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Sharing Water: Multi-Purpose of Reservoirs and Innovations

Hydropower as a catalyst for the energy transition within the European Green Deal Part II: The complex environment for hydropower, biodiversity challenges and the main innovation and research directions

L'hydro-électricité catalyseur de la transition énergétique du Pacte Vert européen Partie II : L'environnement complexe de l'hydro-électricité, les défis de la biodiversité et les pistes primordiales de recherche et développement

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Abstract. The European Union has the ambition to be the first carbon-neutral continent by 2050. To fulfil this objective and integrate into the grid the large amount of power from solar and wind, Europe can rely upon the high storage and flexible capacity of hydropower. Thus, new reservoirs and innovative use of current reservoirs will be needed to provide an effective contribution to this unprecedented European Green Deal. The project Hydropower Europe, funded by the H2020 research programme, is tasked with identifying innovative uses of reservoirs and prioritizing the associated innovation actions targeting an energy system with high flexibility and renewable share. The project deliverables are a Research and Innovation Agenda (RIA) listing the top strategic research and innovation directions and a Strategic Industry Roadmap (SIR) addressing non-technical actions and requests for the hydropower sector. This paper describes the vision of the project: "Hydropower as a catalyst for the energy transition". In Part I of this paper, the Green Deal and the role of hydropower were outlined and discussed. In this Part II, after highlighting the complex environment for hydropower in Europe, and the challenges of biodiversity, the main innovation and research directions extracted from the RIA and the main

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steps of the SIR for combining multipurpose hydropower, in a sustainable, efficient and cost-effective manner, are presented.

Résumé. L'Union européenne a l'ambition d'être le premier continent neutre en carbone d'ici 2050. Pour atteindre cet objectif et intégrer dans le réseau d'électricité la quantité d'énergie croissante provenant du solaire et de l'éolien, l'Europe peut compter sur l'importante capacité de stockage et de flexibilité de l'hydroélectricité. Ainsi, de nouveaux réservoirs et une utilisation innovante des réservoirs actuels seront nécessaires pour apporter une contribution efficace à ce "Pacte Vert" européen sans précédent. Le projet Hydropower Europe lancé par le programme de recherche H2020 est chargé de définir les utilisations innovantes requises des réservoirs et de fixer la priorité des innovations associées visant un système énergétique à haute flexibilité basé sur les énergies renouvelables. Les livrables du projet sont un programme de recherche et d'innovation (RIA) énumérant les principales orientations stratégiques en matière de recherche et d'innovation et une feuille de route stratégique pour l'industrie (SIR) traitant des actions et des demandes non techniques pour le secteur de l'hydroélectricité. Ce document décrit notre vision : "L'hydroélectricité comme catalyseur de la transition énergétique". Dans la première partie de ce rapport, le Pacte Vert et le rôle de l'hydro-électricité sont décrits et discutés. Dans la seconde partie du rapport, après avoir souligné l'environnement complexe dans lequel se situe l'hydroélectricité en Europe et les défis de la biodiversité, les principales innovations et directions de recherche extraites du RIA et les principales étapes de la SIR pour combiner les usages multiples de l'hydroélectricité d'une manière durable, efficace et rentable, sont présentées.

1 Hydropower Europe in a complex world - a global approach system analysis as a basis for action prioritization

Hydropower projects are not only complex, but they are in interaction with a complex environment. In order to obtain wide public acceptance, the critical factors influencing the complex situation have to be understood. This will allow defining the most promising design actions as well as the most effective research and development directions. Thus, to assess the complex environment hydropower is confronted within Europe in particular; a complex system analysis was carried out by using the network thinking approach developed by [1]. This approach was already applied in the hydropower sector successfully to identify project design strategies as well as to find the best synergies in multi-purpose projects [2].

Based on the feedback received from the Hydropower Europe wider stakeholder consultation of the first draft of the Strategic Industrial Road Map (SIR) and the Research and Innovation Agenda (RIA), a list of 103 factors have been identified which are considered relevant for the system analysis [3]. They represent seven sectors, namely Hydropower, Energy and Economic Policy, Electricity Market, Environment and Public Society, Research and Development, Legal Framework and Climate change.

Based on the 103 factors identified, the network of the hydropower market in Europe has been built, which is presented as a whole in Figure 1.

