al., 2024), for example by hindering some ecosystem services that could support local economies and help communities better adapt to a rapidly changing climate (IHA, 2019, Hydropower Sustainability Secretariat, 2021).

There are many transversal barriers currently found within Europe's rivers than those involved in hydropower production. While the link between human activities and barriers may be readily evident in some contexts, many smaller barriers (i.e. with a low head of water) are also historic, with no direct link to current economic activities and may be in a state of disrepair (Belletti et al., 2020). Some of these barriers could be utilised in the future, for example for small hydropower production, however in practice such action may not always be economically viable. This highlights the many opportunities that potentially exist for strategic barrier removal.

A growing number of actors are turning their collective efforts to removing barriers (Mouchlianitis, 2023). Underlying motivations driving barrier removal can vary. To date this has involved actors from the public Sector (e.g. local government with roles and responsibilities key to implementing the EU Water Framework Directive), the third Sector (i.e. environmental non-government organisations and community groups) and from the private Sector, including private foundations and renewable energy companies with sustainability as a core business model (UPM, 2023, Mouchlianitis, 2023). While barrier removal action is often framed around addressing the negative ecological impacts of barriers on river ecosystems, particularly on migratory fish species, in some contexts, barrier removal can also help improve resilience to the impacts of climate change.

To support more strategic barrier removal action there has been a strong focus on developing tools to inform decision making at the catchment scale. Often the focus is on the movement of fish although other factors to assess river connectivity are also starting to be incorporated. Examples include tools being developed within the [EU Dammed Fish project](#) aimed at evaluating structural and functional connectivity of rivers at a catchment scale for improving biodiversity and biotic quality of European rivers (Branco et al., 2022). Another example is [The Nature Conservancy Aquatic Connectivity Assessment Tools](#) (The Nature Conservancy, 2018), now being adapted to the European context.

Box 2: Landscape changes driven by the removal of the Maisons Rouges in the River Vienne catchment in France

Historically populations salmon, shad, sea lampreys and eels were found in the Vienne River. However, in the 1920's a 3.8 metre transversal barrier was constructed to supply energy for a nearby paper mill. This created a total area of 15km of deep, slow flowing and stagnant water. To mitigate the impacts on fish populations three separate fish passes were installed but to little effect. The energy company EDF began utilising the barrier in 1948 but in 1993 the financial viability of operations had reduced and it was identified as a priority barrier for removal. Following 4 years of stakeholder engagement, the main transversal barrier and three sluices were removed in 1999, led by the government, funded by EDF and the public Sector. Following removal, monitoring was undertaken to understand changes in hydromorphology and sedimentology, with improvements in macroinvertebrate, fish and riparian vegetation communities highlighted. Initially, due to the volume of sediment that had built up around the barrier there were some sediment accumulations in the vicinity of a bridge downstream but any negative impacts quickly abated. Since the barrier has been removed, riffles and gravel islands have formed in the river channel and bank side vegetation has established and matured locally and further from the site. A landscape scale assessment highlighted a significantly different landscape aesthetic and visitor experience from before removal.



Sources: Onema (2010), ERN (n.d.), Dam Removal Europe (n.d.)

Examples of barrier removal by hydropower companies do exist. However traditionally such actions have often been driven by the need to comply with regulatory obligations, such as Health and Safety regulations, the EU Water Framework Directive (2000) or EU Habitats Directive (1992). For example, following safety concerns the energy company EDF removed the [Saint-Etienne-du-Vigan Dam](#) (ERN, n.d.-b) and also removed [hydropower barriers in the Sélune river](#) in France (ERN, n.d.-a). Implementing barrier removal measures enhances connectivity and can enhance long term benefits (see Table 2).

The social and ecological benefits of such action by hydropower companies for local communities are often included in sustainability reports and publicised, yet action is often still strongly driven by compliance (e.g. UNIPER, 2021).

A few hydropower companies have already recognised the opportunities that can arise for hydropower companies by removing barriers to restore free flowing river sections. This action is voluntary, going beyond barrier removal driven by compliance and as a traditional mitigation measure. One example is [UPM's Stream Water Programme](#) in Finland (UPM, 2024a, UPM, 2023, UPM, 2024b). Such early adopters are starting to highlight a credible pathway for working with nature driven by the benefits arising for the company.

The following section (section 2) explains the current situation in relation to Sector challenges and potential benefits that could be incorporated into NbS programmes with barrier removal.

2 The Current Situation: Sector challenges and potential benefits

Societal challenges include a rapidly changing climate and a loss of ecosystem integrity. These challenges intersect with challenges experienced within the Hydropower Sector. Multiple challenges are being experienced by those seeking to sustain and develop hydropower activities across Europe. These challenges relate to increasing social and political expectations placed on the Sector and operational challenges linked to ecological and political processes.

2.1 Socio-political challenges and potential benefits for the Sector

Social perceptions of how river ecosystems are managed vary over time, (Wei et al., 2017), across geographies and between different groups, including perceptions of hydropower itself (Cortés-Espino et al., 2023). Recognition of the multiple views and interests relating to the management of riverine ecosystems has led to an increasing emphasis on more holistic catchment management (Hassanzadeh, 2019), for example through integrated river basin management, which has now become a widely accepted approach Sector (Walker-Springett et al., 2016, Yang et al., 2021). There are also increasing political expectations on the Sector to balance renewable energy generation with other societal goals such as reversing the loss of biodiversity, reflected in the objectives of the EU Green Deal (European Commission, 2019) that sets a long term direction of travel for the European Union. Furthermore, a range of policies have also recently been developed that explicitly aim to enhance the sustainability of business activities, notably EU Taxonomy (2020) and the EU Corporate Sustainability Reporting Directive (2022). This is in addition to the suite of nature restoration policies and energy and climate change policies already considered important in the Hydropower Sector (see Table 2).

Table 2: Brief summary of different EU policies relevant to the Hydropower Sector and freshwater ecosystems. Additional sources: Blackstock et al. (2023), Stoffers et al. (2024)

EU Policy	Key objective	Reference to the Hydropower Sector/ infrastructure	Link to NbS/ freshwater ecosystem restoration
EU Renewable Energy Directive (2023)	Transitioning the energy system away from fossil fuels	Role of current hydropower identified. Strategic importance of hydropower in balancing renewable energy production some MS recognised	Mitigation measures are required at hydropower plants to reduce their environmental impacts.
EU Climate Law (2021)	Achieving climate neutrality	Need to transition to a safe, sustainable, affordable and secure energy system relying on the deployment of renewables	Ecosystem restoration to maintain, manage and enhance natural sinks and promote biodiversity while fighting climate change via LULUCF (Land Use, Land Use Change and Forestry)
EU Adaptation Strategy (2021)	Address the growing climate-related risks to health, including more frequent and intense heatwaves, wildfires and floods, food and water safety and security threats.	Explicitly highlights the need for the Hydropower Sector to consider the impact of droughts and low flows on energy production	We need science-based, robust ecosystem restoration and management that helps minimise risks, improves resilience, and ensures the continued delivery of vital ecosystem services and features: food provision, air and water purification, flood protection, biodiversity, and climate mitigation. Multiple references to NbS
EU Environmental Impact Assessment	Understand and apply mitigation measures to avoid, reduce or offset significant effects on the environment of a project	Relates to all types of infrastructure development including hydropower plants (construction and/or	Social, economic, ecological, climate and cultural aspects (impacts and benefits) assessed.

(EIA) Directive (2011)		operation as well as decommissioning/demolition).	
EU Framework to Facilitate Sustainable Investment (Taxonomy) (2020)	A classification system that helps companies and investors identify environmentally sustainable economic activities to make sustainable investment decisions.	Hydropower an explicit sub-Sector. Refurbishment of existing hydropower dams requires ecologically relevant mitigation measures. Construction of new on-line dams requires design informed by assessment at river basin scale and of cumulative impacts. Unavoidable adverse impacts need to be mitigated.	Explicit ecosystem features identified as important are status of water bodies within the same river basin, protected habitats and species directly dependent on water, migration corridors, free-flowing rivers or ecosystems close to undisturbed conditions. Climate adaptation solutions are needed and should favour NbS.
EU Corporate Sustainability Reporting Directive (2022)	Ensure large companies and some listed SME's to disclose information on business environment related and social risks and opportunities and on the impact of their activities on people and the environment.	Relevant to all economic Sectors, including the Hydropower Sector .	Requires the disclosure of nature-related impacts on and risks for biodiversity and ecosystems
EU Nature Restoration Law (2024)	Restoration of ecosystems, habitats and to enable the long-term and sustained recovery of biodiverse and resilient nature and contribute to achieving the EU's climate mitigation and climate adaptation objectives	Assess barriers considering socio-economic function, focusing removal action on barriers no longer required for renewable energy production, inland navigation, water supply, flood protection, or other purposes as well as implement other measures to enhance floodplain connectivity to help restore freshwater ecosystem connectivity.	Multiple references to NbS For example: Restoring ecosystems to good condition means providing NbS that help both mitigate climate change and pursue the objectives of the EU Strategy on adaptation to climate change
EU Biodiversity Strategy 2030 (2020)	To put Europe's biodiversity on the path to recovery by 2030 for the benefit of people, climate and the plane For freshwater ecosystems aims restore at least 25,000 km of rivers into free-flowing rivers	Barrier removal as an explicit activity (to restore freshwater ecosystem connectivity). Hydropower Sector role identified as crucial for barrier removal.	Multiple references to NbS For example: NbS, such as protecting and restoring wetlands, peatlands will be essential for emission reduction and climate adaptation.
EU Water Framework Directive (2000)	The good status in all European water bodies. For the surface waters this entails good ecological and good chemical status.	Barriers recognised as compromising hydro morphological conditions. Energy generation activities explicitly linked to Artificial (AWB) and Heavily Modified Water Bodies (HMWB) Use of mitigation measures for hydropower dams for environmental improvements (fish passes, e-flow licence conditions etc)	Core principle is the importance of freshwater ecosystems Good ecological status defined by biodiversity-related criteria, e.g. abundance and diversity of aquatic organisms

EU Green Deal	to transform the EU into a modern, resource-efficient and competitive economy, ensuring that the net emissions of greenhouse gases will be zero by 2050, providing economic growth decoupled from resource use, while assuring that no one and no region is left behind.	None	The key elements are; zero pollution, climate neutrality, clean & secure energy, industry & circular economy, ecosystems & biodiversity, food system (Farm to Fork), sustainable building & renovating, smart mobility; along with sustainable financing and just transition. General reference to NbS
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In terms of nature restoration policies, the EU Water Framework Directive (2000) identifies hydropower as a key Sector for enhancing good ecological and chemical status of sections of river and this has helped drive some action by the Sector. Other nature restoration and climate policies include an explicit focus on NbS, specifically the EU Nature Restoration Law (2024) and related EU 2030 Biodiversity Strategy (2020), the EU Climate Law (2021) and related EU Climate Adaption Strategy (2021). In the EU Climate Adaptation Strategy (European Commission, 2021b) there is a strong focus on NbS for economic Sectors to adapt to the impacts of climate change, for example low flows and flooding. Nature restoration policies all recognise the negative impact of barriers on freshwater ecosystems and the relevance of removal measures to restore ecosystem integrity. The focus on barrier removal has also been gaining traction within EU nature restoration policy with an explicit focus on removing obsolete barriers to restore free flowing rivers (FFR) (see Box 3 **Fehler! Verweisquelle konnte nicht gefunden werden.**) in the EU 2030 Biodiversity Strategy and the EU Nature Restoration Law (2024) (European Commission, 2021, European Commission, 2024).

Box 3: Barrier removal and freshwater restoration goals within EU policy

The EU 2030 Biodiversity Strategy complements the Water Framework Directive and includes a target for *at least 25000 km of rivers to be restored into free-flowing rivers by 2030 through the removal of primarily obsolete barriers and the restoration of floodplains and wetlands.*

Barriers are understood as *artificial physical obstacles likely to have an impact on river ecosystem connectivity*. These are structures that relate to, either now and/ or in the past, to different economic activities, for example irrigation for farming; the management of drinking water supplies; or to aid inland navigation for trade and/or recreation. Within the EU 2030 Biodiversity Strategy '**obsolete barriers**' are defined as *barriers that no longer fulfil their original purpose or they are no longer needed*. In the EU Nature Restoration Law obsolete barriers are defined as artificial barriers that are no longer needed for renewable energy generation, inland navigation, water supply or other uses.

The EU Nature Restoration law (2024) defines '**free-flowing river**' (FFR) as *a river or a stretch of river the longitudinal, lateral and vertical connectivity of which is not hindered by artificial structures forming a barrier and the natural functions of which are largely unaffected*. For this purpose, **longitudinal connectivity** refers to the capability of rivers to guarantee (i) the continuity of sediment discharges, and (ii) the upstream and downstream movement of fish communities, considering both the natural seasonality and the direction of fish migration. **Lateral connectivity** is understood as the capability of rivers to perform the physical processes of (i) flooding (possibility of overflowing, i.e. presence of a floodplain) and (ii) erosion (hence, lateral mobility). **Vertical connectivity** concerns the exchange of water, nutrients, matter and organisms between the river and the aquifer via infiltration within the hyporheic zone, which is always present when the riverbed is composed of permeable sediments.

The type of barriers and their impact on the flow of water within a river system varies. Barriers that hinder longitudinal connectivity include those that transverse river channels to control water levels. Such transversal barriers involve dams which vary in their capacity to store water beyond the mean daily inflow, weirs and sluices linked to various economic activities. The function, height and storage capacity of transversal barriers varies. River crossings (bridges, fords and culverts) and sills and ramps are also highlighted in policy as potentially hindering longitudinal connectivity. Bank protection and embankments are identified as a hindrance to lateral connectivity, whereas loss of vertical connectivity is associated with riverbed revetment (e.g. when concrete has been placed along the bed of the river).

Sources: European Commission (2024), European Commission (2021), van de Bund et al. (2024), Lutter et al. (2024), Quaranta et al. (2024b)

Thus, political expectations in relation to environmental sustainability, NbS and barrier removal are growing for the Sector. Nature restoration policies also however explicitly recognise that some barriers are necessary for economic activities, including for the production of hydropower. This continued role for hydropower is also set out in the EU Renewable Energy Directive (2023) to help balance the renewable energy mix.

This shifting perspective between, on one hand the role of hydropower and the role of barriers in economic activities more generally, and on the other hand a focus on barrier removal creates a challenging policy landscape for the Sector to interpret and navigate. The focus on economic Sectors adopting an NbS approach however is more consistent, albeit partial across policy domains (see Table 2). This suggests that within the current policy landscape, an NbS approach could help shape a credible pathway for the Sector to better balance multiple policy expectations across renewable energy and environmental sustainability policy domains.

