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The multipurpose water uses of hydropower reservoir: The SHARE concept

Le multi-usage de l'eau des réservoirs hydroélectriques à buts multiples : Le concept SHARE

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ABSTRACT

The production and use of energy and the capture and use of water are vital to the economy and the health and welfare of all nations, and the wise stewardship of these resources is essential to the protection of the environment. After the 6th World Water Forum held in Marseille (France, 2012), Électricité de France (EDF) and the World Water Council (WWC) have agreed to work on "the multipurpose water uses of hydropower reservoirs". This framework bridges between 6th Forum in Marseille and the 7th Forum in Daegu/Gyeongbuk in the Republic of Korea and addresses the following issues: (*i*) how to minimize contradictions/competition among multipurpose water uses of hydropower reservoirs, and (*ii*) how to set an appropriate governance to allow coordinated/integrated water uses management (in terms of strategy, planning, decision-making and operation). This process was conducted under a participative multi-stakeholder approach with governments, banks, NGOs, international organizations, hydropower utilities, and other sectors.

Multipurpose hydropower reservoirs are designed and/or operated to provide services beyond electricity generation, such as water supply, flood and drought management, irrigation, navigation, fisheries, environmental services and recreational activities, etc. While these objectives (renewable and power services, water quantity management, ecosystem services, economic growth and local livelihoods) can conflict at times, they are also often complementary. Although there are no universal solutions, there are principles that can be shared and adapted to local contexts. Indeed the development and/or operation of such multipurpose hydropower reservoirs to reach sustainable water management should rely on the following principles: shared vision, shared resource, shared responsibilities, shared rights and risks, shared costs and benefits. These principles and acknowledgement of joint sharing among all the stakeholders are essential to successful development and management of multipurpose hydropower reservoirs, and should frame all phases from early stage to operation. The SHARE concept also gives guidance.

Based on 12 worldwide case studies of multipurpose hydropower reservoirs, the SHARE concept was developed and proposed as a solution to address this issue. A special focus will be presented on the Durance–Verdon Rivers in France.

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R É S U M É

La production et l'utilisation de l'énergie, d'une part, et la capture et l'utilisation de l'eau, d'autre part, sont essentiels à l'économie, à la santé et au bien-être de toutes les nations, et la sagesse de l'utilisation de ces ressources est essentielle à la protection de l'environnement. Après le 6e Forum mondial de l'eau à Marseille (France, 2012), Électricité de France (EDF) et le Conseil mondial de l'eau (CME) ont décidé de travailler sur « les utilisations multiples de l'eau dans les réservoirs hydroélectriques ». Ce travail a établi un « pont » entre le 6e forum de Marseille et le 7ème forum, qui s'est tenu à Daegu/Gyeongbuk, en république de Corée. Il permet de répondre aux thématiques suivantes : (i) comment réduire au minimum les contradictions/la compétition entre les usages multiples de l'eau de ces réservoirs hydroélectriques ; (ii) comment établir une gouvernance appropriée pour permettre une gestion coordonnée/intégrée de l'utilisation de cette eau (en termes de stratégie, de planification, de prise de décision et d'exploitation). Ce processus a été mené par une approche participative multipartite avec des gouvernements, des institutions bancaires, des ONG, des organisations internationales, des hydroélectriciens et d'autres secteurs économiques.

Les réservoirs hydroélectriques à buts multiples sont conçus et/ou exploités pour fournir des services au-delà de la seule production d'électricité, comme l'approvisionnement en eau potable, la maîtrise des inondations et des sécheresses, l'irrigation, la navigation, la pêche, les services environnementaux et les activités récréatives, etc. Bien que ces objectifs (énergie renouvelable et services électriques, gestion de la quantité d'eau, services écosystémiques, croissance économique et moyens de subsistance locaux) puissent parfois être en concurrence, ils sont également souvent complémentaires. Il n'y a pas de solutions universelles, mais il existe cependant des principes qui peuvent être partagés et adaptés aux contextes locaux. En effet, le développement et/ou l'exploitation de ces réservoirs hydroélectriques à buts multiples devrait s'appuyer, pour atteindre une gestion durable de l'eau, sur une vision partagée dans tous les domaines : ressource, responsabilités, droits et risques, coûts et bénéfices. Ces principes de reconnaissance du partage commun entre toutes les parties prenantes sont essentiels pour le développement et la gestion réussis de ces réservoirs hydroélectriques à usages multiples, et devraient encadrer toutes les phases de tels réservoirs, et surtout dès les phases amont (études). Le concept SHARE correspond à cette approche.

Sur la base de 12 études de cas, au niveau mondial, de réservoirs hydroélectriques à buts multiples, le concept SHARE a été développé et proposé comme une solution adapté pour gérer de façon durable l'eau de ces réservoirs. Une attention particulière sera présentée sur les rivières Durance et Verdon, en France, pour étayer cette approche.

