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GOVERNING THE WATER-ENERGY-FOOD NEXUS:

OPPORTUNITIES FOR BASIN ORGANISATIONS

Technical background document for theme 2: "Water-Energy-Food Nexus"

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Abstract

Good governance of the water-energy-food nexus can improve energy, water and food security, foster synergies, manage trade-offs, support sustainable development and maintain ecosystem services. Basin Organizations (BOs) have a key role to play in governance of the nexus to address challenges of sustainable hydropower, balancing the production of bioenergy with food production and taking into account the energy needs of water. Learning from many examples of BOs implementing IWRM, and some additional experiences in the nexus approach, four main recommendations have been formulated to support governance of the nexus by BOs. These recommendations are: 1) BOs need to have a high level mandate to coordinate and cooperate between the water, energy, food and environment sectors; 2) Build partnerships across sectors and levels and with the private sector; 3) Identify mutual benefits, coordinate planning and jointly implementation common solutions; 6) Capacity building on the knowledge base, analytical tools and institutional development.

Keywords: water-energy-food nexus, governance, basin organisations, sustainability

1. Introduction

1.1. Context

Many of the key issues for sustainable development and green growth revolve around water, energy and food. Millions of slum dwellers lack adequate water, sanitation and electricity, while the world's fast-growing urban middle class is consuming larger shares of water needed for agriculture while demanding more food and energy. Biofuels are cultivated in both developed and developing countries to supply energy, but compete with food crops for land and water. Hydroelectric dams provide energy and can supply irrigation water for agriculture – but may create shortages for downstream ecosystems and users. Water, energy and food insecurity are often associated with degradation of ecosystem services (Hoff 2011).

Worldwide, about 8% of the global energy generation is used for pumping, treating and transporting water, while most forms of power generation are water intensive: energy production accounts for roughly 15% of all water withdrawals, and roughly 75% all industrial water withdrawals (UN Water 2014), though not all of that water is used. Most water is consumed in crop production; in addition to rainwater, some 70% of all freshwater withdrawals from surface water bodies and aquifers globally, is used for agriculture (Molden 2007).

Freshwater resources supply a range of essential ecosystem services (MEA 2005), including these provisioning services for agriculture and energy. They also provide regulating services, for example for floods and droughts, supporting services such as soil formation and nutrient cycling that are both water-driven, as well as cultural services, as water bodies around the world bring deeper meaning for societies (Coates et al. 2013). The *International Conference on Sustainability in the Water-Energy-Food Nexus*, held in June 2014 in Bonn (Germany), highlighted the importance of these linkages – its concluding Call to Action underlines that "considering water, energy and food together in a 'nexus' framework is both necessary and forward looking". A nexus approach can identify benefits across sectors. The Call to Action moreover highlighted the importance of governance for implementing a nexus approach – however, the extensive connections between water, energy and food need to be better understood.

A nexus approach can improve water, energy and food security, address externalities across the various sectors involved, strengthen decision-making and support the transition to sustainability and maintain ecosystem services (UN-ESCAP 2013). River and Aquifer Basin Organizations (BOs) have a key role to play (UNECE 2014). They are well-placed to implement the nexus approach, as they can build on current Integrated Water Resources Management (IWRM) methods. This paper focuses on the opportunities for BOs to undertake a nexus approach and pursue water, energy and food security, along with the steps they need to implement it.

The nexus approach puts ecosystems at the centre and sets sustainable development and human wellbeing as key outputs (Figure 1). A water-energy-food nexus approach can complement and build on IWRM, in which the nexus can serve as a further step in terms of helping to understand and balance water, food and energy security by managing the inter-linkages between the three.

The societal challenge for integrated basin management is to balance water allocations for people (drinking, urban supplies), food (or broader, agroecosystems), industry (incl. hydropower) and nature (e.g. environmental flows). Both the nexus approach and IWRM offer processes towards integrated solutions, using comparable criteria to identify and develop actions (Figure 1). Both approaches address and balance the social and environmental impacts of achieving water security and food security. The nexus approach provides added attention to the food and energy components of sustainable development and a potentially stronger role for stakeholders in these sectors.

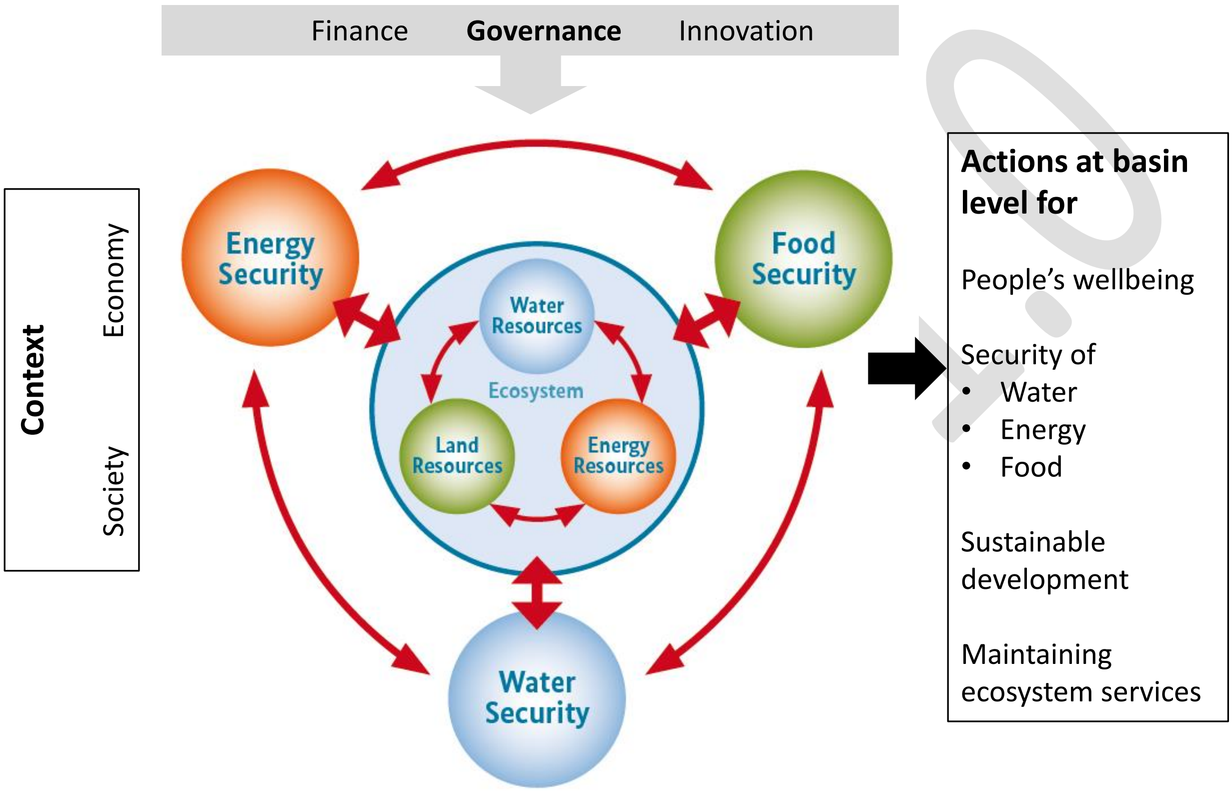

Figure 1. Schematic representation of the water-energy-food nexus and the governance role of Basin Organizations (based on BMZ 2014).

