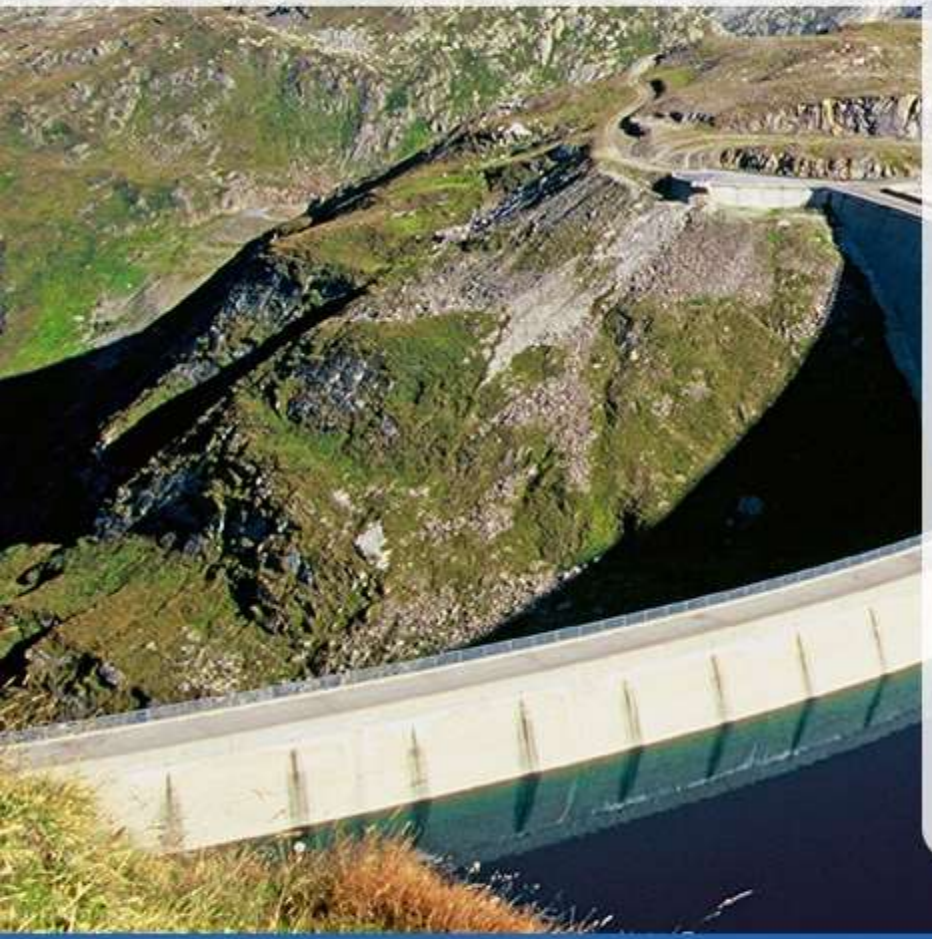
HYDROPOWER EUROPE

The important role of hydropower in the energy transition

Key results from the Research and Innovation Agenda (RIA)



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HYDROPOWER EUROPE Forum Online Event
February 23, 2022

