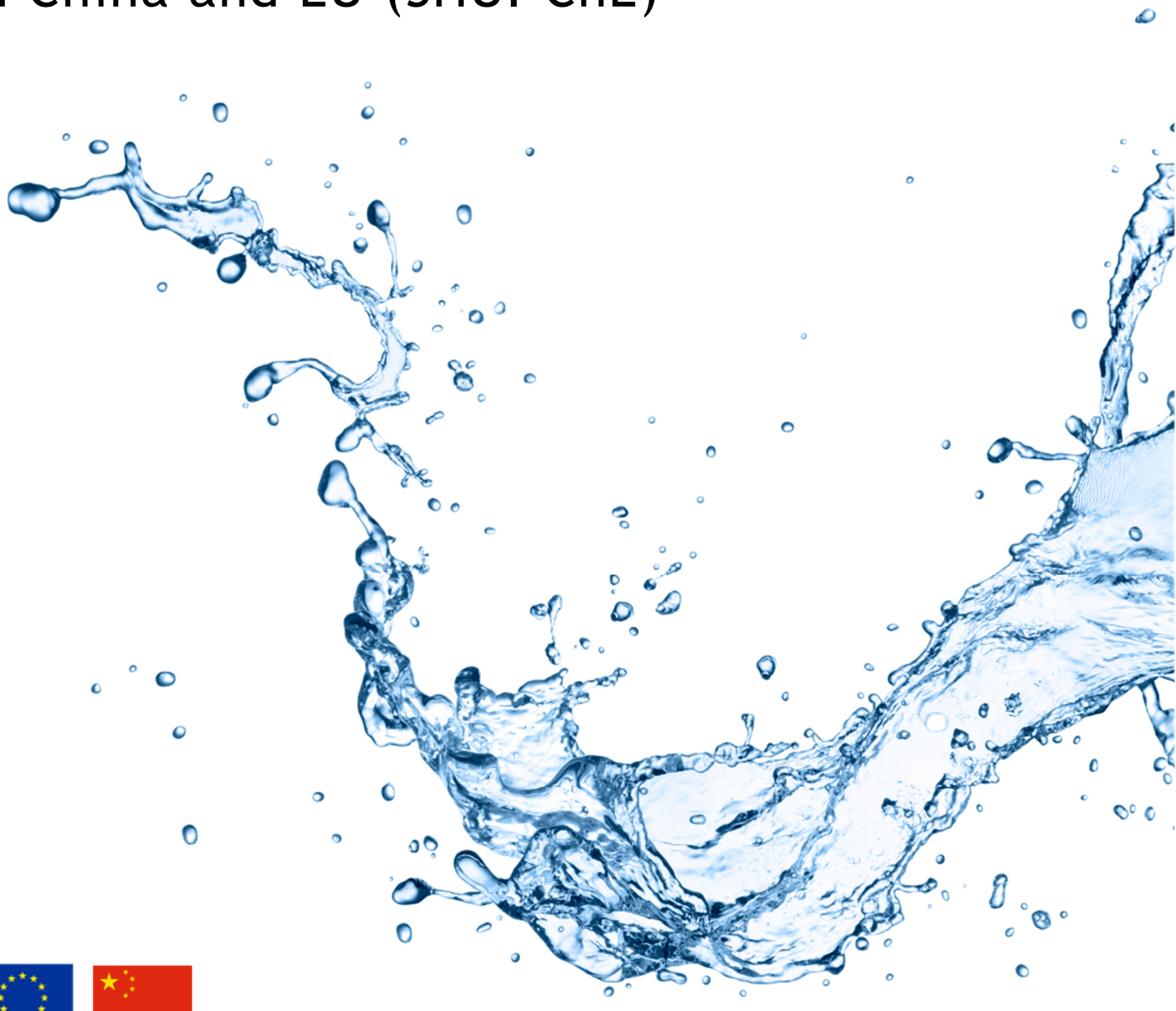
CHINA EUROPE Water Platform

Policy Brief

CEWP PI Lot 4

Sustainable Hydropower Use and Integration in China and EU (SHUI-ChE)



Co-funded by

the European Union and P.R. China

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1. Introduction

The purpose of this Policy Brief is to summarize and disseminate the key findings, policy recommendations and ideas for future cooperation generated by the Partnership Instrument (PI) Lot 4 project: Sustainable Hydropower Use and Integration in China and EU (SHUI-ChE).