1. The water–energy nexus

Water for energy. Energy for water. Two sets of linkages with strong significance for economic growth, life, and wellbeing. Water is needed for all phases of energy production, for fossil-fuel extraction, transport and processing, power production and irrigation of feedstock for biofuels. Water can also be produced as a by-product of fossil-fuel production. Energy is required for a range of water-related processes, such as water transport, wastewater treatment and desalination; energy can be produced as a by-product from wastewater treatment [1]. Limitations on water can restrict energy production, and energy disruptions can limit water provision.

Water is an important input for nearly all forms of energy. Within the energy sector, the power sector is by far the largest source of water withdrawals, although in terms of consumption, primary energy production is larger (see Glossary for definitions).

Fig. 1 provides a vision of the water use for electricity generation by cooling technologies [1].

Thermal power plants made up 70% of total installed capacity worldwide in 2014 and are the main source of water demand in the power sector [1]. Regarding future water requirements for energy production, water is a potential chokepoint for energy, but the risks are not shared evenly across the sector or across the world.

Not only does energy production need water, but water supply is also dependent on energy. The provision of freshwater from surface and groundwater sources or via desalination, its transport and distribution, and the collection and treatment of wastewater all require energy [1]. The amount of required energy varies. It is influenced by a range of factors, such as topography, distance, water loss and inefficiencies, and the level of necessary treatment. Fig. 2 provides an overview of energy use for various processes in the water sector [1].

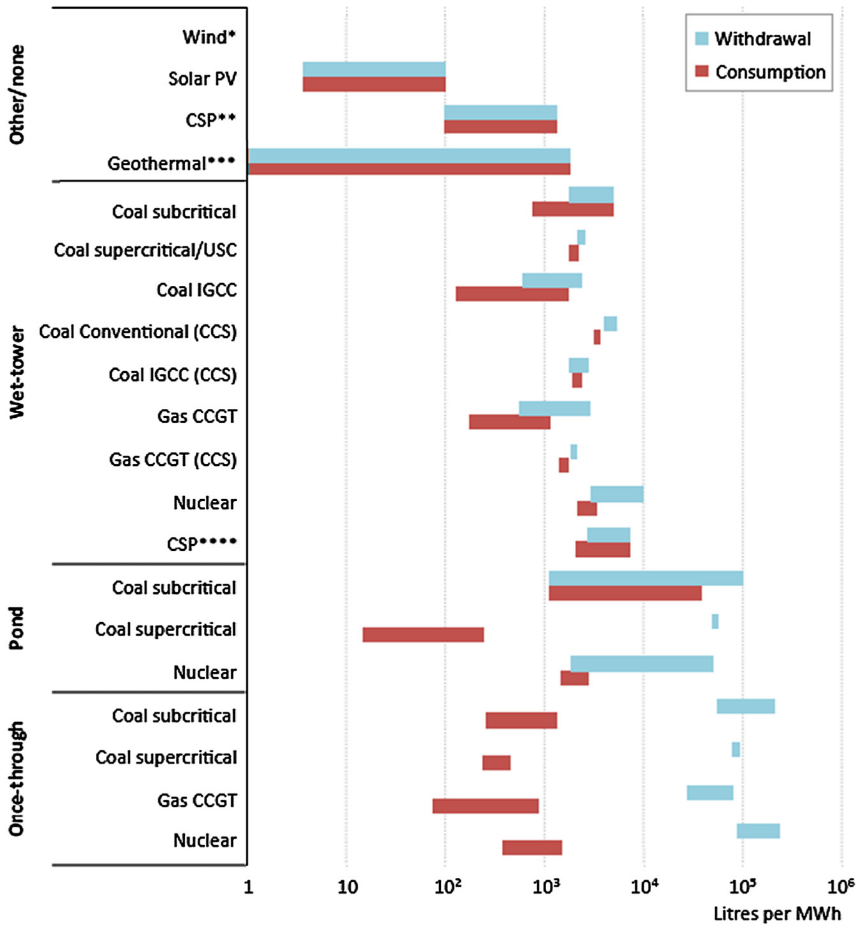

Fig. 1. Water use for electricity generation by cooling technology (adapted from IEA, 2016).