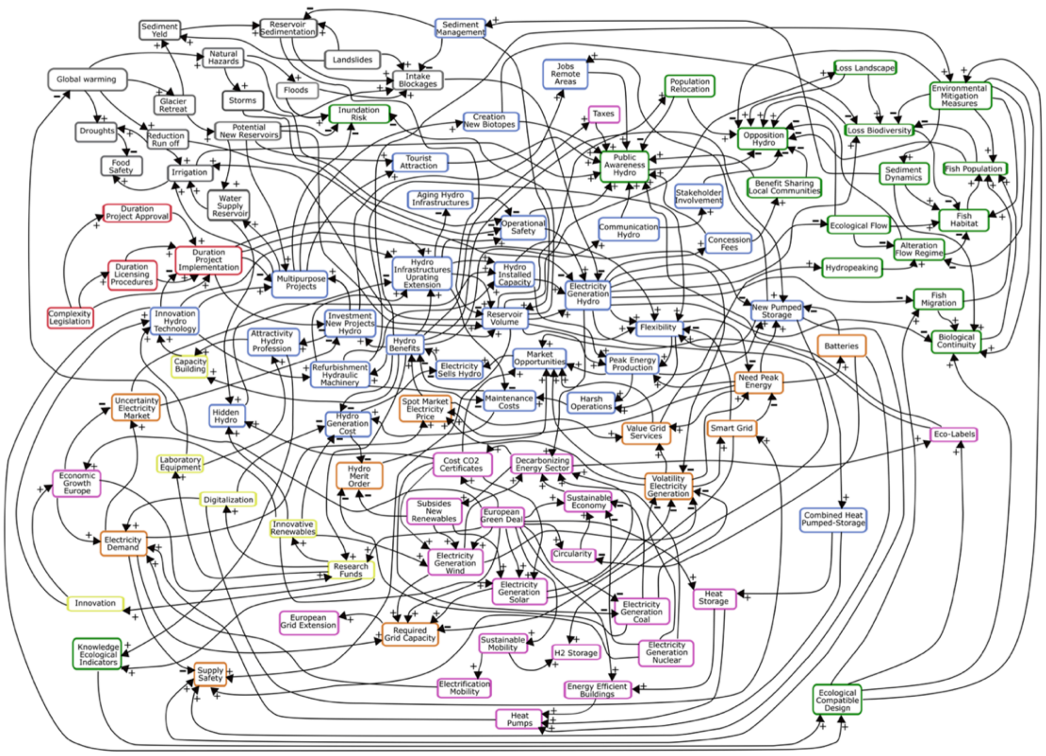

Fig. 1. Hydropower in Europe in a complex environment: Network of factors representing the sectors Hydropower (blue), Energy and economy policy (pink), Electricity market (orange), Environment and public society (green), Research and development (yellow), Legal framework (red) and Climate change (black).

The network was built from its centre by starting with the driving motor for the hydropower sector which is highlighted in Figure 2 as a cut-out of the whole network. This driving motor can be described as follows.

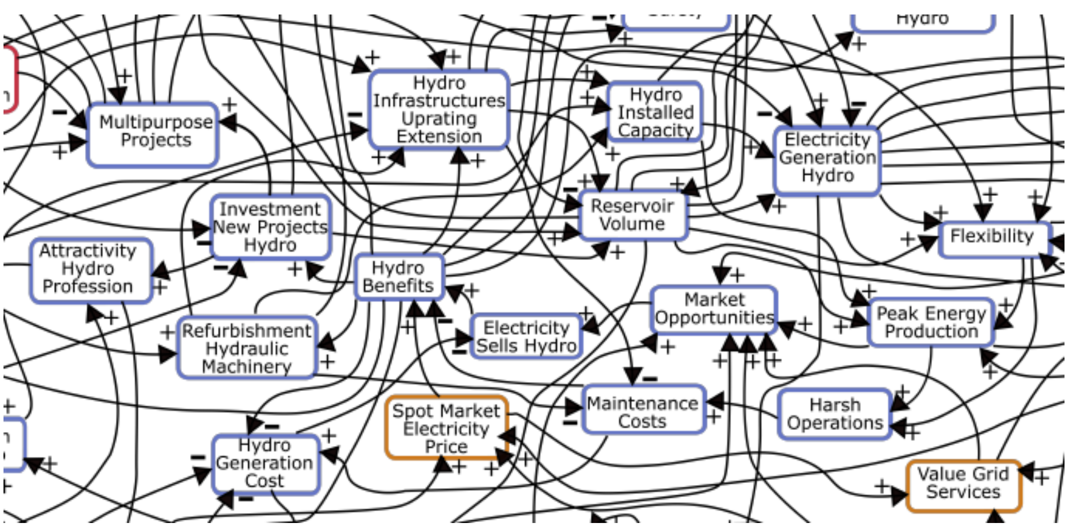

Fig. 2. Driving motor of hydropower market in the complex system.

