HYDROPOWER IN EUROPE: TRANSFORMATION – NOT DEVELOPMENT

Lead authors: Claire Baffert (WWF-EU), Charlotte Macalister

Communications: Alexandra Chevalier (WWF-EU)

Design: Doug Dawson Creative, www.dougdawson.co.uk

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EXECUTIVE SUMMARY

European rivers are the most fragmented in the world, contributing to the rapid decline in freshwater biodiversity. As a result, a drastic transformation of the hydropower sector is urgently needed to reduce its environmental impact. This can be achieved through several steps: the first one is to stop building new hydropower plants which worsen the fragmentation of rivers and lead to the loss of precious habitats and species.

The other steps consist in mitigating the environmental impact of existing plants. This can first be done through implementing mitigation measures at the plant itself, such as installing modern turbines that are less harmful to fish, building by-pass mechanisms for fish or sediment, or introducing requirements for minimum ecological flows (step 2). Those measures should be complemented with building and maintaining natural fishways past the plant to maintain the river continuity and allow fish to migrate and breed (step 3).

When combined with measures that increase electricity generation capacity, they can provide a win-win for biodiversity, climate and the economy. Those mitigation and restoration measures can reduce the ecological impacts to a limited extent - but never eliminate or offset them.

There are also a number of economic and legal 'triggers' to support the needed transformation of hydropower in Europe. Many hydropower plants in Europe were constructed before the adoption of the EU Water Framework or Nature Directives, so there is an urgent need to bring hydropower permits, licences and concessions in line with EU legal requirements (trigger 1).

Furthermore, there is often a strong economic case for refurbishing plants rather than building new (especially small) ones (trigger 2). However, refurbishment must also be assessed against the alternative option of decommissioning, and for the oldest plants but also for the smallest ones, decommissioning is often the more cost-effective option.

Mitigating the environmental impact of the plants in Europe is also a legal obligation under environmental legislation, which the hydropower sector needs to implement and pay for. This falls under both the EU Water Framework or Nature Directives, which require a mitigation of environmental impacts, and stipulate that polluting and destructive industries should finance environmental mitigation measures, under the principles of 'cost-recovery for water services' and 'polluter pays'. These laws need to be applied to the hydropower sector and mainstreamed in the sectoral legislation (trigger 3).

Finally, a shift in public finance is needed, including a phase out of subsidies and loans for new hydropower projects, even small ones (trigger 4).

CONTENTS

INTRODUCTION

From enormous structures that straddle mountain vistas to small, but obstructive barriers across a river, Europe's water courses are saturated with hydropower. Today, Europe is home to the most-fragmented rivers in the world, resulting in dire consequences for freshwater biodiversity.

Over time, European rivers have become littered with structures, amputating tributaries from larger rivers, trapping vital sediments, blocking fish from their natural migratory routes and hugely contributing to the decline in Europe's freshwater health. Only 40% of European surface waters are considered healthy today.[1]

A key signal of the seriousness of the problem is the loss of freshwater migratory fish populations. In Europe, studies show that the decline in those populations is worse than in any other region of the world. Overall, freshwater migratory fish species like salmon, trout and eel have declined by 93% since 1970 and dams are a major driver of this decline.[2]

This paper outlines a three-step approach that can be taken to address the negative impact of hydropower on freshwater species and habitats. The first is simply to stop building new plants. Thousands of new plants are currently planned across Europe, and a large proportion of these are in protected areas.[3] Most of the plants are small, meaning they are unable to generate much electricity while their impact on nature is excessively high.

The second step is to lessen the environmental impact of existing plants through plant environmental refurbishment. From ecological flows to acquiring knowledge on fish migration patterns, hydropower plants can be adapted and managed in a more nature-sensitive manner, as illustrated by a case study on the Allier River in the Loire Valley, France.

The third step is the restoration of the rivers' natural functions, in particular continuity and habitats. The case study on the construction of a reproduction channel next to the Imatra hydropower plant in Finland, illustrates active restoration measures that should be taken to complement mitigation measures at the plant itself.

1. European Environment Agency, *European waters: Assessment of status and pressures* (July 2018).
2. Deinet, S., Scott-Gatty, K., Rotton, H., Twardek, W. M., Marconi, V., McRae, L., Baumgartner, L. J., Brink, K., Claussen, J. E., Cooke, S. J., Darwall, W., Eriksson, B. K., Garcia de Leaniz, C., Hogan, Z., Royte, J., Silva, L. G. M., Thieme, M. L., Tickner, D., Waldman, J., Wanningen, H., Weyl, O. L. F., Berkhuysen, A. (2020) *The Living Planet Index (LPI) for migratory freshwater fish* – Technical Report. World Fish Migration Foundation, The Netherlands.
3. WWF, RiverWatch, EuroNatur, GEOTA, *Hydropower pressure on European rivers: the story in numbers* (November 2019).

DEFINITIONS

Refurbishment: Term most commonly used to designate the technical improvements or upgrades made to existing hydropower plants, which may incorporate modernisation of structures and equipment, introduction of new technologies or devices, and/or uprating of hydropower plants.

Uprating: Increasing the size of the hydropower plant.

Retrofitting: Adding hydropower technologies to a non-powered dam or barrier. Retrofitting is distinct from refurbishment.

In this paper we distinguish between two types of refurbishment, which differ by their objectives:

- Environmental refurbishment: Improvements in the ecological performance of a plant through on-site mitigation measures, leading to reduced environmental impacts.
- Output-oriented refurbishment: Improvements in the generation capacity of a plant.

TRANSFORMATION, STEP 1:

NO MORE NEW HYDROPOWER PLANTS IN EUROPE

Hydropower plants in all their forms disrupt the flow of water and sediment downstream by creating segregated river fragments. Just like all in-stream structures, they alter or impede the natural seasonal flow of a river and change its hydrological characteristics. The blockage that they create also keeps biota, most commonly migratory fish, from moving freely along the river. This disruption of continuity is the primary negative impact that hydropower plants have on freshwater biodiversity by directly degrading habitats.[4]

Hydrological and physical impacts also change the river's physical and biological characteristics, and the ecology of the local catchment and wider watershed. Hydropower plants can cause severe changes in temperature regimes; diminished water quality; and dramatic reductions in sediment transport, resulting in a loss of ecosystem services and biodiversity.[5] Although much less common, hydropower can also trigger earthquakes.[6]

DIFFERENT TYPES OF HYDROPOWER PLANTS

IMPOUNDMENT

Sometimes called storage, an impoundment plant is probably the most well-known type of hydropower plant. They are typically associated with a dam and a corresponding reservoir.

DIVERSION

Also referred to as a run-of-river, these plants channel a portion of a river through a smaller canal and do not require the construction of a reservoir. Often small hydropower plants are diversion plants, but very large diversion plants also exist, such as in the Dinaric karst in the Balkans.

PUMPED STORAGE

These plants work like a battery. When energy needs storing, water is pumped up to the reservoir. When energy demand is high the water is released again.

Some environmental impacts are specific or more common to one type of plant. For instance, water abstraction and lack of residual flow occur mainly in diversion-type hydropower plants. In those types of plants, the dam serves to divert most of the discharge to a distant powerhouse, where it gets turbinated and released to the original river further downstream, but frequently in lower quantities (low residual flow).[7] There are also some impacts that are specific to reservoirs – such as distinct temperature layers, with cooler water residing at the bottom, and thus also a decrease in oxygen concentration in its depth. Most of the impacts on biodiversity and ecosystems are caused by all three types of plants.

Hydropower causes more pressures on ecosystems than its renewable energy counterparts such as solar or wind. According to the European Environment Agency's recent *State of nature in the EU* report, **hydropower is the largest of energy-related pressures for habitats and species (excluding extractive energy sources).**[8]

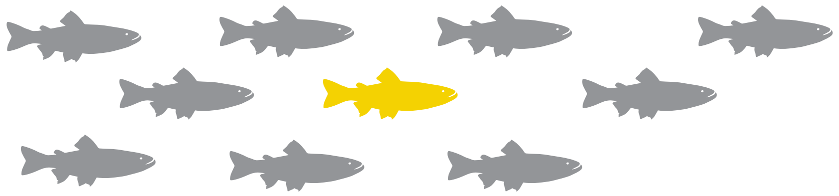
Moreover, the existing situation of freshwater ecosystems in Europe makes a particular case against further hydropower development. Europe has heavily dammed its watercourses, be it for hydropower or for other uses such as irrigation, drinking water impoundments or flood protection. As a result, Europe has the most fragmented rivers in the world with over 1 million barriers.[9] The level of migratory freshwater biodiversity loss is worse in Europe than in any other region of the world. In Europe, populations of migratory freshwater fish have decreased by 93% since 1970, and dams are a major driver of this decline.[10]

Additionally, most of the hydropower potential is already harnessed and expected growth in Europe is estimated to be limited.[11] The potential contribution of new hydropower plants is therefore negligible in terms of the transition to a clean energy system, even in those cases where the electricity they provide is 'dispatchable'. This is why stopping the construction of more hydropower plants in Europe is a necessity, and step 1 of the needed transformation.