The need to avoid, reduce and/ or compensate for the negative ecological impacts of physical developments, e.g. either from building new barriers for hydropower or increasing capacity at existing hydropower plants, is recognised across policy domains. However, socio-ecological impacts will vary across geographies, and some impacts are more difficult to compensate, e.g. loss of fish populations (Hermoso and Filipe, 2021). Politically therefore there is increasing recognition of the need to go beyond harm mitigation at the site level with a shift towards wider, catchment perspectives to understand, manage and reduce impacts and act in ways that actively supports the recovery of freshwater ecosystems. This increases the relevance of off-site action (i.e. across a catchment) for the Hydropower Sector.

Hydropower licences set out conditions for operations for the deliberate, controlled and regular release of water stored in reservoirs (i.e. from large dams) to maintain downstream ecological flow requirements, e.g. for flow sensitive species such as salmon (Alexandra et al., 2023). These conditions are referred to as environmental flows (or e-flows) and aim to help manage trade-offs in riverine ecosystems between hydropower production, ecology and local livelihoods. These compliance requirements will become more challenging to meet with climate change, particularly in arid and semi-arid regions (Bhuiyan, 2022). Furthermore, in some MS Water Framework Directive implementation processes require more stringent environmental conditions for hydropower operations (Puharinen et al., 2024). This increases compliance challenges for the Sector that may require additional investment to achieve, thus creating further challenges for the Sector, particularly for small operators (Xu et al., 2023).

In summary, within nature and sustainability related EU policy a focus on barrier removal has emerged, as has a focus on NbS that entails viewing nature and natural processes as a way to help tackle social challenges. The focus on barrier removal in policy highlights its potential relevance as a mitigation measure in the Hydropower Sector. However, socio-political expectations have begun to shift towards nature positive approaches within the private sector for harm management to enhancement (Arlidge et al., 2018, Nisbet and João, 2022, Cares et al., 2023). The emphasis on NbS in sustainability related policy aligns with this shift as does the EU Sustainable investment Taxonomy (2020) (Dusík and Bond, 2022). Thus, barrier removal can be seen both as a traditional mitigation measure to enable the Sector to comply with legal frameworks by contributing to the restoration of river connectivity. This could involve any barrier, not necessarily a barrier associated with hydropower production. However, when linked to an NbS perspective barrier removal could also provide a pathway for the Sector to create additional, diverse, multiple strategic benefits by enhancing ecosystems (see summary Table 3 below).

Table 3: The mitigation hierarchy, barrier removal and an NbS approach (adapted from: Cares et al. (2023), Glasson and Therivel (2013)).

Mitigation level	Examples of application of barrier removal as a measure
Avoid: Prevent creating impacts from the outset	Not applicable for strategically important hydropower operations
Minimisation: Reduce the duration, intensity and/ or extent of impacts	The removal barriers upstream or downstream of strategically important hydropower operations to help reduce ecological impacts from expansion of hydropower
Remediation: Restore/ rehabilitate degraded ecosystems	The removal of a hydropower barrier once operations cease for localised recovery of natural processes (i.e. hydro morphological and ecological), increasing connectivity and habitat diversity

Offset: Compensate for any residual significant adverse impacts	The strategic removal of barriers elsewhere (within the same catchment or other catchment) to balance out unavoidable impacts arising from strategically important hydropower operations
Enhance: Apply measures to create new benefits (i.e. adopting an explicit NbS approach)	The strategic assessment of and removal of barriers (e.g. that are considered obsolete/ economically unviable) alongside other measures to deliver diverse and multiple benefits for the sector (e.g. linked to socio-political sector challenges and/ or operational challenges for hydropower facilities within a catchment)

Therefore, contributing to strategic barrier removal could benefit the Sector by supporting greater alignment across the increasingly overlapping policy domains of renewable energy, nature restoration, climate change and business sustainability. An NbS approach with barrier removal could therefore help the Sector to better navigate this dynamic and complex policy environment.

Social benefits could also be linked to an NbS approach with barrier removal. For the Sector reputational benefits could also arise from the Sector's involvement in NbS programmes. For individual Companies, relational benefits could also be created by working with partners (e.g. local communities, other businesses/ sectors and organisations with expertise in delivering socio-ecological enhancements).

2.2 Operational challenges and potential benefits for the Sector

Operational challenges (i.e. to maintain hydropower production capacity) also arise in the use of transversal barriers for hydropower. Such challenges require continuous management, for example to remove the build-up of sediment. Nutrient retention (including carbon, phosphorus, or nitrogen) in dammed areas can also lead to the release of greenhouse gases (Ruokamo et al., 2024). This can cause challenges for the Sector in terms of deteriorating water quality and the release of greenhouse gases from hydropower production counteracts the Sector's contribution to net zero. Increasingly alternative management options involving the enhancement and utilisation of natural processes within catchments are being explored and shown to be cost effective to support hydropower production, for example by applying measures such as peatland restoration, riparian planting and catchment scale tree planting (Williams et al., 2024).

Climate change often amplifies these operational challenges with more extreme and frequent fluctuations in water levels within catchments (IRENA, 2023). For example, Opperman (2022) found that 26% of existing and 23% of planned hydropower barriers are within catchments that currently have medium to very high risk of water scarcity. Additionally, 75% of existing and 83% of planned hydropower barriers are in catchments with a medium to very high risk of flooding. This makes balancing water levels for hydropower production whilst complying with licence requirements increasingly difficult to manage. For example, in Romania, where low river discharges are expected to cause a decrease by 11–30% of the hydroelectricity production by 2050 (Costea et al., 2021). The build-up of sediment and low water levels need to be well managed to maintain the capacity of a dam to produce hydropower, otherwise the costs can quickly outweigh the economic viability (IRENA, 2023). These social, political and operational challenges experienced by the Sector can increase multiple intersecting types of business risk within the Sector, such as financial, reputational and compliance risks (Miller et al., 2024).

In summary, transversal barriers regardless of their function, both singularly and cumulatively alter natural processes within riverine ecosystems. The removal of barriers enhances river connectivity and biodiversity and restores more natural hydromorphological processes. Strategic barrier removal could therefore be approached as part of a wider strategy by Hydropower companies to reduce and manage operational challenges linked to the localised environment (e.g. within a catchment or sub catchment). For example, to reduce nature related risks and increase hydropower resilience in the context of a rapidly changing climate. Strategic barrier removal therefore could help the Sector tackle a range of challenges (see Figure 7 below)

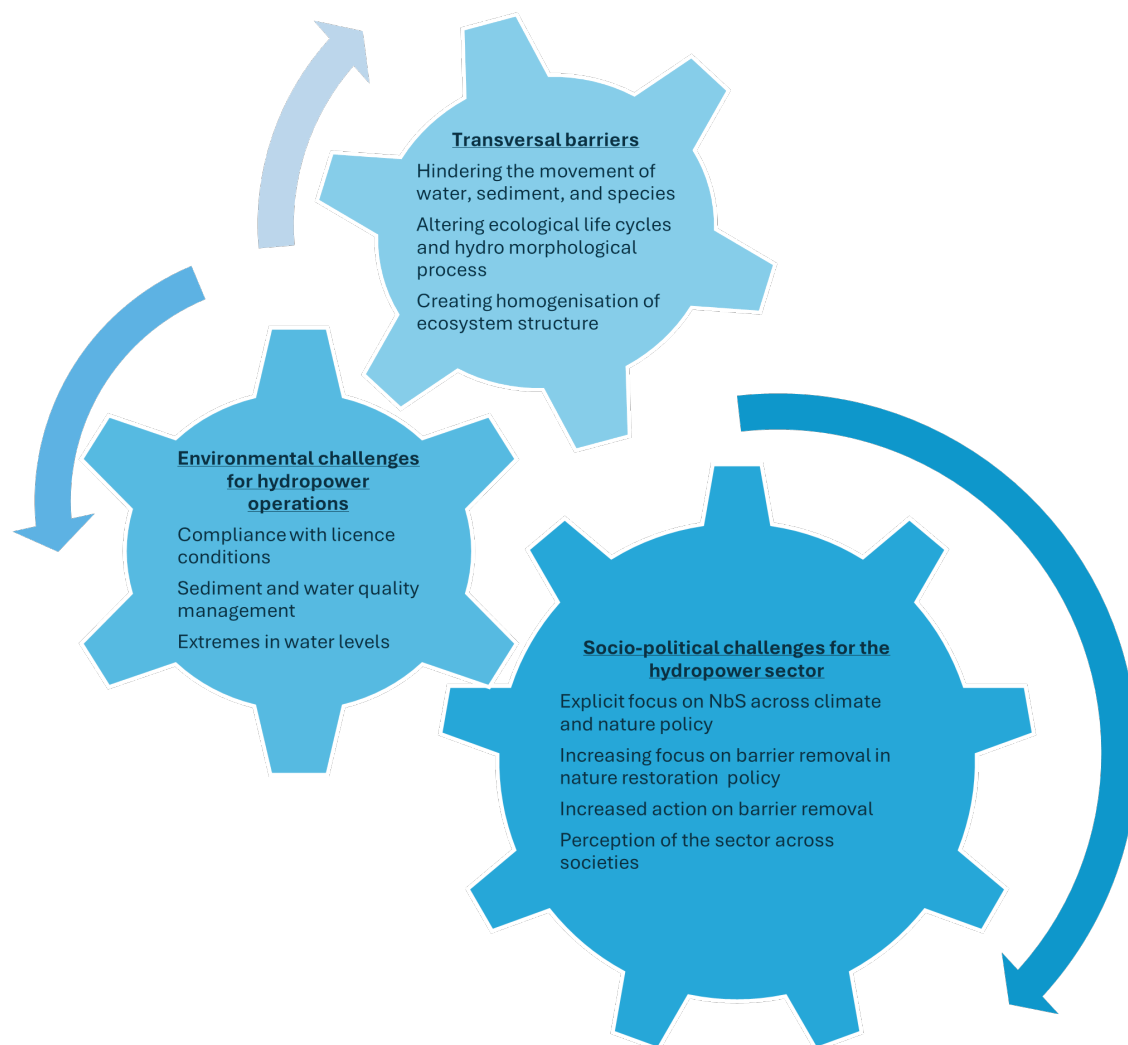


Figure 7: Interconnections between societal environmental challenges, challenges for the Hydropower Sector and the effects of transversal barriers on riverine ecosystems

3 Methodology

A central part of the methodology for developing this Strategy entailed bringing together different actors from the Sector to share ideas, explore challenges and opportunities. This collaborative approach aimed to support collective learning to foster in the longer term an NbS community of practice¹ for the Hydropower Sector (Wenger et al., 2002, Bérczi-Siket A. et al., 2023).

Fostering networks of diverse actors to champion alternative ways of thinking and acting within a particular setting, such as an economic Sector, to support sharing, reflection, learning and collective action is widely recognised as an enabler for guiding transformation and for mainstreaming NbS (Hölscher et al., 2019, Wolfram, 2016). There are private Sector frontrunners (early adopters) from within the Sector who already recognise the business benefits that can arise from barrier removal and thus framing such action in terms of an NbS approach. These Sector frontrunners, Sector representative networks and associations and other NbS proponents working with the Sector (i.e. environmental NGO's and researchers) were invited to participate in exploring what types of institutional change is needed to encourage wider uptake of taking an NbS approach to barrier removal across the Sector. Invitations were distributed widely to also involve hydropower companies interested in adopting barrier removal measures to strengthen an NbS approach within their own company settings. In total 21 different organisations (36 individuals) actively participated in the roundtable discussions, including 8 private Sector organisations (hydropower companies and representative bodies) (see Annex 1).

The process for developing this Strategy primarily involved a series of three roundtable discussions with multiple stakeholders from the Hydropower Sector (see Figure 8). Literature relating to the Sector, barrier removal, and NbS was reviewed before the first roundtable and, alongside roundtable discussions, interviews were also held with key stakeholders, for example from the European Commission and with barrier removal practitioners.

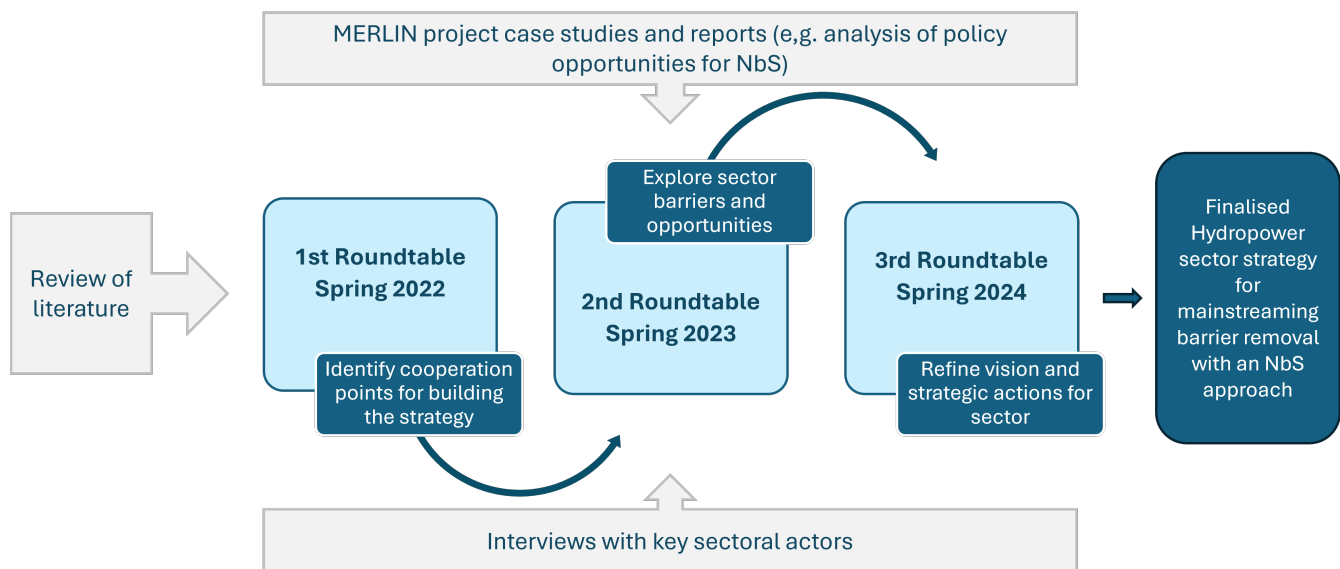


Figure 8: The methodology used to develop this Strategy

Following each roundtable, reports were developed outlining the main discussion points and circulated to participants for comment before being finalised (see Blackstock et al. (2022), Carmen and Nyíró (2023) and Carmen (2024). A policy analysis at the EU and MS level for the six MERLIN economic Sectors was also undertaken (Blackstock et al., 2023).

Discussions in the first roundtable (RT1) focused on general trends within the Hydropower Sector, sustainability in the Hydropower Sector and small barriers (Blackstock et al., 2022). An example from Sweden of barrier removal action was also presented. The primary aim of this first roundtable (RT1) was to identify cooperation

¹ A community of practice are actors with shared concerns, challenges, or passions about a topic who continue to deepen their understandings and activities in this area through ongoing interaction. .

points (Box 4), providing a structure to orientate deeper exploration of issues and opportunities in the subsequent roundtable discussions in 2023 (RT2) and 2024 (RT3).