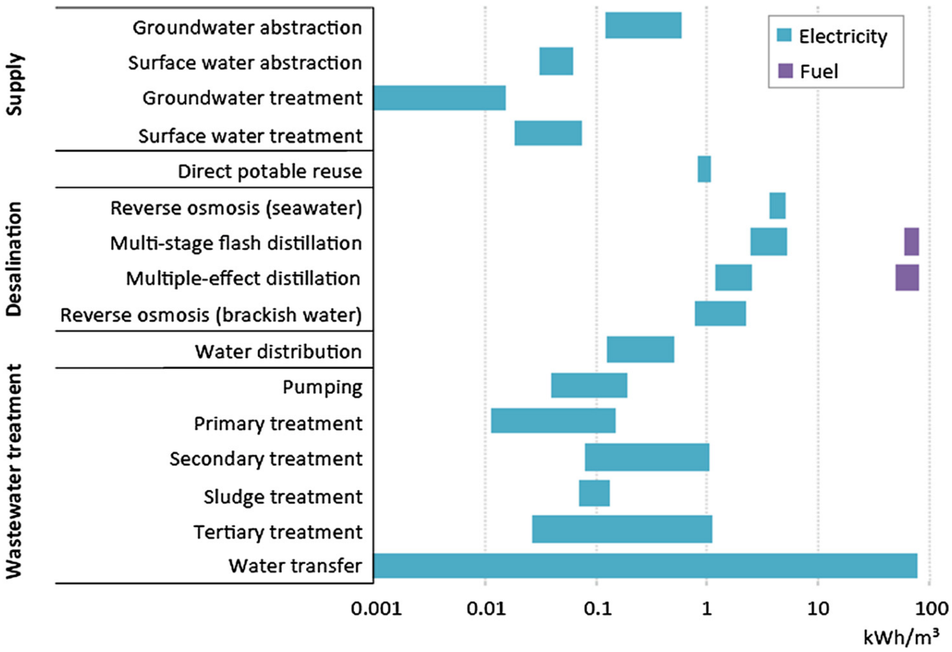

Fig. 2. Energy use for various processes in the water sector (adapted from IEA, 2016).

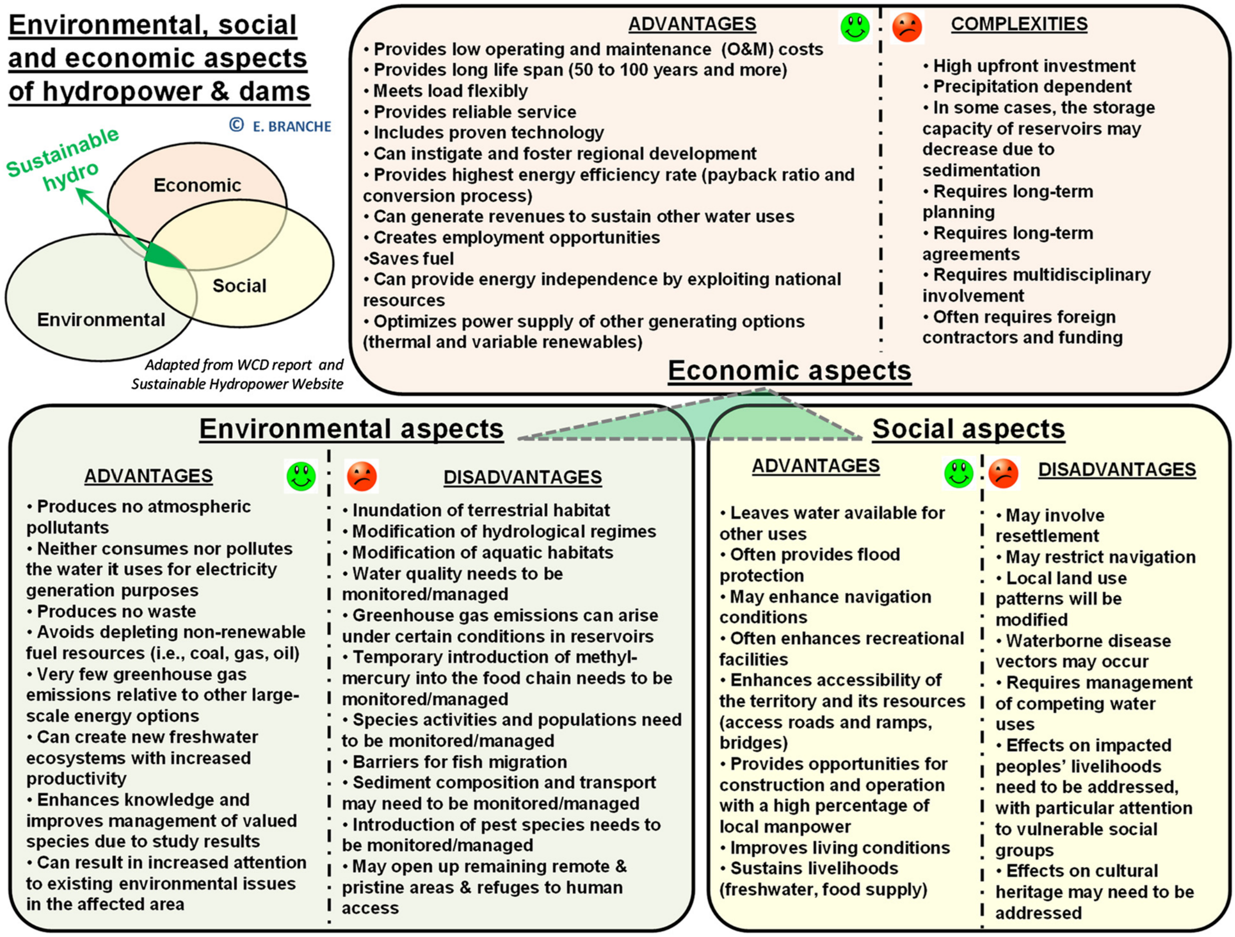

Fig. 3. Environmental, social and economic aspects of hydropower dams.