IN EUROPE, POPULATIONS OF MIGRATORY FRESHWATER FISH HAVE DECREASED BY

93%

SINCE 1970, AND DAMS ARE A MAJOR DRIVER OF THIS DECLINE



4. Vörösmarty, C. J., McIntyre, P. B., Gessner, M.O. et. al. *Global threats to human water security and river biodiversity*. Nature, 467(7315), (2010).
5. Liermann, C. R., Nilsson, C., Robertson, J. & Y. Ng, R., Implications of Dam Obstruction for Global Freshwater Fish Diversity. Bioscience 62, 539–548 (2012). Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L. & Tockner, K. A global boom in hydropower dam construction. Aquatic Sciences. 77, 161–170 (2014).
6. Freyhof, J., Bergner, L. & Ford, M. *Threatened Freshwater Fishes of the Mediterranean Basin Biodiversity Hotspot: Distribution, extinction risk and the impact of hydropower* (2010).
7. Van Treeck, R., Radinger, J., Noble, R. A. A.,, Geiger, F., Wolter, C. *The European Fish Hazard Index – An assessment tool for screening hazard of hydropower plants for fish,* Sustainable Energy Technologies and Assessments, Volume 43, (February 2021).
8. European Environment Agency, *State of nature in the EU*, (October 2020).
9. AMBER Consortium (2020). The AMBER Barrier Atlas. A Pan-European database of artificial instream barriers. Version 1.0 June 29th 2020. *https://amber.international/european-barrier-atlas/* .
10. Deinet, S., Scott-Gatty, K., Rotton, H., Twardek, W. M., Marconi, V., McRae, L., Baumgartner, L. J., Brink, K., Claussen, J. E., Cooke, S. J., Darwall, W., Eriksson, B. K., Garcia de Leaniz, C., Hogan, Z., Royte, J., Silva, L. G. M., Thieme, M. L., Tickner, D., Waldman, J., Wanningen, H., Weyl, O. L. F., Berkhuysen, A. (2020) *The Living Planet Index (LPI) for migratory freshwater fish* – Technical Report. World Fish Migration Foundation, The Netherlands.
11. European Commission, *Technology information sheet, Hydropower*, (2013).

TRANSFORMATION, STEP 2:

IMPROVING THE ECOLOGICAL PERFORMANCE OF EXISTING PLANTS THROUGH ON-SITE MITIGATION MEASURES

The environmental impacts of hydropower plants can be mitigated through three broad types of physical measures at the plant itself:

1) Modifying the hydraulic characteristics of generating technologies (e.g. turbines);
2) Introducing by-pass mechanisms for biological (e.g. fish) and mineral (e.g. sediment) components;
3) Operational / functioning measures, such as ecological flows or hydropeaking prevention.

These measures mitigate three main groups of impacts:

- changes to flow (rate, duration and water levels);
- resultant changes in water quality (chemistry, temperature and sediment load);
- and barriers to fish migration.

There are, of course, many other impacts and effects but these three groups can be practically mitigated through some form of refurbishment.

MODERNISED TURBINES

Although no commonly agreed tool exists to assess the hazards that hydropower plants pose to fish populations, there is evidence that mortality in turbines and inability to migrate have long term negative effects on fish populations. Hydropower plants "cause direct injury and mortality of fish, e.g. by sheer forces, pressure changes and collision with fixed or moving parts during both turbine and spillway passage".[12]

A recent study by the Leibniz Institute for Freshwater Ecology and Inland Fisheries showed a high risk of mortality by hydroelectric power plants for species that travel long distances due to their behaviour and reproduction patterns. According to the study, "downward migrating fish (e.g. eel) and upward migrating fish that reproduce several times in their lifetime (e.g. sea trout) are particularly at risk. Upward-migrating fish that reproduce only once in their life are at risk as juvenile fish. They are particularly at risk because they are only protected from the turbine passage by very narrow rakes. Fish which migrate over long distances within a water system (e.g. common nase) are also at high risk of being killed. In the case of turbine passage, the probability of fatal injury to migrating fish species increases with body size".[13]

The turbine mortality risk for fish can be substantially lowered by implementing fish protection devices like fine screens, in combination with easily accessible bypasses. In particular, power plants need to be equipped with racks to prevent smolts going through the turbines. Some modern turbines can also reduce mortality rates. Mortality rates are found to be higher for Francis and Kaplan turbines compared to Archimedean screws and water wheels.[14]

BY-PASS MECHANISMS

Building fish passes can reduce the adverse impacts of river fragmentation by hydropower dams to a certain extent but is not enough to overcome them. Even if fish passages are built, habitat conditions stay less favourable for fish, also the effectiveness of fish passages varies per species.[15] Effectiveness is especially low for fish species that are not strong swimmers and even designing fish passes for salmonids has been challenging. The effectiveness of specific fish passages for salmonid species will also depend on differences in attraction flow provided by the pass. Still, for salmonid species the variance in passage efficiency is 0-100%. For fish species that aren't strong swimmers, low slope fish passes generally have higher passage efficiencies – but because of the multitude of physical and biological variables that affect fish passage, scientists seem to be unable to recommend any particular fishway type that would allow the passage of most species.[16] In addition, fish passes alone are not always sufficient. Experts recommend a combination of mechanical fish deflectors, adequately installed fish ladders and descent aids, "the functionality of which must also be continuously checked and ensured."[17] Downstream migration for smolts and also for adult big fish, eels and sturgeons should be ensured in all fish pass projects.

OPERATIONAL/FUNCTIONING MEASURES

Operational and functioning measures refer to actions which can be implemented, as a complement to physical measures mentioned above, with no or limited additional physical intervention on the infrastructures, namely measures to restore ecological flows, prevention of hydropoeaking and management of large reservoirs to avoid periodic disconnectivity with upstream tributaries. Ecological flows are an essential element in meeting the objectives of the EU Water Framework Directive (see box below). In Austria for instance, a 2015 study showed that the majority (>85%) of the more than 2000 existing hydropower plants lacked

12. Van Treeck, R., Radinger, J., Noble, R., A., A., Geiger, F., Wolter, C. *The European Fish Hazard Index – An assessment tool for screening hazard of hydropower plants for fish*, Sustainable Energy Technologies and Assessments,Volume 43, February 2021.
13. Leibniz Institute of Freshwater Ecology and Inland Fisheries, *Hydropower: the mortality risk for fish at turbines* (October 2020).
14. *Ibid*
15. Van Puijenbroek, P. J. T. M., Buijse, A. D., Kraak, M. H. S. et al. *Species and river specific effects of river fragmentation on European anadromous fish species*, 35, 68–77, (2019)
16. Bunt, C. M., Castro-Santos T., Haro, A., Arena paper, *Reinforcement and Validation of the Analyses and Conclusions Related to Fishway Evaluation Data from Bunt et al.: 'Performance of Fish Passage Structures at Upstream Barriers to Migration'*. (2016)
17. Leibniz Institute of Freshwater Ecology and Inland Fisheries, *Hydropower: the mortality risk for fish at turbines* (October 2020).

regulatory requirements for ecological flow, as it is obligatory only since 1990.[18] Restoring ecological flows, through setting a minimum flow (calculated to allow fish migration and good ecological status in general) and/or setting restrictions on reservoir and/or run-of river operations therefore is absolutely crucial. So is preventing hydropeaking, oscillations in discharges occurring at short time scales. Measures generally consist in reducing the rate at which flow ramps down, including using a bypass valve, while morphological measures can also be taken, such as installing a (series of) balancing reservoir(s) in the river channel. While the implementation of ecological flows and management of hydropeaking improves conditions for freshwater ecosystems located downstream of dam reservoirs, the management of water level in large reservoirs also needs to be considered, especially to ensure connectivity with upstream tributaries.

ECOLOGICAL FLOWS IN THE EU WATER FRAMEWORK DIRECTIVE

"The EU Water Framework Directive, as well as the Birds and Habitats Directives, set binding objectives on protection and conservation of water-dependent ecosystems. These objectives can only be reached if supporting flow regimes are guaranteed. The establishment and maintenance of ecological flows, in the sense used in this document, is therefore an essential element in meeting those objectives. Therefore consideration of ecological flows should be included in national frameworks, including binding ones as appropriate [...]."