The Hydro Installed Capacity has a direct increasing effect on the Electricity Generation Hydro. The higher the latter is the better are the Market Opportunities which then results in higher Electricity Sells Hydro and consequently in enhanced Hydro Benefits. These can be used for new investments as Investment in New Projects, Refurbishment of Hydraulic Machinery or Infrastructure Uprating/Extension which closes the circle or driving motor by increasing the Installed Capacity. A second branch of the driving motor reflects the fact that investments in New Projects or in Uprating/Extension can result in a higher Reservoir Volume which enhances the Flexibility as well as Peak Energy Production. This then influences the driving motor by improving the Market Opportunities. This driving motor, of course, can turn in an increasing or decreasing sense. All the factors of the different sectors influencing the hydropower market outside of this driving motor are creating a kind of friction, inertia or acceleration and finally stabilising the system.

Since the European Green Deal will have, without doubt, an influence on the future hydropower development in Europe, it has been integrated into the network as shown by the enlarged cut-out part in Figure 3 below.

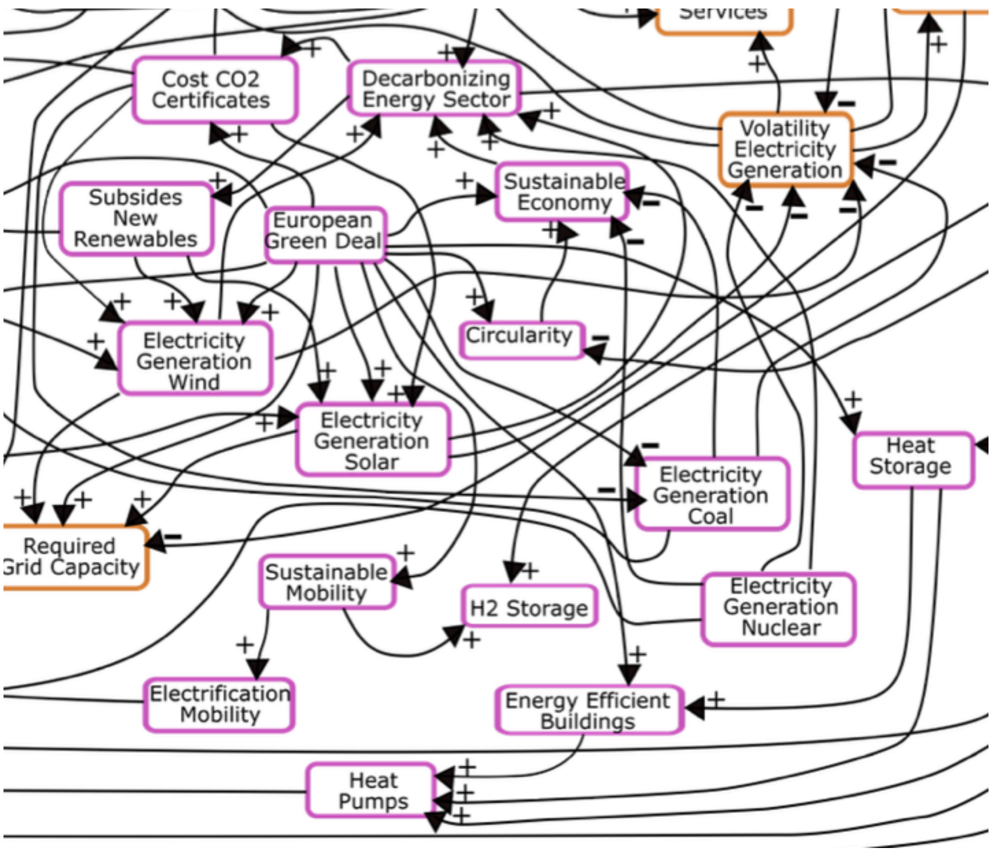

Fig. 3. Implementation of the European Green Deal in the network.