1.2. Drivers of water, energy and food insecurity; opportunities for the nexus

A strong driver for the implementation of the sustainability dimension of the nexus is the mitigation of the adverse impacts of hydropower on river fragmentation and aquatic ecosystems. The sustainability dimension is also important in terms of the needs and impacts of agricultural water use on ecosystems. Potential conflicts between water uses for agriculture and energy are also important drivers (see Section 2).

Joint solutions for common problems in water, energy and food production, could result in less conflict, mitigation of trade-offs and optimisation of synergies between various sectors (see Chiramba et al. 2014; Lloyd and Korsgaard et al. 2013). By integrating externalities into a joint approach that aims for water, energy and food security, and sustainable development, while maintaining ecosystem services (Figure 1), there is less risk of negative impacts and high potential for sustainable food security and improved resilience. Good governance of the sustainability dimension of the water-energy-food nexus can help to improve livelihoods and facilitate an equitable share of benefits.

The water-energy-food nexus typically can be addressed at various scales from the local to the sub-basin and sub-national scale to the national and international scale. Issues at different scales, however, are closely interrelated, as are the consequences of actions pursued. The implementation of the nexus hence requires effective multi-level governance and thus engagement of stakeholders across sectors and levels. This paper proposes governance options for BOs that could support the effective implementation of the nexus at different scales, supported by empirical evidence on existing practices.

2. Challenges to the governance of the water-energy-food nexus

2.1. Nexus challenges

Basin Organizations, like other stakeholders, have experience on various aspects of the water-energy-food nexus, such as the management of water for food production and biomass (wood, biofuels), flood management, hydropower and water for ecosystems. Background research for this report investigated 16 examples of approaches to the nexus. These are presented in Table 1 that highlights the specific challenges addressed in each case. Below the table some of these interactions (nexus challenges) are discussed in a bit more detail. Several examples relate to multi-purpose sustainable hydropower, where flood risk management, agricultural water needs and ecosystem conservation are included. Four case studies address the industrial use and pollution of water by water utilities, and power plants (thermal and nuclear); three case studies address the use of biomass for energy; and five case studies address the water and energy needs for food production. No single example, however, presents all aspects assessed. All of these case studies come with their own characteristics and present different ways in which impacts are addressed. A common denominator in the case studies is that coordination provided benefits that could not have been accomplished when working in isolation. While all case studies have a specific context, some common, or even generic, lessons can be learned. General recommendations based on these cases are presented in Section 3.

Table 1. Nexus challenges addressed in various case studies.

Case study	Country/Region	challenges						
		(sustainable) hydropower	Bioenergy crops	water security	thermal and nuclear power (cooling water)	Flood protection	Food security	ecosystem services
AFRICA								
Inner Niger Delta	Mali	X	X			X	X	X
Lesotho Highlands water project	Lesotho	X					X	X
AMERICAS								
Latin American Water Funds	Examples from Ecuador and Costa Rica			X				X
Sarapiqui wetlands	Costa Rica	X						X
Penobscot River	USA	X				X		X
Austin City, Texas	USA			X				
Great Lakes Commission	USA	X		X	X	X		X
ASIA & PACIFIC								
Mekong River Commission	South East Asia	X				X	X	X
Four Major Rivers Restoration Project	South Korea	X				X		X
Lighted village scheme	Gujarat, India						X	
Nam Theun hydropower scheme	Laos	X				X	X	X
Biofuels on contaminated land	Thailand		X					
Alazani/Ganikh River Basin	Azerbaijan and Georgia	X	X			X		X
Murray-Darling river basin	Australia	X						X
EUROPE								
Danube / Sava	South East Europe	X			X	X		X
Jucar river basin	Spain			X	X	X		X

Energy vs environment

Sustainable hydropower aims at reducing the negative impacts of hydropower on the environment and downstream communities while also providing multiple services including water supply, irrigation (food) and flood risk management (Opperman et al. 2011; Pittock 2010). Sustainable hydropower is a response to the substantial protests around the world when new hydropower dams are planned – including protests by environmental groups that fear for loss or degradation of ecosystems, by local communities that need to be relocated and by downstream communities that fear reduced flows (Locher et al. 2010). The major challenges here are that it will be difficult and expensive to upgrade or refurbish the dam and related infrastructure, if hydropower has not been designed to consider ecosystem and societal impacts. Measures such as fish ladders or revised water release operations can be potential solutions (planned, for example in the Mekong and Danube Basins; Box 1). Solutions that are focused on a single site however, are likely to result in trade-offs where benefits for one party (e.g. environmental protection) comes at the expense of energy production.

A basin scale approach for integrated hydropower, food production and ecosystem restoration planning greatly expands the set of options. Working at basin scale however requires the alignment of all owners and managers (e.g. hydropower dams and irrigation perimeters). Individual economic losses and water needs often prevail over basin-wide interests if no compensation mechanism is foreseen (seen, for example, in the Murray-Darling basin in Australia). Energy and water can be sold, e.g. to large irrigation perimeters, while the net benefits from ecosystem restoration and the downstream agriculture potential does not generate revenues to hydropower operators. Another challenge to sustainable hydropower is that licenses for dams are given for periods of 30-50 years and do not necessarily include measures to reduce negative impacts such as fish passage, reduction of sediment, downstream water allocations, or health impacts of stagnant water. In addition, siting of hydropower dams is usually based on the highest potential for hydropower generation. Unfortunately, some optimal locations might result in substantial negative environmental and social impacts. Less optimal locations or distribution of smaller dams across the basin might reduce the negative impacts (as in the Penobscot River, USA). Analytical tools and data to assess these and other cumulative impacts at basin scale are scarce.