Hydropower is at the heart of the water–energy nexus. Hydropower has a special role to play in economic development, social justice, and environment caution, which represent the basic pillars of sustainable development. Indeed, hydropower is at the crossroad of two basic human needs, which are energy and water supply. It corresponds to the generation of power by harnessing energy from water. Electricity is generated through the transformation of hydraulic energy into mechanical energy to activate a turbine connected to a generator.

2. Main issues around multipurpose hydropower reservoirs

Hydropower is currently the largest renewable power generation source in the world (1085 GW installed, 3200 TWh/year). It accounts for 16% of the total electricity generated worldwide [2], or 76% of all electricity renewables. The potential for additional hydropower remains considerable.

The contribution of hydropower to decarbonising the energy mix is twofold: the primary benefit is its clean and renewable electricity, whereas the second one is an enabler to allow a greater contribution from variable renewables on the grid, as hydropower helps stabilize fluctuations between demand and supply. The need for affordable and clean energy, for water in adequate quantity and quality, and for food security will increasingly be the central challenges for humanity: these needs are strongly linked to the water–energy nexus and to hydropower.

Multipurpose hydropower reservoirs are designed and/or operated to provide services beyond electricity generation, such as water supply, flood and drought management, irrigation, navigation, fisheries, environmental services, and recreational activities, etc. While these objectives (renewable and power services, water quantity management, ecosystem services, economic growth and local livelihoods) can conflict at times, they are also often complementary. *Only 25% of large dams in the world have hydropower as one of their purposes* (single or multipurpose reservoirs) [2].

Hydropower dams have both positive and negative impacts. After several decades of experience, hydropower reservoir's strengths and weaknesses are thus well known and understood. Whilst not all negative impacts of hydropower reservoirs can be avoided, many of them can be minimized, mitigated or compensated.

Fig. 3 provides an overview of the potential advantages and disadvantages of hydropower dams [2].

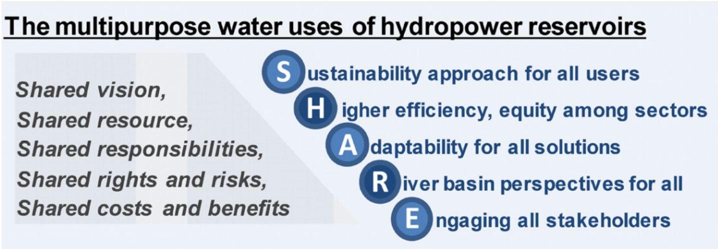

Fig. 4. Summary vision of the SHARE concept.

3. The SHARE concept as the solution to address multipurpose reservoirs

Sustainable development requires attention to a wide range of economic, social and environmental objectives. Energy and water for sustainable development depend not only on supply choices, but also on how these choices are implemented.

A major challenge with multi-purpose reservoirs is sharing water amongst competing users. Although there are no universal solutions, there are principles that can be shared and adapted to local contexts. Indeed the development and/or operation of such multipurpose hydropower reservoirs to reach sustainable water management should rely on the following principles: *shared vision, shared resource, shared responsibilities, shared rights and risks, shared costs and benefits*. These principles and acknowledgement of joint sharing among all the stakeholders are essential to the successful development and management of multipurpose hydropower reservoirs, and should frame all phases from early stage to operation.

The *SHARE concept* also gives guidance through being an acronym for: Sustainability approach for all users, Higher efficiency and equity among sectors, Adaptability for all solutions, River basin perspectives for all, and Engaging all stakeholders. Using this concept for multipurpose water uses of hydropower reservoirs both as an overarching principle and as a reminder of the five value propositions can help in making these reservoirs more sustainable and equitable. Fig. 4 summarizes the SHARE concept.

Addressing the sustainability of multipurpose hydropower reservoirs could be classified in the five following "shared" value propositions (SHARE concept).

3.1. Sustainability approach for all users

The degree to which multipurpose hydropower reservoirs can advance sustainable development objectives depends on careful planning, construction, operation, management, and governance. It is important to implement an adequate governance model that fosters equity across water reservoir users and ecosystems in line with agreed sustainability objectives. There are no one-size-fits-all solutions as each project is site specific and as, water governance, is place-based and context-dependent. It is therefore essential to customise the governance model to local conditions. The Hydropower Sustainability Assessment Protocol for these multipurpose reservoirs creates a common language among stakeholders and provides a measurement of the sustainable profile of the project and guidance for continuous improvement. In addition, governance mechanisms are vital tools for achieving equitable access to – and provision of – ecosystem services.