The aim of the SHUI-ChE project was to enhance the co-generation and exchange of knowledge through synthesizing and sharing experiences and best practices between EU and China targeting sustainable hydropower in realizing low-carbon development pathways and market integration.

Hydropower sits at the heart of water and energy nexus. It has played and will continue to play a critical role in enhancing both water and energy securities. Yet sustainable hydropower development remains a major common challenge for both EU and China. Centred with hydropower development and operation, **the SHUI-ChE project focuses on three specific objectives divided into five work packages** (Work packages 2-6):

Objective 1: To enhance the co-generation and application of knowledge on "green" hydropower operation and development, as well as tapping/uncovering hidden energy potentials and hydropower scheme optimisation. We refer to this objective as the "green" dimension of sustainable hydropower. (Work packages 2 and 3)

Objective 2: To enhance the co-generation and application of knowledge on the "blue storage" function and the role of hydropower for enhancing regional energy cooperation and renewable energy system transition in the context of low carbon development in both EU and China. We refer to this objective as the "blue" dimension of sustainable hydropower. (Work packages 4 and 5)

Objective 3: To encourage and facilitate cross-sectoral multiple stakeholder communication and dialogue between Europe and China on sustainable hydropower by establishing the EU-China Sustainable Hydropower cooperation and Innovation platform. (Work package 6)

2. Key findings

2.1 Key findings regarding green hydropower and tapping hidden energy potentials

Through our project activities implemented regarding green hydropower operation and development, as well as tapping/uncovering hidden energy potentials and hydropower scheme optimisation (Objective 1, Work packages 2 and 3), the following three key findings were concluded:

1. **Green hydropower (GHP) standards are innovative and important tools to evaluate the sustainability of hydropower plants with regard to environmental, social and economic aspects.** Standards used for GHP assessment are developed worldwide often targeting specific challenges in a basin, country or even at international level. Hydropower fulfills a special role in renewable energy sector, since it is able to balance and store volatile energy sources such as wind and PV. However, hydropower is also associated with environmental impacts on the aquatic ecosystem. In

this context, GHP standards contribute to data-based decision making to reduce negative impacts while optimizing energy production. Comparing different green hydropower standards (e.g. GHC from Switzerland, LIHC from USA, HSAP by IHA, GEHMP by MRC, Hy:Con from Austria and ESGSHP from China) under the consideration of the scope, assessment method and successful application, as well as identifying specific characteristics, advantages and disadvantages of individual standards will provide suggestions on how to improve individual GHPs. Based on the existing standards, new standards are easy to be developed based on shared experiences. The aims and scopes of the standards are the most important factors which decides the framework and implementation of the standards (Zhenhua Cui et al. in prep). Due to the differences on the role of hydropower, priorities, data availability and understandings of green hydropower, the standards vary in scope, framework, method and implementation. There are some gaps existing at the standards and the implementation of standards. Newly developed standards can help to implement the state of the art and research results in the update process other standards.

2. **What is a healthy river?** In the beginning of the project Chinese experts expressed their need to define and assess river health from a hydro-morphological perspective. The technical note developed by the project team supported the development of a Chinese approach. By emphasizing the planning process of hydropower construction or restauration, the different activities are embedded in the overall long-term river management. The approach focuses on finding the right balance between water-, ecosystem- and energy- interests and takes advantage of tapping hidden potentials of hydropower by making existing plants more efficient. This approach is not fully based on ecological criteria as in Europe under the WFD, however it is a sufficient baseline and an important step in making small hydropower plants more sustainable. As such also the assessment of existing and potential small hydropower plants benefits from including criteria based on the biological, physico-chemical and hydromorphological elements of the river.