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The outcomes of the Forum

R&I Priorities

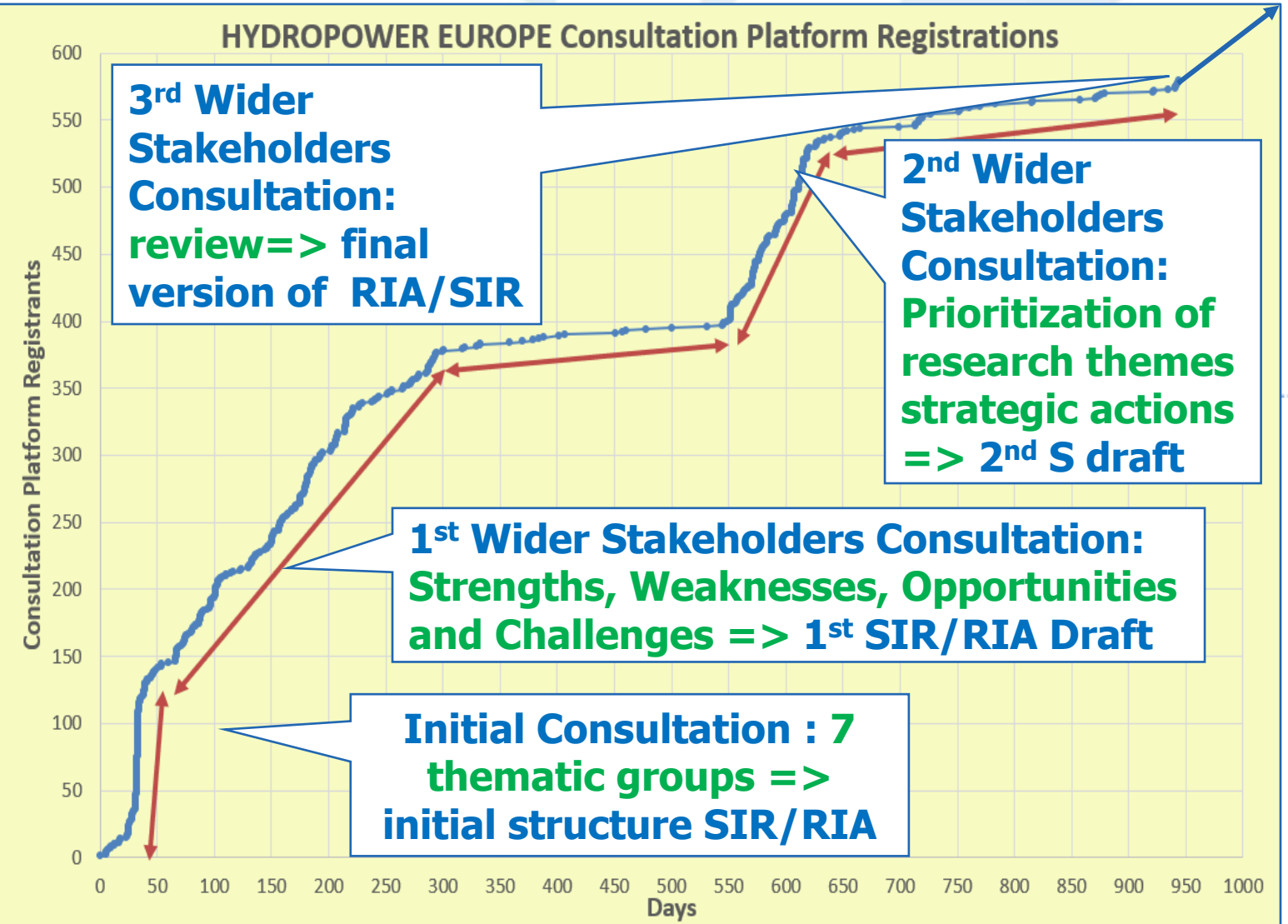
Barriers

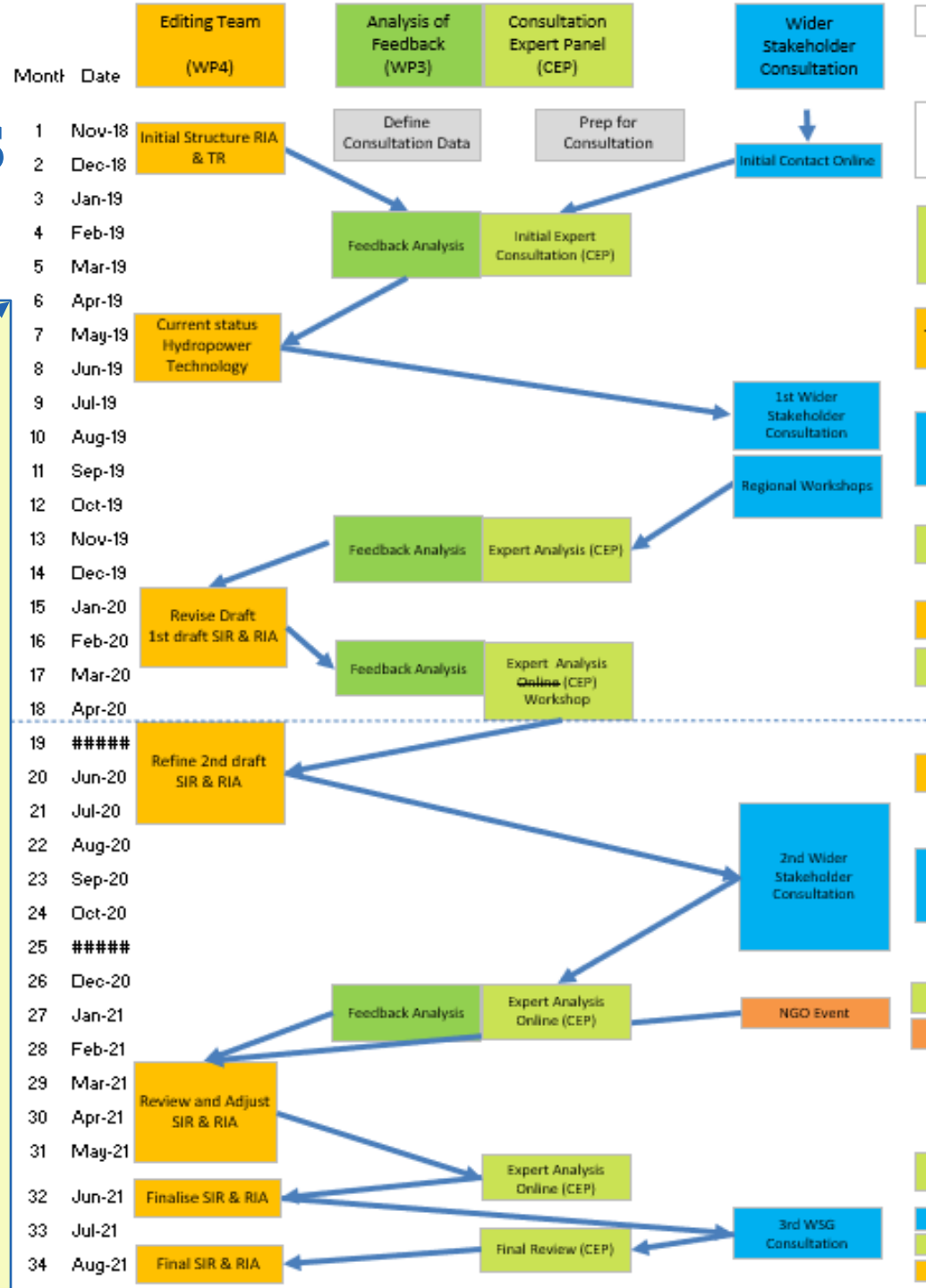
RIA
Recommandations
18 Research Themes – 80 topics