3.2. Higher efficiency and equity among sectors

Economic data and innovative financial mechanisms are crucial for equitable and efficient sharing of benefits among water users. A major challenge is that many of the additional benefits around hydropower reservoirs are currently not recognized or scaled in monetary unit. Putting a value for all benefits is necessary to allow discussions and negotiations between different water users, and to find optimal and efficient solutions. In addition, it is essential to have such values to bridge the gap between financial and economic viability. Many additional purposes of hydropower reservoirs may not be financially motivated in the short term, but would give more equitable long-term benefits that are not reflected in the financial analysis. Trying to assess the economic value of all services is important for investors; this is also a good way to bring stakeholders around the table to estimate collectively a value for water and for energy. Innovative financial mechanisms will be essential to address this gap between financial and economic feasibility, especially since hydropower reservoirs comprise such large up-front capital intensive infrastructure. The challenge is to find ways of framing long-term strategies, securing long-term finance sources, and shielding them as effectively as possible from short-term constraints. In the developing world, funding and guarantees from bi-lateral or multilateral development banks are important financing instruments that can provide low-cost financing over long repayment periods, and act as a catalyst for other investors. Pension funds are another example of financing with long-time perspectives, which may unlock private sector capitals to invest in long-term sustainable infrastructure, such as multipurpose hydropower dams.

3.3. Adaptability for all solutions

It is essential to provide greater flexibility and adaptability in the way water is allocated among users during the whole lifetime of the reservoir. History has clearly shown that multipurpose reservoir developments are long-term investments that can benefit to various generations: new purposes, demands or preferences may appear during this long lifetime due to the evolution of social and environmental values and requirements. In recognition of the significant uncertainty associated with future changes in climate, economies and demographics, there is a need for the physical design of hydro reservoirs and for the implementation of their governance systems to be able to respond to these changes. The multiple dimensions of projects as they emerge over time should be more explicitly addressed in the institutional management and operation arrangements. Hydropower as a renewable energy plays a key role in climate change mitigation. In addition, the water stored in the reservoir could help adapt to climate change; hydropower is climate-sensitive and it is also very important for the energy security and economic development of countries. River flows are vital for healthy ecosystems and their services. The mitigation of reservoir sedimentation should be addressed with a multi-stakeholder approach from the early stages of project planning through to operation.

3.4. River basin perspectives for all

An integrated approach is essential to reach a holistic view of the river basin. An important over-arching framework for sustainable hydropower reservoir development is Integrated Water Resource Management (IWRM) and basin development planning. Many hydropower projects are evaluated independently of an overall basin planning framework, and issues arise due to competing or conflicting needs and uses of the basin resources. The creation – and effective functioning – of transboundary river commissions (e.g., the Danube, Rhine, Mekong, Senegal Rivers, etc.) with the purpose of enabling information exchange and better transboundary cooperation with water infrastructure development and operation is essential for upstream and downstream countries or for those having the same river as a national border. However, some river commissions are not operating as intended. River basin organizations need political commitment to address the very sensitive discussions around dam/reservoir projects, a broad representation of stakeholders and should also be equipped with capabilities related to staff, finance, expertise, skills, know-how, infrastructure etc., in order to carry out their duties effectively. Cross-sector coordination should be foreseen for greater policy coherence and consistency of multipurpose reservoirs uses. Water allocation in river-basin planning is a very important step forward to achieve sustainable use of stored water among users. In addition, stakeholder initiatives may also provide interesting opportunities for better integration of the different reservoir water users.

3.5. Engaging all stakeholders

Stakeholder engagement is critical for success in multipurpose reservoir management in terms of sustainability and efficiency. It is necessary to identify all stakeholders likely to influence or be impacted by decisions on the reservoirs, and engage them in the early stages to participate on a voluntary basis to the dialogue. It is important that the groups need to see there is a reason for them to engage, i.e. that they can influence decisions and outcomes that would be better than if they had not participated. It is crucial to understand early in the process stakeholder interests and power relations between these stakeholders. Most of them may not know or understand the perspective of the other stakeholders involved; it is therefore useful to raise awareness among them. Leadership within the community and across stakeholders is a key for success. Equity, transparency and accountability should drive the solutions. Different viewpoints generate alternative priorities and highlight different challenges among stakeholders. Coordination and potential improvements are required to manage multipurpose water use issues between different stakeholders. Policy makers should increase their engagement with all stakeholders to improve their understanding of issues and better communicate their impacts. Communication and diplomacy will be essential. Policy makers should also provide the enabling environment for result-oriented stakeholder engagement, and strive to include the inputs of engagement processes towards improved decision making. The quality of the data sources and the availability of information vary considerably at the local and state levels; making all this information accessible, timely, understandable, usable and useful is a real challenge. Strengthening partnerships and mobilizing resources remain essential to achieve effective multipurpose reservoir management.