Source: CIS guidance document n°31 – *Ecological flows in the implementation of the EU Water Framework Directive* (2015)

The measures described above can reduce to some extent some environmental impacts of hydropower plants, but only to a limited extent, especially for small hydropower plants.[19]

REFURBISHMENT OF THE POUTÈS DAM, RIVER ALLIER, AND COLLABORATIVE MANAGEMENT, LOIRE VALLEY, FRANCE.

CASE STUDY A

The Allier is the main tributary of the Loire River and a primary spawning ground for remaining populations of Atlantic salmon in Western Europe. The need to protect this emblematic species has led the French Government to invest tens of millions of Euros in conservation and restoration programmes in the Loire over the last 20 years. Despite this, the Loire salmon remains on the verge of extinction.

Three dams located between 793-825 km from the Atlantic block access to the spawning areas on the Allier, estimated to represent 42% of the total potential productive spawning area in the Allier basin.

The Poutès hydropower dam was constructed on the Allier River during the 1940s and the original licence to operate the dam, awarded in 1956, ended in 2007. Since its construction the loss of 90% of the Loire-Allier wild salmon population has been attributed to the dam, sparking protests by fishermen and environmental groups that ran for 20 years from 1991.

The lobby for the removal of the dam intensified in 2004 when the dam's operator, EDF, applied for a 50-year renewal of the license. This was the trigger for a national campaign organised with support from WWF and Patagonia. In 2011 a consensus was reached and the French Ministry of the Environment announced the reconfiguration of the Poutès dam. EDF received a renewal for a further 50 years with major concessions for fish passage, sediment restoration and environmental flows at the Poutès site.

The refurbished dam will be 7m high with two central sluice gates, containing a 400m-long reservoir, This compares to the current 3500m-long reservoir. The gates will allow morphogenic floods (around 100m³/s) to restore sediment transport during the flood season and will be open for 91 days in spring and autumn for upstream fish migration. An elevator and fish pass will also be operational all year.

The turbine flow will be 28m³/s, compared to 20m³/s in the initial project, but with no power generation during the three-months of open sluice gates. Downstream migration will be optimised by grids with a finer intake of 12mm as opposed to the previous 20mm. Retrofitting and refurbishment is now underway and should be completed in 2021.

Additional improvements are also planned. Since 2009, in collaboration with the operator, EDF, Conservatoire National du Saumon Sauvage (CNSS) has been assessing the downstream migration rhythms of Atlantic salmon using a rotary screw trap. Under the EU-funded AMBER project, CNSS will install an additional rotary trap in the Loire-Allier, and compare the results with the existing baseline data. The aim is to develop flow management guidelines specific to each of the three dams on the Allier to reduce the impact of turbines on smolt passage, whilst optimising hydropower production.

Using multiple datasets on smolt migration collected under a range of conditions, CNSS hope to identify the critical times and flows necessary for safe downstream passage in the Loire-Allier catchment. This information will be used to request reduction or shut down of turbines during vital days of the year. Such measures serve as a great example of adaptive barrier management, easily implemented without additional facilities or retrofitting.

Source: European Rivers Network (ERN – *https://www.ern.org/*), AMBER (*https://amber.international/*), and Conservatoire National du Saumon Sauvage (*http://www.saumon-sauvage.org/*).

Are those measures detrimental to the overall electricity production and profitability?

Mitigating the risks of hydropower installations for fish usually comes with a slight loss of generation capacity (e.g. by increasing discharge in upstream migration facilities) and with increased costs (e.g. for maintaining and servicing fine screens at the turbine intakes), which can result in small plants being relatively less profitable. Different estimates show that the implementation of the EU Water Framework Directive (WFD) through minimum flow requirements and other mitigation measures might affect overall hydropower production by around 3%.[20,21] On the other hand, some mutual benefits are also to be observed. In many cases, replacing an old sub-optimal turbine with a new 'fish-friendly' turbine, and debris and sediment removal (technological and waterway management), are also likely to increase plant efficiency.

In 2011 the Governor of Upper Austria issued an ordinance for mitigation measures in the priority river stretches defined in the 2009 River Basin Management Plan, obliging the introduction of river continuity measures at 310 barriers, 100 of which are barriers of hydropower plants. In a study, the losses in generation through mitigation measures were evaluated and it was found that while losses can be considerably high for single plants, in total they are less than 1 % of the hydropower generation in Upper Austria.[22] Given this low impact, **on-site environmental mitigation measures must become a mandatory standard for all hydropower plants.**

18. CIS guidance document n°31 – *Ecological flows in the implementation of the EU Water Framework Directive* (2015)
19. Lange, K. et.al. *Small hydropower goes unchecked*, Frontiers in Ecology and the Environment 17(5):256-258 (June 2019).
20. Arcadis/Ingenieurbüro Floecksmühle: Hydropower generation in the context of the EU water framework directive, May 2011, quoted in EEB/CAN Europe's *Paris Agreement Compatible energy scenario* (page 33).
21. CIS guidance document n°31 – *Ecological flows in the implementation of the EU Water Framework Directive* (2015)
22. ICPDR, *Hydropower Case Studies and Good Practice Examples* (2013).

TRANSFORMATION, STEP 3:

BEYOND REFURBISHMENT: RESTORING RIVERS' NATURAL FUNCTIONS

The mitigation measures described in the previous section are useful to a limited extent, but far from being sufficient. In order to reduce the impact of existing plants, it is also necessary to holistically address the impact of the plant at the catchment level, which means going beyond environmental refurbishment of the plant itself, and engaging in larger-scale river restoration measures, such as natural fishways or restoration of habitats.

Natural fishways enable fish to avoid the river section where a hydropower plant is built. One well-known example is the 14.2 km bypass channel built in 2016 at the Ottensheim Wilhering hydropower plant on the Austrian Danube. The bypass, which discharges an average of 17m³ per second at its lowermost section, enables both upstream and downstream fish migration and provides high quality key habitats.[23] If the costs of such measures are high – in Finland, the costs of construction of a natural bypass channel are estimated at an average of 20.000 € / height meter of the obstacle to circumvent[24] – their benefits are also substantial. They enable the restoration of river continuity, hence allowing migration for all species (including weak swimmers), creating ecological corridors for mammals and bird juveniles, and new habitats for spawning and rearing. They also have landscape value and tourism benefits, if well designed. Compared to more traditional fish passes, natural fishways are suitable for all species.

However, if natural bypass channels help address connectivity issues, they do not directly tackle the loss of reproduction habitats resulting from damming rapids to stagnant conditions and altering their morphology. Natural bypass channels themselves might be subject to uneven discharges, and be improper for reproduction. Since the 1950s, Canadian scientists have been working to address this issue and developed the practice of building side channels dedicated to the sole reproduction of Atlantic salmon. Usually drawing from a side arm of the river or from the main arm of the river, they would aim at providing safe conditions for eggs and juveniles, such as even discharges, low gradients (normally 0,05-0,2%), meanders and ponds. In those Canadian reproduction channels, scientists observed densities up to 150 juveniles/100 m² [25], bigger than in natural rivers, and survival rates of fry in spawning channels which can be four to eight times higher than in natural rivers.[26] This practice needs to become more standard in Europe too, based on successful trials such as in the following case study.

FINLAND - CONSTRUCTION OF A REPRODUCTION CHANNEL IN IMATRA, FINLAND

CASE STUDY B

The "Imatra city brook" was constructed in 2014 next to the local hydropower plant to restore the lost habitat for the Brown trout stock *salmo trutta*. 1 km-long, with an elevation of 25 m and a 2-5 meters width, it provides a regular discharge of 0.3 m³/sec (summer), and 0.15 m³/sec (winter), and includes 7 meanders, a tunnel, and two ponds. It was designed to include very shallow spawning gravel areas with very low gradients and flow velocity, a bit deeper but still low-gradient areas suitable for small juveniles under 10 cm, and steeper, higher-velocity sections. The Imatra city brook was inaugurated in 2015 and monitoring of fish and macroinvertebrates conducted in 2016 and 2017. In 2016, the local news reported "2016: Fish willing to spawn is searching for a mate in the City Brook". Actually, with a high average density (an average of 40-43 individuals/100 m² and up to 136/m² in the tunnel), a survival rate of 76 % which is much higher than normally in natural streams, and good condition factors, trout juveniles showed stable conditions and much higher productivity of the stream than in natural rivers. Benthic macroinvertebrates also showed increasing diversity and good availability for fish as nourishment. This example demonstrates that constructed reproduction channels have a great potential in compensating lost habitats and natural reproduction of trout and salmon.