SIR
Steps to new hydro deployment
11 Strategic Direction – 40 Detailed Actions

European Commission

The Consultations





Building the Research & Innovation Agenda

➢ **The seven thematic groups**

- Increasing Flexibility
- Optimisation of operations and maintenance
- Resilience of electromechanical equipment
- Resilience of infrastructures and operations
- Developing new emerging concepts
- Environmental-compatible solutions
- Mitigation of the impact of global warming

Building the Research & Innovation Agenda

- **Consultation process through workshops (both regional and Brussels-based) and online discussion groups to seek *perceptions, views and expectations on the current and future research and innovation needs of the hydropower sector***

- **More than 600 hydropower experts from across Europe contributed their inputs regarding research needs from a technological and regulatory point of view**

Birsfelden run-of-river power plant on Rhine River

Building the Research & Innovation Agenda

- The consultations process was accompanied and validated by the Consultation Expert Panel (CEP) within the total of four workshops and consequent consolidation.
- The final consultation produced *priority levels* for each research theme and respective topics; their *time perspective* and *needed budget* as well as *desired TRL levels*.
- Finally, from the seven thematic groups, 18 research themes and in total some 80 detailed topics were included in the Research & Innovation Agenda (RIA).

Almendra Dam (202 m) and reservoir in Spain

The RIA Research Priorities (1/5)

Challenges	Research Themes	Priorities	Recommended Call	Recommended Funding Scheme
Increasing fexibility	3.1.1. Innovation in flexibility, storage design and operation	Very High	before 2025	€ 26-35 million
	3.1.2. Innovative design of turbines including reversible pump-turbines and generators	High	before 2030	€ 16-25 million
	3.1.3. New models and simulation tools for harsher operation conditions	High	before 2030	€ 8-15 million
	3.1.4 Development and application of a business model for flexibility	Very High	before 2025	€ 8-15 million

The RIA Research Priorities (2/2)

Challenges	Research Themes	Priorities	Recommended Call	Recommended Funding Scheme
Optimisation of operations and maintenance	3.2.1. Digitalisation and artificial Intelligence to advance instrumentation and controls	High	before 2030	€ 16-25 million
	3.2.2. Monitoring systems for predictive maintenance and optimised maintenance intervals	High to Very High	before 2030	€ 2-7 million

The RIA Research Priorities (3/5)

Challenges	Research Themes	Priorities	Recommended Call	Recommended Funding Scheme
Resilience of electro-mechanical equipment and infrastructures	3.3.1. New materials for increased resistance and increased efficiency of equipment	Medium High to High	before 2030	€ 8-15 million
	3.4.1. New materials and structures for increased performance and resilience of infrastructure	Medium High to High	before 2030	€ 8-15 million
	3.4.2. Databases of incidents and extreme events, integrated structural risk-analysis models and innovative solutions for multi-hazard risk analysis	High	before 2030	€ 8-15 million
	3.4.3. Innovative sediment management technologies for sustainable reservoir capacity and river morphology restoration	High to Very High	before 2025	€ 8-15 million
	3.4.4. Innovative techniques for enhancement of working life of concrete structures	Medium High to High	before 2030	€ 8-15 million
	3.4.5. Innovative techniques for enhancement of overtopping safety of embankment and rockfill structures	High	before 2035	€ 2-7 million

The RIA Research Priorities (4/5)

Challenges	Research Themes	Priorities	Recommended Call	Recommended Funding Scheme
Developing of new emerging concepts	3.5.1. Development of innovative storage and pumped-storage power plants (e.g. multipurpose PSH, sea water PSH, etc.)	Very High	before 2030	€ 16-25 million
	3.5.2. Marine energy	Medium High to High	before 2030	€ 8-15 million
	3.5.3. Hybrid & virtual power plants	High to Very High	before 2030	€ 8-15 million

The RIA Research Priorities (5/5)

Challenges	Research Themes	Priorities	Recommended Call	Recommended Funding Scheme
Environmental-compatible solutions and mitigation of the impact of global warming	3.6.1. Flow regime management, assessment of environmental flow release, innovative connectivity solution for fish and biodiversity protection and improvement of stored water quality in reservoir	Very High	before 2025	€ 16-25 million
	3.6.2. Assessment of the general impact and contribution of hydro-power to biodiversity and the identification of innovative approaches and guidelines to support more sustainable hydropower development	Very High	before 2025	€ 8-15 million
	3.7.1. Innovative concepts of hydropower infrastructure adaptation and tapping hidden hydro	Very High	before 2030	€ 16-25 million