Box 4: Cooperation points identified from the first roundtable (RT1) to guide the development of the hydropower Sector Strategy

- Help to prepare cost-benefit analysis about hydropower plants which includes externalities as well, such as biodiversity degradation and socio-economic impacts.
- Offer tools to the Sector based on cost-benefit analysis on where to remove or refurbish economically no longer viable dams.
- Draw on existing examples of dam removal (such as the La Roche qui Boit example above) to develop understanding of NbS and barrier removal across the Sector.
- Work to support the development of cross Sector partnerships involving hydropower organizations for more holistic approaches and large catchment scale NbS for restoration through barrier removal.
- Develop an understanding about key entry points into decision making processes about future economic viability of dams to ensure consideration of NbS as an option.
- Develop an understanding and awareness of different finance mechanisms for supporting dam removal and NbS as a financially feasible path for the Sector.

The second roundtable (RT2) introduced a more explicit focus on exploring obsolete barriers as an opportunity for action led by the Sector and included a focus on an example of a barrier removal programme developed by an energy company (Carmen and Nyíró, 2023). Other issues explored were decision-making processes and tools, cross Sector collaboration and financial resources. The third roundtable (RT3) involved an example of a decision support tool in use in Finland, with discussions structured around the proposed vision and strategic action areas which were shared in a document with participants before the event (Carmen, 2024). Following RT3, a bilateral meeting was held with a key sector representative organisation to help better understand views within the Sector on key aspects of the strategy. A draft of the strategy was then circulated to participants in November 2024 who were given 2 weeks to provide feedback. The bilateral discussion and written feedback following on the November 2024 draft strategy highlighted some key points of contestation from the Hydropower Sector towards the focus of the strategy on barrier removal, the methodology applied and contents of strategy (see Annex 8.2 for a summary of all feedback received in response to the November 2024 draft). This feedback was invaluable and guided the authors of this strategy in the development of the final version. Despite this some sector representatives remained unhappy and requested their participation in the process remains confidential. Some names in the participant list have therefore been redacted to respect these wishes.

The overall aim was to work with the Sector to develop strategic actions that together could lead to deeper and more widespread uptake (i.e. mainstreaming) of barrier removal within an NbS approach (i.e. driven by benefits from the Sector). To guide identification of sub actions, key features and action types involved in transformation processes were used heuristically to reflect upon possible gaps (Carmen et al., 2024) (see the full framework and practical matrix in Annex 8.1.1).

Critical to any strategy is a vision to help develop actions, guide implementation and to aid an iterative approach (i.e. evaluating progress and adapting strategies). A strategic vision for 2030 (the timeframe for this strategy) and a longer-term vision for 2050 is presented in the following section.

4 Strategic Vision

A strategic vision creates a shared understanding of the overall direction of travel for change, setting expectations for groups of actors on the pace and scope of change proposed 2. This may also involve interim objectives and actions to recognise the complexity of large scale change and the need for an iterative approach (Fuenfschilling and Truffer, 2016). The overall strategic vision for this Hydropower Sector Strategy aligns to the EU Green Deal 2030 and 2050 timescales.

The long-term **2050 vision** for the Sector is: by 2050 for the Hydropower Sector has made an active and significant contribution to the restoration of freshwater ecosystems by taking an NbS approach to barrier removal, working in partnership with other stakeholders in the Sector to co-develop multiple public and private socio-ecological benefits across different catchments, MS and regions of Europe.

Achieving this 2050 vision involves developing supportive institutional arrangements that set out action pathways for the Sector.

Developing the necessary institutional arrangements by 2030 is the aim of this Strategy. Specifically, the **2030** vision is that the Hydropower Sector;

- **Has embedded an NbS approach involving removal of barriers no longer economically viable for hydropower or other economic activities as an explicit activity within company sustainability strategies and guidance.**
- **Has helped create clear delivery pathways aligned to an NbS approach at the MS and EU level, working with other actors to better organise the removal of barriers which are no longer necessary.**
- **Is contributing to and leading the designing and delivering NbS programmes to remove barriers that are not economically viable for the future.**
- **Is sharing and developing knowledge, learning and building the necessary skills and expertise within the Sector to contribute to more ambitious action led by the Sector.**

The following sections present the proposed strategic actions for achieving this 2030 vision with the Sector.

5 Strategic Actions

To better enable the Hydropower Sector to take an NbS approach to barrier removal the following five strategic actions are proposed.

- A. Increase understanding of an NbS approach to barrier removal
- B. Highlight synergies between energy/climate change and nature restoration policies
- C. Develop finance pathways guided by an NbS approach
- D. Build Sector capacity for leadership and collaboration
- E. Provide Sector specific tools to design NbS programmes with barrier removal

Each strategic action is explained in the following sections (also see Table 4: A summary of the actions identified in this strategy Table 4). For Strategic Action C no clear way forward was identified, instead different options are presented to inform action. For each Strategic Action potential implications are also explored to draw attention to aspects of actions that, if not considered in the implementation process, may hinder progress towards the 2030 and 2050 vision.

Table 4: A summary of the actions identified in this strategy

What is the action?	Lead implementing actors	When should action be delivered?	Where?
Strategic Action A: Increase understanding of an NbS approach to barrier removal → Communicate what this entails by linking to existing examples of NbS interventions from the Sector → Use evidence to highlight the type of benefits that can arise from barrier removal and link to examples → Integrate barrier removal as a measure into sector standards and guidance, framed around an NbS approach (i.e. focusing on sector challenges and potential benefits) informed by the IUCN principles	Hydropower Company representative entities, researchers and ENGO's	2026	EU level
Strategic Action B: Highlight synergies between energy/climate change and nature restoration policies → Clarify the role of the Sector in EU Nature Restoration Policy → Clarify the role of mitigation and NbS approaches to barrier removal in EU Renewable Energy Policy → Co-develop sectoral (i.e. Hydropower Sector specific) National barrier removal Strategic Plans with an NbS framing → Integrate a removal condition into licences regulating the use of barriers. → Integrate NbS and barrier removal into National Energy and Climate Change plans (NECP's)	EU policy actors (EU policy links and oversee MS level actions) and MS policy actors from nature restoration and climate change/ energy policy domains. Hydropower Sector representatives	2026	EU level and MS level
Strategic Action C: Develop finance pathways guided by an NbS approach (link to Strategic Action B) → Explore different finance models already in use; ○ Options 1: Cost recovery model ○ Option 2: Sector led model ○ Option 3: Blended finance model → Design MS level finance pathways using the NbS principles and by considering the how incentives influence the distribution of costs and benefits	EU level policy actors (oversight), MS level policy actors from nature restoration and climate change/ energy policy domains. Hydropower companies and hydropower representatives (including	2028	MS level

(ecological and socio-economic benefits in the Sector)	small hydropower representatives)		
Strategic Action D: Build Sector capacity for leadership and collaboration Hydropower operators; → Targeted development of sector examples and evidence to influence decisions at the executive decision makers, linking to corporate responsibilities, sector standards and investment benefits (link to Strategic Action A) → Identify required expertise for companies to design and deliver NbS programmes with barrier removal and ways to build internal capacity MS level Public Sector nature restoration actors (Link to Strategic Action B); → Led meaningful multistakeholder deliberation processes to identify catchment collaborations and to inform the design of sector led programmes (link to Strategic Action B) → Clarify policy related expectations to inform the design of NbS programmes by companies → Collaborate with hydropower companies to overcome institutional obstacles to deliver NbS and barrier removal programmes	NbS and barrier removal early adopters and proponents from hydropower companies and the public sector	2029	MS
Strategic Action E: Provide Sector specific tools to design NbS programmes for barrier removal (link to Strategic Action C & D) → Develop with the sector NbS tools for use by large hydropower companies that include barrier removal. → Ensure tools are relevant, useable and accessible by different companies → Ensure tools adopt a catchment scale perspective and help understand cumulative outcomes and are informed by evidence For small hydropower operators; → Adopt (and potentially adapt) tools to assess present and future economic viability of hydropower operations to inform their decision-making on whether to continue or retire	Hydropower Sector representatives, multidisciplinary researchers and ENGO's	2028	MS level

5.1 Strategic Action A: Increase understanding of an NbS approach to barrier removal

The first strategic action focuses on increasing understanding across the Hydropower Sector on what barrier removal within an NbS approach entails. This is necessary as understanding varies within the Sector about what is an NbS approach undertaken by hydropower operators (i.e. action motivated by the diverse social-economic benefits that can arise from working with nature) and the potential socio-ecological benefits of barrier removal. The success of subsequent actions hinges on this understanding and requires sub actions that are explained in the following sections.

5.1.1 Communicating by linking to examples and evidence

Understanding of what an NbS approach by the Sector entails varies within the Sector. There is a need therefore to clearly communicate across the Sector what taking an NbS approach to barrier removal involves, i.e. *“that it’s about pragmatic solutions and that it is about coming up with good solutions”* (Hydropower Sector representative, RT2). The focus of action needs to involve a clear emphasis on an NbS approach as a different way of thinking in the Sector about working with nature, with action by the Sector primarily driven by the potential benefits that can arise for the Sector (see section 1.3). For example, *“sometimes these nature-based solutions are also cheaper....from an economic perspective considering alternatives... [it’s] one of the possible ways you can improve the condition around your plant”* (Researcher, RT3).

Drawing on existing examples of where *“hydropower plant owners benefit if some weirs are removed”* (Hydropower Sector representative, RT2) could help enhance understanding in the Sector on how barrier removal could fit with an NbS approach. This should highlight the benefits of the removal of obsolete barriers (that may or may not have been linked to hydropower activities). Also highlighted should be the opportunities for small hydropower operators to benefit from funding programmes to support the removal of barriers that are no longer considered economically viable for the future. Lastly, the removal of barriers by and for the Sector to maintain and enhance capacity should also be identified, as one roundtable participant highlighted, *“in Germany for example....[a company] said yes we’re going to remove this one hydropower plant...and this was a mutual agreement without any problems because of these kinds of economic benefits, but it was from an ecological point of view much better.... [as] further downstream [there was] another hydropower plant which would then be much more effective so it was kind of like a win-win situation”* (Hydropower Sector representative, RT2). Examples also need to highlight how barrier removal could be integrated into NbS programmes alongside other measures that together are better able to address Sector challenges within a catchment than single measures and by working at single locations. A useful way to present this could be to contrast an NbS approach involving barrier removal to traditional restoration approaches (see section 1.3) and traditional technological approaches widely used in the Sector.

Developing a catalogue of evidenced examples can also help dispel some simplistic assumptions about the benefits of retaining barriers in some contexts. For example, one RT participant commented *“I was involved in a project restoring a small (lowland) river ...and there they believe that the barrier itself would....in times of low water flow [be].... beneficial, and I think at that time we missed very clear information that this is a was very likely not the case. If you have the stream in....a more natural state it’s not as deep...we have a shallow river with a small content.... I think this gives good arguments for removal of barriers but at the time, a couple of years ago when the decision was taken, that information was lacking”* (Policy actor, RT3). A further example is the relationship between barriers and flood risk and/ or drought conditions is not simple. Some barriers with significant capacity to store water can help reduce peak flows downstream during flood events while other barriers types of barriers and in different geographies may exacerbate flood risk (Ma et al., 2022). Similarly, in some contexts barriers may aggravate drought conditions downstream (Van Loon et al., 2022).

5.1.2 Raising awareness by integrating an NbS to barrier removal into Sector guidance

Furthermore, Sector networks and representative entities could help develop understanding within the Sector about the less tangible benefits of an NbS approach, for example the reputational and relational benefits in the context of increasing social and political expectations for the Sector (see section 2.1). Sector representative organisations have established communication pathways across the Sector and have already developed guidance accepted within the Sector. These could more explicitly apply an NbS framing and draw on examples of taking an NbS approach to barrier removal. For example, Eurelectric has recently produced [Sector guidelines](#) for working with nature (Miller et al., 2024). Furthermore, some companies are already exploring how to better work with nature and have developed guidance to help guide this, for example within Fortum’s biodiversity manual (Fortum, 2020). Further traction for taking an NbS approach to barrier removal could be gained by highlighting potential investment related benefits for business to help align to the EU Taxonomy (European Commission, 2020) and for EU Corporate Sustainability Reporting (European Commission, 2022) (see Table 2). Communication must *“avoid certain vocabularies [that can] trigger really quite a lot of fear and resistance [for*

hydropower operators]” (Hydropower Sector representative, RT2) and this can be avoided if action to enhance understanding is led by Sector representatives.

5.1.3 Proposed implementation actors and timeframe

This understanding is a prerequisite for the implementation of the subsequent strategic actions in this Strategy. A proposed timeframe for achieving this action is therefore 2026. Understanding is needed across the Sector, particularly however within private and publicly owned Sector hydropower companies (who are or could lead the development of NbS programmes). Representatives of these companies are therefore particularly key in delivering this action, supported by other actors such as researchers (i.e. to distil and link clearly to evidence) and ENGO’s with expertise on the links between climate change and biodiversity in relation to transversal barriers.

5.2 Strategic Action B: Highlight synergies between energy/climate change and nature restoration policies

Strategic Action B focuses on highlighting potential synergies between hydropower dimensions of renewable energy policies and nature policy objectives to set out a clearer NbS pathways for action by the Sector. It involves action at the EU and MS levels. This is needed as policy (and policy actors) can influence how actions are seen as relevant by the Sector.

5.2.1 EU Policies: Clarify the role of the Sector

The current EU policy landscape does not currently provide a clear pathway to support the uptake of an NbS approach to barrier removal by the Sector. Many of the building blocks are already in place but links between these are often unclear, as one RT participants commented *“there are these 2 objectives....[currently it seems] if you apply one you will never accomplish the other”* (Researcher, RT2). However, *“if we only see this from a climate energy side then we run the risk of overlooking other targets which are crucial”* (ENGO, RT2).

EU Nature Restoration Policies: Clarify the role of the Sector

In EU nature restoration policies there is a focus on both NbS and the removal of barriers (i.e. the EU 2030 Biodiversity Strategy and EU Nature Restoration Law (2024)). These policies emphasise removing obsolete barriers, defined in the EU Nature Restoration Law (2024) as barriers that are no longer needed for renewable energy generation, inland navigation, water supply or other uses (European Commission, 2024) (see Box 3, page 24). The ambiguity of the term ‘obsolete’, and the relationship between the Sector and barriers was a recurring theme in roundtable discussion. The need to extend the type of barriers considered for potential removal was emphasised (see Strategic Action E on tools for programme design, section 5.5). This was highlighted by one RT participant, who commented *“if hydropower dams [are]...exempt by the Nature Restoration Law I think that is a very biased approach”* (ENGO, RT2). This is important as a narrow focus on removing barriers with no obvious present economic function (i.e. as ‘obsolete’ implies) could lead to missed opportunities, for example to support the removal of hydropower barriers that are becoming increasingly uneconomical to operate. The scope of barrier removal programmes needs to be very clear in policy guidance to clarify the expected role of the Hydropower Sector in meeting the EU target for barrier removal and to guide strategic catchment scale assessments to identify which barriers could be removed. More explicit Sector-specific guidance taking an NbS approach to barrier removal could complement current EU policy guidance on barrier removal for river restoration (see European Commission, 2021).