3. **Hydropower as a tool for stabilizing the energy grid.** Another important finding refers to hydropower as a tool for stabilizing the energy grid. Storage facilities and the upgrading of upstream power plants can also be used in the future for rid stabilisation through pumping and turbine options. This means that other renewable energy sources such as wind and PV can also be integrated into the grid through controllable hydropower.

2.2 Key findings regarding hydropower's "blue storage" function and its role for enhancing regional energy cooperation and renewable energy system transition

Through our project activities implemented regarding the "blue storage" function and the role of hydropower for enhancing regional energy cooperation and renewable energy system transition in both EU and China in the context of low carbon development. (Objective 2, Work packages 4 and 5), the following nine key findings were concluded:

1. **The role of Pumped Hydro Storage in the flexibility scenario.** The flexibility that Pumped Hydro Storage can provide to the electricity system is not only due to the amount of installed power capacity and energy storage but also to the capability of the single plant to follow the variable combination of system load and excess Variable Renewable Energy Source production both in turbine mode (storage discharging) and pump mode (storage charging). While hydraulic machines operating as turbines can provide a certain degree of freedom in power regulation, this is unfortunately not the case for the operation in pump mode for the standard fixed-speed

configuration. Following the new operation challenges, Pumped Hydro Storage Technology started in the last decades an evolution towards technical solutions, called Advanced PHS, specifically designed to provide additional operating flexibility to balance strong Variable Renewable Energy fluctuations in the system such as Variable Speed Pumped Storage and Ternary Systems with hydraulic short-circuit. Presently, advanced PHS plants are in operation only in Japan and in Europe.

2. **The growing role of Pumped Hydro Storage in the energy system of the People's Republic of China.** Although being a latecomer in worldwide PHS deployment, in a couple of decades China overtook the former leader, Japan, in terms of installed capacity, and has presently reached a total of nearly 39 GW of capacity in operation. No advanced PHS is presently installed, and within the future installations, only one plant is based on advanced PHS: Fengning Pumped Storage Power Station in Hebei Province, 1.8 GW to be commissioned in 2025.

3. **The future of Pumped Hydro Storage.** In accordance with the requirements of the Renewable Energy Law, in 2021 the PRC's National Energy Agency elaborated and issued the "Medium and Long-term Development Plan for Pumped Storage (2021-2035)". The aim is to guide the development of pumped storage in the medium and long-term following the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of Vision 2035 and the 14th Five-Year Plan for Modern Energy System. The plan spans until 2035, therefore also including the future 15th and 16th Five-Year plan periods, and it aims to reach the relevant PHS installed operational capacity of 305 GW by 2035, with the development of a modern pumped storage industry with advanced technology, high-quality management, and strong international competitiveness. The planned schedule is to reach 62 GW cumulative installed capacity by the end of the 14th FYP (2025), 120 GW capacity by the end of the 15th FYP (2030), and finally 305GW by the end of the 16th FYP (2035).

4. **Power system flexibility is critical for accelerating renewable energy transition.** The key constraining factor for accelerating renewable energy transition has been quickly shifting in much of the world, China and Europe included, from high costs to the lack of flexibility of the exiting power system. And there is a growing and strong realization of the balancing role of hydropower, both pumped storage and conventional hydropower, for enhancing such flexibility as a source of long duration energy storage option.

5. **There are far-reaching implications for enabling and maximizing the 'balancing' role of hydropower.** First, by changing the operational schemes, a much more flexible operation of exiting hydropower especially the conventional hydropower would change and add new considerations and requirements for the design and modification of mitigation measures to minimizing the environmental and ecological impacts (e.g., hydropeaking). Second, to enable sustainable and economical operation of hydropower with high flexibility contribution, a range of policy innovations are required on the power market design (e.g., pricing mechanism, trading, regional energy cooperation, and power grid integration). And third, creating the incentive structure is key to attract and mobilizing financing and investment from all sectors both public and private.