Source: Jukka Jormola, Saija Koljonen, Kirsti Leinonen, Markus Tapaninen, Pekka Vähänäkki, Finnish Environment Institute SYKE, Southwest Finland ELY-Centre, International Symposium on Ecohydraulics ISE 2018, Tokyo, (19-22 August 2018).

The function of recreating conditions for reproduction can also be added to natural bypass channels, by designing special sections of the bypass channel with low gradient for habitats, and steeper sections for migration. In that case, the downstream entrance of the bypass channel should always be located as close as possible to the turbine to ensure upstream migration (through a fish ladder or lift if necessary), but in the case of a larger bypass channel, another entrance could also be built further downstream.

As shown by the table on the next page, **the improvement measures on hydropower plants that have the strongest positive effects on environmental challenges are not in fact the on-site mitigation measures this report has already discussed, but sediment and habitat restoration measures.** The table clearly shows that the most effective measures are by far weir and barrier removal, whose cost, at least for large dams, is estimated to be "an order of magnitude less than that of repairing."[27]

So it is important that existing hydropower plants undertake regular assessments to evaluate the added value and relevance of extending their lifetime against the alternative option of removal.

23. WWF, *Bringing life back to Europe's waters*, 2018, page 26.
24. Jukka Jormola, Finnish Environment Institute SYKE, Presentation given at the Peer Review of Jucar river basin district, Valencia (19-23 October 2015).
25. Results obtained in the Granite Canal compensation creek, Newfoundland, 2003, quoted by Jukka Jormola.
26. Roos, J.F. "Restoring Fraser River salmon". The Pacific Salmon Commission, Vancouver (1991). p.214.
27. Perera, D., Smakhtin, V., Williams, S., North, T., Curry, A., (2021). *Ageing Water Storage Infrastructure: An Emerging Global Risk*. UNU-INWEH Report Series, Issue 11. United Nations University Institute for Water, Environment and Health, Hamilton, Canada.

Table 1: Mitigation measures at hydropower plants and their suitability for addressing environmental challenges

Strong positive effect
Moderate positive effect
No detectable effect

Overall challenge			Habitat degradation		Fish migration		Sediment management		Flow adjustments	
Library of possible measures			Instream degradation	Shoreline and off-channel degradation	Barriers obstructing upstream migration	Barriers obstructing downstream migration	Barriers trapping sediments	Surplus of sediments	Consistent additional release	Freshets and peaks
Habitat	Instream habitat adjustments	Placement of spawning gravel							Some	
		Placement of stones							Some	
		Cleaning of substrate – ripping, ploughing and flushing								Yes
		Dead wood and debris							Some	
	Restoring habitat	Removal of weirs								
		A river-in-the-river								
		Construction of off-channel habitats								
	Shoreline habitat	Environmental design of embankments								
		Restoration of the riparian zone vegetation								
Fish migration	Downstream	Barrier removal								
		Operational measures								
		Sensory & behavioural barriers								
		Fish-friendly turbines								
		Skimming walls								
		Bypass combined with other solutions							Some	
		Fish guidance w/harrow bar spacing								
		Fish guidance w/wide bar spacing								
		Bottom-type intake							Some	
		Other measures								
	Upstream	Barrier removal								
		Nature-like fishways							Some	Some
		Pool-type fishways							Some	
		Baffle fishways							Some	
		Fishways for eels/lamprey							Some	
		Fish lifts, screws and locks								
		Truck transport								
Sediment	Routing	Drawdown reservoir flushing								Yes
		Sediment sluicing								Yes
	Removal	By-pass sediment channel								Yes
		Off-channel storage								Yes
		Mechanical removal of fine sediments (dredging)								
		Measures for minimizing the sediment arrival to the reservoir							Some	
	Restoration in rivers	Placement of gravel and stones								
		Removal of bank protection								
		Debris removal								
		Hydraulic conditions for sediment transport							Yes	Yes

Source: Reproduced from: Harby, A, David, L, Adeva-Bustos, A, Hansen, BT, Rutkowski, T, (2019) *https://www.fithydro.eu/wp-content/uploads/2020/03/D4.2_Functional_application_matrix_for_identification_of_potential_combinations_of_improvement_measures.pdf*

When removing an existing hydropower plant is not relevant, the restoration of habitats should be systematically considered. Constructed reproduction channels, in particular, have a great potential in restoring lost habitats and natural reproduction, at the very least of trout and salmon, and should always be added into planning concepts of fish passes in existing power plants. A full application of the cost-recovery principle to the hydropower sector, as described in section "Trigger 2", can ensure sufficient funding and facilitate the monetary contribution of the hydropower companies to those large-scale restoration measures.

To be effective, a well-designed environmental refurbishment program should incorporate all relevant refurbishment measures: on-site environmental mitigation measures, and restoration measures. All improvement measures should be planned as part of a watershed management scheme, incorporating all control structures. Installing fish passes or implementing ecological flows in a single plant might not be of much use, if other hydropower plants in the same river upstream do not have any mitigation measures. Such an integrated planning approach must also be continuous throughout the operational life of the plant.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TRIGGER 1:

OBSOLESCENCE AND RENEWAL OF PERMITS

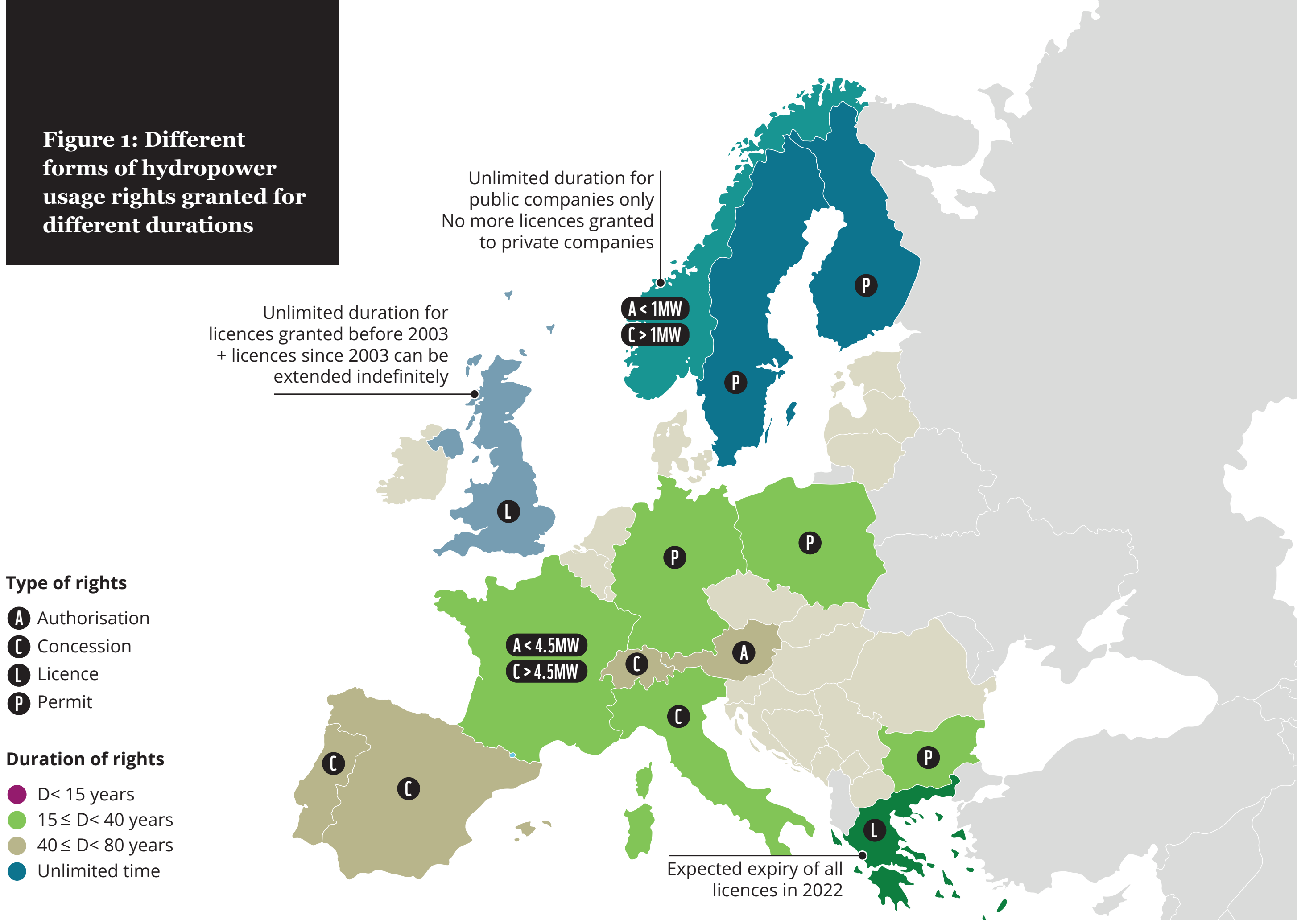
Many hydropower plants in Europe are several decades old. In a majority of European countries, the median age of large dams (including hydropower dams, but also dams for other purposes than electricity production) is over 50 years.[28] Small hydropower plants are no exception to it, as about 65% and 50% of small hydropower plants located in Western and Eastern Europe, respectively, are >40 years old.[29] The long lifetime of many hydropower plants – often over 50 years, and up to a century – is largely explained by the fact that civil structures including dams and tunnels can function for several decades before requiring major renovation. It is not completely the same for electromechanical equipment, which may be outdated within 15 years, and will anyway need to be upgraded or replaced within 30 to 40 years, sometimes less than that.[30]