The network reveals the complexity of the situation. Nevertheless, it is difficult to draw conclusions directly. Thus, the interconnection of all factors in the network is reported in a matrix which allows us to determine the activity and reactivity of each factor. Normally the analysis is started by considering only the direct connections - respectively the first degree of influences. Then, in order to have better insight, also the connections of the second degree are analysed.

In the matrix the activities and reactivities of each factor have been summed up. Regarding the active or critical factors, it has to be distinguished between two important categories: those you can control directly by an action and those who are not controllable. In the following discussion the factors which can be directly controlled are underlined in the text. They can be used as a lever and are therefore important for the prioritization of any actions.

The result of the matrix analysis considering the second degree of influences (connections) in the network is shown in Figure 4. For better visibility the factors have been numbered in the Figure 4.

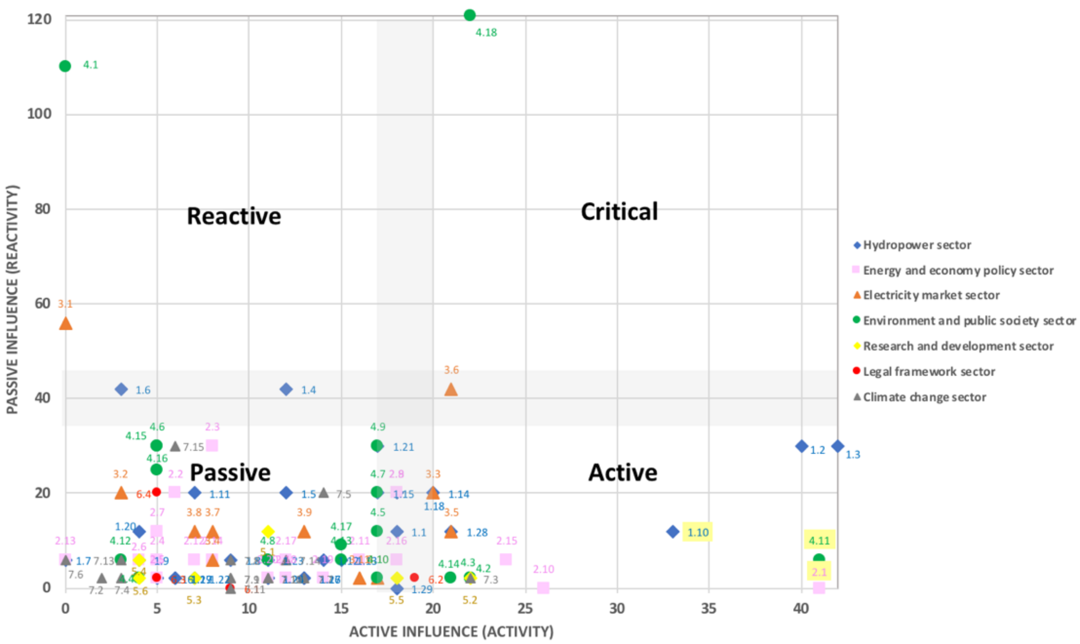

Fig. 4. Result of matrix analysis considering second degree of influences (connections).

Critical factors: *These elements have a strong influence on the system, but they are at the same time strongly influenced by other elements if controllable. They can be used as levers, but they have to be operated with care in order not to provoke a system overreaction.* Two factors are in the critical domain namely Volatility of the Electricity Generation (3.6) and Public Awareness Hydro (4.18). In principal both cannot be controlled directly. Nevertheless, the latter may be indirectly controlled by more investment in Communication Hydro (1.17).

Active factors: *These elements have a strong influence on others. Using them as levers, they can play an important guiding role for the management of the problematic situation.*

Reservoir volume (1.2), Electricity Generation Hydro (1.3) and Hydropower Benefits (1.10) of the hydropower sector are clearly in the domain of the active factors. Since they are also quantitative factors, they can be considered as so-called indicators of the system. Reservoir volume (1.2) is characterising existing powerplants and is a design parameter for new projects which can be controlled (thus underlined in the text). Nevertheless, it cannot be freely chosen and are influenced by many other factors and constraints. Electricity Generation Hydro (1.3) and consequently and Hydropower Benefits cannot be controlled directly and is the result of a certain design or performance of a hydropower plant. Nevertheless, they are important indicator for the system' state. Environmental Mitigation Measures (4.11) has a very high activity and is a promising lever since it can be controlled by innovative project designs. Also, the European Green Deal (2.1), which is not directly controllable, has a very high activity, but is not influenced passively by other factors.