Bioenergy vs food crops

Agriculture is the world's biggest user of solar energy as crops use solar radiation to create biomass. In turn, biomass (or biological sources, such as firewood, biofuels, agricultural by-products, charcoal, peat and dung) can be a direct source of renewable energy: bioenergy. More than two billion people in the world rely on firewood and charcoal for their daily energy needs (Ren21 2012). Biomass is also used on a larger scale for the generation of electricity in power plants consuming wood chips and forest residues. Many forms of biomass energy need land and water (UNEP 2011): forests that produce firewood as well as specific energy crops (biofuels). Substitution of fuel wood by natural gas (as in the Alazani-Ganikh River Basin in Azerbeijan and Georgia) or charcoal (as in the Inner Niger Delta in Mali; Box 6) can reduce the pressure on trees. A main challenge is that trees are often cut for free (in terms of the immediate monetary price), while the alternatives come at a cost that may be too high for vulnerable households. Measures to change behaviour and the provision of alternative livelihood opportunities are thus needed to achieve change. Biofuel, as a specific type of bioenergy, is often promoted as an alternative to fossil fuels to reduce greenhouse gas emissions. The production of bioenergy may potentially generate more revenues than staple food, which could generate conflicts in areas where land and water is scarce. However, bioenergy crops compete directly with food crops. Unsustainable biofuel production can have significant local implications for the state of water resources (including downstream pollution), land ownership, food security and ecosystems (GEA 2012; De Fraiture et al. 2008; FAO 2008; Fargione et al. 2008). Similar to the challenges of hydropower, individuals may gain from energy crops while others may lose due to lack of sufficient access to water and energy and reduction of agroecosystem services. New policies and guidelines to better monitor and manage future biofuel production are needed (Groom et al. 2008). Various studies have been carried out on the linkages between biofuels and food security, many of which are discussed in Mirzabaev et al. (2014).

Energy for water

Water use often entails energy costs, in particular for water utilities (drinking water supply and wastewater treatment) and irrigation *(*mainly related to pumping). In irrigation, techniques are increasingly being used to improve water efficiency (more crop per drop). However, these techniques are often energy-intensive (e.g. pressurised sprinklers, energy requirements for pumping) and hence costly. While the techniques might result in net benefits, the high energy use might generate conflicts, for instance in areas where energy security is insufficient or where subsidies play an important role (e.g. Shah et al. 2012; Mukherji et al. 2009). Food production and irrigation are often considered at basin scale and may be managed as part of an integrated water resources management (IWRM) plan and hence often covered by BOs (this has been the case for the Great Lakes Commission, USA). Insufficient maintenance or dimensioning of irrigation perimeters may result in leakage, obstruction of ducts or stagnant water pools, resulting in loss of both water and energy. Due to low efficiency, excess water may need to be pumped around which again requires energy.

For water utilities, the energy needs to treat and transport water are high, and water utilities are large energy users. Reducing the volumes to treat directly relates to lower energy requirements – and can have ecosystem benefits as well. The challenge here is mainly to improve efficiency and benefit from synergies and cooperation, thereby considering both water and energy needs (see the case of the Jucar River Basin in Spain, Box 2). Even though it is expected that integrated water-energy efficiency will result in cost savings and increased ecosystem services, little evidence is available to demonstrate this. Water utilities are largely connected to the basin at abstraction points or source areas of drinking water (e.g. Austin City, Texas, USA, see Box 2).

Water for energy

Thermal and nuclear power plants require large volumes of cooling water for production. Globally some 15% of water withdrawals go for energy production, of which some 11% is consumed (IEA 2012). A major challenge here is that in times of water scarcity and drought, insufficient water is available for cooling. Cases are known where power production has been reduced or shut down due to lack of available cooling waters (seen in North America, for example in the Great Lakes Commission, USA). The cooling water itself is discharged as thermal water and is known to have negative impacts on the local biodiversity, if not allowed to sufficient cool before discharging.

Water-food-ecosystems: food security

With increasing population growth, urbanisation and rising incomes, there is ever increasing pressure on the earth's water resources to produce food (as well as fodder and fibre), leading to potentially fundamental detrimental impacts on ecosystem services (Boelee 2013). Key to increasing food security now and in the future is increasing productivity, i.e. producing higher yields with less inputs (Molden 2007). One of the pathways towards increased productivity is multiple use of water within basins for various sectors, such as coordinating water releases from dams so these serve both power generation and irrigation of crops. Moreover, water can yield more ecosystem services when it is managed as part of a multifunctional landscape of agroecosystems, thus benefitting, for example, biodiversity, groundwater recharge and erosion control as well (Keys et al. 2012).

2.2. Role of BOs in governance of the nexus

Most of the challenges and impacts described above need improved and targeted governance so they can be effectively addressed. Good governance can set the foundation for the protection of natural resources and ecosystems in the nexus. The mutual recognition of social, economic and environmental interdependencies between water, food and energy can foster better cooperation and implementation of sustainable development. Adopting a nexus approach can help address water scarcity, irregular supply of energy, food security and scarcity of land while at the same time saving costs, in particular for larger users (Hardy et al. 2012).

Many barriers exist to the good governance of the inter-linkages between water, energy and food. There are also large disparities in both barriers and opportunities for implementation between the developing countries and developed world. Some generic barriers can be identified, in addition to the specific nexus challenges above, which have to be overcome to successfully govern the water-energy-food nexus and manage negative impacts. These include limited data availability, limited institutional capacity, insufficient funding, limited integration of other sectors, issues related to implementation, maintenance and operations and lack of policy coherence and coordination. A majority of these barriers are similar to the classical barriers for implementing IWRM, particularly in the development and implementation of management plans at basin scale and selection of the most appropriate management options (Brils et al. 2014). The UN Status Report on the Application of Integrated Approaches to Water Resources Management (UNEP 2012), presented at Rio+20, reported that since 1992 80% of countries have embarked on reforms to improve the enabling environment for water resources management, including for instance capacity building for IWRM and increased funding. Lessons can be drawn from the development and implementation of IWRM on how to involve multiple stakeholders in joint decision making (e.g. OECD 2014), which is what makes a Basin Organisation a good starting point for governance of the nexus. However, good governance of the nexus requires a higher level and even more comprehensive approach to address the various challenges listed above and aiming for sustainable water, energy and food security (Schmeier 2013; sub-section 2.1).

Basin Organisations (BOs) are involved in water resources management at the scale of a river or aquifer basin and are well-positioned to involve other sectors and initiate dialogues on governance of the water-energy-food nexus. The institutional set-up, mandate and capacity of BOs vary considerably across basins, representing strong boundary conditions for the range of governance options that BOs may deploy to expand (further) into the water-energy-food nexus. Many BOs suffer from a combined load of insufficient authority and mandate, limited capacity, difficulties to implement effective multi-level governance and access to funding.