EU Renewable Energy Policy: Clarify the role of NbS approaches to barrier removal

Highlighting a role for an NbS approach within EU renewable energy/ climate mitigation policies could set out a clearer action pathway for the Sector to work more synergistically with nature. This can clarify role expectations for the Sector to *“at least guarantee that some connectivity exists, so even [for] large barriers connectivity enhancement actions should be taken ...because on some [hydropower] dams we have to agree that we cannot remove, but connecting enhancement actions [such as barrier removal measures and by-pass channels] need to be taken into account and operation should be in line with nature”* (Researcher, RT2).

The role of barrier removal measures could also be clarified as a relevant mitigation action within and between catchments by the Sector. This barrier removal could be undertaken as compensation for unavoidable *“trade-offs [when there is an]....increase [in] the height of a [hydropower] dam in one place then you can remove some other barriers somewhere else... [for] example...in France where through the refurbishment of an existing plant six old plants... have been removed”* (Hydropower Sector representative, RT2). To fit with an NbS approach however there needs to be a focus also on creating *“synergies through integrated projects”* (Hydropower Sector representative, RT2), going beyond a narrow focus on mitigation and compliance challenges to also integrate a

wider range of benefits for business, local communities and biodiversity net gain. This is also beneficial for the Sector as a narrow focus could be *“a red flag [if] ecological compensation [is seen as] greenwashing for companies”* (Researcher, RT2) and the need to act at the ecosystem level is increasingly recognised. This was highlighted by one RT participant: *“Fish ladders may be helpful for fish, but not for the ecosystem, and we now have to think about the ecosystem and ecosystem functions. So, something more has to be done and this kind of barrier removal not on site could be a way for an ecological compensation for Hydropower Sector to do something good”* (Researcher, RT3). Barrier removal within an NbS framing could also be identified in policy guidance for the Sector linked to the EU Sustainable Finance Taxonomy (European Commission, 2020) and EU Corporate Sustainability Reporting Directive (2022) (European Commission, n.d.) as an example of how the Sector can better manage impacts and risks linked to nature and the climate.

5.2.2 MS policies: The role of the Sector in barrier removal and NbS

EU policy is implemented at the MS level, thus increasing coherence between national renewable energy and national nature restoration plans is also important. This is needed to clarify expectations and guide the Sector to seek *“win-win solutions”* (Hydropower company, RT1) aligned to the differing contexts found within Europe.

National plans: involving the Sector in barrier removal

The development of National Nature Restoration Plans will entail an assessment of barriers (of all types and functions, not just transversal or those linked to hydropower) to identify barriers that could and should be removed, and those that are still necessary (Stoffers et al., 2024). A Sectoral approach within these plans could support early involvement of the Hydropower Sector and stimulate more ambitious Sector led barrier removal action and could feed into the design of NbS programmes. Bringing relevant strategic stakeholders together (e.g. public water agencies and renewable energy agencies, and hydropower companies and representatives of smaller operators) to explore options and agree priorities. This can help create a shared understanding and thus clarify expectations. This could strengthen collaborative working between the public and private Sector.

In Sweden a strategic plan has been co-developed with the Hydropower Sector focused on improving environmental practice in the Sector (see **Box 5**). This has been significant as *“whatever the future prospects are, it's always better if those prospects are clear”* (Researcher, RT3). This strategic plan is now considered *“the driving force”* (Policy actors, RT1) for action by the Sector, including action to remove barriers. In Sweden *“the lessons learnt is that it's very good to have a National Plan because then we don't have to have a discussion about balancing energy and environment every time we step into hydropower. It's a political agreement.... We have much better discussions based on facts. The previous discussions have not been very constructive and not always facts based”* (Policy actors, RT1). In Sweden, this national plan has led to more ambitious action by the Sector *“[who] actually do a lot of restoration nowadays because of the National Plan. [Even when] it's not part of National Plan...they [may] do it”* (Policy actors, RT1).

A national Sector plan that adopts an explicit NbS framing will involve a strong focus on socio-economic benefits. This is helpful as barrier removal can be contentious and potentially locally fractious. For example, in the Basque Country, Spain, barrier removal² has been a controversial issue ([MERLIN Case Study 2](#)). The learning from this experience has informed calls to develop a national barrier removal movement to strengthen the ability to deliver similar action in the future (Colls et al., 2024).

² This programme focused on historic, obsolete barriers and did not involve the hydropower Sector or barriers linked to hydropower production.

However, an inclusive approach within national Sector plans is important. For example, consideration from the outset of all types of barriers, not only focusing on abandoned, historic structures or ones linked to hydropower functions. There is also a need to consider implications for smaller operators who may have less resources available to change their activities.

Box 5: A national plan for modern environmental conditions for hydropower (NAP) in Sweden

Co-developed: Swedish Agency for Marine and Water Management and National Energy Agency, the hydropower Sector, NGO's and two local authorities between 2014 -2019 and adopted in 2020.

Objective of plan: Hydropower Sector activities incorporate modern environmental provisions in a way that maximizes benefit to the aquatic environment and an efficient supply of hydropower electricity.

Scope: Over 11 000 regulated and unregulated hydropower related barriers

Key dimensions in developing the plan:

- Catchment scale perspective
- Strategic importance of hydropower for supporting transition to renewable energy within the context of wider changes to where, when and how electricity is produced
- Ecosystem services supported by hydropower, including cultural value
- Importance of freshwater ecosystem for climate change resilience
- Negative impacts from hydropower (current and new) including biodiversity, heritage and recreation (with key catchments identified for no hydropower development in future) and impacts on Natura 2000 sites, legally protected species and good ecological status.
- Cumulative impacts including impact connectivity with freshwater ecosystems functions more broadly (i.e. floodplains)
- Safety of hydropower dams
- Importance of ensuring availability to electricity
- Upgrade potential of existing hydropower dams (to increase efficiency and capacity)
- Hydropower license conditions to better achieve environmental standards
- Responsibility of hydropower operators to demonstrate operations do not lead to deterioration of environmental quality and need for operators to implement protection measures to avoid deterioration, including change at existing hydropower plants

Source: Swedish Agency for Marine and Water Management (2019)

A further, different lever for change at the MS level are hydropower licences that set out conditions for hydropower operations. Specific after use conditions could be introduced for the removal of barriers when hydropower operations cease. This sets clear expectations to include removal costs in business planning. There is already a move towards more stringent licence conditions in many European countries, often driven by the EU Water framework Directive (2002). For example, *“in Italy each time a licence is exchanged the...environmental requirements become stricter”* (Hydropower Sector representative, RT2). However, the institutional arrangements vary between MS. In some MS hydropower permits do not have a time limit, such as in Finland where *“hydropower licences are eternal”* (Researcher, RT2) and altering licences can be complex, for example where responsibilities for water management and issuing permits are split between multiple public bodies (Puharinen et al., 2024). However, *“we're seeing in Europe a tendency that the licencing periods are getting shorter”* (Hydropower Sector representative, RT3). Thus, although complex, there is already momentum around changing licence conditions and the NbS approach to licencing could be built into River Basin Management Plan programmes of measures.

MS energy and climate change policy objectives: including NbS and barrier removal measures

A focus on the role of NbS in terms of the benefits to hydropower operations, particularly for adapting to climate change, could also enhance coherence between renewable energy and nature restoration policy objectives to provide a clearer pathway for action by the Sector. Specifically, this could be made explicit within National Energy and Climate Change plans (as a core requirement under the EU Climate Law (2021). Including examples of measures from MS restoration plans could help this connection with an NbS framing to show the

relevance of barrier removal measures (alongside other measures) for the Hydropower Sector. This can be particularly important to guide investment decisions in contexts where hydropower is a priority, with increasing operational challenges and where NbS may be a particularly novel idea. For example, the operation of hydropower plants by 3 public energy companies has altered the hydrology of the Hutovo Blato Wetlands ([MERLIN Case Study 6](#)) causing drying out of 2,128 km² of wetlands. Within current MS energy policy hydropower operations are identified for expansion (WWF Adria, 2022).

5.2.3 Proposed implementation actors and timeframe

Nature Restoration Law MS are due in 2026, therefore the proposed timeframe for delivering this strategic action is 2027. Enhancing policy coherence at the EU level needs to include EU policy actors from DG Energy, DG Clima and DG Environment, alongside the Sector representatives and other supporting strategic actors (i.e. ENGO's and researchers).

Similar types of actors should be involved in enhancing coherence at the MS level between nature restoration policy objectives and energy/climate change policy objectives via the development of national Sectoral plans and hydropower regulations. Private Sector companies and representatives already orientated towards enhancing sustainability and adopting an NbS approach, particularly involving barrier removal, may provide important insights. Stakeholders with expertise in NbS for climate adaptation could provide expertise but could also adopt a mediation role to help build connections between policy domains that may not have worked together much in the past.

5.3 Strategic Action C: Develop finance pathways guided by an NbS approach

Strategic Action C focuses on creating clearer finance pathways to support programmes involving barrier removal within the Hydropower Sector. This is important as barrier removal can be costly. Business decisions are strongly guided by an understanding of costs and benefits to the business. Many factors influence strategic decisions and this includes finance incentives that favour some types of action over others. Finance pathways need to be designed to support action by those in the Sector with resources (i.e. large corporations) and to enable those with fewer resources (i.e. single hydropower barrier operators) to also benefit. Of particular importance for larger hydropower operators is the need to align finance to an NbS approach (i.e. via the IUCN principles – see page 16, Box 1) and clear links to policy requirements, for example the EU Taxonomy (2020). Finance pathways can entail a mix of finance mechanisms (i.e. different instruments and sources) and be designed to support stronger collaboration, for example between the public and private Sector. Creating effective financial pathways entails many considerations. Thus, this section sets out three existing finance models already in use, highlighting key implications with the aim of better informing the design of MS level Sector specific finance pathways.

5.3.1 Option 1: Cost recovery finance model

The first type of model focuses on collecting resources from Hydropower Sector (and potentially other Sectors) through a bespoke cost recovery mechanism. Such a model could utilise the hydropower licence fees, WFD cost recovery mechanisms (article 9) or national tax systems. As highlighted in strategic action B in section 5.2, institutional arrangements for hydropower licensing can be complex. Furthermore, use of the Water Framework Directive cost recovery mechanisms also varies across MS (Schmidt G. and Rogger M., 2021) and is insufficient for delivering the action needed in the context of accelerating socio-ecological challenges such as climate change (Farnault and Leflaive, 2024). In France a water tax (see Box 6) has been in use since the 1970's and has been instrumental in enhancing freshwater ecosystems, including through support of barrier removal initiatives.

Box 6: Water Users Tax in France

In France a water tax has been in place since 1964 and follows what is referred to as the water-pays-for water principle. This fund is created from “*water bills and...everybody's who's utilising water, whether it's in the cities or whether it is industry or hydropower, they have to pay for the water they use, it's essentially a tax*” (Researcher, RT3). First introduced to improve water supply and sanitation infrastructure, the fund alongside its underlying legal framework, evolved to encompass a wider remit to freshwater ecosystem restoration. This has resulted in “*many small river restoration [actions],....there are many obsolete barriers in France dating back almost millennia, and they have been able to remove those largely thanks to this fund*” (Researcher, RT3). The fund administered nationally and allocated regionally by the public Sector. Some critics however highlight a lack of coherence between the amount of taxes paid within a Sector and the incentives provided under other policy domains, notably in relation to the agriculture Sector.

Additional sources: Bommelaer and Devaux (2012), Thomas and Zaporozhets (2017)

Such finance pathways gather resources from all regulated hydropower operators, thus careful consideration on accessibility and distribution of funds (and thus benefits) is needed, particularly for smaller operators. Furthermore, not all water users require regulation, although large and medium hydropower operators are likely to be included in regulatory framework. As per the French Water Users Tax, this model could also include finance sourced from and thus accessible to other economic Sectors and therefore could be designed to support cross Sector collaboration. If unregulated smaller operators could and should access such funding is however an important design consideration.

5.3.2 Option 2: Sector led finance model

A second model that could inform the development of finance pathways at the MS level entails an element of self-organisation by the Sector to develop and administer a bespoke fund. This could focus on barrier removal or include other measures like bypasses. An important consideration is how to support the uptake of an NbS approach to guide more action by the Sector. Developing this type of Sector driven finance model may hinge on preconditions “*so the Sector is [positioned as] a partner*” (RT2, Hydropower Company) alongside the public Sector, and where the expected role of the Sector in removing barriers and for adopting an NbS approach is clear across policy domains (see Strategic Action B, section 5.2.2). This type of finance model is applied in Sweden **Box 7: The Hydroelectric Environment Fund in Sweden**. The advantage of this finance model is that the Sector collects and distributes funds. A strong focus on sharing benefits with small operators, leading to the removal of some smaller hydropower barriers has also been incorporated in this model in Sweden. Cost neutrality however is likely to be an important factor for the Sector for establishing this type of model.

Box 7: The Hydroelectric Environment Fund in Sweden

The Hydroelectric Environment Fund is a €1 billion fund established by 9 hydropower companies and emerged from their participation in the development of the Sweden's National Plan for Modern Environmental Conditions for Hydropower (see Box 5). In parallel *"the hydropower Sector got a tax break of about the same quantity as the funds will be, so it's almost sort of cost neutral for the Sector"* (Researcher, RT3).

The fund provides up to *"85% of the environmental costs for the hydropower plant and also the [licence] revision process"* (National water management agency, RT1) and therefore aims to create *"a more economically feasible situation"* (Policy actor, RT1) for delivering environmental measures, particularly for smaller hydropower operators where new requirements for environmental measures may result in additional financial burdens.

The type of measures supported by the fund reflect those considered within the national hydropower plan. This fund has supported barrier removal, as one RT participant emphasised: *"roughly 20% of the smallest hydropower plants are choosing the choice to actually decommission the plants and just take the funding from the Environmental Fund, and that is not based on the new environmental requirements, it's just economically a good solution"* (Policy actor, RT1). The fund is therefore providing a financial incentive for the removal of some hydropower related barriers in Sweden whilst enabling larger operators of strategically important hydropower facilities to demonstrate their commitment to improving Sweden's rivers and contribution to the WFD goals. A key principle driving the fund is therefore fairer distribution of resources and action in the Sector to enable better manage of trade-offs between nature and hydropower objectives.

Additional sources: Puharinen et al. (2024)

5.3.3 Option 3: Blended finance model

A third finance model to support an NbS approach involving barrier removal within the Sector is a blended finance model. This explicitly involves the public Sector part funding costs through grants, with the remaining finance being supplied by hydropower companies. This model is used in Finland under the NOUSU programme (see Box 8 below). Public Sector resources are important to provide *"a real incentive to start this different kind of....project as it shows that it's the right thing to do and the government is backing this"* (Hydropower Sector representative, RT3). Furthermore, the private Sector's financial contribution can be adjusted to reflect the varied capacities and resources of different hydropower operators, making the model adaptable and inclusive. Another advantage is that by combining public and private Sector resources *"one of the best features....is that it really brings different stakeholders together and it's done together"* (Hydropower Sector representative, RT3). Thus, this model more explicitly supports a collaborative approach from the start for the design and delivery of action.