3.6. Case studies

There are *twelve* (12) *case studies analysed in details to support the "Sharing water uses of multipurpose hydropower reservoirs"*. Each project is site specific, but these cases represent a wide range of situations worldwide in terms of geography, size, type, purposes, and topics: two (2) in Latin America (Peru, Costa Rica), two (2) in North America (United States of America), two (2) in Europe (France), two (2) in Africa (Cameroon, Niger), two (2) in Asia (Nepal–India, China) and two (2) in Oceania (Australia).

4. Some concluding remarks on the SHARE concept

The **SHARE concept**, developed within this international multi-stakeholder initiative (governments, banks, NGOs, developers, etc.), is a useful framework to address the potential conflicts that will or may appear around multipurpose water uses of hydropower reservoirs.

There *are no one-size-fits-all solutions*. However thanks to these *twelve* (12) *international detailed case studies, it is possible to find guidance to address particular issues of multipurpose water reservoirs*. These examples offer the SHARE users the possibility to find case studies matching their needs.

This *SHARE concept should now be shared within all multipurpose reservoir stakeholders*; it should be implemented by multipurpose reservoir planers, developers, operators, decision-makers and other stakeholders to foster a sustainable water management of such reservoirs.

It is also important to *continue collaboration with research initiatives on this multipurpose issue* (the economic value, new financial mechanisms, and adaptive design), in particular with ICOLD and IEA Hydro.

Future investments in hydropower projects should embrace the SHARE concept and take a multipurpose approach where appropriate together with the co-financing necessary to make it work. In the coming decades, it is important that there will be a sustained and steady focus on the utilization of multi-purpose opportunities for investment and operation, firstly on existing infrastructures. The way forward for each developer/sponsor *is to work out a reasonable decision making process that meets these objectives with a duration that is predictable and compatible with the urgency of the needs to be met*.

5. The example of the Durance–Verdon Rivers in France

The Durance–Verdon Rivers form a major river basin located in the south of France (Mediterranean climate). The hydroelectric infrastructures in the Durance and Verdon valleys contribute to the supply of water and renewable energy across the region and foster territorial development. Water resources are under a high level of pressure due to significant abstractions for various water uses (irrigation, hydropower, drinking water, industrial use and recreational activities) and the need to maintain ecological services. The hydropower reservoir is managed to reconcile the needs resulting from all forms of water use and the safety of individuals and property. EDF actively invests in coordinated efforts with all water stakeholders, to determine shared action programmes for the benefit of all water users, the river and its ecosystems.

The effects of climate stress and the evolution of demographic and socioeconomic territories on water resources and water demand require the development of adapted strategies. Among the strategies for climate change adaptation used in the Durance–Verdon river basin are the R2D2 2050 project, the value creation methodology, and water-saving agreements.

The Durance–Verdon river basin is an excellent example of how a collaborative approach involving all stakeholders can lead to sustainable water management in the face of climate change as a result of robust water infrastructures.

5.1. Description of the Durance–Verdon Rivers

The Durance–Verdon Rivers form a major river basin located in the south of France (see Fig. 5). The hydroelectric infrastructures in the Durance and Verdon valleys, together with the Serre-Ponçon and Sainte-Croix water reservoirs, mainly contribute to the supply of water and renewable energy across the region and foster sustainable territorial development [2].

The Hydropower Management Unit of the Durance and Verdon valleys runs 30 plants and 17 dams based in the Hautes-Alpes, Alpes-de-Haute-Provence, Var, Vaucluse and Bouches-du-Rhône Departments (southeast France). It produces an average of 6.5 billion kWh per year, using clean and renewable energy, equal to the annual residential consumption of a city of over 2.5 million inhabitants. It accounts for 40 per cent of the electricity produced in the Provence–Alpes–Côte d'Azur Region. In particular, the Serre-Ponçon and Sainte-Croix water reservoirs and, more generally, the hydroelectric infrastructures in the Durance and Verdon valleys help to meet the various demands for water and renewable energy across the region and in turn foster territorial development. The Unit guarantees fully synchronized operations capable of generating power up to 2,000 MW in less than 10 minutes, and thus supply customers in a competitive and responsive manner.

Construction was started in 1955 by Électricité de France (EDF), who have operated the Unit ever since. The Serre-Ponçon dam and all of the hydroelectric production structures in the Durance and Verdon regions form a source of solidarity-based water management in the Provence–Alpes–Côte d'Azur Region. From its very inception, the Serre-Ponçon site—an immense water reservoir holding 1.2 billion cubic meters of water—was designed to capture and store water resources and redistribute them to respond to various demands. These include renewable energy, drinking water supply, agricultural and industrial water supplies and providing for the tourist activities developed around the reservoirs that contribute to the region's business activities and attractiveness. A structure unparallelled anywhere in France in size, the Serre-Ponçon dam secures regional water management by averting the consequences of droughts for the Provence region, and by regulating the huge flooding to which the Durance has been subject in the past.