Hydropower in Europe in a complex world

A global system analysis approach as a supporting tool for evaluating strategic actions and research directions

Ruppoldingen run-of-river power plant on Aar River in Switzerland

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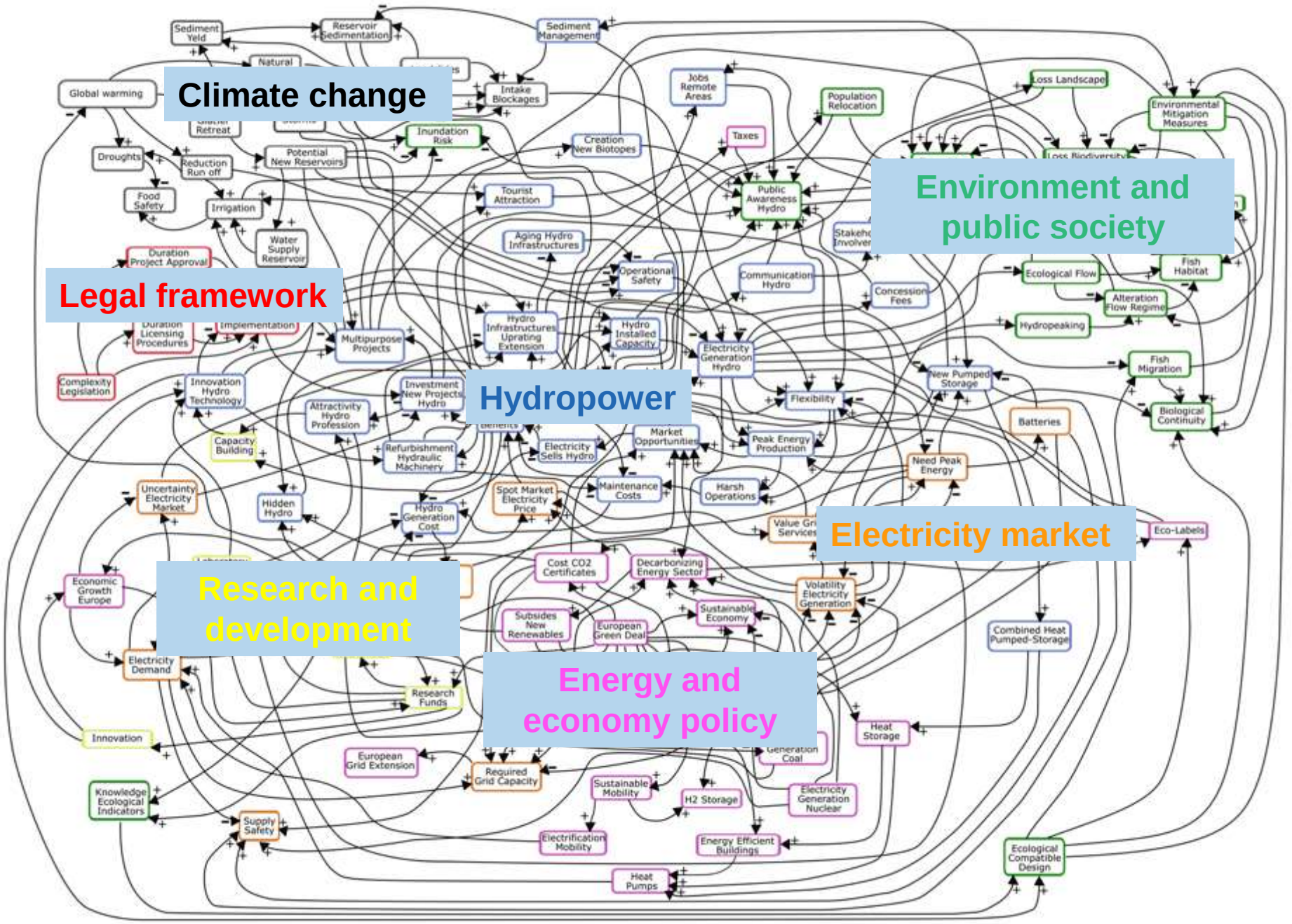