Several factors from the Environment and public society sector have quite a high activity, namely Benefit Sharing Local Communities (4.2), Ecological Flow (4.3) as well as Population Relocation (4.14). Nevertheless, having a small reactivity, they are little influenced by other factors. Also, Innovation Hydro Technology *(can be controlled only indirectly)* (1.28) and Innovation Renewables (5.2) are clearly in the active domain, which underlines the high importance of research and development actions. From the electricity market sector, the factors Need of Peak Energy (3.5) and Electricity Demand (3.3) became active being passive before. Both are indicators but cannot be controlled directly. The factors Cost CO_2 Certificates (2.15) and Electricity Generation Nuclear (2.10) have a relatively high activity but are little influenced passively by other factors. Finally, the Potential New Lakes in de-glaciered areas (7.3) has a significant activity confirmed already by new dam projects ongoing in the Alps.

Several factors are on the border between the passive and active domain and can be also used as lever for actions in order to increase hydropower success in future:

- Hydropower sector: Hydro Installed Capacity (1.1), Multipurpose projects (1.18), New Pumped-storage (1.21), Sediment Management (1.29)
- Energy and economy policy sector: Electricity Wind Generation (2.8), Eco-labels (2.16).
- Electricity market sector: Electricity Demand (3.3)
- Environment and public society sector: Alteration Flow Regime (4.5), Fish Habitat (4.7), Loss Biodiversity (4.9), Loss Landscape (4.10)
- Research and development sector: Digitalization (5.5)
- Legal framework sector: Duration Licensing Procedures (6.2)

The active factors, which can be directly controlled (underlined in the text), can be used as a lever and therefore they are important for the prioritization of any actions.

Reactive factors: *These factors have a weak influence, but they are strongly influenced by others. They do not allow controlling the situation, but they may be used as indicators or fixed points for the analysis of the development of the problematic situation.*

Opposition Hydro (4.1) has the highest reactivity. Thus, investing more in communication is highlighted. Supply safety (3.1) is also a factor with high reactivity. The most reactive factors from the hydropower sector are Flexibility (1.4) and Market Opportunities (1.6).

Passive factors: *These factors are not influenced and do not influence other factors significantly in the system. Because of its weak dynamic, normally they can be neglected in the search of solutions or actions.*

The analysis of the network, considering the second degree of connections between the factors, gives a clear and coherent picture. The following conclusions can be drawn regarding the impact level of actions.

a) Two critical factors could be identified, which are influencing the success of hydropower development in Europe in a dominant way, namely the Volatility of the Electricity Generation (3.6) the Public Awareness Hydro (4.18). Both factors are not directly controllable and have to be influenced by other active factors in the system in a direct or indirect way. The Public Awareness Hydro (4.18) can be influenced directly by Communication Hydro (1.17). Any strategic action or research initiative, which has a direct or a close indirect effect on Communication, has the first highest impact level.
b) The controllable active factors are Reservoir volume (1.2), Environmental Mitigation Measures (4.11). They have a very high activity and can be considered

also as first highest impact level when ranking strategic actions or research initiatives.

c) Being also among the controllable active factors, Benefit Sharing Local Communities (4.2), Ecological Flow (4.3) and Population Relocation (4.14) from the environment and public society sector, can be used as levers and are very important when defining strategic actions and research initiatives. Any actions which can influence these factors is among the second highest impact level. This is also the case for Innovation Hydro Technology (1.28) but which depend highly on the available research funds.

d) Finally, a certain number of controllable factors are situated at the border between the passive and active domain as Hydro Installed Capacity (1.1), Multipurpose projects (1.18), New Pumped-storage (1.21) and Sediment Management (1.29) from the hydropower sector. Regarding energy policy also Eco-labels play an important role but are difficult to control directly. Fish Habitat (4.7), Loss Biodiversity (4.9) and Loss Landscape (4.10) can be used also as lever when defining actions. At last, but not at least Digitalization (5.5) of the Research and development sector is an important factor on which actions should concentrate. Thus, all the factors mentioned under d) may be among the third highest impact level when ranking strategic actions or research initiatives.

This identification of the controllable, active factors having a high impact level in the hydropower system can be used, together with the feedback obtained by the wider stakeholder consultation, to propose a final prioritisation of the strategic actions and research initiatives in Industrial Roadmap (SIR) as well as in the Research and Innovation Agenda (RIA).