5.2. The R2D2 project: a multi-stakeholder partnership to assess the impacts of climate change on the Durance river basin

The R2D2 2050 programme is a partnership project aimed at assessing the possible impacts of climate change on the quantity and quality of water resources, on biodiversity, and on the changing demand and uses in the Durance–Verdon river

Fig. 5. Overview of the Durance–Verdon Rivers in France.

basin in the year 2050 [3]. This project sought to engage the stakeholders in a co-construction scenarios goal for the future water demand and to share the results of the project, increasing ownership of the key findings.

Several EDF teams contribute to the large-scale programme dubbed the R2D2 2050 project (risk, water resources and sustainable management in Durance in 2050). EDF works in collaboration with the "Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture" (IRSTEA; i.e. the National Research Institute of Science and Technology for Environment and Agriculture), which is a public scientific and technical institute directed conjointly by the Ministry of Research and the Ministry of Agriculture. The goal is to inform communities and public authorities about the measures required in order to adapt itself to one of the 21st century's greatest challenges.

Funded under the "Gestion et impact du changement climatique" (GICC) programme of the MEDDE (French Environmental, Sustainable Development and Energy Ministry) and the Rhone-Mediterranean and Corsica Water Agency, the R2D2 2050 project was implemented by seven partners coordinated by IRSTEA: IRSTEA, EDF R&D LNHE Chatou, EDF DTG Grenoble, "Université Pierre-et-Marie-Curie", Paris, LTHE Grenoble, the "Société du canal de Provence", and ACTeon. The project lasted three years (2012–2015), with the final report having been published in October 2015).

Research activities were conducted in close collaboration with key stakeholders in the area. They involved targeted interviews and local workshops on themes that complemented the prospective workshops planned.

This project models the climatic dependence of the Durance–Verdon system: availability of the natural resource, water requirement for non-energy uses and energy production (see Fig. 6).

This multi-stakeholder research project 'R2D2 2050' provides insights on:

- changes in the hydrological regime of the major rivers of the watershed and the water supply,
- applications to current and future water use (hydropower, agriculture, tourism, etc.), including the main aquatic ecosystems, local or external, which put pressure on the Durance–Verdon water resource,
- potential future imbalances resulting from the confrontation supply/demand under scenarios of climate change and socioeconomic development,
- leeway and management alternatives to ensure 'balanced and sustainable' management of water resources in line with the objectives and challenges of planning,

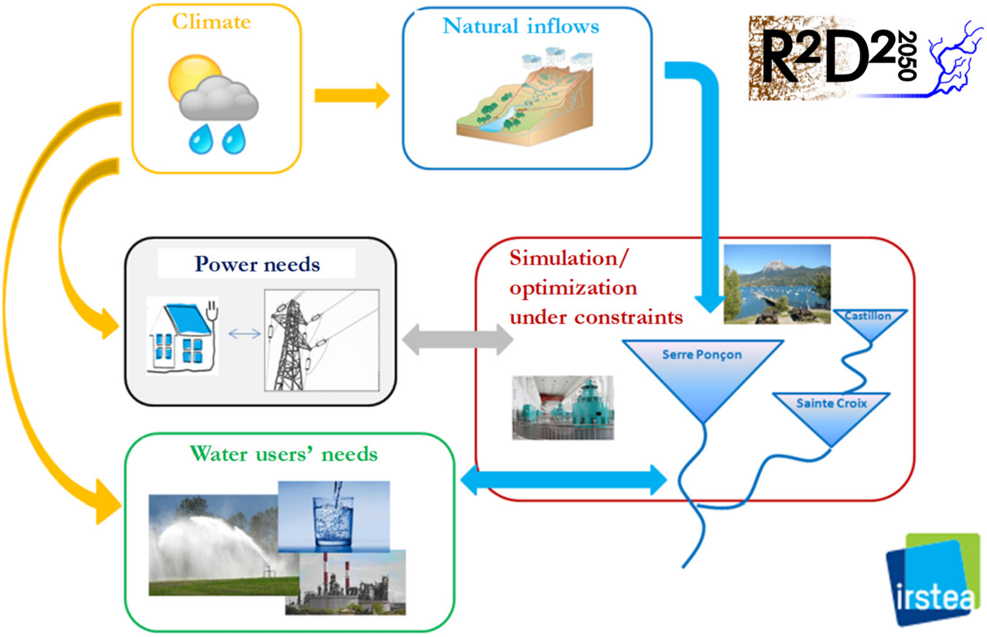

Fig. 6. R2D2 simulation/optimization approaches.

- uncertainties associated with the main results obtained, as well as the relative importance of potential sources of uncertainty.