BOs habitually work closely with the agricultural sector, especially when water has to be supplied (irrigation) or drained; with the environment sector (e.g. with respect to environmental flows, such as for aquatic ecosystems in the Murray Darling Basin (Koehn et al. 2014; Pittock and Finlayson 2011), or incorporation of wetlands into IWRM (e.g. Rebelo et al. 2013)); with the energy sector, particularly for hydropower; but also with cities (where synergies can sometimes be found more easily, see e.g. CBD 2012) and industry. These partnerships can be extended to include other sectors, as well as civil society and the private sector to deal effectively with nexus issues. This may pose additional institutional challenges as strong sectors, such energy, often have limited interest in joint decision-making. Hence some sectors insufficiently see the benefits of cross-sector cooperation and coordination and may need specific incentives or powerful legislation.

In the next section four main recommendations have been formulated to help BOs deal with the challenges above and lead effective governance of the water-energy-food nexus.

3. Recommendations for Basin Organisations to help govern the water-energy-food nexus

In this section, four recommendations are proposed that basin organisations could adopt, in one form or the other, to integrate a sustainable nexus approach. Depending on their specific context, this requires cooperation with other public administrations, companies and the civil society. The four recommendations are based on the experiences of many basin organisations with IWRM, as well as initial experiences with the nexus approach. The four recommendations are:

1. Aim for a high-level mandate to coordinate and cooperate between the water, energy, food and environment sector;
2. Build partnerships across sectors, levels (including the local level) and with companies;
3. Coordinate planning and implementation for mutual benefits and solutions;
4. Build capacity on knowledge base, analytical tools and institutional capacity.

These recommendations are visualised in Figure 2. An essential aspect to help govern the water-energy-food nexus is coordination and cooperation across sectors (at least water, energy, food and environment), levels (local, basin, national and international) and between the public and private sector. To make this happen, two major conditions are needed: i) a high-level mandate (for example, at Ministerial level) to cooperate and coordinate between sectors, and ii) partnerships across sectors, levels and with companies. Partnerships can be either formal partnerships or a more loose participation process. The main aim of the coordination is firstly to identify mutual benefits and common solutions and incentives for each party and secondly plan and implement the solutions. Moreover, capacity building for each of the above recommendations is needed to strengthen the knowledge base, analytical tools and institutional capacity.

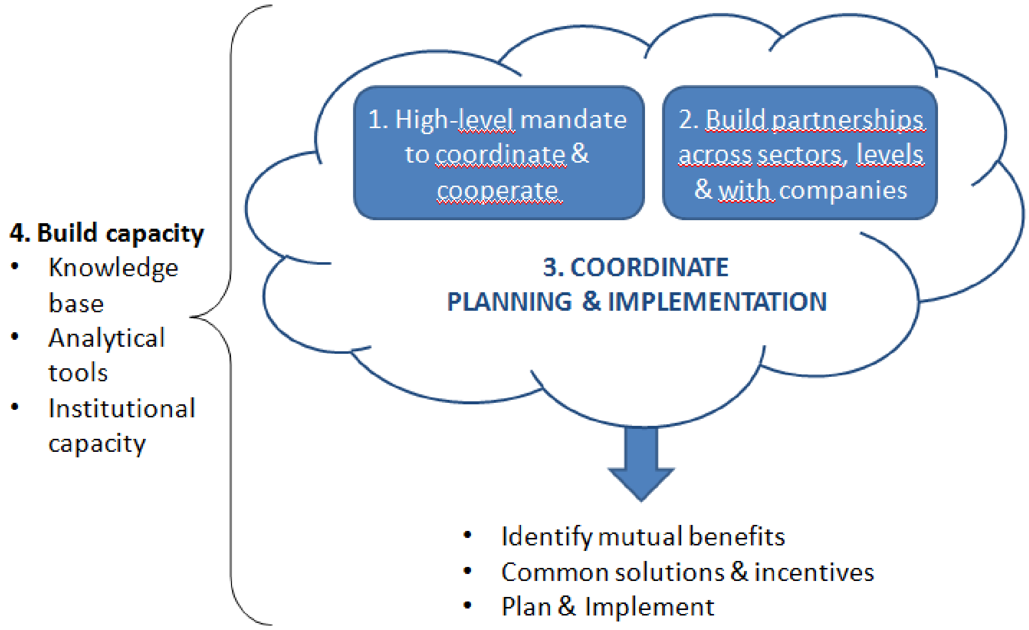

Figure 2. Main recommendations for governance of the water-energy-food nexus. Numbers refer to subsequent sections (Recommendation 1 will be discussed in Section 3.1, recommendation 2 in Section 3.2, etc.).

The costs and benefits that are related to bring the nexus into practice are substantial, but difficult to quantify. The majority of costs are personnel costs (e.g. to run a secretariat, for stakeholder meetings, to organize events, planning and development of related documents) to implement the incentives and processes). In addition, costs are expected for logistics (e.g. for workshops, catering, travelling, facilities) and communication (e.g. printing costs, website). In the inception phase, one-off investment costs are related to the initial intensive stakeholder identification and engagement process. Recurrent costs are related to maintain the coordination and cooperation process and regular feedback meetings to a broader stakeholder group. Other types of costs of governing the nexus are more indirect and difficult to quantify, such as social costs in case of conflict, reputational damage, and other, less foreseeable costs.

The benefits of bringing the nexus into practice depend on the local context and parties involved in nexus implementation. Typical parties are basin organisations, local level and national level authorities and line agencies, plus the private sector. Involved companies typically are water and energy utilities, constructors, beverage and food companies, and commercial farms. Depending on the local context, water and energy utilities might be either public or private organisations.

Potential benefits are:

- Less adverse consequences of actions (trade-offs) of one sector for another, either intended or unintended;
- Multiple benefits from multi-purpose measures and the development of synergies e.g. multi-purpose dams or ecosystem restoration;
- Water and energy savings, advantageous in particular for water and energy scarce regions, and resulting in addition to cost savings, where water and energy is to be purchased;
- Further increased efficiency and costs savings related to join actions where resources can be pooled, data can be re-used and shared; and less mitigation actions to compensate the potential adverse effects of measures from one sector for another;
- Increased trust and confidence between parties, a social corporate image (for the private sector, including water and energy utilities), increased awareness.

The recommendations are further elaborated below. For each recommendation, good practice examples are given. The good practices are based on a review of 16 case studies worldwide. The case studies are listed in Table 1 and Table 2. A more extensive description of seven case studies is given in text boxes in the text as showcases to the recommendation. A brief overview of the other case studies in given in the appendix. While the case study text boxes are placed as showcase for one recommendation, they might be relevant or even good practices for other recommendations as well.

Table 2. Governance recommendations illustrated in the case studies. Crosses signify that a certain recommendation is covered in the example; dark cells refer to the recommendation where that particular case is discussed.