Box 8: The NOUSU Migratory Fish Programme in Finland

The NOUSU programme in Finland was established by the Ministry of Agriculture and Forestry to aid delivery of the national fish passage Strategy. This is a public Sector funding programme that aims to help Finland achieve objectives of the UN Convention on Biological Diversity with a strong focus on migratory fish as well as other freshwater biodiversity.

Removal of barriers is explicitly identified as a key measure, alongside other measures such as developing fish pass channels and improving aquatic. While there is a strong focus on fish migration, wider ecological and social benefits of barrier removal have also arisen, such as recreation for local communities and for visitors to support local economies.

The programme provides a proportion of the funding required to deliver measures such as barrier removal. The public funding available *"that's possible to get for the bigger companies, it's not so big as 50%"* (Hydropower Company, RT3) however, *"in some cases even more than the 50% [can be provided]"* (Hydropower Company, RT2).

Additional sources: The Ministry of Agriculture and Forestry of Finland (n.d-b), The Ministry of Agriculture and Forestry of Finland (n.d-a)

5.3.4 Key considerations in developing MS finance pathways

Several key learnings can be identified from the application of these models. First, it is important to link finance mechanism for barrier removal to a clear, enabling policy environment (see Strategic Action B, section 5.2.2). Without this connection there is a risk that funds may only be applied to undertake *ad-hoc* barrier removal in a case-by-case basis, and not support an NbS approach to design wider catchment scale programmes (Puharinen et al., 2024). There is also a risk that “*non-charismatic barriers*” (Researcher, RT3) will be overlooked. For example, barriers that could be removed but where the direct benefits are predominantly ecological and cumulative (i.e. dependent on the removal of other nearby barriers).

Second, the Sector varies in terms of capacities and resources. It is important to consider how resources are gathered and how financial benefits are distributed. Specifically, funds need to support action by large and small operators and action on hydropower owned sites and more widely to incentives removal of non-hydropower barriers within an NbS approach.

Third, financing pathways can be designed to encourage, or even require, collaboration between different actors. Working in partnership with other types of actors, (i.e. the public Sector, environmental NGO's and community groups), also creates additional finance opportunities, for example other EU funds [such LIFE programme](#) funding, crowdfunding and private donations.

Finally, mixing different sources of finance encourages ownership and accountability, avoiding “*excessively costly actions and measures*” (Researcher, RT3). Applying the IUCN NbS principles (see section 1.3) to help inform allocation of funding could be useful to guide good practice in terms of barrier removal (i.e. complemented by other measures). Further, not all hydropower companies are privately owned, some are managed as public entities, and this may influence the type of incentives required for action by this type of hydropower company.

5.3.5 Proposed implementation actors and timeframe

The differing institutional conditions and varying role of hydropower across MS suggests that a single EU finance mechanism may not be suitable. Developing finance pathways will require the involvement of the Hydropower Sector (hydropower companies and Sector representatives) and the relevant public sector bodies from renewable energy/ climate change and nature restoration policy domains. However, EU level oversight is critical, particularly as many Hydropower companies are multinational and some catchments are transboundary. Environmental NGO's seeking to mainstream an NbS approach and environmental economists from the research community can also support the design of finance pathways. Proposed timeframes for developing clear finance pathways in key MS (e.g. Austria, Germany, Italy and Spain) is 2028.

5.4 Strategic Action D: Build Sector capacity for leadership and collaboration

Strategic Action D focuses on the need for leadership in and collaboration between the public and private Sectors. This is needed across different stages of programme development and delivery. A programme approach (i.e. planning at the catchment scale) is often necessary to effectively address Sector challenges and deliver diverse benefits, but can also add complexity for planning, designing and delivering the desired outcomes. Key to developing leadership (alongside the other actions in this Strategy) is having clear roles and responsibilities that help foster a collaborative and learning ethos. Discharging these roles and responsibilities however also requires knowledge and expertise. This collaborative leadership is essential to overcome obstacles and to ensure that NbS approaches to barrier removal measures are both effective and sustainable.

5.4.1 Hydropower companies' roles and responsibilities

Decisions to instigate formalised NbS programmes with barrier removal measures arises at the executive level in hydropower companies. Views at this organisational level are therefore critical if an NbS approach to barrier removal measures are seen as relevant and a worthwhile course of action. This was emphasised in the second roundtable where one participant commented, “*you have to look at the power, where are the real decisions taken and you have to organise the process around that power*” (Policy actor, RT2). There are already high-level actors in the Sector “*who really want to really make a bold decision, make a bold move, make a radically different version of the future compared to what exists now*” (Policy actor, RT2). However, in other companies such measures, even within an NbS approach is not yet part of discussions.

Some within the Sector (within companies and representative entities) are increasingly aware of the potential benefits of barrier removal for the Sector. These actors need to be supported (i.e. through collaborative working) to apply a more explicit NbS framing to co-develop plausible, relevant narratives that resonate at the Executive level. For example, the need to adapt to climate change to sustain core business activities and the

benefits of working with nature to help achieve this. Furthermore, finding effective ways to highlight the links between barrier removal and corporate risk management and investment (i.e. the EU Taxonomy (2020) and the EU Corporate Sustainability Reporting Directive (2022)). Targeting understanding at the Executive level is important *“because in the end of the day, we’re talking about a lot of voluntary commitments”* (Policy actor, RT3). This action is therefore directly linked to Strategic Action A (section 0) which focuses on enhancing understanding of an NbS approach across the Sector. Including barrier removal examples in existing Sector standards and guidelines (see section 5.1) could also be helpful. For example, *“The idea [of the Hydropower Sustainability Standard] is that it is more a holistic approach....and we’re now seeing a few hydropower dams become certified and we’re going to see many, many more but there could be guidelines that could be applied in line with the standard for looking at [and removing other barriers]”* (Hydropower Sector representative, RT2).

For execution of programmes, developing the right mix of expertise and skills within hydropower companies is important. Designing and delivering NbS programmes with barrier removal measures requires different areas of expertise, including ecological and stakeholder engagement. However, expertise gaps in hydropower companies may exist, as one RT participant with experience working in the Finnish context commented, *“it’s not a problem of that people don’t understand [the business value of barrier removal], it’s more of getting the skilled people to work with hydropower and especially at the moment people with a biological background”* (Researcher, RT3). External expertise can help, for example through partnership working (i.e. with the third Sector and with socio-ecological researchers) or by employing consultants. However, a focus on building internal capacity is important to guide multiple aspects of programme design and implementation. To help address knowledge and skills gaps and share good practice, the emerging NbS Community of Practice (CoP) could develop as a learning network for the Sector.

5.4.2 Public Sector roles and responsibilities

The public Sector also has a role in guiding the development and effective delivery of Sector led NbS barrier removal programmes. One key responsibility is bringing together key strategic actors. Relevant actors to involve in such strategic dialogue are actors from across economic Sectors that benefits from barriers or that may benefit from barrier removal, such as the insurance Sector. Also, actors from renewable energy, climate change and nature policy domains, researchers and eNGO’s. The public Sector organising deliberative processes involving a *“multiple stakeholder approach is very important...to get the right ideas together [from the start]”* (Hydropower company, RT3). This must be informed by evidence, foster a collaborative ethos and can be designed to instil an NbS way of thinking from the start. Such processes can also help identify knowledge gaps. Aspects of Strategic Action B, section 5.2 could strengthen the resolve of the public Sector to organise such a multistakeholder NbS and barrier removal engagement process. Regardless, it is important to ensure *“the attitude that we’re not trying to help one organisation or one agenda [is important]...so that everybody feels involved”* (Policy actor, RT2) and to make *“sure that you start a process where the commitment is at the beginning to find a solution for a problem and then you [also need]....the right people at the table”* (Policy actor, RT2).

The public Sector is also responsible for regulatory oversight for many activities within riverine ecosystems. For the design of NbS and barrier removal programmes the public Sector has a strategic role to help the Sector incorporate policy requirements. As one RT participant highlighted, *“we’re talking about a lot of voluntary commitments....but it’s good to distinguish on also what they are obliged to do in terms of policy implementation and I think it’s where public water management have to step to step in and say like look, this needs to happen in the next years because of the framework directive or the nature restoration regulation”* (Policy actor, RT3). Furthermore, the public Sector also has a role to ensure public benefits are incorporated, for local communities, for nature and for society more widely. This includes supporting access to policy tools and analysis to better link policy needs to company level planning. This led on RT participant to comment, *“local, regional or national water authorities are quite key in this approach. Because at the end of the day... they areresponsible for river connectivity and ecological water quality and they should indeed have a river basin analysis of all the barriers”* (Policy actor, RT3).

The public Sector also has a role supporting companies to navigate the complexities in implementation of programmes. This includes helping programme leaders to navigate institutional arrangements that may be hindering action. For example, in the Deba River catchment in the Basque Country ([MERLIN Case 2](#)), progress to remove a historic barrier was initially hindered by a heritage designation, however government agencies eventually agreed a balanced solution involving partial removal allowing both restoration of river connectivity while also preserving local heritage (Colls et al., 2024). Another hinderance to action can be landownership. Here, for example, the public Sector can have various roles to help overcome obstacles. First, where ownership is unclear the public Sector may have local knowledge and/or ownership records. Second, experience delivering the NOUSU programmes in Finland (see section 5.3, Box 8) has identified the importance of a clear ownership transfer process, for example from a small hydropower operator to an intermediary organisation to coordinate

the removal process. Thus, the public Sector has an important role in enabling more widespread action to removal barrier and to support action by the Sector that goes beyond its own land.

5.4.3 Proposed implementation actors and timeframe

Creating the conditions to instigate, design and deliver barrier removal driven by an NbS approach requires coordinated action across the Sector. Sector representatives and NbS and barrier removal proponents from early adopters within the private Sector need to work together to address knowledge and skills gaps across levels and functions within companies. Working with social researchers and eNGO's can support this. Public Sector leadership to create supportive institutional conditions for Sector led programme design and deliver needs to be integrated into to existing (national and local) public Sector structures and processes with a focus on linking nature restoration and renewable energy policy domains. Due to the multiple dimensions involved in this Strategic action and its importance for continuing to strengthen the uptake of an NbS approach to barrier removal beyond 2030 the proposed timeframe for delivering this strategic action is 2029.

5.5 Strategic Action E: Provide Sector specific tools to design NbS programmes with barrier removal

The fifth and final Strategic Action focuses on providing tools to help guide future investment decisions in the Sector. This includes tools for both large companies/Sector associations and tools for small hydropower operators. First, we need to collaboratively develop tools with large hydropower companies and the Sector representatives to design NbS programmes for barrier removal. Such tools are necessary to avoid an ad hoc site-by-site approach dominating Sector action and to stimulate more ambitious action beyond barriers that could be seen as 'low hanging fruit'. A different type of tool (i.e. not adopting an NbS lens) is also needed to inform investment decisions of small hydropower operators to create opportunities for removing small barriers that may not be economically viable for continued hydropower production in the future.

5.5.1 Factors to consider in the design of tools for large companies

Tools needs to be co-developed with the Sector, for the Sector to design NbS programmes with barrier removal. These tools need to be adaptable to fit the different business settings found across the Sector.

Such tools need to be framed around Sector challenges and desired benefits to illustrate potential win-win opportunities. They also need to support understanding about different social, financial and ecological factors that shape the current operating environment and future scenarios (see Table 5 below). For example, for companies to better understand "if we remove this [barrier] will it help[what could be the] ecological value removing this particular barrier? Or is it too much to lose to remove this barrier? So, trying to find the balance" (Hydropower company, RT1).

Table 5: Key factors to incorporate into Sector-orientated tools to support barrier removal measures within NbS programmes (source: RT1, RT2, RT3)

Relevant themes for developing Sector specific tools	Factors that could shape decision making in developing Sector led programmes
Sector operational challenges in catchment	What are key operational and business challenges linked to strategically important hydropower facilities?
Economic functions of barriers	Are there any currently economic activities associated with a barrier? What?
Structural conditions of barriers	What are the structural characteristic of a barrier (height, materials, integrity etc)?
Ownership	Who is responsible for the barrier structure and any activities involved (if known)?
Consequences of barrier for ecosystem function	What are the negative consequences for ecosystem function (e.g. sedimentation, fish migration, low flows etc).
Link to societal challenges	Could removal contribute to ecosystem connectivity, biodiversity net gain, climate mitigation, climate adaptation for local communities (e.g. reduce flood risk or water scarcity)?
Legal designations and regulatory requirements	What licences and conditions are involved?

	Are there any designated conservation sites in proximity (e.g. under the EU Habitats Directive)? Does the barrier have any cultural value/ legal protection? Is the barrier identified for potential removal under the WFD/ EU Nature Restoration Law (i.e. to enhance river connectivity)?
Local values and community connections	Are there any positive connections to the barrier for local communities? E.g. flood risk, water quality, recreation etc.?
Estimated costs	What are the estimated costs of removal (including access and actual removal)? Cost of supplementary/ complimentary measures for addressing challenges?
Future projections	What are the local climate change projections (more rainfall, less rainfall etc for the catchment)? Are licence conditions linked to barriers likely to change (e.g. under the WFD)? How? What costs could be involved? Is it likely that the barrier will be utilised in the future for hydropower (e.g. retrofitted for small hydropower)? Are there any negative environmental impacts due to barrier removal that may be generated to an ecosystem?

The need to consider such diverse factors at a catchment scale is an example of a recurring concern in the Sector to ensure a simplistic “*one-size fits all*” (RT1) approach is avoided in the identification of barriers that could be removed. This was a particular concern in relation to understanding of the term obsolete, which was a contested focus of action for some in the Sector, particularly small hydropower representatives. A further issue with a simplistic, narrow focus on the term ‘obsolete’ in practice is that this term may not be applicable across all MS countries, as one RT participant highlighted, “*I’ve heard that in southern Europe there are many, obsolete barriers, but in Finland, I have not encountered obsolete barriers. There is always some benefit flows associated [with barriers] to some citizens or entities. So, it’s the costs and the benefits of the alternatives and the current use are the ones that should be discussed*” (Researcher, RT3).

There are already a range of barrier removal tools under development (see section 1.4). These could feed into the design of Sector tools. Furthermore, standards setting out different sustainability considerations and tools already being used by some hydropower companies that could also inform the development of NbS and barrier removal planning tools. For example, the Hydropower Sustainability Alliance developed the Hydropower Sustainability Standard to establish good practice for Environmental and Social Governance (ESG) management in hydropower development and operation (Hydropower Sustainability Secretariat, 2021), as well as the recently published HYDROSELECT tool for early-stage decision making in the development of hydropower (Hydropower Sustainability Alliance, 2023). These tools are important, but insufficient on their own to guide decision making and the design of NbS programmes with barrier removal as a core component to support new and existing hydropower activities and future capacity.