Regarding the main conclusions of this project, there is a predominant role of air temperature on hydrology in climate change scenarios resulting in:

- reduced snowpack,
- early melting period,
- increased evapotranspiration.

However, changes in rainfall and flood regime are uncertain. It is expected that flows will be lower in spring and low water levels will be more severe and longer. A decrease in overall water demand across the territory is forecasted, which is more dependent on territorial changes than on climate change. This is especially likely in the Durance River as the demand on the Verdon grows. There will be contrasting effects on uses between Durance and Verdon.

The physical design of the reservoirs can meet water use demand; however, storage capacity is limited by the available volume of reserves, especially on the Durance River.

Hydropower generation, being directly affected by the reduction of natural inflows, undergoes a significant reduction of its flexible generation capacity due to changes in flow regimes and filling objectives resulting from climate change.

The tourism management of the Verdon River could be deeply impacted. Serre-Ponçon reservoir operation will be highly dependent on: (1) the water savings, (2) the management operated by EDF, and (3) the capacity of local actors to develop the lake banks.

The spilling risk during flood events could be increased and will have to be taken into account to control the associated flood risk.

5.3. The water saving conventions: a win–win strategy for all stakeholders

EDF is required to deliver 200 Mm^3 of water to irrigators between 1 July and 30 September annually (as the Ministry of Agriculture financed part of the dam construction), and an information bulletin is sent every week to farmers about irrigation flows. A first water-saving convention was initiated in 2002 between EDF and Canaux de Vaucluse [2]. This replicable and innovative voluntary economic approach is based on the following:

- an obligation to deliver the requested value, with obligation of results,
- a reviewable water-saving target set by the Canaux de Vaucluse,
- compensation to be paid by EDF if the goal is reached,
- a strong degressive taxation to be applied if the target is not reached,
- incentives to reach the target and to go beyond.

The Water Saving Convention was signed in 2003. The agreement requires EDF to pay back a part of the saving costs if the targeted objectives are reached. EDF encourages farmers to save water by financing modern systems to reduce water consumption. Through this, the agricultural consumption for one partner decreased from 310 Mm^3 in 1997 to 220 Mm^3 in 2012; 60 million m^3 of this has been achieved thanks to the agreement.

This is a win–win solution for stakeholders. Indeed, thanks to this convention significant water savings were reached (30 per cent reduction of water by the irrigators), and benefits achieved in several sectors:

- *irrigators*: attractive compensation and improved control of the Serre-Ponçon reservoir,
- *energy*: better seasonal use with the saved stored water volume (which could be generated during peak hours), but a limited energy gain (as those savings are located downstream the end of the chain; the valuation is recovered at 20% on the energy side and 80% regarding appropriate time generation),
- *environment*: water savings that were achieved by EDF means more water is released to the environment rather than being consumed,
- *tourism*: keep the reservoir water level of Serre-Ponçon.

The evaluation of energy loss is based on a method developed jointly by EDF and the Rhône–Méditerranée–Corse Water Agency, which supplies part of the financing [2]. It is a simplified method that provides a reference point in negotiations between EDF and other users for the cost of hydropower generation under new external constraints or uses. It consists in evaluating losses due to lost or shifted energy, with respect to a year divided into five specific periods, and then evaluating them on the basis of a representative price of electricity market futures. The idea is to compare two scenarios: one based on current water withdrawn by the irrigators, and another one with x Mm^3/year of water savings.

Water saving is becoming an essential issue on the Durance–Verdon basin, and water stakeholders are working together on incentive mechanisms to manage these water efficiencies in a sustainable way. The issue is now on the future of these water savings: environmental requirements and water for scarce territories, and a daily operation to meet multipurpose requirements. For instance, EDF in association with the Water Agency and DREAL[1] are currently working towards basin-level water savings. Innovative mechanisms are being discussed so that a part of these water savings could be distributed back to the environment and to water deficit areas in the basin.

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[2] E. Branche, Sharing the water uses of multipurpose hydropower reservoirs: the SHARE concept, in: 7th World Water Forum, Daegu, Republic of Korea, April 2015, p. 130, this document can be downloaded for free at: http://www.hydroworld.com/content/dam/hydroworld/online-articles/documents/2015/10/MultipurposeHydroReservoirs-SHAREconcept.pdf.

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Glossary

Water withdrawal: the volume of water removed from a source; by definition withdrawals are always greater than or equal to consumption.

Water consumption: the volume withdrawn that is not returned to the source (i.e. it is evaporated or transported to another location) and by definition is no longer available for other uses.

Power sector: it covers the electricity generation sector, i.e. generation from nuclear, thermal, and renewables power plants. This sector is thus part of the whole energy sector.

Primary energy production: it includes fossil fuels (coal, natural gas, oil) and biofuels production.

[1] http://www.paca.developpement-durable.gouv.fr.