Case study	Country/Region	High-level mandate to cooperate across sectors and levels	Formal partnerships with local scale or private sector	Coordinated planning and implementation	Capacity building	Text box / appendix
AFRICA						
Inner Niger Delta	Mali	X	X	**X**	**X**	Box 6
Lesotho Highlands water project	Lesotho	X		**X**		Box 6
AMERICAS						
Latin American Water Funds	Examples from Ecuador and Costa Rica		**X**	X	**X**	Box 3
Sarapiqui wetlands	Costa Rica		X	X		A 6.1
Penobscot River	USA	X	X	**X**		Box 5
Austin City, Texas	USA		X			A 6.2
Great Lakes Commission	USA	X		X	**X**	Box 7
ASIA & PACIFIC						
Mekong River Commission	South East Asia	**X**		X	**X**	Box 1
Four Major Rivers Restoration Project	South Korea	X		X		A 6.3
Lighted village scheme	Gujarat, India		X			A 6.4
Nam Theun hydropower scheme	Laos	X				A 6.5
Biofuels on contaminated land	Thailand		X			A 6.6
Fuelwood substitution, Alazani/Ganikh River Basin	Azerbaijan and Georgia	X				A 6.7
Murray-Darling river basin	Australia		X	X		A 6.8
EUROPE						
Danube / Sava	South East Europe	**X**		X	**X**	Box 1
Jucar river basin	Spain		**X**	X	**X**	Box 2

3.1. Aim for a high-level mandate to coordinate and cooperate between the water, energy, food and environment sector

In order to break through the sectoral isolation that exists in many countries worldwide, a high-level mandate for better cooperation and coordination across sectors is needed, preferably at Ministerial level. The high-level mandate can consist of the expected outcomes of the coordination and cooperation, a commitment for joint planning and implementation, as well as an understanding of the costs and benefits of cooperation and coordination and how they will be shared among the parties.

The mandate for cooperation and coordination needs to cover at least the water, energy, agricultural and environment sectors, but can also be extended to other sectors that are typically needed for planning and implementation at basin scale, such as departments for planning, budgeting, economic and social development and where applicable poverty reduction. While in a first step a commitment at Ministerial level is to be sought, in further steps a high-level mandate from the local and global level cannot be neglected. Mayors can provide a high-level mandate at the local level to facilitate practical implementation of measures and community buy-in. A global level mandate might provide an additional incentive for Ministers to cooperate. The high-level mandate could in addition aim to strengthen, where needed, the functioning and role of Basin Organisations. While the mandate of BOs varies worldwide, it may not include cooperation and coordination with the targeted sectors, or may not enable joint planning and implementation. The mandate for cooperation and coordination would also require novel organisational schemes since the other sectors, unlike Basin Organisations, do not have the basin scale as the operating unit. The energy sector often consists of strong and influential organisations, often with national coverage and monopoly positions. The food sector includes, typically, a national agriculture ministry and its departments and agencies along with farmers' associations and other stakeholders, while the environment sector may be represented by a national Ministry together with national park organizations and environmental groups.

While a high-level mandate is an essential component of the enabling environment to help govern the water-energy-food nexus, other components are needed as well, including a legal and policy framework and cooperative institutional structure (Hellegers et al. 2008). A high-level mandate together with other components of the enabling environment can be the first steps to initiate the process. However, these steps are often time consuming. It is advised, where possible, to initiate the stakeholder consultation, partnership formation (see recommendation 2) and gain an understanding of the mutual benefits and solutions (see recommendation 3) in parallel or prior to obtaining a high-level mandate. That experience will furthermore provide the necessary background information to motivate the urgency for a high-level mandate.

Box 1 provides examples from the Mekong (South East Asia) and Danube (South East Europe) Rivers that illustrate how a strong mandate and favourable environment can support governance of the water-energy-food nexus in multi-country transboundary basins. Trans-boundary basins add an international dimension and hence more complexity: upstream-downstream differences in interests, political or economic power differences, spill-over effects and interdependencies. Other cases that have a high-level mandate between countries are the Niger Basin Authority (Inner Niger Delta case), the Lesotho Highlands project (with a high-level mandate to transfer water from the Senqu river in Lesotho to the Vaal river in South Africa) and the Alazani/Ganikh River Basin, where Azerbaijan and Georgia are negotiating the investment in green infrastructure to substitute fuelwood (KTH 2014). The Penobscot river and Great Lakes Commission both have a high-level federal mandate in the USA, whereas the Four Major Rivers Restoration Project and the Nam Theun hydropower scheme are examples of hydropower projects with a high-level mandate in Asia (respectively South Korea and Laos).

Box 1 – International River Commissions illustrate the importance of a high-level mandate to initiate action for sustainable hydropower

Coordination across sectors, and where needed across countries, is essential to help govern the water-energy-food nexus. Bringing parties together with different background, concerns, priorities and degrees of influence, as is the case for the water, energy and food sectors, is however not straightforward. Hydropower is an important source of energy in both the Mekong and the Danube river basins, but has led to protests and negative impacts on livelihoods and ecosystems. In order to manage the growing number of hydropower plants in both basins, and their cumulative and trans-boundary impacts, both River Commissions independently agreed on initiatives to promote sustainable hydropower. In both cases, decision-making at ministerial conferences in combination with a broad participatory process within the participating countries provided the necessary mandate for action. In both cases, the projects were driven by the need for more (renewable) energy. Irrigated agriculture however is important in both basins and will be affected by the modified flow regimes. The relationship however is not straightforward. Upstream and near the reservoir, more water resources are available, but also arable land is lost after flooding. Downstream impacts for agriculture can be mitigated by ensuring minimum so-called environmental flows. Environmental flows are to guarantee the basic water requirements for the environment, agriculture and downstream communities.

The **Mekong River Commission (MRC)**, upon decision by the countries' Ministers and in response to various studies (e.g. Dugan et al. 2010), have launched the 'Initiative on Sustainable Hydropower'. This has resulted in a number of planning and analytical tools including the Rapid basin-wide hydropower sustainability assessment tool (RSAT), the identification of ecologically sensitive sub-basins for hydropower development, guidelines for the evaluation of multi-purpose hydropower projects and options for benefit sharing for hydropower on tributaries of the Mekong River. The Initiative for Sustainable Hydropower is launched in 2008. A 3-yr consultation process resulted in 2011 in a Programme of Actions for the period 2011-2015. The RSAT tool has been published in 2013. Other reports are underway.