Understanding key functional requirements can help steer the process. First, tools need to adopt a “*whole catchment scale or regional scale [as] some of the decision support tools don’t really capture that*” (Researcher, RT2). This is important “*to not get too focused on any single barrier*” (Researcher, RT2). Second, tools need to be able to assess cumulative impacts, which a common challenge for policies affecting the Sector, for example in the Water Framework Directive (2000) and the EU Taxonomy (2021). Third, tools need to be co-developed with hydropower companies and/ or their representatives. This is important to ensure tools are relevant (i.e. using Sector language), useable, accessible and shared widely. Fourth, tools need to be adaptable. This involves the ability of different companies to adopt and adapt tools to fit different business contexts and geographies, for example different companies targets and metrics. It also involves the ability to update tools to reflect realities on the ground, for example when barriers are removed. Finally, tools must also be underpinned by evidence whilst also aiding understanding about potential knowledge gaps.

Furthermore, Sector specific NbS metrics to assess the potential and actual impact of action are critical, but may be currently lacking within some companies, potentially hindering action. Developing Sector tools could help develop standardised metrics for use within the Sector.

5.5.2 Adopting tools to support decision-making of small hydropower operators

Action to remove barriers can also involve small hydropower operators with a focus on better understanding future economic viability and to decide whether retirement and removal is a viable action. This reinforces the need to move beyond a simple focus on the term obsolete to guide action in the Sector. Such tools however need to be aligned to financial incentives (see section 5.3) and recognise property rights including the right of operators to continue hydropower operations. One such tool focused on economic viability is being used in Finland (see Box 9 below) linked to the NOUSU programme in Finland (see section 5.3, Box 8: The NOUSU Migratory Fish Programme in Finland).

Box 9: A decision support tool for small hydropower operators in Finland – Assessing Net Present Value

A tool has been developed to work with small hydropower operators in Finland. It is being used in discussion to explore future options for hydropower barriers that face investment decisions, for example relating to the need to comply with additional environmental licence conditions.

Assessing the Net Present Value
<https://kalahavainnot.luke.fi/en/vesivoimalaskuri>

EN | FI

Permit requirements

Construction costs of the fish passage, if not yet made	300,000	€
Year	2025	▼
Average quantity of water in fish passage	1.0	m ³
Average river flow	10.0	m ³
Annual high monitoring	10,000	€

Results

Present value of the net revenue stream	1,051,883.76	€
Present value of investment costs	-312,120.6	€
Net present value of the facility	739,763.16	€

Download XLSX

The tool assesses the long-term economic value of a hydropower facility, taking into account the sales revenues, operation and maintenance costs, investment costs and their timings as well as compliance costs of current or upcoming environmental requirements. This net present value estimates then inform the decisions of the hydropower operator. In some instances, this has led to the decision to remove the barrier as investment costs are too expensive for the operator to continue. In other instances, decision making is a lengthier process and has led to some operators deciding to invest and maintain the barrier as a functioning hydropower facility. A key aspect of this is the provision of financial support through the NOUSU programme to help fund the removal of barriers. As of May 2024, through the application of this tool, four barriers have been removed, five removal processes are underway, eight operators have decided to continue activities and a further nine are under review.

Additional sources: (Carmen, 2024, LUKE, unknown, LUKE, 2021)

5.5.3 Proposed implementation actors and timeframe

The adoption of tools like the net present value tool being used in Finland could be happen relatively quickly but needs to be aligned to finance pathways (see Strategic Action C, section 5.3). Key actors are EU and MS level public Sector nature and water management policy actors. Therefore, we propose a time frame of 2028. Co-developing Sector-orientated NbS support tools, involving (but not limited to) barrier removal requires expertise and resources, to ensure meaningful collaboration with hydropower companies. The proposed timeframe is therefore 2030. Co-developing such a tool with companies could be the focus of a future EU research and innovation action funded project.

6 Discussion

This Strategy proposes five strategic actions to support the Hydropower Sector's contribution to the removal of transversal barriers (dams, weirs and sluices that control water levels within river channels). These barriers may not be currently utilised for hydropower production.

Currently, very few companies are voluntarily developing barrier removal programmes. Instead the removal of barriers is driven predominantly by compliance with legal and regulatory requirements. Regulation will continue to be a factor, particularly for those unwilling to adapt and change. At the same time, other factors also guide business decision making and could be better utilised to stimulate more ambitious action with a focus on win-win outcomes. This is the essence of an NbS approach, and of mainstreaming.

During the development of this Strategy (between 2022-2024) the EU has adopted the Nature Restoration Law which explicitly sets out the need for the removal of some of the many barriers found within Europe's catchment. This new law reinforces the importance of taking an NbS approach and persuading economic Sectors to support restoration. During this strategy development process, the Sector has itself also continued to develop guidance for working with nature. Many of the sub actions therefore entail building on and refining existing pockets of good practice (maintaining actions) and Hydropower company frontrunners are demonstrating the benefits that can arise from barrier removal using an NbS approach.

The focus is on taking a NbS approach to barrier removal, identifying barriers that if removed, could address societal and Sector challenges and create multiple, diverse benefits for the Sector and for society. This Strategy therefore brings together two action domains already starting to develop within the Sector, namely barrier removal and an NbS approach. These types of action are not currently widespread in the Sector. Barrier removal could be undertaken as a traditional mitigation measure to comply with legislative framework, for example to upgrade or develop new hydropower facilities. An NbS approach is important as it brings to the fore the opportunities from such action to support future business activities, particularly in the context of a rapidly changing climate and shifting social and political expectations. This can be understood as an additional level on the mitigation hierarchy (see Table 3) for the Sector, where ecosystems are enhanced and natural processes restored to benefit the Sector in multiple ways. Achieving this in practice requires deliberate efforts to mainstream these ideas throughout the Sector and to develop the necessary institutional arrangements to support clear action pathways.

Five Strategic actions were identified through a series of roundtables with multiple actors from the Sector, including some large hydropower companies and Sector representatives. These strategic actions focus on developing the necessary institutional arrangements by 2030 to enable more widespread barrier removal. These strategic actions are:

- A. Increase understanding of an NbS approach to barrier removal**
- B. Highlight synergies between energy/climate change and nature restoration policies**
- C. Develop finance pathways guided by an NbS approach**
- D. Build Sector capacity for leadership and collaboration**
- E. Provide Sector specific tools to design NbS programmes with barrier removal**

Mainstreaming is not simple, particularly when the European Hydropower Sector has diverse perspectives, objectives, actors and resources. Some Strategic Actions identify a clear set of sub actions, whereas for others there is no clear way forward and different options are available (i.e. for Strategic Action C). Choices also need to be made at the MS level to align action to different contexts. For these reasons, the strategic actions are a starting point and require further exploration to identify a way forward and to get to the 2030 vision that is the aim of this Strategy. To achieve the 2050 vision, moving from creating institutional arrangements to a widely celebrated, positive socio-ecological outcomes achieved by the Hydropower Sector, further actions will also be needed.

Taking forward some actions first requires a strong focus on coalition building to develop stronger partnerships between actors that may not have traditionally worked together. Leadership to foster this is however critical. While EU coordination and MS level involvement is important across all Strategic actions, action at the MS level is particularly important and Actions B and D aims to provide a strong steer to help achieve some of the early buy-in this will require. Specifically, the public Sector is seen as critical in shaping enabling policy environments for Sector led action and for supporting more ambitious planning and action. The public Sector is also seen as important for creating opportunities for cross Sector collaboration, identified as relevant by hydropower companies as only a proportion of barriers are linked to hydropower activities. Despite efforts, this

collaborative dimension remained underexplored in the development of this Strategy and needs further attention. It is possible the Sector is seeking greater clarity first, before turning to ideas about how to support better collaboration between private Sector actors across economic Sectors.

This Strategy brings to the fore several key issues that need to be foregrounded as key considerations in guiding in future efforts. The **first consideration** (particularly for Strategic Actions C and E) relates to the diversity of private sector actors involved in the Hydropower Sector. There are different categories used to disaggregate the Sector, e.g. the type of technology used, the size of dam/barrier used, the amount of energy produced. The Sector ranges from large international corporations to single individuals generating electricity primarily for their own use. The available resources and thus ability to deviate from the current activities therefore varies between hydropower operators. In designing new finance mechanism and tools to support investment decisions, this disparity needs to be a primary consideration. Creating opportunities for all in the Sector to participate in action is important for both the Sector and for nature restoration policy objectives. Large corporations need to be incentivised to instigate ambitious NbS programmes involving barrier removal, whereas smaller operators need to be informed and supported if they are unable to meet new licence conditions. Inclusivity within the Sector thus need to remain at the fore in implementing this Strategy. This is critical to increase the relevance and legitimacy of action to secure long lasting change at an institutional level and across different catchments within Europe.

The **second consideration** relates to the types of barriers to remove. There are many small barriers across Europe (in terms of height of the structure). Some of these have no clear economic function, some are used to produce hydropower but have limited capacity and do not make a significant contribution to national net zero goals (although may provide local energy security). Other barriers are linked to Sector such as agriculture, navigation and water services. Many of these smaller barriers are still required, however others could be removed. In developing this Strategy, the term ‘obsolete’ was contested as too simplistic to guide action, instead participants emphasised the importance of identifying opportunities based on assessments of multiple factors to contextually determine which barriers could be removed. A primary focus of action however for the sector will be to remove barriers no longer considered economically viable for hydropower production (e.g. for retrofitting for small hydropower operations).

A **third consideration** therefore for the future relates to the broader question of how discussions are framed from the outset. Traditional, dominant ways of thinking in the Sector could lead to resistance to change within the Sector and within hydropower companies themselves. For example, traditionally economic activities have been viewed as a threat to nature and vice versa. Such binary thinking is pervasive across society and NbS is increasing acknowledged as helping move beyond this simplistic view. However, understanding how to accelerate this shift in thinking is not easy. Fundamentally, embedding an alternative collective way of thinking and acting in relation the natural environment across the Hydropower Sector is a complex process fraught with potential pitfalls. As already highlighted, deliberate collective efforts and an iterative approach (e.g. a stepwise approach focusing on action and refinement within the process) is essential.

The importance of framing is a key premise driving the development of this Strategy with the focus on an NbS way of framing action. However, opposition from hydropower companies and their representatives to the focus on barrier removal increased as the Strategy progressed. This is despite efforts to focus group discussions on exploring how action pathways can be developed to balance renewable energy and nature restoration objectives for the Sector (i.e. an NbS approach). The Sector’s current reliance on barriers (both large and small) for producing hydropower introduces an unavoidable tension. Starting out with a focus on barrier removal may have consolidated adversarial positioning in the process. Furthermore, a lack of trust may hinder key NbS and barrier removal proponents in the Sector committing to future involvement in taking forward the actions identified in this Strategy. In future dialogue, a narrow focus on the removal of barriers may not be helpful to encourage openness to share and explore new ideas, potential partnerships and ways of working. It is critical the Hydropower Sector is viewed as a key strategic actor and involved as a partner in future discussions and planning. An NbS lens is important, but instead of barrier removal per se, a focus on how the Sector can help enhance river connectivity and /or for increasing hydropower resilience by working with nature, both drawing on a range of complementary and supplementary NbS type measures at a catchment scale, could be more productive.

7 Conclusion and Next Steps

Enabling more widespread action by the Hydropower Sector to be involved in removing barriers involves institutional change including developing incentives, clarifying expectations and highlighting opportunities to deliver benefits for business, people and nature. For this to happen in practice an NbS approach is required. Different types of actors from the Sector have contributed to the ideas and actions found in this Strategy. However, gaps remain, and continued effort is required to refine actions and strengthen the collaborative ethos required for collective action between actors lacking a shared history of working together. This strategic document is therefore a starting point, laying out some key ideas and options. Change is already underway. It is hoped that this Strategy can help some key actors work together to guide and accelerate change to develop win-wins for hydropower production and for nature restoration.

Next steps include the following:

- Share the final Strategy with those organisations who have contributed to the development of this Strategy
- Share the final Strategy with those in Sector invited and interested in joining the process but were unable to engage (e.g. due to busy schedules)
- Propose additional bilateral discussions with key EU and MS level strategic actors, e.g. Sector representatives to discuss relevant developments in the Sector and opportunities for future collaboration to take forward some of the ideas and actions included in this Strategy
- Explore collaborative funding opportunities for taking aspects of this Strategy forward that are seen as useful/ relevant by key Sector actors.
- Develop a policy brief on the concept of 'obsolete' aimed at EU policy actors developing guidance on free-flowing rivers highlighting why it was a contested term
- Develop policy briefs on the importance of framing when seeking to include strategic actors such as the Hydropower Sector in planning and delivering change. For example, framing action around enhancing river connectivity (e.g. encompassing by-pass and barrier removal) and / or adoption of an NbS approach to enhance hydropower resilience (i.e. a focus on the multiple benefits for hydropower facilities, hydropower operators and the Sector more widely).
- Develop academic papers to share insight with researchers with interests linked to hydropower, mainstreaming NbS, catchment management

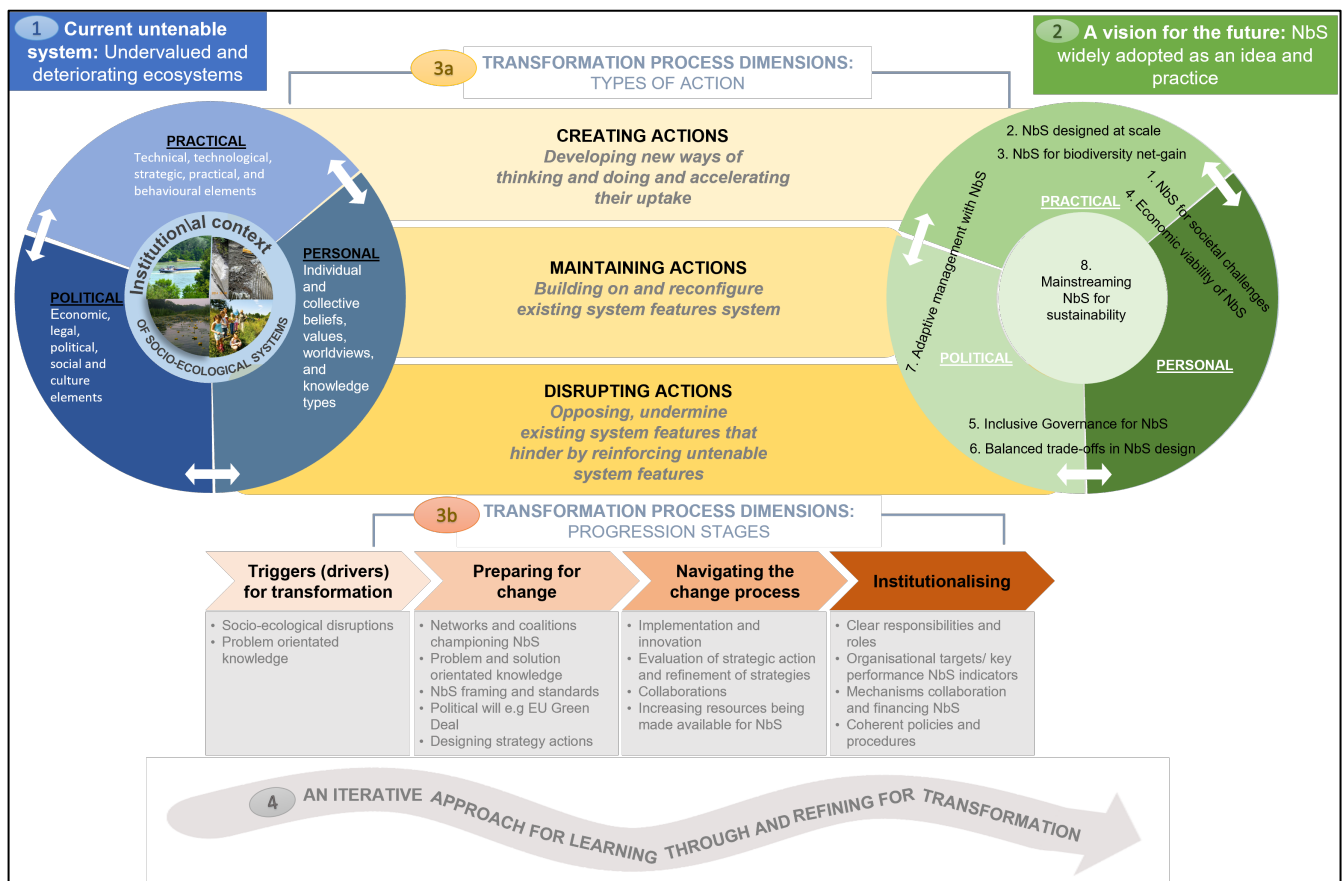
8 Annex

8.1 Annex 1: Extended methodology

The Annex provide some more information about the process of creating the Strategy.