As identified above, environmental mitigation measures have a very high activity and can also be considered as first highest impact level when ranking strategic actions or research initiatives. They have a direct influence on biodiversity which is addressed in the following.

2 How sustainable hydropower can promote biodiversity

2.1 The IPBES alarm

In May 2019, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) launched its landmark Global Assessment Report on Biodiversity and Ecosystem Services [4]. It triggered headlines around the world about the fact that 1 million species of plants and animals are now threatened with extinction. In many ways, it woke the world to the urgency of the crisis facing biodiversity and the role nature plays in peoples' lives. The decline in biodiversity is unprecedented, but it is not too late to act. However, incremental change will not be sufficient.

Decision-makers are better poised than ever to transform biodiversity concerns into tangible actions, which can help ensure a more sustainable future for people and nature. Human development is the main cause of cutting forests, polluting oceans and devastating wetlands, which is leaving much of the global fauna without the essential habitat they need to survive. Developing more renewable energy is key to our fight against climate change, but it needs to happen in a way that does not harm biodiversity. Science shows that transformative change is urgently needed to restore and protect nature. The situation is, in fact, filled with opportunities for innovative solutions to address our nature and climate challenges.

2.2 Protection of the fresh water ecosystem

Rivers provide essential services for humanity, including tourism, navigation, fishing and agriculture. Yet, the health of rivers continues to be challenged by growing pressures from human activities, including pollution, irrigation and agriculture and industry, as well as from infrastructure such as dams and weirs. Rivers act as natural corridors for both aquatic and terrestrial species, helping maintain biodiversity value across landscapes. Global freshwater vertebrate populations have suffered major declines, especially amongst fish species. A part of this is caused by hydroelectric dams, and the sector needs to recognise its responsibilities [5].

2.3 European policies pave the way for protecting freshwater ecosystems

The European Union has launched various policies to tackle ecosystem degradation [6]:

- 1992. Habitats Directive: objectives are to maintain and restore habitats in favourable status and improve ecological coherence of the Natura 2000 network [7].
- 2000. Water Framework Directive: objectives are to reach good ecological status by 2027 at the latest in all rivers, lakes, transitional and coastal waters; to require non deterioration of status – exemption only under strict and exceptional conditions and to implement river restoration and mitigation measures [8].
- 2007. Eel regulation: objectives are to protect and restore Eel populations.
- 2018. Pan-European action plan for sturgeon: objective to set a framework to conserve the last sturgeon populations
- 2020. Biodiversity strategy for 2030: objectives are 30% of EU land and sea protected, a third of which is under 'strict protection', increased efforts to restore freshwater ecosystems and the natural functions of rivers, for instance to restore 25,000 km of free-flowing rivers and member states review permits to restore ecological flows.

These directives and regulations protect and enhance the EU's natural capital. However, there are still major gaps in implementation and sometimes conflicts with the EU Energy directive. To reach the WFD objectives by 2027 and better manage conflict between directives, the EU advocates better integration of sectoral policies with the WFD and energy policy at the strategic planning level.

In practice, green field projects, causing deterioration of water status/potential or non-achievement of WFD objectives, cannot be authorised and consequently it requires exemption from the WFD "no deterioration principle". Exemption is only allowed under the following conditions (WFD Article 4.7) [9]:

- All practicable mitigation measures are taken:
- There are no significantly better environmental options.
- The benefits of the development outweigh the benefits of achieving the WFD objectives: the development is of overriding public interest.
- The project and the reasons for it are set out and explained in the River Basin Management Plans.

Existing reservoirs of hydropower plants are classified as water bodies and as heavily modified if hydromorphological changes needed to achieve good status would significantly affect the use or wider environment. Thus, mitigation measures are required to reach « Good Ecological Potential ». The "Good Ecological Potential" criteria are defined by Member States. The best approximation of ecological continuum is a key aspect of ecological potential.

2.4 The deployment of best practice

The construction of a hydropower project will inevitably change the river on which it is built. Identifying the extent of these impacts, and managing them responsibly, is crucial to ensure the conservation of biodiversity. The most common approach to managing biodiversity impacts from hydropower is by applying the mitigation hierarchy. The mitigation hierarchy – avoid, minimise, mitigate and compensate – is a sequential process. First, a project should always seek to avoid or prevent negative or adverse impacts. For hydropower, this can include changes in site selection or project design to avoid the flooding of critical biodiversity areas. When avoidance is not possible, projects should look to minimise adverse impacts. For example, a project can alter operational controls or implement environmental flows to minimise downstream impacts on river health. In cases where avoidance and minimisation are not practicable, projects should aim to mitigate and compensate the identified impacts. This can be done by restoring lost habitats and re-establishing biodiversity value to the affected area.