This means that a significant number of hydropower plants were constructed in Europe before the adoption of the Water Framework or Nature Directives, and are operating under 50 years old conditions. **Therefore it is urgent that national authorities initiate processes to revise hydropower permits, licenses and concessions across Europe to bring them in line with the requirements of the WFD, and other national and international obligations related to biodiversity and state of the freshwater bodies.** Any plants coming to the end of licenses or permits predating these Directives, need to comply with their terms in subsequent periods, under new permitting arrangements. In many cases that could mean the introduction of mitigation measures for environmental impacts not anticipated in the original plant design, such as timely release of environmental flows, fish-friendly turbines or fish passes for example.

Legislation for granting or renewing the rights to use hydropower varies a great deal from one country to another, with the duration of usage rights ranging from a few years (in Great Britain, for new hydropower plants) to unlimited duration (Sweden), but mostly comprised between 15 and 80 years (see figure below).[31] It is therefore very hard to foresee the rate of renewal at European scale in the coming decades, but it roughly corresponds to the rate of renewal imposed by the obsolescence of electro-mechanical equipment highlighted above. In France, about one fourth of the concessions for hydropower plants (and about 20% of the cumulated electricity generated by hydropower) are expected to expire during the present decade.[32]

28. Perera, D., Smakhtin, V., Williams, S., North, T., Curry, A., 2021. *Ageing Water Storage Infrastructure: An Emerging Global Risk*.UNU-INWEH Report Series, Issue 11. United Nations University Institute for Water, Environment and Health, Hamilton, Canada.
29. Van Treeck, R., Radinger, J., Noble, R. A. A.,, Geiger, F., Wolter, C. *The European Fish Hazard Index – An assessment tool for screening hazard of hydropower plants for fish*, Sustainable Energy Technologies and Assessments,Volume 43, (February 2021).
30. Kumar, A., T. Schei, A. Ahenkorah, R. Caceres Rodriguez, J.-M. Devernay, M. Freitas, D. Hall, Å. Killingtveit, Z. Liu, 2011: *Hydropower*. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
31. Jean-Michel Glachant, Marcelo Saguan, Vincent Rious, Sébastien Douguet, *Regimes for granting the right to use hydropower in Europe*, Florence School of Regulation, European University Institute (October 2015).
32. *Ibid.*

Figure 1: Different forms of hydropower usage rights granted for different durations



Source: Reproduced from: Jean-Michel Glachant, Marcelo Saguan, Vincent Rious, Sébastien Douguet, *Regimes for granting the right to use hydropower in Europe*, Florence School of Regulation, European University Institute (October 2015).

Overall, while it is true that the normal renewal rate of usage rights does provide some opportunities for refurbishment in the short-medium term, the process is too slow to foster a transformation of the sector at the pace that would be necessary to bring European waters back to good status and restore freshwater biodiversity.

For this reason, some countries have chosen to somehow accelerate the process. In 2019, Sweden, which used to have unlimited licenses, passed a law that obliges a nationwide re-licensing of almost all hydropower plants between 2022 and ~2040 to bring them in line with the EU Water Framework Directive. A plan was approved in 2020 to organise this process, with the objective that all hydropower plants have modern environmental permits within 20 years and that licenses would have a maximum duration of forty years. Several elements raise however concerns: one is the strong encouragement to maximize the use of exemptions in the EU Water Framework Directive, in combination with a large number of designated heavily modified water bodies. Another one is the separate 'guide value' presented to ensure that the loss of national hydropower production would not exceed 2.3% or 1.5TMH annually. Swedish authorities recognise that the re-licensing process will require stakeholder dialogues in each catchment to set suitable mitigation goals/measures before court proceedings,[33] but that will not be sufficient. The process will likely require a much higher level of ambition and broader range of measures to actually reverse the biodiversity loss in Swedish rivers during this 20-year period.

The European Commission in the EU Biodiversity Strategy has asked Member States to review all permits for impoundment structures by 2030 and will provide guidance on how to do so in 2023.

33. Jakob Granit, Director General Swedish Agency for Marine and Water Management, Presentation: *Swedish Water Act: new legislation Towards sustainable hydropower*, Vaasa (21 May 2019).

TRIGGER 2:

THE ECONOMIC CASE FOR REFURBISHMENT

Refurbishment often makes more economic sense than building new plants and requires less time for implementation.[34]

This is first and foremost because the main cost component of hydropower is the investment cost during the construction phase, while operating and generation costs are relatively low.

In general, hydropower has a low levelised cost of electricity (LCOE).

ECONOMIC LEXICON: LCOE AND CAPEX

LCOE: the averaged (expected) cost of producing a unit of electricity during the generating lifetime of a plant. It includes the cost of financing and building a power plant along with the lifetime operations and maintenance costs, and it incorporates economic 'discounting' to account for changes in materials, labour, fuel and currency fluctuations over time.

CAPital EXpenditure (CAPEX): the cost of delivery of a plant as if no interest was incurred during construction, measured in EUR/kW.[35]

There are many reasons why hydropower compares favourably with other generation technologies, not least the fuel component of the LCOE, water. This fuel is essentially free to the generator and there is no ongoing fuel cost once the plant is complete. Hydropower plants also have a very long operating lifetime, with the potential for continuous 'life-extension', so long as civil works and generating technological components are maintained and updated periodically. Furthermore, ongoing Operation and Maintenance (O&M) costs typically range from 1 – 4% of annual investment costs. However, environmental and social costs are rarely, if ever, factored into installed costs or LCOE.

But, and even if this is highly site sensitive and project specific, hydropower does have high upfront investment costs. Mechanical equipment and civil engineering works account for two thirds of upfront investment costs. These costs represent the largest portion of the cost of producing electricity averaged over the operating life or the economic life of the plant. This is particularly true for very small plants with capacities of less than 1 MW where the investment cost per kW can be very high – two to three times higher than for small (1-10 MW) and large plants (>10MW) (see table 2).[36] This can be explained by the fact that small projects have higher investment and average costs than larger projects, due to the proportional contribution of electro-mechanical equipment dominating total installed costs.

Table 2: Hydropower performance and cost statistics for plants by installed capacity

Installed capacity range	Very small <1 MW	Small 1-10 MW	Large >10 MW
Construction time, months	6-10	10-18	18-96
Technical lifetime, yr.	Up to 100	Up to 100	Up to 100
Max. turbine efficiency %	Up to 92	Up to 92	Up to 92
Load/ capacity factor**	0.4-0.6	0.34-0.56	0.34-0.56
Investment cost, USD kW	3,400-10,000	1,000-4,000	1,050-7,650
O&M cost USD kW yr.	45-250	40-50	45 (average)
LCOE USD MWh*	270 or more	20-100	20 – 190

**the LCOE or 'Production Cost' is calculated here with and economic lifetime of 30 years and using a 10% interest or discount rate.*

***the capacity factor is the proportion of time in the year when a plant is producing power. For comparison wind power has a range of around 0.2-0.3 (20-30%), and solar power is typically around 0.1 (10%).*

Source: Charlotte Macalister, commissioned by WWF. Data from: IRENA (2015) Technical Review of international hydropower costs.