In the **Danube river basin**, the EU Renewable Energy Directive is a driver for more hydropower in the basin and the resulting reduction of greenhouse gas emission. At the same time, the Danube countries are committed to implement binding European Union water and nature protection targets. Aware of the negative impacts of hydropower plants on the riverine ecosystem, the Ministers of the 14 cooperating states asked the International Commission for the Protection of the Danube River (ICPDR) in 2010 to develop guiding principles on sustainable hydropower order to ensure a balance and integrated development, following a broad participative process. The guidelines, published in 2013, cover the technical upgrade of existing hydropower plants, options for ecological restoration, a strategic planning approach for new hydropower development, as well as mitigation of negative impacts of hydropower.

Sources:
http://www.mrcmekong.org/about-mrc/programmes/initiative-on-sustainable-hydropower/
http://www.icpdr.org/main/activities-projects/hydropower

3.2. Building partnerships across sectors and levels and with companies

The challenges related to water, food and energy security are too large for one entity, whether public or private, to tackle on their own. In fact, as stated by UN Water (2014), uncoordinated decisions are one of the driving factors of water, energy and food insecurity. The formation of partnerships is hence an essential way to address water, food and energy insecurity at current and in the future. Partnerships are also a practical way to facilitate cooperation and coordination across sectors, level and with companies. Partnerships can take many forms, ranging from a broad stakeholder participation process, advisory boards, goal-oriented partnerships and formal, more long-term partnerships such as public-private partnerships where resources are pooled and costs and benefits shared. The type of partnership depends on the parties, the specific challenge to be addressed and the expected outcome. Partnerships ideally consist of partners across sectors and levels. Some partnerships address the basin scale, for instance in the case of multi-purpose dams that are used for hydropower, agriculture, ecosystems and water supply, while others address the urban scale. Urban partnerships are found to work between water and energy utilities or to operate more broadly and aim for sustainable urban water management, resulting in water and energy savings, but also in investments in green infrastructure.

For effective governance of the water-energy-food nexus, a multi-disciplinary, cross-sector and cross-level coordination process is needed. Typically, partnership formation starts from a broad stakeholder consultation process, evolving along the way to more structural forms of partnerships. The stakeholder consultation process firstly aims to identify mutual benefits, common solutions and incentives for each party while also making visible the risks of uncoordinated action. After agreeing on the need for cooperation and prioritising common solutions, mechanisms for coordinated planning and implementation are needed where each partner has equal rights and responsibilities.

Basin organisations can be catalysts to address water-energy-food nexus challenges. Water resources are essential for all targeted sectors and basin organisations have practical experience integrating multiple disciplines and levels and work across sectors through the application of IWRM. Basin organisations on their own cannot govern the water-energy-food nexus: solutions will depend on partnerships bringing together water stakeholders with energy, food and ecosystem stakeholders.

In Boxes 2 and 3, examples of partnerships are described, in which a basin organisation is one of the partners and where other partners are from other sectors, the local community and private sector. Box 2 shows examples of a partnership to achieve sustainable stormwater management in the Jucar river basin (Spain) and the water contracts in France, Spain and Belgium. Box 3 presents the innovative financial mechanisms of the Latin-American water funds partnerships, that are now in place in 30 sites in Latin-America, with examples from Ecuador and Costa Rica. Similar partnerships that involve basin organisations are the integrated planning of natural resources in the Inner Niger Delta (Mali, Niger Basin), sustainable hydropower and ecosystem restoration in the Penobscot river basin (USA) and various programs of the Murray-Darling Basin Authority

(Australia). Other case studies demonstrated more local partnerships, e.g. for the payment for ecosystem services scheme in the Sarapiqui wetlands (Sarapiqui river basin), the synergies between water and energy utilities in the city of Austin (Texas, USA), the lighted village scheme in India, and the project in Thailand where biofuels are produced on contaminated land. The cases that are not described in Box 2, are briefly documented in Annex.

Box 2 – Partnerships for governing nexus challenges

In many cases, the water, energy and food sector work independently and in some cases take actions to counteract measures of the other sector, intended or unintended. In order to take advantage of synergies in the water, energy and food sector and avoid negative impacts on other sectors, coordination is needed. Formal partnerships are expected to be effective, mainly as a consequence of clear commitments and targets to achieve. Examples from Europe and Latin America are described.

In the **Jucar River Basin (Spain)**, a partnership between the water and energy utilities, the municipality Benaguasil and the Jucar river basin aims to improve energy efficiency in the urban water cycle and in buildings by promoting the use of innovative stormwater solutions such as Sustainable Drainage Systems (SuDS) and other types of green infrastructure. This project frames in the E2Stormed project. About 10-20% of energy reductions are foreseen by reduced water treatment and pumping. In addition, green roofs, a typical SuDS measure, provide insulation to buildings and reducing the heat island effect in cities, thus resulting in reduced energy demands for air-conditioning in the hot season. The E2Stormed Decision-Support Tool (under development) allows to calculate water and energy analysis in combination with cost-benefit analyses and can propose various scenarios that can be used as basis for discussion by decision-makers.

For rivers in **Spain, France and Belgium**, partnerships are formalised by "**river contracts**". A river contract is a means to restore, improve or conserve a river through a series of actions that are agreed in a broad participatory process with all basin users, private and public entities involved in water management. It often involves regional and local authorities. Parties to the Contract define their own management objectives and guidelines and develop a plan of action which benefits from the input of local expertise. A river committee acts as the permanent secretariat of the river contract. Typically involved sectors are the water, agriculture and environment sector. Examples have not been found where the energy sector is involved. However, this type of partnership could be easily tailored to contract for a water-energy-food nexus partnership.

Sources:
http://www.e2stormed.eu/
http://www.eea.europa.eu/soer/countries/be/national-and-regional-story-belgium-2

Box 3 – The success of the American Water funds partnerships

In the Latin-American water funds partnerships, downstream water users (e.g. companies, city authorities) direct payments to upstream communities (e.g. farmers, ranchers) and land conservation organisations to invest in long-term ecological restoration and protection efforts within the watershed. These are usually referred to PES, or Payment for Environmental Services (see e.g. Dunn 2011; Van Eijk and Kumar 2009; Kelsey Jack et al. 2008; Wunder et al. 2008; Smith et al. 2006). For cities and many companies the continuous availability of clean water is essential. As partner in a Latin American water fund, food and beverage companies and water and energy utilities have been convinced to invest in upstream nature restoration and conservation, for following reasons: 1) it is more cost-effective to prevent water quality deterioration than treating it at industrial site; 2) continuous availability of clean water is essential for the company's activities.