The internationally recognised Hydropower Sustainability Tools [5] provide further guidance to industry on achieving good practice in hydropower development with regard to biodiversity conservation. By assessing themselves against the requirements of the Biodiversity and Invasive Species guidelines and assessment criteria, hydropower projects can demonstrate their commitment to biodiversity in line with international standards.

The tools' performance criteria address ecosystem values, habitats and issues such as threatened species and fish passage in the catchment, reservoir and downstream areas, as well as potential impacts arising from pest and invasive species associated with the planned project. The intent is that there are healthy, functional and viable aquatic and terrestrial ecosystems in the project-affected area that are sustainable over the long-term, and that biodiversity impacts arising from project activities are managed responsibly.

Impacts on terrestrial and aquatic connectivity, especially on migratory aquatic species, are among the most important priorities for hydropower developers and operators.

2.5 Need of knowledge and science on ecological continuity

The hydropower industry knows measures to mitigate the effect of HPPs on fish but has very limited knowledge on the behaviour and reactions of the fish population (and not individual) to its powerplants. There is an urgent need of knowledge and science on fish population. FIThydro, a 4-year EU-funded H2020 research project (2016-2020) has fortunately brought knowledge on mitigation measures and strategies to develop cost-effective environmental solutions and on strategies to avoid fish damage and enhance population development. It has developed tools to support risk assessment (e.g., risk classification system for fish species, assessment of cumulative impacts) at hydropower plants: Risk-based Decision Support System and knowledge sharing (wiki) for planning, implementing and monitoring mitigation measures. It addresses decision support in commissioning and operating hydropower plants by use of existing and innovative technologies. In the future more efforts should focus on preserving suitable hydro-morphodynamic and therefore habitat conditions and on quantification of the effect of turbines to fish and the specific hazard to fish species (fish hazard index).

2.6 Public acceptance and decision making

A hydropower boom occurred in the mid-20th century at a time where poor environmental standards were applied. Now knowledge and perception of the impacts have changed, and hydropower cannot continue to keep "business as usual" but needs to build an honest and direct partnership between all stakeholders.

In order to help conserve biodiversity, industry, governments and NGOs need to work together to identify and address the negative impacts of hydropower on biodiversity and come up with innovative solutions to help avoid, minimise, mitigate and compensate these impacts as early as possible in the project cycle. There is a vast number of restoration and mitigation activities that hydropower can start implementing today.

3 The need for knowledge and innovation

Seven priority directions for further developing hydropower in Europe have been selected to help achieve the European Green Deal targets:

1. Increasing Flexibility: innovation in flexibility storage design and operations (especially pumped-storage); innovative turbines' (including reversible pump-turbines) and generators' design; new models and simulation tools for harsher operation conditions.
2. Optimisation of operations and maintenance: digitalisation and Artificial Intelligence to advance instrumentation and controls; monitoring systems for predictive maintenance and optimised maintenance intervals.
3. Resilience of electromechanical equipment: new materials for increased resistance and increased efficiency of equipment
4. Resilience of infrastructures and operations: new materials and structures for increased performance and resilience of infrastructures; databases of incidents and extreme events, integrated structural risk-analysis models and innovative solutions for multi-hazard risk analysis; innovative sediments management technologies for sustainable reservoir capacity and river morphology restoration; innovative techniques for enhancement of useful life of concrete structures; innovative techniques for enhancement of overtopping safety of embankment and rockfill structures.
5. Developing new emerging concepts: development of innovative storage and pumped-storage power plants (multipurpose PSP, sea water PSP, etc.), marine energy and hybrid power plants.
6. Environmentally compatible solutions: flow regime management, assessment of environmental flow release, innovative connectivity solution for fish and biodiversity protection and improvement of stored water quality in reservoir.
7. Mitigating impact of global warming: innovative concepts of hydropower infrastructure adaptation and tapping hidden hydro.

4 Towards a European Technology and Innovation Platform

European Technology and Innovation Platforms (ETIPs) are recognised by the European Commission as a tool or framework under the Horizon 2020 and Horizon Europe programmes to help strengthen cooperation with stakeholders under the Strategic Energy Technology Plan (SET Plan). In 2015 nine ETIPs were supported, representing different sectors of the renewables energy market; in 2021 ETIPs under eleven different sectors – including hydropower – are likely.