34. Kumar, A., Schei, T et al. *Hydropower* in IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, Cambridge University Press (2011).
35. JRC (2014) ETRI *Energy Technology Reference Indicator projections for 2010-2050*, Ed. Carlson Johan. JRC N°: JRC92496 (2014).
36. IRENA (2015) Hydropower Technology Brief, IEA-ETSAP and IRENA Technology Brief E06, International Renewable Energy Agency, Abu Dhabi.

For this reason, increasing the generation capacity of existing plants has the lowest investment costs, while the development of greenfield sites is most expensive. This makes sense as a large component of site development, namely civil works, representing at least 30% of total cost, would be minimal for existing sites. In 2012, the IRENA reported costs for the development of greenfield sites typically ranging from €800-2900/kW, and estimated the LCOE for refurbishment and upgrades 2 to 4 times lower than the LCOE for building new large hydropower projects (see table 3).[37]

Table 3: LCOE comparison of new hydropower sites and refurbishment

	Refurbishment and upgrades	Newly built large hydropower projects	Newly built small hydropower projects in developing countries
LCOE range[38] USD/kWh	0.01- 0.05	0.02 – 0.19	0.02 – 0.10
LCOE range €/kWh	0.008 – 0.04	0.016 – 0.16	0.016 – 0.08

Source: Data from IRENA, Renewable Energy Technologies: Cost Analysis Series. Volume 1: Power Sector. Issue 3/5, *Hydropower*, (2012).

According to the International Energy Agency (IEA), pre-1960 turbines can frequently obtain output increases up to 30% and efficiency increases greater than 5% by replacing original turbine runners with updated technology according to the IEA and General Electric.[39,40] With such upgrades of electro-mechanical equipment, the life of the plant can also be significantly extended. Regularly refurbishing or replacing some components may potentially extend the life of plants to up to 100 years.[41]

Another explanation of why refurbishment makes more economic sense than building new plants is that the investment costs for building new plants are on the rise because new plants are now mostly built in more remote areas. The Joint Research Centre noted already in 2014 that “slightly increasing CAPEXs are expected due to the fact that the most attractive sites have been or will be exploited before the less attractive ones.”[42]

The cost-effectiveness of refurbishment also needs to be evaluated against the option of decommissioning.

In some cases, decommissioning might be a more cost-effective alternative to the construction of new hydropower plants than refurbishment. This is particularly true for the oldest plants, in the light of public safety, growing maintenance costs, progressing sedimentation of the reservoir, and the need for environmental restoration. According to the University of the UN, for large dams (hydropower and other types of dams), the cost of dam removal is estimated to be an order of magnitude less than that of repairing.[43]

For small hydropower plants, whose contribution to electricity generation is negligible, environmental refurbishment is also often too costly to make any economic sense. According to a recent study by the Leibniz Institute of Freshwater Ecology and Inland Fisheries, small hydropower plants would be “most likely unprofitable if they were equipped with the necessary fish protection.”[44] In this case decommissioning small hydropower plants (and if necessary, substituting them with other technologies, such as solar and wind), might be more appropriate than investing in environmental refurbishment. Investments and especially public spending on environmental refurbishment of small hydropower plants should therefore be carefully considered in the future, as those investments could have the adverse effect of artificially supporting and extending the lifetime of hydropower plants that are insignificant for electricity generation, do considerable damage to the environment, and are not profitable anymore.

It is therefore mostly for hydropower plants above a certain size that the economic case for environmental refurbishment investments seems justified against both alternatives of building new plants, and decommissioning.

37. International Renewable Energy Agency (IRENA) Renewable Energy Technologies: Cost Analysis Series. Volume 1: Power Sector. Issue 3/5. *Hydropower*. (2012)
38. The lower range corresponds to standard refurbishment with additional capacity and the upper range, to a more extensive upgrade (with 10% capital cost).
39. IEA Hydro (2020) website of the *International Energy Agency Technology Cooperation Programme on Hydropower*, downloaded 20 June 2020.
40. GE *website* (18 June, 2020) reports 6,000 assessments conducted on over 2,000 hydro generators worldwide.
41. Kumar, A., Schei, T et al. *Hydropower* in IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, Cambridge University Press (2011).
42. JRC (2014) ETRI *Energy Technology Reference Indicator projections for 2010-2050*, Ed. Carlson Johan. JRC N°: JRC92496 (2014).
43. Perera, D., Smakhtin, V., Williams, S., North, T., Curry, A., 2021. *Ageing Water Storage Infrastructure: An Emerging Global Risk*, UNU-INWEH Report Series, Issue 11. United Nations University Institute for Water, Environment and Health, Hamilton, Canada.
44. Leibniz Institute of Freshwater Ecology and Inland Fisheries, *Hydropower: the mortality risk for fish at turbines* (2020).

TRIGGER 3:

A BETTER IMPLEMENTATION OF THE EU ENVIRONMENTAL LEGISLATION

The EU environmental legislation sets a framework for the protection of freshwater ecosystems which imposes strict boundaries for the activities of the hydropower sector.

Programmes of measures and the implementation of the cost-recovery principle under the EU Water Framework Directive's (WFD) 3rd River Basin Management Plans

In their December 2020 resolution on the implementation of the EU water legislation, the European Parliament recalled " that the WFD imposes strict criteria for the protection of hydromorphological conditions; call[ed] on the Commission and the Member States to ensure that strict assessments of the impacts of resulting alterations on water quality and quantity and ecosystems are carried out and that the objectives of the WFD are respected in all existing and potential new hydropower projects".[45]

With hydromorphological pressures still being highlighted as the main pressure impeding the achievement of good surface water status nearly twenty years after its adoption,[46] it is clear that the implementation of the WFD has not been sufficient to alleviate the environmental impacts of hydropower on rivers.

But it remains that the WFD contains key provisions which, if strictly implemented, should drive a transformation of the way the hydropower sector operates:

First, maintaining good hydromorphological conditions is a key WFD requirement. River continuity is one of the hydromorphological quality elements that form the definition of Good Ecological Status. Even Good Ecological Potential – the threshold to be achieved for rivers designated as Heavily Modified Water Bodies – can be reached only if a condition close to the best approximation of ecological continuum is achieved, "in particular with respect to migration of fauna and appropriate spawning and breeding grounds".[47]

Second, article 4(7) of the WFD imposes strict conditions for being allowed to derogate from the obligation to achieve Good Ecological Status/Potential or to prevent deterioration of groundwater/surface status because of "new modifications to the physical characteristics of a surface water body", commonly called the "article 4(7) test" (see box below).

EU WATER FRAMEWORK DIRECTIVE, ARTICLE 4(7):

"Member States will not be in breach of this Directive when:

- failure to achieve good groundwater status, good ecological status or, where relevant, good ecological potential or to prevent deterioration in the status of a body of surface water or groundwater is the result of new modifications to the physical characteristics of a surface water body or alterations to the level of bodies of groundwater, or
- failure to prevent deterioration from high status to good status of a body of surface water is the result of new sustainable human development activities

and all the following conditions are met:

(a) all practicable steps are taken to mitigate the adverse impact on the status of the body of water;

(b) the reasons for those modifications or alterations are specifically set out and explained in the river basin management plan required under Article 13 and the objectives are reviewed every six years;

(c) the reasons for those modifications or alterations are of overriding public interest and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development, and

(d) the beneficial objectives served by those modifications or alterations of the water body cannot for reasons of technical feasibility or disproportionate cost be achieved by other means, which are a significantly better environmental option."