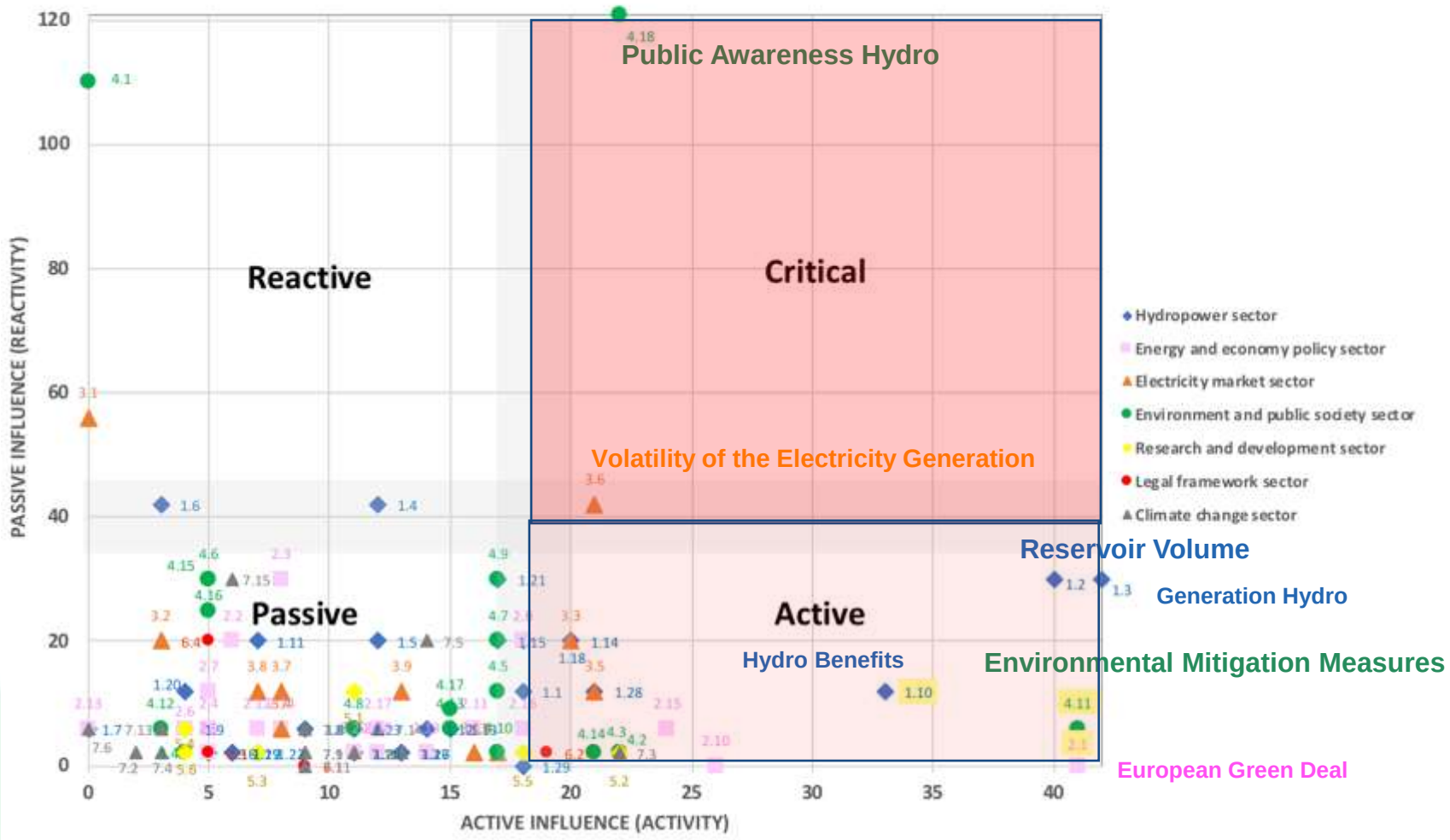
Network of 103 factors representing the sectors Hydropower (blue), Energy and economy policy (pink), Electricity market (orange), Environment and public society (green), Research and development (yellow), Legal framework (red) and Climate change (black).