6. **Power market transformation is a race for flexibility.** In Europe, a market-based electricity market has provided a good basis and enabled quick development of power market integration such as the application of spot-market. In China, the slow progress of its electricity marketization reform remains to be a major challenge for resolving much of the structural barriers for power grid

integration. For both EU and China, much policy innovations remain for the regulation and pricing frameworks on ancillary services that are essential for the flexibility and stability of the power system.

7. **Rapid policy awareness and development.** During the SHUI-ChE implementation, there is a quick change of policy awareness on the balancing role of hydropower in China. A series of national policies have been developed, for example, integrated source-grid-demand-storage planning and development; river basin based integrated wind-solar-hydro planning and development; the medium- and long-term development plan for pumped storage hydropower (2021-2035), just to name a few.

8. **Multiple stakeholder policy dialogue is essential and remains desirable in both China and Europe.** To address the wide-ranging challenges and promote integrated water and energy planning, intersectoral and multiple stakeholder engagement and policy dialogues are critically important and remains a common challenge for both China and Europe. But it is an area Europe has and can offer much more useful learning and best practices to China.

9. **China's Medium- and Long-term Development Plan for Pumped Storage Hydropower (2021-2035)** is extremely ambitious, and it sets the context as well as offering a massive opportunity for strengthening EU-China cooperation on sustainable hydropower in all CEWP pillar areas – research, governance and business.

2.3 Key findings regarding cross-sectoral multiple stakeholder communication and dialogue between Europe and China on sustainable hydropower

Through our project activities implemented regarding cross-sectoral multiple stakeholder communication and dialogue between Europe and China on sustainable hydropower by establishing the EU-China Sustainable Hydropower cooperation and Innovation platform (Objective 3, Work package 6), the following four key findings were concluded:

1. **There are strong needs and interests from both Europe and China** for having a long-term platform (especially after the end of the SHUI-ChE project) for cross-sectoral multiple stakeholder communication and dialogue between Europe and China on sustainable hydropower.

2. **Mutual learning should be the aim and focus.** The EU-China Sustainable Hydropower cooperation and Innovation platform should contribute to mutual learning between Europe and China on issues that are of interest for both sides.

3. **A wider range of stakeholders needs to be engaged.** The EU-China Sustainable Hydropower cooperation and Innovation platform needs to continue its efforts to identify and engage a wider range of stakeholders in order to optimize its impact and added value for all involved organizations.

4. **Potential for wider impact beyond China and Europe.** Enhanced cross-sectoral multiple stakeholder communication and dialogue on sustainable hydropower between Europe and China might result in opportunities for joint actions and positive change in additional countries or regions.

3. Policy Recommendations

3.1 Policy recommendations regarding green hydropower and tapping hidden energy potentials

Based on the project activities implemented and the presented key findings regarding green hydropower operation and development, as well as tapping/uncovering hidden energy potentials and hydropower scheme optimisation (Objective 1, Work packages 2 and 3), the following five policy recommendations were concluded:

1. **China and the EU should continue the dialogue on sustainable hydropower as under the green deal.** The EU has not only set ambitious objectives for Europe, but also for global issues. As such EU energy diplomacy aims to accelerate the global energy transition, promoting energy efficiency and renewable technologies, amongst other things. At the same time there is a commitment to support the achievements of the SDGs. A continuous dialog on sustainable hydropower can support both objectives and is of particular importance as companies from China and the EU are developing also hydropower plants outside their territory.

2. **Compilation of "best-off" examples where hydropower is further upgraded but also more environmentally friendly.** Such developed concepts on minimizing environmental impacts and improving efficiency especially at the HHP cascades support the implementation of green HP standards and hydro power plant upgrading, and can also be applied to other similar sites and regions. Beside environmental mitigation measures, HPP refurbishment with regard to site-specific capacity increase including optimization of the plant sites in consideration to maximum generation, topographical constraints, balance between length and head of the diversion, storage opportunities and pumped storage opportunities for flexibility needs to be considered.