Since the creation of the first Water Fund in Quito (Ecuador) in 2000, more than 30 Water Funds have been launched in Latin America. The Quito water fund was established to pay upstream landowners to protect the water supply for the city of Quito. 80% of the drinking water originates from an area used by 27,000 locals for cattle, dairy and timber. The main challenge in this river basin is related to poor livestock management and agricultural practices in nearby areas, which cause water pollution, soil erosion and adversely impact nature conservation. Downstream users are the drinking water company, irrigators, flower plantations and hydro-electric power stations. Companies in the partnership provide a percentage of their profits to the Fund. Starting small in 2000, The Quito water Fund now has $10 million. This capital provides a stable, long-term financial mechanism, using revenues derived from its equity to co-finance activities in the watershed and cover operational costs.

In the Costa Rican water fund, a hydropower plant recognized the need for watershed services and pays upstream land users $10/hectare because each lost cubic meter of water results in a loss of one kilowatt of electricity. Thus they are securing 460,000 cubic meters of water per year for energy production.

A reference used in the early adoption of the water funds - and still considered as a prime example for Latin-American water funds – is a barley farm in the Silver Creek Valley in Idaho, USA is. Investment in conservation practices increased yields and saved approximately 549 million liters of water in the 2012 season. Energy costs where cut in half. representing about 9% of the farm’s annual water use, while also reducing about 10-20% of energy use.

Sources:
http://www.fondosdeagua.org/en/
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/idaho/explore/natures

3.3. Coordinate planning and implementation: mutual benefits and solutions

Coordinated planning and implementation is essential to address the many complex water-energy-food nexus challenges. In many cases, sectors work independently and can take actions that conflict with the measures of in other sectors. Cooperation between sectors is often limited; partly because the benefits of cooperation are insufficiently understood. A first step to identify the mutual benefits of cooperation, and thus proper governance of the nexus, starts from the building of a common understanding of each other's practices, priorities and concerns (for instance environmental impacts). Secondly, based on a common understanding, mutual benefits can be identified, as well as intended and unintended trade-offs of actions from one sector to the other. Next, common solutions (Box 4) can be identified, preferably in a neutral setting where all partners have equal rights and responsibilities. After agreement on common solutions, the solutions can be broken down into specific measures for which the costs, benefits and impacts for each sector are to be assessed. The latter requires tailored analytical tools as well as mainstreaming into sectoral planning, e.g. River Basin Management Plans (RBMP) for Basin Organisations. Possible solutions range from technological measures, financial incentives, green infrastructure to awareness raising. However, the knowledge and analytical tools to assess the multiple benefits, cumulative costs and effectiveness across sectors are often lacking and capacity building is required (Recommendation 4; section 3.4). Box 5 discusses the case of the Penobscot River, where the identification of mutual benefits and dialogue led to the implementation of win-win solutions. Box 6 presents examples from Africa where the balance between ecosystems, livelihood and financial viability of hydropower is demonstrated.

Box 4 – Examples of common solutions to support the water-energy-food nexus

Common solutions include green infrastructure and other innovative ideas. Green infrastructure refers to (semi) natural systems that provide water resources services for water resources similar to conventional, built ("grey") infrastructure (Bertule et al. 2014). For instance, using natural riverine floodplains for storage during high water levels will reduce the impacts of floods downstream, where embankments can be lower. Incorporation of green infrastructure (Krchnak et al. 2011; Totten et al. 2010) can also enhance efficiency and support an ecosystem-based approach. In hydropower, sustainable dam management is increasingly applied to mitigate adverse effects e.g. from hydropower on the ecosystem or from over-abstraction of water for production of cash crops and help meet water, energy and food demands (IHA 2014). Environmental flows (see e.g. Korsgaard et al. 2008; Krchnak et al. 2009) are crucial elements in basin water allocations. Even though well recognized, environmental flows are applied in few locations only, worldwide.

Box 5 – The implementation of common solutions to the water-energy-food nexus turns trade-offs into win-win situation

Under scarcity of water, energy or food, options to improve access and security of resources often are framed in terms of trade-offs, where benefits for one party comes at the expense of another. Examples of trade-offs are ecosystem restoration versus sub-optimal hydropower production and more water efficiency in irrigation versus higher energy uses. The Penobscot river restoration project (USA) however demonstrates that ecosystem restoration has not resulted in diminished hydropower generation in the basin. A broader range of options appear when planning of current and future energy demands and supply is done at basin scale rather than at the level of an individual site.

Abundant fisheries are the cultural foundation for the Penobscot Indian Nation and the economic driver of the local economy. A series of hydropower dams built over the past century contributed to the decline of the river's overall health, blocking access for salmon and other species and thus reducing the potential for fisheries. The power company, the Penobscot Indian Nation, environmental groups and numerous state and federal agencies and riverside communities joined forces to restore more than 1,000 miles of river habitat without diminishing hydropower generation in the basin. This effort involves removing two dams in the lower river, installing a state-of-the-art fish bypass to a third dam further upstream and increasing energy production at dams elsewhere in the basin where impacts on fish are low.

Three factors triggered the process towards sustainable hydropower.

- The legal recognition of the Penobscot Indian Nation gave the Indian Nation the right to harvest fish within the waters of their reservation. The Federal government was hence required to restore fish continuity.
- In 2000, all hydropower projects on the lower Penobscot river were consolidated under a single owner with a high-level mandate, which enabled planning at basin-scale.
- A basin-scale review of hydropower licensing responded to the increasing tensions between hydropower development, fisheries and recreation. Applications for licensing of new hydropower projects and relicensing of existing dams were bundled. Several licenses were rejected while the design of others needed to become fishing proof.

As conclusion, in the Penobscot river basin, the energy production after implementation of the ecosystem restoration project were equivalent as in the original condition. Yet in the new state, the hydropower project has significantly lower environmental and social costs and comes closer to retaining a largely functional river system.

Source: Opperman et al. (2011)

Box 6 – The balance between ecosystems, livelihood and financial viability of hydropower: Examples from Africa

Large multi-purpose hydropower dams in Africa are a miracle for the regional economy, but lead in many cases to adverse impacts for downstream agriculture and ecosystems. In two projects in Africa (both with a high-level mandate), solutions have been provided to balance the financial viability of hydropower with the mitigation actions to compensate downstream ecosystems and livelihoods.