Result of matrix analysis considering second degree of influences (connections)

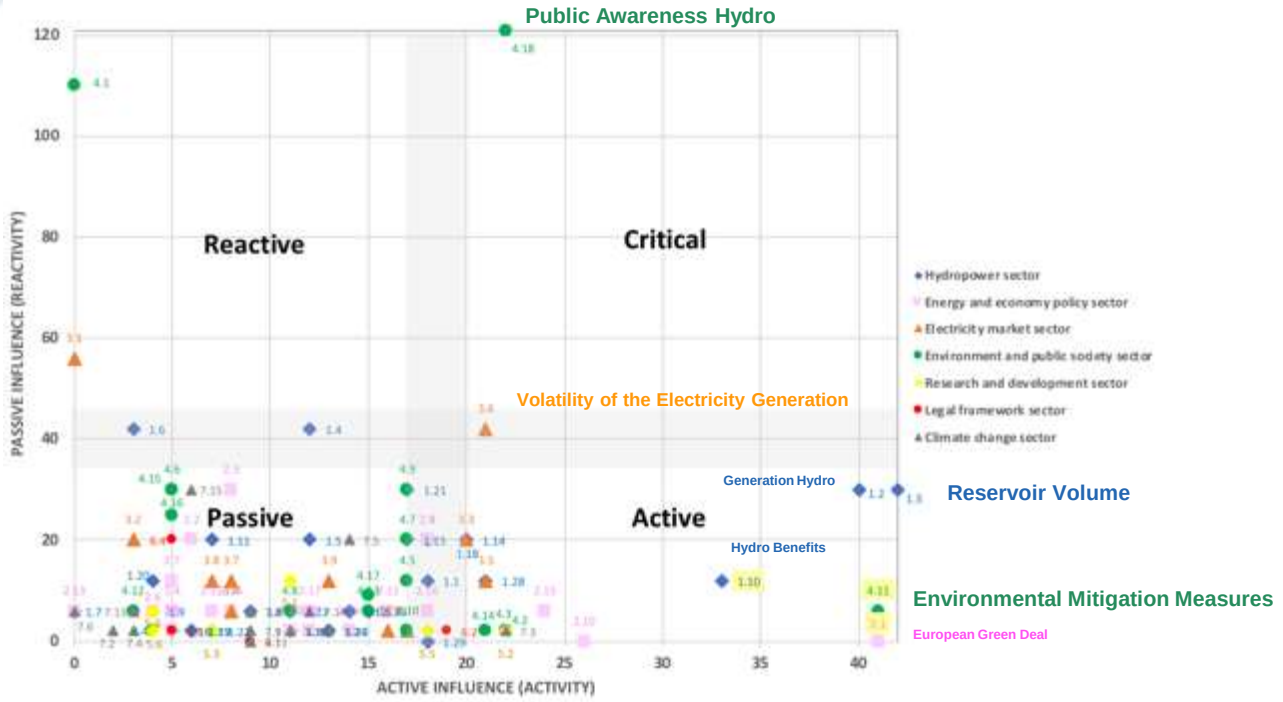


Ranking of of controllable active factors

1st highest activity
- Communication Hydro (1.17/4.18)
- Reservoir Volume (1.2)
- Environmental Mitigation Measures (4.11)

2nd highest activity
- Benefit Sharing Local Communities (4.2)
- Ecological Flow (4.3)
- Population relocation (4.14)
- Innovation Hydro Technology (1.28)

3rd highest activity
- Hydro Installed Capacity (1.1)
- Multipurpose Projects (1.18)
- New Pumped-storage (1.21)
- Sediment Management (1.29)
- Eco-labels (2.16)
- Fish Habitat (4.6)
- Loss Biodiversity (4.9)
- Loss Landscape (4.10)
- Digitalization (5.5)



The controllable active factors can be used as a lever to improve the hydropower situation in the system and therefore they are important for the prioritization of any strategic actions and research directions.

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Comparison of the research themes and priorities with the controllable, active factors of the complex system analysis.

1st (orange), 2nd (yellow), 3rd (green) highest impact level factors in the complex system network.

Priority categories given by CEP: Very-high (VH), High to Very High (HVH), High (V), Medium High to High (MHH)

Complex System Analysis Hydropower in Europe

Hydropower Europe R&I themes	Communication Hydro	Reservoir Volume	Environmental Mitigation Measures	Benefit Sharing Local Communities	Ecological Flow	Population Relocation	Innovation Hydro Technology	Hydro Installed Capacity	Multipurpose Projects	Sediment Management	Eco-labels	Fish Habitat	Loss Biodiversity	Loss Landscape	Digitalization
3.1.1. Innovation in flexibility, storage design and operation		VH					VH	VH	VH						
3.1.2. Innovative design of turbines including reversible pump-turbines and generators							H								
3.1.3. New models and simulation tools for harsher operational conditions							H								
3.1.4 Development and application of a business model for flexibility							VH								
3.2.1. Digitalisation and artificial intelligence to advance instrumentation and controls		H					H			H					H
3.2.2. Monitoring systems for predictive maintenance and optimised maintenance intervals							HVH			HVH					
3.3.1 New materials for the increased resistance and efficiency of equipment							MHH			MHH					
3.4.1. New materials and structures for increased performance and resilience of infrastructure							MHH	MHH		MHH					
3.4.2. Databases of incidents and extreme events, integrated structural risk-analysis models and innovative solutions for multi-hazard risk analysis							H			H					H
3.4.3. Innovative sediment management technologies for sustainable reservoir capacity and river morphology restoration		HVH	HVH				HVH			HVH		HVH	HVH		
3.4.4. Innovative techniques for enhancing the working life of concrete structures							MHH			MHH					
3.4.5. Innovative techniques for the enhancement of overtopping safety of embankment and rockfill structures							H								
3.5.1. Development of innovative storage and pumped-storage power plants (e.g. multipurpose PSH, sea water PSH, etc.)		H					H	H	H						
3.5.2. Marine energy		MHH					MHH	MHH	MHH						
3.5.3 Hybrid & virtual power plants		HVH					HVH								HVH
3.6.1. Flow regime management, assessment of environmental flow release, innovative connectivity solutions for fish and biodiversity protection and improvement of stored water quality in reservoirs			VH		VH		VH				VH	VH	VH	VH	
3.6.2. Assessment of the general impact and contribution of hydropower to biodiversity and the identification of innovative approaches and guidelines to support more sustainable hydropower development			VH		VH		VH				VH	VH	VH	VH	
3.7.1. Innovative concepts of hydropower infrastructure adaptation and tapping hidden hydro		VH					VH	VH	VH						

HYDROPOWER EUROPE

Examples of « VERY HIGH » Priority Research Themes from Summary Brochure

Development and application of a business model for flexibility

Priority: Very High
Recommended call: initiate research before 2030
Recommended funding scheme: €8-15 million

Background and challenges

The hydropower business case is representative of some of the issues facing the development of an adequate market model for a new energy system. The energy market has traditionally been based upon competition driven by fuel costs. In the past hydro was in competition with fossil fired thermal plants. Since the decarbonisation policy has led to decommissioning of fossil fired plants, a new energy system, in which only renewable (solar, wind, water) and other low carbon sources will be developed, needs a new appropriate market model.