Several guidance documents have provided useful clarification to further frame how those conditions should apply to hydropower. In particular:

- With regards to condition c, a hydropower activity is not automatically of overriding public interest just because it will generate renewable energy.[48]
- With regards to condition d, for hydropower activities to pass the article 4(7) test, alternative ways to achieve the beneficial objectives must be assessed, including "other forms of renewable energy generation, measures to increase energy efficiency or alternative locations for hydropower generation, or other forms to balance energy supply and demand" (relevant for pumped storage hydropower plants).[49]

Third, the WFD requires Member States to define water pricing policies whereby water users contribute proportionally to recovery of costs associated with water services, including environmental costs (article 9). The European Commission considers that hydropower generation should be one of those activities included in the definition of water services; however only a minority of Member States were doing so in the second management cycle[50], while many use the article 9.4 derogation. This would have broad

45. European Parliament *resolution of 17 December 2020 on the implementation of the EU water legislation* (2020/2613(RSP)).
46. European Commission, *Fitness Check of the EU Water Framework Directive and the Floods Directive*, SWD(2019)439.
47. CIS guidance document N° 37 – *Steps for defining and assessing ecological potential for improving comparability of Heavily Modified Water Bodies* (2020).
48. CIS issue paper, November 2011 – *Water management, EU Water Framework Directive & Hydropower* ; CIS guidance document N° 36 – Article 4(7) Exemptions to the Environmental Objectives, provisions 1697-1699.
49. CIS guidance document N° 36 – *Article 4(7) Exemptions to the Environmental Objectives*, provisions 1635-1639.
50. European Commission, Commission Staff Working Document, *European Overview - River Basin Management Plan* (26 February 2019), SWD(2019) 30 final."

implications, as it could significantly affect the cost model of hydropower plants and provide additional incentives for improving the efficiency of the plants (which in many cases might play in favour of refurbishment). Those additional revenues from water charges could be earmarked for measures to protect water bodies, obliging in a way hydropower operators to contribute to river restoration. **It is therefore urgent that Member States integrate hydropower generation in the definitions of water services in the third River Basin Management Plans.**[51]

Positive conservation measures in Natura 2000 habitats

According to the Habitats Directive, Member States must implement conservation measures corresponding to the ecological requirements of habitat types and species, and avoid any deterioration of habitat and species. In two guidance documents[52], the European Commission has given a number of clarifications regarding the interactions of the WFD and Habitats Directive for hydropower activities, including:

- Hydropower installations located in Natura 2000 sites must also comply with any more ambitious conservation objectives going beyond non-deterioration.
- If hydropower development potentially affects both a WFD objective and a Natura 2000 site, then both the Article 4(7) procedure under the WFD and the Natura 2000 assessment procedure under Article 6.3 of the Habitats Directive must be undertaken. “If the project does not compromise the objectives of the WFD but does adversely affect the integrity of a Natura 2000 site then it cannot be approved under the WFD unless an exemption under the Habitats Directive has also been accepted.”[53]
- When performing the appropriate assessment required under the Habitats Directive, the cumulative effects of hydropower plants at the scale of a catchment area should be considered, in our outside Natura 2000 sites, including those not yet implemented.

Those requirements also speak in favour of refurbishing existing plants rather than building new ones. The challenge is enormous: despite those rules, 28% of all planned hydropower is planned in protected areas (33% in the case of the EU) including Natura2000 sites.[54]

28%

OF ALL PLANNED HYDROPOWER IS PLANNED IN PROTECTED AREAS (33% IN THE CASE OF THE EU) INCLUDING NATURA2000 SITES

51. For more information, please consult *Third River Basin Management Plans: WWF recommendations* (July 2020).
52. Guidance on the requirements for hydropower in relation to EU Nature legislation, 2018: *https://bit.ly/2nNSHkx* ; Commission guidance document on streamlining environmental impact assessments, 2018: *https://bit.ly/2miqJg*
53. Guidance on the requirements for hydropower in relation to EU Nature legislation, 2018: *https://bit.ly/2nNSHkx*.
54. WWF, EuroNatur, GEOTA, RiverWatch, *Hydropower pressure on European rivers: the story in numbers* (2019).

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TRIGGER 4:

A SHIFT IN PUBLIC FINANCE

EU public finance should also accompany this transformation. This requires a phase out of subsidies and loans for new hydropower projects, including small plants.

Most EU Member States, with the exception of Cyprus, Malta and more recently Finland, give state aid to hydropower, under the form of feed-in tariffs, feed-in premiums, green certificates or investment grants. In 2016-2017 in those countries, the weighted average support level to hydropower was comparable to the weighted average support level to onshore wind. In total, 4.3 billion euros of state aid went to hydropower in the EU and Norway in 2016-2017.[54]

The volume of support schemes to hydropower has overall increased since 2009 and is today around 30% higher than a decade ago. This is no wonder: since 2009 and the adoption of the EU Renewable Energy Directive, schemes for renewable energy sources have been a key mechanism to help achieve the renewables goals.

From 2014 onwards, countries had to adapt their schemes to comply with the new European Commission Guidelines on State Aid for Environmental Protection and Energy (EEAG) aimed at allowing for more market integration of renewables. The EEAG imposed for instance the replacement of feed-in tariffs with market premium additional to the market price, as well as tendering procedures.

However, small hydropower plants benefit from two exemptions under the EEAG: plants producing less than 1 MW are exempted from tendering procedures, and plants producing less than 500 kW can still receive feed-in tariffs. This has fueled the development of micro-hydropower plants that make a negligible contribution to renewable electricity generation, have a very poor funding efficiency, and yet are adding to the already large fragmentation of European rivers.

SMALL HYDROPOWER BOOM IN ITALY

Italy is among the top three hydroelectric energy producers in Europe, together with France and Spain, with a current installed capacity of approximately 18,092 MW. The potential of hydroelectric resources in Italy is used to approximately 95% and the maximum possible exploitation limit has been reached. In Italy, nearly 2,000 new plants of capacity <1MW have been built in the last decade. They increased from 1270 in 2009 to 3123 in 2018. This is due to a very generous system of support schemes, placing Italy as the biggest Europe donor of public support to hydropower in volume, far before France, Germany, and the UK.[55] In Italy, the incentives for new hydroelectricity amount to nearly 1 billion euros per year. The smaller the installations, the higher the support level, which pays three to five times the market price for 20 years. This is hardly justifiable, given the fact that hydropower is not a new technology requiring unsustainable private research and development, and that new hydropower, given the small size of the installations currently built, does not contribute significantly to national strategic objectives.

Source: http://www.freeriversitalia.eu/news/201001_ITALY%20HYDROPOWER.pdf


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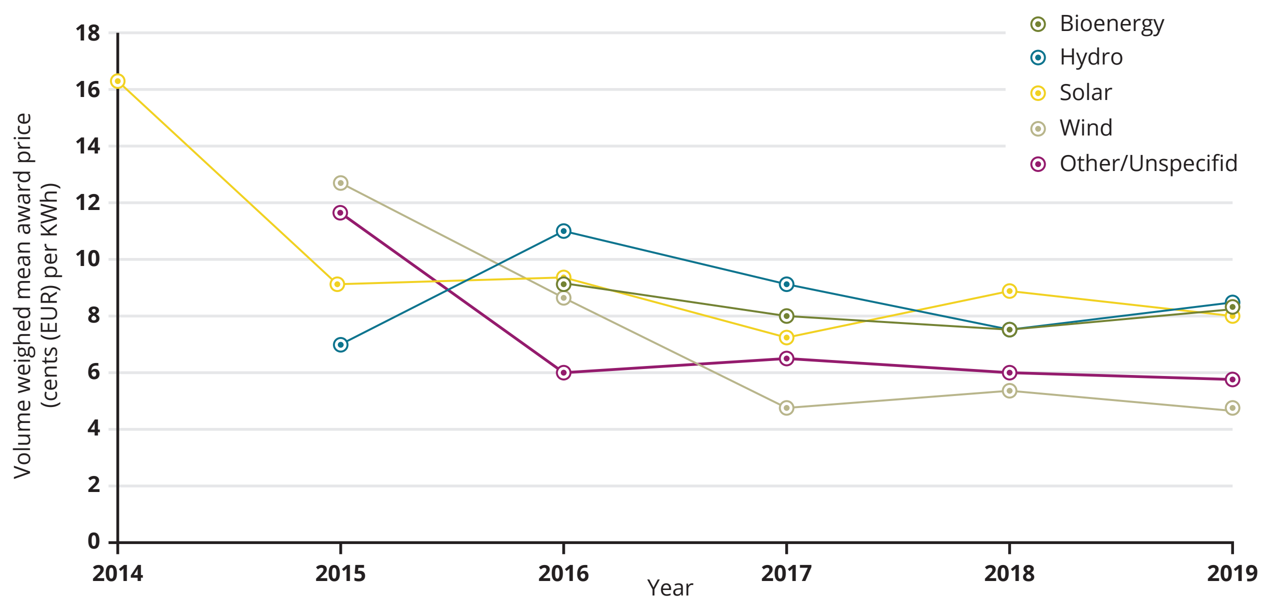
Construction of a small hydropower plant on the Mis river, in the Dolomiti Bellunesi National Park, also a UNESCO Heritage site. The works were interrupted only in 2012 after a ruling of the Court of Cassation, but since then nothing has been done to restore the river even if the decision of the Supreme Court provides for the demolition of the structure and restoring the river.