The role of an ETIP is to facilitate stakeholder engagement as part of the transition to a clean energy system and the achievement of the zero emissions target. In particular, ETIPs should help consolidate strong and sustainable networks in the different technology areas covered by the SET Plan and its integrated roadmap and support cooperation between ETIPs and similar fora, whilst implementing steps helping to achieve the SET Plan goals.

The work undertaken by the Hydropower Europe project and the creation of the Hydropower Europe Forum (and the associated consultation programme and platform) aligns closely with the goals of a hydropower focussed ETIP. The Hydropower Europe Forum brings together stakeholders from all areas of the hydropower value chain and is positioned to facilitate the inclusion of hydropower into the wider clean energy transition programme. Production of the Research and Innovation Agenda (RIA) and the Strategic Industry Roadmap (SIR) during the Hydropower Europe programme means that a hydropower ETIP can now focus on helping to deliver action on those research priorities, and towards finding acceptable solutions that can address the various barriers and issues affecting implementation of hydropower solutions today, whilst simultaneously meeting expectations, aspirations and regulations for associated societal and environmental issues.

It is envisaged that European financial support for an ETIP will last for ~3 years, beyond which the ETIP will need to be self-sustaining. Such a role will need to provide clear industry value and fit within the current fragmented structure of industry associations. Initial concepts for Forum sustainability are being produced as part of the remaining Hydropower Europe project programme.

5 Conclusion: our vision for the role of hydropower

We believe that the next generation deserves a healthy planet and hydropower as an important renewable energy has a crucial role to play in building the future Green Deal. In particular, the key strategic avenues that we envision for development are outlined as follows:

1. Innovative solutions to protect fresh-water ecosystems and to restore river continuity.
2. Increasing hydropower production through the implementation of new sustainable, multipurpose hydropower schemes and by using the hidden hydro potential within existing infrastructures.
3. Increasing the flexibility of generation from existing hydropower plants by the adaptation and optimisation of infrastructure and equipment.
4. Increasing storage by the heightening of existing dams and construction of new reservoirs, which have to ensure not only flexible energy supply, but which also support food and water supply and thus contribute to the Water-Energy-Food NEXUS and achievement of the Sustainable Development Goals of the United Nations.
5. Strengthening the contribution of flexibility from pumped-storage power plants, by developing and building innovative arrangements in combination with existing water infrastructures.

As already mentioned, climate change i.e. global warming will also be an important issue for such a hydropower development in Europe. The effect of climate change will not only change the availability of water resources in time but also change the behaviour of the catchment areas by an increased sediment yield and more frequent natural hazards, and thus considerably endangering hydropower production in the near future. Finally, reservoirs of hydropower plants will have to contribute more and more to the mitigation of climate effects as already mentioned before.

Acknowledgement

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References

1. P. Gomez, G. Probst, Die Praxis des ganzheitlichen Problemlösens, Paul Haupt Verlag, Bern, Switzerland (1995)
2. P. Heller, E. Bollaert, A.J. Schleiss, *Comprehensive system analysis of a multipurpose run-of-river power plant with holistic qualitative assessment. International,* Journal of River Basin Management, Vol. 8, No 3-4, doi: 10.1080/15715124.2010.517672, pp. 295-304 (2010)
3. A.J. Schleiss, P. Manso, *Hydropower in Europe in a complex world - A global system analysis approach,* Hydropower Europe, Technical Report, June (2020)
4. IPBES, *The global assessment report on biodiversity and ecosystem services.* ISBN No: 978-3-947851-13-3 (2019)
5. IHA. *Hydropower sustainability assessment protocol.* ISBN 978-0-9566228-1-5. May (2020)
6. Boughaba, *EU environmental policies relevant for hydropower,* Hydropower Europe interactive workshop – 12 October (2020)
7. European Commission, *Guidance on the requirements for hydropower in relation to Natura 2000* (2018)
8. European commission, *Common Implementation strategy for the water framework directive (2000/60/EC), Guidance document n°4.* ISBN 92-894-5124-6 (2003)
9. European Commission, *Common implementation strategy for the water framework directive and the floods directive, Guidance Document No. 36.* Exemptions to the Environmental Objectives according to Article 4(7), 4-5 December (2017)