The revised Renewable Energy Directive (RED III) increases the overall Union target for renewable energy in 2030 to 40%. The RED III proposals, however, fall short in terms of supporting energy storage deployment to facilitate renewable energy sources (RES) integration. More precisely, the main challenge for Hydropower is the limited payoff in today's markets of flexibility, although hydropower is unique in its ability for providing system flexibility across all timescales. To demonstrate the solution and to give an accurate price to the flexibility, a market design must be built on an economic model taking account the wide portfolio of renewable energy sources, the interconnection and the liquid power markets.

SUGGESTED RESEARCH TOPICS with high to very high priority

Development and application of a business model for flexibility to decarbonise the energy sector
Expected TRL: 6-7 Budget range: €8-15M

Innovation in flexibility, storage design and operations

Priority: Very High
Recommended call: initiate research before 2025
Recommended funding scheme: € 26-35 million

Background and challenges

Today, pumped-storage hydro (PSH) and reservoir hydro is currently the cheapest and most mature large-scale technology for energy storage and balancing the electricity network. In addition, it has a long lifetime, offers attractive grid services (e.g. black start availability, synchronous inertia response, and island grid build up) and is not dependent on rare materials. However, there can be significant environmental and social barriers to PSH deployment and projects also have high CAPEX. Nevertheless, it is a key enabler for reliable electricity supply in the context of increasing variable RES generation.

European reservoirs are large and can be used for flexible operation. Today's storage capacity in European hydropower reservoirs exceeds 185 TWh, making it the largest 'battery' available and an energy storage system for other renewables. Storage capacity is huge and available from a technical point of view and there is still a considerable untapped potential in Europe. A significant potential exists uprating of existing storage hydropower schemes either by increasing installed capacity (adding new parallel waterway systems and powerhouses) or increasing storage capacity by heightening of dams. Only relatively few of the existing reservoirs are equipped with pumps or pump-turbines, and therefore active electrical energy storage (i.e. storing electricity flowing through the network) is not possible in most hydropower reservoirs. Transforming conventional storage power plants into pumped-storage power plants would contribute to increasing the current active electrical energy storage capacity by several orders of magnitude.

The massive and fast penetration of solar PV and wind generation will undoubtedly place enormous pressure on grid stability and balancing requirement. By consequence, this means creation of market and/or regulatory mechanisms to stimulate entry of storage and flexibility providers is a high priority. In this context, hydropower advantages as a well understood technology with low lifecycle costs will enable it to compete with other technologies in the power market. By connecting existing large seasonal reservoirs with PSH, they can under certain conditions also enhance the seasonal transfer of energy storage requirements.

SUGGESTED RESEARCH TOPICS with high to very high priority

Developing and optimising hydraulic design and control strategies for pump turbines and waterway system in existing PSH
Expected TRL: 6-7 Budget range: €7-10M

Enhancing flexibility of run-of-river power plants and using existing run-of-river cascades for energy storage
Expected TRL: 6-7 Budget range: €4-6M

Developing design algorithm and innovative construction technologies for new PSH parallel to existing storage powerplants by using existing upper and lower reservoirs
Expected TRL: 6-7 Budget range: €4-6M

Overall assessment models of run-of-river, storage and pumped storage power plants regarding market and socio-economic issues
Expected TRL: 6-7 Budget range: €1-3M

Developing new designs and concepts for distributed pumped storage systems and improving feasibility and cost-efficiency of underground PSH
Expected TRL: 4-5 Budget range: €1-3M

Improving feasibility and cost-efficiency of seawater PSH
Expected TRL: 6-7 Budget range: €4-6M

Further improving the efficiency and operation range of variable speed pump turbines
Expected TRL: 8-9 Budget range: €4-6M

Developing suitable equipment for low-head PSH
Expected TRL: 4-5 Budget range: €4-6M

Examples of « VERY HIGH » Priority Research Themes from Summary Brochure

Development of innovative storage and pumped-storage power plants (e.g. multipurpose schemes, sea water PSH, etc.)

Priority: Very High
Recommended call: initiate research before 2030
Recommended funding scheme: €16-25 million

Background and challenges

Multipurpose schemes refer to the use of reservoirs to provide other services beyond electricity generation. Hydropower projects present multiple opportunities to create environmental and socio-economic value for their host communities and regions. Through multipurpose schemes, hydropower reservoirs can contribute to appropriate water management, including water supply, flood and drought management, irrigation, navigation, fisheries, environmental services and recreational activities. Many dams have been built most often to serve only one of the above-mentioned purposes. However, due to the increasing demand for the various provided services, their spatial and temporal overlaps, the increasing threat posed by climate change and national and international sustainability goals, construction and/or retrofitting multipurpose uses of dams has been favoured in recent years as they can fulfil several purposes with a single facility. Multi-purpose water infrastructure encompasses all constructed water systems, including dams, dykes, reservoirs and associated irrigation canals and water supply networks.