8.1.1 Conceptual Framework and analytical matrix

Transformation is a process of guiding fundamental structural, functional, relational and cognitive change that leads to qualitatively different patterns of interactions, processes and outcomes (O'Brien, 2012, Patterson et al., 2017, Waddock, 2020). Undertaking this in practice is a complex, non-linear social process (Fazey et al., 2018) and increasingly challenging as the socio-spatial focus of change expands (Dentoni et al., 2017). Thus, to achieve the desired socio-ecological benefits for and from an economic Sector such as the Hydropower Sector, further iterations of strategic actions may be necessary (Feola, 2015, Fuenfschilling and Truffer, 2016). To guide the development of this strategy a framework involving key insights from scientific literature on sustainability transformations was developed along with a practical matrix for practical application (Carmen et al., 2024). This helped support reflection in developing this strategy on type of levers and actions being identified as potentially relevant.



This framework focuses attention on the following five dimensions for guiding fundamental large-scale change. The framework was applied heuristically to guide identification of sub actions and to reflect upon possible gaps

1. Developing an understanding of the current situation (in the Sector and the ways the Sector is thinking about and acting towards freshwater ecosystems)
2. Gaining a direction of travel, clarifying the focus and developing a vision for the future.
- 3a. Developing actions that work with different system levers, such as;
 - **Personal levers**: Individual and shared subjective assumptions, values, beliefs and paradigms which guide how people perceive problems and how solutions are defined.
 - **Political levers**: Structures, processes and mechanisms that either facilitate or constrain decision making, the involvement of different actors and collective action.

- **Practical levers:** Technical, technological and behavioural factors (e.g. skills, resources available and the types of measures applied)
- 3b. Understanding the potential need for different types of actions, such as;
 - **Creating actions:** Entails developing new ways of thinking and doing and accelerating their uptake.
 - **Maintaining actions:** Building on and reconfiguring existing system features that could contribute to achieving an intended outcome (e.g. national plans and models already in use in certain parts of the Sector or within a Member State (MS))
 - **Disrupting actions:** Overcoming or undermining existing ideas, processes and practices that are hindering progress towards achieving a desired outcome. (e.g. that perpetuate continued reliance of unsustainable practice)
- 4. Recognising that collective large system change as a difficult and uncertain process. Evaluation and learning is critical and may lead to understanding of the need for additional/ alternative actions and outcomes as change unfolds.

Reflections using this framework and simple matrix of actions brought to the fore that the sub actions identified in this Strategy utilise different levers (personal, political and practical) and encompass different types of actions (creating, maintaining and disrupting actions) (see Table 6 below). Thus, together these strategic actions could support fundamental change for different ways of thinking and action in relation to the natural environment within the Sector. One potential weakness revealed by reflecting on the different levers and actions is the lack of disrupting types of action. Disrupting actions focus on overcoming traditional, dominant ways of thinking in the Sector that could lead to resistance to change within hydropower companies themselves.

Table 6: Summary of the sub actions Identified within this Strategy linked to the type of levers (practical, political and personal) and types of actions (creating, maintaining and disrupting) to help guide transformation

	Creating actions that entails developing new ways of thinking and doing and accelerating their uptake.	Maintaining actions to build on and reconfigure existing system features that could contribute to achieving objectives for a future system	Disrupting actions to undermine existing system features that hinder progress towards the intended outcomes.
Practical levers Technical, technological and behavioural elements (e.g. skills and resources available/ type of measures undertaken, etc.)	 Action A (Understanding): Using the NbS principle use examples to highlight how an NbS approach is already starting to emerge in the Sector (i.e. natural by-pass channels and the benefits for the Sector beyond compliance) that also help increase river connectivity.	 Action A (Understanding) & Action D (Leadership): Incorporate a more explicit focus on (and explanation of) an NbS approach in existing Sector sustainability and nature-related guidelines.	
	 Action D (Leadership): Develop internal capacity (with the required skills) within hydropower companies to design and deliver NbS programmes with barrier removal as a core measure.	 Action B (Policy): At the MS level build on hydropower licence reviews to introduce a barrier removal condition.	
	 Action D (Leadership): The public Sector to develop an ownership transfer mechanism to coordinate the removal of barriers.	 Action D (Leadership): Access knowledge and expertise to support the design and delivery of company led NbS and barrier removal programmes via partnerships with other actors involved in the Sector.	
	 Action E (Tools): Co-develop Sector specific multi factor tools for assessing scenarios at a catchment scale to inform NbS programme design. Develop standardised sector metrics for barrier removal with an NbS approach.	 Action D (Leadership): Local government to support companies to navigate and overcome institutional issues that may hinder barrier removal action.	
		 Action E (Tools): Build on net present value tools (e.g. being used in Finland) to inform decisions of operators about future economic viability to create more opportunities for barrier removal.	
Political levers Structures, processes and mechanisms that facilitate or constrain decision making, involvement of different actors and collective action.	 Action B (Policy): At the MS level adopt a Sector approach in the development of National Nature Restoration Plans. For the Hydropower Sector develop a national plan for barrier removal.	 Action A (Understanding): Work with existing Sector representatives (associations and networks) to spread the idea of an NbS by the Sector involving barrier removal.	
	 Action D (Leadership): The public Sector to create deliberative, multi actors processes (involving multiple economic Sectors) to inform barrier removal programmes and support collaboration.	 Action B (Policy): In EU nature restoration policy guidance make more explicit that the focus on action by the Sector for the removal of barriers is not limited to historic, abandoned barriers (obviously obsolete). Clarify a focus on removal of barriers that are not economically viable to	

		expand understanding that all types of barriers should initially be considered in assessments.	
		 Action D (Leadership): Sector representatives to support knowledge sharing and development to enhance good practice via learning networks.	
		 Action B (Policy): In EU Renewable Energy policies and MS Energy and Climate Change Plans make more explicit the role of an NbS approach with barrier removal and barrier as mitigation to support future hydropower activities.	
		 Action B (Policy): In impact and business disclosure policy highlight barrier removal as a relevant mitigation action and risk reduction action.	
		 Action C (Finance): Develop a better understanding of the implications of existing finance models for incentivising action by all types of hydropower operators to inform the development MS level Hydropower Sector finance mechanisms for barrier removal, linked to the IUCN NbS principles.	
Personal levers Individual and shared subjective assumptions, values, beliefs and paradigms which guide how people perceive how problems and solutions are defined.	 Action A (Understanding): Develop understanding across Sector of the overlap between NbS and barrier removal – framed around socio-economic benefits for the Sector. Contrast traditional technological measures with NbS measures and traditional restoration approaches.	 Action A (Understanding): Draw on examples of barrier removal action in the Sector (aligned to an NbS approach v action driven by legal requirements) to illustrate the relevance to the Sector of barrier removal undertaken within an NbS approach.	 Action A (Understanding): Disrupt simplistic assumptions by linking examples to evidence to highlight that not all barriers are socially desirable (i.e. some can help alleviate flood risk, some can exacerbate flood risk, poor water quality and water scarcity).
	 Action D (Leadership): Create better awareness at the executive level in hydropower companies of the business benefits from an NbS approach including barrier removal measures. Link to corporate sustainability needs and legal responsibilities.		

8.1.2 Data sources

A diversity of data sources and methods were drawn on to support the development of this strategy (see Table 7 below).

Table 7: Data sources and methods used to develop this strategy

Data collection method	Description
Desk-top review and Briefing for the Hydropower Sector	Review of policy, Sector and scientific documents pertaining to current Sector trends, challenges and opportunities.
2022 EU Hydropower Sector roundtable (Blackstock et al., 2022)	Transcripts of semi-structured groups discussions on: 1. Sector trends; 2. Sustainability; 3. Small barrier removal.
2023 EU Hydropower Sector roundtable (Carmen and Nyíró, 2023)	Transcripts of semi-structured group discussions on: 1. Hydropower dam related Decision-making; 2. Obsolete barrier related decision-making; 3. Finance and cross Sector collaboration for barrier removal.
European Commission interviews	Semi-structured interviews with EU level actors from across policy domains (e.g. climate change, environment, water, navigation, agriculture).
European and MS level policy analysis (Blackstock K. et al., 2023)	Six EU policies (Green Deal (2019); Proposed Nature Restoration Law (2022); Water Framework Directive (2000); Common Agricultural Policy (1962/2023); Climate Law (2019) and Adaptation Strategy (2019); and the implementation of these policies in seven Member States (Austria, Finland, Hungary, Netherlands, Portugal, Romania and Spain). Analysis of interconnections between NbS, freshwater ecosystems and six economic Sectors (including Hydropower Sector).
European Commission policy workshop	Webinar presenting initial findings from cross Sectoral policy analysis with semi-structured group discussions with EU level policy actors, e.g. from DG ENV, DG CLIMA.
Questionnaire: Nature-based Solutions and economic Sectors (including the Hydropower Sector)	Open and closed questions to explore perceptions of Sector challenges (environmental and socio-economic), need for change in water management practices and understandings of and role of NbS. Hydropower Sector respondents: 2 ENGO and 4 private Sector hydropower representatives.
Barrier removal and nature restoration practitioner interviews	Transcripts and interview notes of semi-structured interviews with barrier removal and nature restoration practitioners to identify good practice within Europe for achieving barrier removal by the Hydropower Sector.
2024 EU Hydropower Sector roundtable (Carmen, 2024)	Transcripts of semi-structured group discussions on the draft vision and 5 strategic actions identified from analysis of multiple data sources

8.1.3 Participants involved in developing this Strategy

In total 21 organisations participated in developing the content for this strategy (see Table 8 below). How they participated and when in the process however varied. Informed consent was sought as participants joined the process and all were invited to continue to participate in the process unless they explicitly request to withdraw. A participant from an organisation formally withdrew in February 2023 but their organisation was represented by another participant.

Table 8: Participants involved in developing the contents of this strategy

Participating Organisation	Level	Type	Total number of people	RT1	RT2	RT3	Bilateral meetings
REDACTED	European	Sector representative	4	3	1	2	2
REDACTED	Global	Sector representative	3	1	1		
REDACTED	Global	Hydropower Company	1		1	1	

The Nature Conservancy	Global	ENGO	1				
REDACTED	National	Hydropower Company	1	1		1	
REDACTED	National	Sector representative	1	1	1	1	
SYKE	Global	Research	2	1	1	1	Yes
REDACTED	European	Sector representative	2	1	2		
WWF	Global	ENGO	3	2	2	2	Yes (MERLIN CS6)
REDACTED	Global	Hydropower Company	1		1	1	
University of Kent	Global	Research	1		1		
University of the Basque Country	Global	Research	2		2	2	Yes (MERLIN CS2)
Swedish Agency Marine and Water Management	National	MS Policy	1	1			
REDACTED	European	Hydropower Company	2	1	1		
EC DG CLIMA	European	EU Policy	1		1	1	Yes
University of Lisbon	Global	Research	3		1	1	Yes (MERLIN CS12)
Swedish University of Agricultural Sciences (SLU)	Global	Research	1				1
EC DG JRC	Global	Research/ policy	2	1	1	1	
University of East of Finland	Global	Research				1	Yes
University of Natural Resources and Life Sciences, Vienna	Global	Research				1	Yes (MERLIN CS7a)
The James Hutton Institute	Global	Research	4	3	4	4	

Throughout the participatory process and strategy revision, we received many insights which were invaluable to foster discussion, though they sometimes revealed conflicting views which did not always lead to a consensus or a resolution. Therefore, the Strategy uses these insights, but the content does not necessarily reflect the views of all organisations involved.

8.2 Annex 2: Participant feedback

8.2.1 Direct feedback on draft reports and the strategy from participants

In addition to involvement in roundtable discussions and bilateral meetings participants were also given the opportunity to provide feedback on written documents produced in support of the development of this strategy. There was variation in the type of comments and which organisations provided comments and when in the process (see Table 9 below).

Table 9: Where in the development of the strategy feedback was requested and received from participants

Participating Organisation	Level	Type	Comments received on;			
			Draft RT2 report	Draft Strategy (May 2023)	Draft RT3 report	Draft Strategy (November 2024)
REDACTED	European	Sector representative	Yes	No	No	Yes
REDACTED	Global	Sector representative	Yes	Yes	Yes	Yes
REDACTED	Global	Hydropower Company	No	No	No	Yes
The Nature Conservancy	Global	ENGO	n/a	No	n/a	No
REDACTED	National	Hydropower Company	n/a	No	No	No
REDACTED	National	Sector representative	No	Yes	No	No
SYKE	Global	Research	No	Yes	No	No
REDACTED	European	Sector representative	No	Yes	No	No
WWF	Global	ENGO	Yes	Yes	Yes	Yes
REDACTED	Global	Hydropower Company	No	No	No	No
University of Kent	Global	Research	No	No	n/a	No
University of the Basque Country	Global	Research	Yes	Yes	Yes	Yes
Swedish Agency Marine and Water Management	National	MS Policy	n/a	No	n/a	No
REDACTED	European	Hydropower Company	No	No	No	No
EC DG CLIMA	European	EU Policy	Yes	No	No	Yes
University of Lisbon	Global	Research	No	Yes	Yes	Yes
Swedish University of Agricultural Sciences (SLU)	Global	Research	N/a	No	n/a	No
EC DG JRC	Global	Research/ Policy	Yes	Yes	Yes	Yes
University of East of Finland	Global	Research	n/A	n/a	Yes	Yes
University of Natural Resources and Life Sciences, Vienna	Global	Research	n/a	n/a	n/a	No
The James Hutton Institute	Global	Research	Yes	Yes	Yes	Yes

8.2.2 Summary of feedback from all types of participant on November 2024 draft Strategy

Different types of participants provided suggestions and feedback on the draft strategy circulated to roundtable participants in November 2024. This led to multiple suggested edits to enhance the clarity of key points examined in the document. These were reviewed and incorporated where appropriate.