3. **Hydroenergy as one part of the renewable energy mix:** Both China and the EU should carefully evaluate what hydropower can and can't do for energy supply, also in the light of trade-offs. Strategic planning is necessary to balance hydropower exploitation and environmental conservation under consideration of energy-economic and environmental criteria. In order to balance the trade-offs between improvement of ecological status and energy goals, hydropower plant refurbishment needs to follow also the principle of hydropower by design.

4. **Environmentally friendly HP requires the assessment and implementation of a wide range of measures including avoidance, mitigation and finally compensation.** Due to the long tradition of HP development and environmental awareness, expertise in technical and environmental research areas related to the mitigation of hydropower-induced impacts, further cooperation between China and the EU lead to improved GHP in the future. The assessment of healthy rivers has been promoted and carried out for important rivers and lakes in China. However, in the case of medium and small rivers, especially in the mountainous regions where SHPs are located, defining and achieving healthy rivers is also recommended.

5. **Strengthen Research cooperation**: Research cooperation on regional and basin-scale assessment and response strategies on cumulative effect of hydropower development on riverine ecosystems is highly recommended.

3.2 Policy recommendations regarding hydropower's "blue storage" function and its role for enhancing regional energy cooperation and renewable energy system transition

Based on the project activities implemented and the presented key findings regarding hydropower's "blue storage" function and its role for enhancing regional energy cooperation and renewable energy system transition (Objective 2, Work packages 4 and 5), the following eight policy recommendations were concluded:

The aim of the policy recommendations 1-4 is to support the implementation, in the shortest possible time and with fewer efforts also from the economic point of view, of advanced PHS to provide flexible and reliable energy storage. This is also in line with the "Medium and Long-term Development Plan for Pumped Storage (2021-2035)". These recommendations refer to the technical issues related to the present state of the art of advanced Pumped Hydro Storage solutions. The policy recommendations 1-4 are targeting the improvement of Pumped Hydro Storage flexibility in the Chinese Electricity system. These could bring China to lead at a global level not only in terms of Pumped Storage installed capacity but also in terms of system flexibility to properly deal with the new energy scenarios, while supporting the development of a modern pumped storage industry with advanced technology, high-quality management, and strong international competitiveness.

1. **Full and fair remuneration of the Ancillary Services.** Apart from the basic storage service, Pumped Hydro Storage can provide most of the Ancillary Services that are extremely necessary to a decarbonised electricity grid: frequency regulation and control, voltage control and reactive power provision, contingency reserves (spinning and non-spinning) and system inertia provision above all. The higher the flexibility of the Pumped Storage Plant, the higher the technical value of the Ancillary Services provided to the grid. Not all these services are currently fairly remunerated. Some are under-remunerated or not remunerated at all. In this case, providing advanced flexibility may not result in a direct economic benefit for the plant owner. The Chinese market mechanism presently in force is already on the right track, but additional efforts must be done to implement a market that is able to fairly remunerate all the Ancillary Services provided by a Pumped Storage Plant. In the so-called "two-part tariff" scheme, the capacity fee remunerates only services of power system reserve, regulation, and black start. The market mechanism should be extended to all the other Ancillary Services that the Pumped Storage Plant can provide. The economic value of most of these ancillary services is difficult to be accurately measured and calculated. The policymaker, together with the relevant administrative bodies, should as a first step calculate a fair remuneration tariff for all the Ancillary Services, also considering, when possible, the level of flexibility at which each service can be provided to the grid. These tariffs should be then included in the new market mechanism.

2. **Support to revamping of existing Pumped Storage Plants in the direction of additional and advanced flexibility capacity.** Part of the potential to increase the flexibility of Pumped Storage Plants in China can be obtained by upgrading the already operating fleet that needs revamping. The easiest way to achieve additional flexibility is by substituting the old fixed-speed units with new variable speed units. This kind of intervention increases the flexibility of the plant as well as increasing, in general, the operation head range, the efficiency of the whole cycle, and the resilience to the operation balancing Variable Renewable Energy Sources. A new variable-speed unit needs additional space if compared with the old fixed-speed one. Since upgrading means operating on already existing spaces, the cost of the operation is increased by the need to create

additional space in the cavern. Capital Expenditures of upgrading are therefore higher when a higher level of flexibility is achieved. Most of the benefits of this new configuration are for the whole system rather than only for the plant owner. The Policymaker should elaborate fair support measures, aligned with the remuneration mechanisms for the additional flexibility, to incentive the plant owners to upgrade their plants in the direction of higher flexibility.