Through these uses, the profitability of storage and pumped storage plants can be improved, while at the same time making HPPs amenable for the wider public. However, clarification of the legal framework is needed to put in place some of these uses. Even if not yet widely used, seawater pumped storage plants and tidal range plants are already mature technologies and these technologies have a potentially large market. They are highly predictable and there is no competition with freshwater resources.

SUGGESTED RESEARCH TOPICS with high to very high priority

Integrating storage and pumped storage in hybrid and virtual power plants
Expected TRL: 6-7 Budget range: €4-6M

Transforming a storage power plant into a Pumped Storage Plant
Expected TRL: 6-7 Budget range: €4-6M

Development of a new type of heat storage in underground reservoirs of PSH
Expected TRL: 4-5 Budget range: €1-3M

Developing and optimising Integrated Sea Water PSH and Desalination Plant (SWRO) schemes
Expected TRL: 6-7 Budget range: €4-6M

Estimation and analysis of increased sediment yield into reservoirs due to climate change and impact on hydropower generation
Expected TRL: 4-5 Budget range: €4-6M

Flow regime management, assessment of environmental flow release, innovative connectivity solution for fish and biodiversity protection and improvement of stored water quality in reservoir

Priority: Very High
Recommended call: initiate research before 2025
Recommended funding scheme: €16-25 million

Background and challenges

Multipurpose schemes refer to the use of reservoirs to reduce the negative impact of hydropower plants on the environment, R&I activities are needed to address the impacts of hydropower on upstream and downstream ecosystems to improve the ecological conditions and re-establish connectivity. One of the key issues is to determine and re-stablish the environmental flows that mimic the natural water flow whilst maintaining the necessary climate protection (e.g. one of the tools to determine the necessary environmental flow is the use of airborne laser bathymetry data with high resolution). Another issue is to also ensure sustainable ecosystems and population consistent with human needs for land-use and water-use, sometimes in heavily modified water bodies (e.g. appropriate measures and approaches need to be developed to balance different needs in a fair way). Nevertheless, environmental measures such as environmental flows need to be site-specific – there is no one size that fits all (e.g. concerning the Water Framework Directive). More research should also be undertaken on ecological flows within Mediterranean contexts as well as for high altitude alpine contexts and on the assessment of the impacts of hydropeaking on the dynamics and resilience of biological community populations based on the typology of rivers and the multiple pressures they experience. Other important issues are bearing the costs invested in hydro morphology (e.g. private companies, public organisations, etc.); and the fact that public services provided by operators (cleaning waste from rivers, flood protection, grid stabilisation, climate change mitigation) are not taken into account. The protection of fish populations by reducing mortality at power plants is another key issue and there is still a need for development and finding solutions for downstream fish migration devices and guiding fish to such downstream bypass systems. All mitigation measures have to be defined by taking into account the future needs of a carbon neutral energy system.

SUGGESTED RESEARCH TOPICS with high to very high priority

Measures and approaches to protect biodiversity
Expected TRL: 6-7 Budget range: €4-6M

Development and testing of solutions for improved biodiversity and fish protection
Expected TRL: 6-7 Budget range: €4-6M

Investigating linked effects on biological community's resilience population dynamics and diversity through analysing different ecological flows in various geographical contexts
Expected TRL: 4-5 Budget range: €4-6M

Evaluate, study and propose improvement of river ecology and fish habitat
Expected TRL: 6-7 Budget range: €4-6M

Examples of « VERY HIGH » Priority Research Themes from Summary Brochure

Assessment of general impact and contribution of hydropower to biodiversity and identification of innovative approaches and guidelines to support more sustainable hydropower development

Priority: Very High
Recommended call: initiate research before 2030
Recommended funding scheme: €8-15 million

Background and challenges

The Global Assessment Report on Biodiversity and Ecosystem Services (IPBES, 2019) points out that there is an urgent need for action to better conserve and sustainably use biodiversity. The circularity assessment of materials used for the implementation of hydropower schemes and their reuse is also an issue.

This challenge can be addressed with various actions or measures, both technical and non-technical, through cross-sectoral and multidisciplinary collaboration among decision-makers and other stakeholders at all levels. Such technical measure can include, for example side channel reconnection, removal of bank protections and river bed protection / structures, restoration of floodplain habitats, reduction of land use intensity, restoration of sediment continuity, hydrological aspects, etc. Before launching these actions, greater knowledge on ecosystems is needed for the development of the best and most effective solutions. Technical and environmental innovations have to guarantee that there will only be acceptable impacts. The question arises as to how to develop new green field hydropower projects in such an environmentally friendly and sustainable way that they can contribute to the achievement of the European Green Deal?

SUGGESTED RESEARCH TOPICS with high to very high priority

Assessment of the general impact and contribution of hydropower to the biodiversity
Expected TRL: NA Budget range: €7-10M

Innovative and comprehensive approaches for successful hydropower projects and win-win situations
Expected TRL: NA Budget range: €4-6M

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Full report (130 pages) and summary brochure (24 pages) available at

https://hydropower-europe.eu

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