In addition, some participants also provided feedback on some broader issues needing to be addressed. These broader critiques were reviewed by multiple members of the MERLIN team and the structure and contents of the strategy amended where appropriate. These broader issues and the type of actor highlighting these issues is summarized in the Table 10 below.

Table 10: Summary of feedback on the November 2024 draft strategy

Issue	Type(s) of participant	Authors response
Scope: The focus on barrier removal is too narrow and adversarial. Need for a more integrated perspective.	Hydropower Sector representatives	The framing of this strategy narrowly around barrier removal is now highlighted as problematic especially as it reinforcing adversarial positions of key actors who need to work together to implement many of the ideas outlined. This is now highlighted in the key messages, executive summary and more explicitly in the discussion section (where this issue was previously highlighted). Alternative ways of framing future dialogue are suggested with emphasis on the importance of involving the sector in strategic discussions on connectivity in the future. For example, a focus on how the sector can contribute to enhancing river connectivity with more widespread uptake of an NbS approach. Thus, highlighting the value of a more integrative perspective in terms of types of measures (i.e. not just barrier removal). The need for barrier removal alongside other measures in the design of NbS programmes is now signposted throughout the document better. For example, on page 1 of the introduction the following text has been included: “The removal of barriers is however one of several measures the hydropower Sector could integrate into the design of NbS programmes to support future business activities, for example installing naturalised by-pass channels, restoring in-channel features upstream, reconnecting floodplains, and riparian planting.”
The role of the sector: The text does not highlight the role of hydropower in climate migration and balancing the energy mix.	Hydropower Sector representatives Researcher	This was highlighted on page 8 of the strategy but after the introduction section. This is now highlighted earlier in the contents, in the key messages, executive summary and introduction section (subsection 1.2 on the role of the Hydropower Sector). The section on the Hydropower Sector now includes more detail about the technologies, categories and role of the Sector in supporting energy security and in reaching net zero policy goals.
Existing sector action: The sector already works with NbS type measures to align with policy (especially WFD, but also other policies) yet acknowledgement is lacking. Request removal of a box in the text providing details of a sector led barrier removal programme	Hydropower Sector representatives	The document now includes examples of existing NbS type measures already being promoted in the sector – namely naturalised fish by-pass channels (see Introduction – subsection on the Hydropower Sector). Also, the application of naturalised bypass channels to enhance river connectivity around strategically important barriers (e.g. still required for other economic functions such as the supply of water) is now highlighted as a relevant NbS measure already being used (See (see Introduction – subsection on the nature-based solutions)). The policy drivers of action by the sector is now highlighted, for example the removal of barriers to align with the Water Framework Directive but also health and safety legislation in the section on ‘The current situation’. A more detailed description was provided about a barrier removal programme that has already been developed by a hydropower company was included in the November 2024 draft. The company involved requested this box be removed from the document and this request has been honoured.
The social-economic role of barriers:	Hydropower Sector representatives Researcher	The multifunctionality of barriers has now been better signposted in the text.

The multifunctionality of barriers and role of other economic sectors is missing. The beneficial role of barriers underplayed, e.g. for flood risk and reducing impact of droughts		For example, in the introduction the text now includes: “the Hydropower Sector is not the only economic Sector with economic links to barriers and potential benefits that could arise from removal programmes.” Furthermore the first sentence of the section on The Current Situation now begins “For centuries there has been a strong reliance on managing and controlling water levels in Europe’s rivers and surrounding land through the construction of barriers – a practice that continues (Angelakis et al., 2024). Such barriers, like most infrastructure, can have varying and multiple socio-economic functions (Schmutz and Moog, 2018). These functions include, but is not limited to, hydropower production.” More neutral language is now used when highlighting the impact of barriers on river ecosystems (e.g. ‘alter’ instead of ‘negative impacts’). For example, in the section of The Current Situation – sub section on transversal barriers the following text is now included. “Barriers therefore alter riverine ecosystems upstream and downstream of barriers (Parasiewicz et al., 2023), however, the impacts and how these are perceived by different actors can vary (Gasparatos et al., 2017). While often the focus has been on the impact of large barriers that may still be supporting economic activities (i.e. hydropower production), cumulatively smaller barriers also have a large impact on ecosystem integrity of river ecosystems, even more so given their high abundance. However, smaller barriers have often in the past been overlooked in strategic planning (Belletti et al., 2020, Manders et al., 2016)
Avoid simplistic assumptions on the link between barriers and flooding/ water scarcity: Highlight the benefits of barrier removal can include reduced flood risk and water availability.	ENGO Researcher	The nuanced link between barriers and the impacts of too much/ not enough water within a channel is now highlighted better with examples and references (Strategic Action A and Strategic Action E text). The storage capacity is now highlighted as a key factor in the relationship between flood risk and a barrier (sub section on Nature-based Solutions). Low water levels/ water scarcity and flooding highlighted as a risk to hydropower operations. (sub-section 2.1.2 Operational challenges and potential benefits for the Sector).
Need for more involvement of the sector: Lack of constructive consultation with sector No faith by sector that feedback will be incorporated into the strategy.	Hydropower Sector representatives	The methodology for developing this strategic document is presented I section 3, highlighting key events in the process for the involvement of the sector. A lack of trust is also highlighted. This is now highlighted in several places within the document, including the key messages and Executive summary. The final strategy now has a clearer emphasis on the need to see the hydropower as a partner and to include the sector in strategic discussions about barrier removal in the future. Many ideas and perspectives were explored during the development of the strategy and insights provided by the sector helping to refine the focus as the roundtable discussions progressed. For example, hydropower companies and their representatives highlighted a discussion on the relevance of aging hydropower dams as lacking credibility as companies maintain and upgrading barriers to maintain economic viability and structural integrity. Similarly, a focus on and potential issues with action driven by the term ‘obsolete’ was explored and concerns by small hydropower about future opportunities integrated into the strategy.
Complexity of action underplayed: Need holistic approaches to assess barrier removal options Lack of clear criteria to evaluate barriers effectively. Trade-offs of action not acknowledged. Use a comprehensive cost-benefit analysis to evaluate implications of action.	Hydropower Sector representatives	Strategic Action E on Sector specific tools to design NbS programmes for barrier removal for large companies addresses this issue. It identifies some of the factors that need to be considered in sector decision making, such as challenges, costs and benefits to explore different scenarios and select appropriate actions to incorporate into the design of NbS programmes. It also identifies the need to be informed by evidence and to help identify knowledge gaps.

Develop locally relevant criteria for barrier management		
Lack of clear definitions: Need to define what type of barriers are the focus Need to define ‘obsolete barrier’	Hydropower Sector representatives Researcher	Sector terminology applied to describe the different types of hydropower activities. The focus on transversal barriers (dams, weirs and sluices) that have a strong link to longitudinal river connectivity is explained in the key messages, executive summary and introduction section (sub-section purpose of this strategy). For example, in the latter subsection the following text is included; “<i>The overall aim is to support the Hydropower Sector’s contribution to the removal of transversal barriers (dams, weirs and sluices that control water levels within river channels). These barriers may not be currently utilised for hydropower production. The main focus is on supporting the uptake of an NbS approach to barrier removal, identifying barriers that if removed, could help address sector challenges and create multiple, diverse benefits for the Sector and for society.</i>” Definitions from policy on key terms such as ‘obsolete barrier’ and ‘free flowing rivers’ and ‘longitudinal connectivity’ are now provided in Box 3 (sub section on key challenges for the sector). The identification of barriers for removal is emphasised as arising from strategic catchment scale, holistic assessments (supported by tools as defined in Strategic Action E). Issues with a narrow focus and simplistic definitions of ‘obsolete barriers’ as the scope for action are highlighted in the key messages, executive summary, Strategic Action E text and the discussion.
Contents not endorsed by sector: The contents do not represent the views of the sector (businesses and their representatives) and therefore all reference to participation should be removed.	Hydropower Sector representatives	A disclaimer statement has been included and inserted on the inside front cover. Even with this disclaimer some Hydropower Sector actors remained unhappy and requested their involvement as participants in roundtables in the strategy to be removed from the document. To honour this request, whilst demonstrating the rigorous social science methodology applied in developing this document, the names of these organisations have now been redacted in the participant list in the Annex.
Representation of sector views and attribution of stakeholder input: Lack of balanced representation and evidence base in developing strategy, including attribution of stakeholder input.	Hydropower Sector representatives	The type of actor is now identified where quotes are used in the text to clarify the balance of views included.
Cross sector collaboration: Barrier removal is inherently a collaborative endeavour.	Hydropower Sector representatives	This is a key consideration in Strategic Action D that focuses on how the public and private sector needs to align and work together to ensure appropriate, impactful barrier removal is undertaken. The relevance other economic sectors as potential partners is emphasised in the document (i.e. insurance).
Climate neutrality of hydropower: Highlight that the impacts of barriers can involve greenhouse gas emissions and avoid claims that hydropower is climate neutral.	Researcher	This is now more clearly stated and references included in section on the hydropower sector (section 1.2)

8.2.3 Hydropower Sector’s Statement on the Merlin Project’s Report on “A Hydropower Sector Strategy for Mainstreaming Barrier Removal within an NbS Approach”

The following collective statement from the Hydropower Sector was received on 24th January 2025 reiterating various concerns Hydropower Sector representatives had raised in response to the November 2024 draft.

STATEMENT

1. Background

The hydropower sector has a long-standing commitment to adhering to EU regulations, consistently investing in measures to enhance biodiversity and preserve ecological integrity in alignment with the Water Framework Directive (WFD) and other relevant policies. From the outset of the Merlin Project, the organisations undersigning this statement actively participated in constructive dialogue, frequently providing insights under tight deadlines, on managing river barriers and formulating strategies to balance water management, ecological protection, and energy objectives. Despite this engagement, the hydropower sector strategy paper: A hydropower sector strategy for mainstreaming barrier removal within an NbS approach fails to reflect the sector's contributions, including scientific research, field experience, and perspectives. This raises serious concerns about the report's impartiality and the scientific rigour of its conclusions.

2. Lack of Representation of the Hydropower Sector

The report conveys a narrative that appears biased against hydropower, lacking a robust scientific methodology to evaluate river barriers effectively. It fails to acknowledge the sector's critical role in achieving climate targets, ensuring energy grid stability, and mitigating water stress through the prevention and management of water scarcity, droughts, and floods.

By framing the strategy around barrier removal, the report positions the debate in an unnecessarily adversarial manner. This approach oversimplifies complex ecological, social, and operational trade-offs, while underestimating the potential negative impacts of the proposed actions.

The report neglects the multifunctional role of hydropower, portraying it as inherently at odds with Nature-based Solutions (NbS) rather than recognising the synergies between the two. Additionally, it overlooks the ecological benefits provided by certain river barriers, such as biodiversity conservation, sediment regulation, and ecosystem adaptation.

Further, the evidence presented lacks balance and transparency. The absence of clear attribution of stakeholder input, including contributions from hydropower representatives, undermines the credibility of the report and its strategic recommendations.

While the hydropower sector remains committed to constructive engagement and environmental responsibility, the Merlin Project's report falls short of ensuring balanced representation and evidence-based strategies. Its failure to reflect hydropower's indispensable role in Europe's clean energy transition and climate resilience objectives is particularly concerning.

The undersigned organizations are disappointed by the lack of constructive consultation to identify integrated solutions that balance the interests of all stakeholders. Consequently, we cannot endorse the report and request the removal of any references to hydropower organizations as contributors to its conclusions.

This poor engagement underscores that the Report's conclusions do not reflect the views of the hydropower sector. Rather, they represent the perspectives of the Merlin Project alone, failing to incorporate the sector's contributions and insights.

3. Recommendations and Positions

To foster future collaboration and ensure the credibility of similar initiatives, the hydropower sector makes the following recommendations:

- 1) **Improve the Stakeholder Consultation Process:** Ensure adequate time for comprehensive consultations, explicitly disclose stakeholder inputs in the findings, conclusions, and recommendations, and maintain rigour with clear feedback loops.
- 2) **Foster Integrated Solutions:** Address river barrier removal collaboratively through in-depth consultation among all stakeholders, rather than isolated, independent contributions.
- 3) **Address Ecological Trade-Offs Transparently:** Adopt a holistic approach to assessing biodiversity, sediment transport, and ecosystem adaptation when considering barrier removal.
- 4) **Promote Balanced Narratives:** Recognise the contribution of hydropower to renewable energy targets, grid stability, and climate resilience. Avoid negative portrayals unsupported by robust evidence.
- 5) **Ground Proposals in Evidence:** Employ comprehensive cost-benefit analyses to evaluate the ecological, economic, and clean energy implications of proposed actions.

- 6) **Refine Report Scope:** Clearly define key terms such as “obsolete” and establish locally relevant evaluation criteria for barrier management.
- 7) **Strengthen Policy Alignment:** Ensure alignment with EU policies, highlighting synergies between hydropower operations and NbS in addressing climate adaptation and mitigation.

The hydropower sector reaffirms its commitment to technical innovation, ecological responsibility and collaboration but calls for adequately reflecting complexities, contributions, and potential of hydropower within the broader context of environmental sustainability, climate change mitigation and the energy transition.

Signatories

[International Hydropower Association](#)

[Eurelectric](#)

[ETIP Hydropower](#)

[EurCOLD](#)

[European Renewable Energies Federation- Small Hydropower Chapter](#)

[Finnish Energy](#)

[Kleinwasserkraft Österreich - Small Hydro Power Austria](#)

8.3 Annex 3: Other NbS measures that could be included into the design of NbS programmes within the Hydropower Sector

Below are some illustrative examples of the types of measures that Hydropower Companies, working with other strategic actors, could integrate into the design of NbS programmes alongside barrier removal and creating naturalised by-pass channels. The examples below (Figures 10-12) are taken from the MERLIN project case studies, however none of these [MERLIN case studies](#) were driven by the specific need to address Hydropower Sector challenges.



Figure 9: Wildflower planting of buffer strips as an NbS measure that can help reduce sediment/ nutrients entering watercourses (source: MERLIN Case Study 16 (Scheldt, Belgium))



Figure 10: Floodplain reconnection and river channel restoration as a measure that can help reduce flood risk (before/ during/ after implementation. Source: MERLIN Case Study 15 (Tzipori catchment, Israel))



Figure 11: Reconnecting and rewetting degraded peatland as a measure that can help regulate water levels within a catchment (before/ during/ after implementation. Source: MERLIN Case Study 14 (Komppasuo, Finland))

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