3. **Support re-design of the planned and under construction plants in the direction of adding flexibility capacity.** The plants that will be commissioned in the next future should be designed to provide the highest level of flexibility to the grid, in order to best match the Variable Renewable Energy Sources production. When possible, the future plants characterised by low flexibility technology solutions should be re-designed in order to achieve the highest level of flexibility that is compatible with the planned hydraulic system. Policymakers should create measures to ease and support actions of re-design of the plant going in this direction, facilitating, streamlining, and simplifying the authorisation and licensing processes, also elaborating fair support measures, aligned with the remuneration mechanisms for the additional flexibility, to incentive the plant owners to upgrade their design.

4. **Elaboration of a plan for Pumped Storage addressing system flexibility and stability needs.** The actions proposed in the previous points need to be supported by a clear vision of the whole system and the future scenarios. Pumped Hydro Storage development requires a clear plan addressing system flexibility and stability needs as well as policy and market barriers. The "Medium and Long-term Development Plan for Pumped Storage (2021-2035)" already deals with the planning of Pumped Hydro Storage in terms of installed capacity but is still not fully focussed on the issue of adopting advanced technology solutions, that are more in line with the needs of a grid with high penetration of Variable Renewable Energy Sources. Therefore, the Policymaker should elaborate a plan for the Pumped Storage flexibility necessary characteristics following an assessment of the system flexibility, adequacy and stability needs to 2030 and beyond, and of potential gaps in national regulatory frameworks.

The realization of the critical importance of flexibility of the power system to enable high penetration of renewable energy power has only rapidly increased during the period of SHUI-ChE implementation. The policy recommendations 5-8 are linked specifically to the role of hydropower for enhancing the flexibility – as important emerging dimension of sustainable hydropower development, which we see as priority areas for hydropower related water policy development in China, as well as areas where further EU-China cooperation can be enhanced.

5. **Clarity and strategic positioning of sustainable hydropower development in the overall national strategy for realizing the 'dual carbon' objective in China** (i.e., peaking carbon emission before 2030 and achieving carbon neutrality before 2060). China leads the world in both investment and magnitude of renewable energy development. Still, for realizing its ambitious carbon emission peaking before 2030 and carbon neutrality before 2060 targets, a significant acceleration of renewable energy development is indispensable for all possible pathways. One of the growing and major constraining factors preventing the acceleration is the lack of flexibility of the existing power system to absorb a high integration of VER, manifested in periodical emergence of high renewable energy curtailments. Of the wide range of flexibility options from power generation sources to power grid, energy storage, to demand side responses and management, hydropower's role is critical in both short- and long-term for China and globally. Clearly articulate such strategic role in

the national strategy and policy makings for clean energy transition is vital for the sustainable hydropower development in China.

6. **Strengthen R&D investment for research and policy support for realizing and maximizing the full potential of hydropower's balancing role for flexibility.** While the potential of hydropower, not only as a major source of clean energy by itself but also a source of flexibility (e.g., as long duration energy storage option), is widely recognized and tested, there are a wide range of implications on river environment and ecology, industrial policy, power market design and regulation frameworks, only to name a few. All those areas require urgently strengthened R&D investment for research so that it can provide evidence-based policy support that is keenly needed. To start with, we particularly recommend R&D support during the current 14th FYP period for comprehensive evaluation of the balancing role of hydropower for enhancing flexibility and power market integration in China, including national and regional assessment of the potentials, as well as understanding implications for power market design on one hand, and mitigations of environmental and ecological impacts on the other.