The fact that hydropower development is promoted under the Guidelines on State Aid for Environmental Protection and Energy (EEAG) stands in the way of the implementation of the EU Water Framework Directive and the EU Biodiversity Strategy commitment to restore free-flowing rivers. Moreover, **it is not cost effective as the fitness check on state aid modernisation showed that contrary to solar and wind, the mean awarded price for hydropower resulting from the different auctions, and therefore the amount of aid/kWh, has increased between 2014 and 2019, while it has more than halved for solar and wind** (see figure below).[56]

54. Council of European Energy Regulators, *Status Review of Renewable Support Schemes in Europe for 2016 and 2017*, Public report (14 December 2018)."
55 *Ibid*.
56. European Commission, *Commission Staff Working Document Fitness Check of the 2012 State aid modernisation package, railways guidelines and short-term export credit insurance*, part ¾, SWD(2020) 257 final (October 2020).

Figure 2: Volume weighted mean price per kWh in sampled schemes split by high-level technology category, 2014-2019



Source: European Commission, Commission Staff Working Document *Fitness Check of the 2012 State aid modernisation package, railways guidelines and short-term export credit insurance, part 3/4*, SWD(2020) 257 final (October 2020).

As the European Commission is revising the EEAG in 2021, it is time to revise the approach to supporting hydropower. **Hydropower facilities should no longer be eligible for state aid**, both feed in tariffs (still allowed for plants below 0.5 MW), and other types of aid. This should at the very least apply to the construction of new hydropower plants. If some state aid to hydropower was to remain, then it should only finance either the ecological improvement of existing hydropower plants if they are already in line with the minimum ecological requirements imposed by the legislation (WFD, Birds and Habitats directives, Environmental Impact Assessment, Strategic Environmental Assessment), or their decommissioning. **In line with the cost-recovery and polluter pays principles, the financial responsibility to mitigate any deterioration to the water body should be borne primarily by hydropower companies.**

Finland has already chosen this way and stopped giving subsidies (both investment premiums and investment grants) to the hydropower sectors in 2019. This is the reflection of the strong dam removal policy in the country. In 2019, the new government included dam removal to the national programme for Finland and earmarked 14-16 million euros for dam removals and natural fish ways in the next 4 years.

Another shift of public finance could also come from the European Investment Bank. In a 2018 report, Bankwatch identified 445 million euros of EIB direct lending for individual hydropower projects in the Western Balkans, to which add another 22 million euros supported through financial intermediaries.[57] The NGO community has largely described the dramatic impacts that some of those projects have, either on biodiversity (such as the Ilovac plant in Croatia, built in a Natura 2000 area due to environmental impact assessment surprisingly showing no significant impact on species, while four years after operation studies reveal a coincidental loss in biodiversity) or on people (such as the 280-megawatt Nenskra hydropower plant in Georgia approved in 2018, which would affect the rights of 1,000 indigenous people).

KFW INVESTMENTS IN HYDROPOWER IN THE WESTERN BALKANS

The KfW development bank, owned by the German State, has invested 100 million euros in the hydropower company EP HZHB, for the construction of a pumped storage hydropower station located in Livanjsko Polje, Bosnia and Herzegovina, despite it being a Ramsar-protected site. For over 40 years, the very same company has operated in another Ramsar site, the Hutovo Blato Nature Park in Bosnia and Herzegovina, where they have refused to apply any mitigation measures to the pumped storage hydropower plant, despite the fact that the Federal Ministry of Environment had included concrete mitigation measures in the renewed Environmental Permit for Capljina hydropower station in 2015.

Source: WWF Adria.

The "Environmental, Climate and Social Guidelines on Hydropower Development" guidelines published in October 2019 have strengthened some of the conditions for EIB financing, including on impact assessments and alignment with the EU Water Framework Directive requirements, but failed to include key safeguards, for instance the prohibition of hydropower development in protected areas.[58] The revision of the EIB Environmental and Social standards, scheduled for 2021, provides an opportunity to fill in those gaps. In Europe in particular (including the Balkans, the Eastern Neighborhood region, EU candidate and potential candidate countries), the **EIB should stop supporting new hydropower projects and instead focus on dam decommissioning and removal where relevant,** building on Guideline n° 4 in the EIB Hydropower Guidelines, **or on environmental refurbishment of existing plants including active restoration measures if adequate contribution of the hydropower company is ensured (following the cost recovery and polluter pays principles).**

EIB ENVIRONMENTAL, CLIMATE AND SOCIAL GUIDELINES ON HYDROPOWER DEVELOPMENT, GUIDELINE 4

"In line with the requirements of the Standard on the Assessment and Management of Environmental and Social Impacts and Risks (and the Environmental Impact Assessment Directive), the description, within the E(S)IA of reasonable alternatives studied by the promoter, must: a) have evaluated decommissioning as an alternative option when rehabilitation of an existing hydropower project is considered and presented a robust justification for the option selected; and b) justify proposals for a new, greenfield hydropower project in river basins where old hydropower projects exist against the alternative of rehabilitating or refurbishing those existing hydropower plant(s)."

These guidelines though do not go far enough. As long as the objectives set by the EU Water Framework Directive and the EU Biodiversity Strategy are not achieved in Europe, the EIB should exclude from its portfolio all projects involving the construction of greenfield hydropower plants, and consider only decommissioning environmental refurbishment projects.

57. Bankwatch, *Financing for hydropower in protected areas in Southeast Europe: 2018 update*, March 2018.

58. The guidelines say that "the EIB will not finance any projects that will have a potential measurable adverse impact on any UNESCO World Heritage Site", but does not exclude projects in other types of protected areas including Natura 2000 sites.

CONCLUSIONS AND RECOMMENDATIONS

- Most of Europe's hydropower potential has already been harnessed, with disastrous impacts on freshwater ecosystems and biodiversity. With European rivers being the most fragmented in the world, stopping the development of new hydropower plants in Europe and transforming existing hydropower plants is an absolute necessity. Massive and rapid improvements in the ecological performance of existing hydropower plants are needed to reduce the environmental impact of hydropower. European rivers cannot be saved without a significant transformation of the hydropower sector.

- On-site mitigation measures help reduce to a limited extent the environmental impacts of existing hydropower plants. While the best environmental option to restore river continuity is the decommissioning of hydropower plants, measures to restore the river's natural functions, such as well-maintained natural fishways and reproduction channels should systematically be considered as part of environmental refurbishment.

- There is often an economic case for refurbishing hydropower plants rather than investing in new ones, as the power gained by upgrading old plants can be cheaper, per MW, than the power gained by constructing new plants, especially small ones. However, the option of refurbishment must also be assessed against the alternative option of decommissioning. For the smallest hydropower plants, but also for the oldest ones approaching the end of their investment cycle, decommissioning is often a more cost-effective option than refurbishment, and brings more environmental and safety benefits than the benefits of electricity generation. Investments in extending the lifetime of the smallest and oldest plants are likely to be suboptimal and should be avoided.

- For large hydropower plants, combining improvements in the generation capacity of a plant (output-oriented refurbishment) and improvements in its ecological performance through on-site mitigation measures (environmental refurbishment) can provide a win-win for states, hydropower operators and local communities: an increased installed capacity, and reduced environmental impacts.

- National authorities need to initiate processes to revise hydropower permits, licences and concessions across Europe to bring them in line with the EU, national and international water and biodiversity legislation.

- The hydropower sector should also mitigate its environmental impact through contributing, according to the polluter pays principle, to large scale environmental restoration and endangered species recovery. This is necessary to comply with the objectives set by the EU Biodiversity Strategy, and the requirements of the Water Framework and Nature Directives. In the third River Basin Management Plans, Member States should integrate hydropower generation in the definitions of water services, in order to recover the environmental costs of hydropower generation and finance river restoration actions.

- Legal and financial incentives must also be shifted in order to increase incentives for the transformation of the sector. At the occasion of the revision of the EU Guidelines on State Aid for Environmental Protection and Energy, new hydropower facilities should no longer be eligible for state aid.

- Financial institutions, starting with the European Investment Bank, should also revise their policy. Through the revision of its Environmental and Social Standards, the EIB should stop supporting new hydropower projects and instead focus on dam decommissioning and removal where relevant, or on environmental refurbishment of existing large hydropower plants if adequate contribution of the hydropower companies is ensured.

IMPROVEMENTS IN THE ECOLOGICAL PERFORMANCE

OF EXISTING HYDROPOWER PLANTS ARE NEEDED TO REDUCE THE ENVIRONMENTAL IMPACT OF HYDROPOWER.

For more information:

Claire Baffert,
Senior Policy Officer, Water
WWF European Policy
cbaffert@wwf.eu

www.wwf.eu/what_we_do/water/

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together possible™ www.wwf.eu

WWF European Policy Office, 123 rue du Commerce, 1000 Brussels.

For contact details and further information, please visit our website at **www.wwf.eu**