7. **Economically sustainable business model for pumped storage hydropower (PSH).** Operational frameworks and business model remain to be the key obstacle for successfully realizing the full potential of pumped storage hydropower (PSH) in China, thus, a priority area for realizing the ambitious Medium- and Long-term Development Plan for Pumped Storage (2021-2035). There are a set of specific further policy recommendations derived from SHUI-ChE WP4 on the PSH. It suffices to only highlight here that this is also an integral part of the on-going electricity marketization reform in China, which in turn, is also essential for construct and development of the New Type Power System in China.

8. **Stakeholder engagement and inter- and cross-sectoral policy dialogue is essential.** Policy awareness raising and promoting innovation through inter- and cross-sectoral and multiple stakeholder engagement and dialogue processes is absolutely crucial for realizing the system solutions and innovations required for sustainable hydropower development in the context of climate and clean energy transition. While there are considerable differences of policy context between EU and China, the challenge is command given the diverse actors and interests involved and the needs for balancing multiple objectives and enhancing policy coherence. Currently there is minimal inter-sectoral interactions such as between water resource and engineering research institutions and those focusing on energy and power systems in China. In Europe, much has been learned through the implementations of Water Framework Directive and the energy development directives, which offers a rich context for continued dialogue, exchange, and mutual leaning with China. The establishment of the China-EU Sustainable Hydropower Cooperation Platform through the SHUI-ChE project is exactly towards this purpose.

4. Future Cooperation

In the pursuit of achieving carbon neutrality in both China and Europe, the water sector plays a significant role, not the least through better integrated water and energy planning. This remains a common area of policy challenge for both Europe and China, thus massive potential for future collaboration. One of the

most valuable outcomes of the SHUI-ChE implementation is the strong partnership we have developed with research institutions from both water and energy sectors in China.

Closely linked to the policy recommendations, we see the following ten specific thematic areas for future collaboration in the Water and Energy Security focus area under CEWP:

1. Continued policy dialogue on economically sustainable business models for the operation and maintenance of pumped storage hydropower, especially on pricing mechanisms for compensation of ancillary services, linking to accelerating the on-going power market reform in China, as well as the implementation of the Medium- and Long-term Development Plan for Pumped Storage Hydropower (2021-2035).

2. Joint proposal for a major R&D research project on assessing the full potential and implications of 'flexible' hydropower in China. We have had discussions already with the Nanjing Hydraulic Research Institute and the Joint Research Center for International Cooperation on Water Resource and Engineering.

3. Integrated water and energy planning for high quality development pathways in the upstream of the Yellow River Basin, linking to the major water policy priority areas in the 14th FYP in China. Discussion with key partners is on-going with strong mutual interests.

4. Impact of climate change and its mitigation/adaptation measures on the development, planning and operation of hydropower.

5. Hydropower's impacts on sediment transportation downstream, its ecological impacts and mitigation measures.

6. Several EU funded projects are presently studying different implementation solutions for increasing the flexibility of the existing Pumped Hydro Storage fleet such as the HYDRO project (xflexhydro.net), the HydroFlex project (h2020hydroflex.eu) and the ALPHEUS project (alpheus-h2020.eu). The Water and Energy Security focus area under CEWP can facilitate the connection between the activities running in both China and Europe in the field of advanced PHS, supporting the knowledge exchange and the technology exchanges.

7. Continued development of the China-Europe Sustainable Hydropower Innovation and Cooperation Platform established in 2020 under the SHUI-ChE project (CEWP-PI Lot 4) for promotion and facilitation of China-Europe cooperation on sustainable hydropower through knowledge/information sharing and technical/policy dialogues.

8. Application for joint research projects with focus on biological monitoring. Particularly, joint activities in the field of cumulative effect on fish habitat and its simulation with a focus on hydropeaking, but also joint project applications in the area of continuity restoration are indicated.

9. The National Research Institute for Rural Electrification (NRIRE) of the Chinese Ministry of Water Resources plans several training workshops each year. They are planning to invite experts from BOKU to contribute to some courses in the future. This might not only bring benefits to China but also to other developing countries.

10. Research cooperation on basin-scale assessment and response strategies on cumulative effect of hydropower development on riverine ecosystems.

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This action is co-funded by the European Union and P.R. China.
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