The **Lesotho Highlands Development Authority** (LHDA) manages one of the largest intra-basin transfers in the world, transferring large volumes of water from the water rich Lesotho Highlands to the industrial hub and water stressed region of Johannesburg (South Africa). Two large dams are already in place and third one is under construction. Currently, 26 m^3/s is transferred from Lesotho to South Africa. By 2020, 70 m^3/s is expected to be transferred. Even though energy production is Even though hydropower generation is minor (75 MW), this generation has made Lesotho nearly independent of South Africa for power. The new Phase 2 scheme, which is now in design stage, will generate 1200MW in a pumped storage scheme, at which time Lesotho will then sell primarily electricity storage to South Africa. The dams capture much of the river flow for transfer, which negatively affects the downstream livelihoods and ecosystems. Since a treaty established between South Africa and Lesotho to implement this project, required that the downstream ecosystem and people were not negatively affected, two mitigations options have been implemented: 1) a sophisticated downstream flow release regime that guarantees minimal flows the very poor downstream communities that need water for agriculture and 2) financial compensation of the natural resources lost as a consequence of the modified flow regimes. Annual compensation for loss of resources is paid to rural people to the extent of USD 1.8 million per annum. For the Phase 2 dam development, the compensation mechanism has been evaluated and improved. A new risk assessment is now used to statistically assess the risk of failure to provide each of the different ecosystem services (e.g. riparian grazing for cattle, fish stocks, domestic water). Future challenges of the LHDA are related to keeping the balance between the protection of ecosystem and livelihood and the financial viability of the scheme to sell water to South Africa.

In semi-arid Mali, the Niger river is the main supplier of both water and energy (by means of several hydropower dams). The **Markala dam in Mali** supplies water for the 60,000 ha large irrigation perimeter called the 'Office du Niger'. The Office du Niger is of high importance for the economic development and food security of Mali. However, the downstream impact on the Inner Niger Delta is detrimental (Leten et al. 2010). The natural flooding of the Inner Niger Delta (up to 6m difference of water level in average), essential for high yields in fisheries, cattle grazing and rice production, has been cut by half (depending on the year),thereby threatening the livelihood of local farmers, herders and fisherman while also threatening the protected habitats (Liersch et al. 2013). Alternative income generating activities are scarce in the Inner Niger Delta. Aware of the difficult trade-off, and the need to support the downstream Inner Delta, the 2011 plan for the integrated management of the Inner Niger Delta, part of the bigger Niger basin, foresees in two mitigation options: 1) The conversion of naturally flooded rice to irrigated rice. While the yields of irrigated rice are higher (5-6t/ha) compared to 1-2 ton/ha for naturally flood rice, the energy costs are also substantial (10-35% of the total cost). In order to compensate for the higher energy costs, the Inner Niger Delta development plan promotes the cultivation of commercially interesting vegetables, fruits and herbs. 2) The "bio-rights approach" provide micro-credits for investments in sustainable farming or fishing. Instead of paying interest, the communities take environmental action, such as replanting trees and refraining from cutting firewood. The 'shared vision' of the Niger Basin (2003) is the basis for the current Sustainable Development Action Plan (PPD-DIN 2011).

3.4. Build capacity: knowledge base, analytical tools and institutional capacity

Actively implementing the recommendations listed above needs, in many cases, further strengthening of the governance aspects of the water-energy-food nexus, in particular to expand the knowledge base and develop practical analytical tools to identify and demonstrate the multiple benefits. This helps address the need to better understand the conditions and scale under which multiple benefits can and cannot be expected, which measures or combinations of measures can result in synergies, and how trade-offs can be identified and mitigation options designed. An important focus is to assess how the available information can be shared and combined.

Institutional capacity has to be enhanced as well, in order to cooperate in equal and trustworthy partnerships, and to actively search for synergies, mitigate potential trade-offs and facilitate multiple benefits. This includes demonstrating the relevance and potential benefits to businesses for getting involved in the water-energy-food nexus and thus providing incentives to coordinate with the public sector and potential competitors.

Nexus challenges have common characteristics worldwide. Therefore mechanisms to share existing data, information and good practices are essential. Even though tools and practices cannot be directly transferred from one area to another, lessons can be learned from other cases. Moreover, generic methods and tools are needed that work in a range of contexts. Hence, tools that are able to function in a data- and resource poor environment are as valuable as tools for a data and resource rich context.

Box 7 – Map viewers and guidance documents to enhance the capacity to govern the water-energy-food nexus

A variety of documents, tools and websites has been developed to improve the knowledge base and analytical tools on the water-energy-food nexus. Two main types have been identified: interactive web map viewers (or web atlas) and guidance documents on how to apply a method or tool.

Several case studies have developed an atlas or web map viewer where maps illustrate the importance of the water, food, energy and environment sector. In all cases, maps have been developed at the scale of the river basin, often ordered by the BO. Examples are the atlas and interactive viewers of the Mekong River Basin (http://portal.mrcmekong.org/), the Great Lakes Commission (http://glc.org/projects/energy/glew/glew-maps-and-tools/), the Danube River Commission (http://www.icpdr.org/main/publications/maps) and the Inner Niger Delta (Zwarts et al. 2005).

Guidance documents have recently been developed for specific tools and methods that been developed in the various case studies. These include the 2013 Rapid basin-wide hydropower sustainability assessment Tool (RSAT) of the Mekong River Commission (http://www.mrcmekong.org/about-mrc/programmes/initiative-on-sustainable-hydropower/rsat-overview-the-basin-wide-hydropower-sustainability-assessment-tool/), the 2013 'Guiding principles on Sustainable Hydropower' from the Danube River Commission (http://icpdr.org/main/activities-projects/hydropower) and the 2013 'Primer for Monitoring Water funds' for the Latin-American Water Funds Partnerships (http://icpdr.org/main/activities-projects/hydropower). A guidance document, and decision-support tool to implement sustainable stormwater management in Spain (urban context in the Jucar river basin) is under development.

4. Conclusion

Coordinated governance can improve energy, water and food security, foster synergies, manage trade-offs, support sustainable development, maintain or restore ecosystems and the services they provide to society. Basin organisations can be catalysts to help govern the water-energy-food nexus. Water resources are essential for all targeted sectors and basin organisations have practical experience integrating multiple disciplines and levels and work across sectors through the application of IWRM. On the other hand, basin organisations on their own cannot implement the water-energy-food nexus: solutions will depend on partnerships bringing together water stakeholders with energy, food and ecosystem stakeholders.

The 16 examples analysed in this paper have demonstrated that the identification of mutual benefits is recognized as crucial in all cases. This does not automatically mean that decision-makers in sectors are aware of the mutual benefits, nor does it suggest there is a common understanding amongst parties. However, the identification of mutual benefits is a first step towards a nexus approach and can provide incentives to partners for engaging in the nexus.

Similarly, in half of the cases, a high level mandate at national level or basin level (sub-national or trans-boundary) has been a key to success. Partnerships are clearly important. In four case studies a partnership of a BO with local actors (and potentially others) was a necessary lever for action. Moreover, the majority of cases worked through a partnership with the private sector, including the constructors or operators of hydropower dams, or water utilities. In about half of the case studies, a broad participation process has indeed been organized to discuss elements, impacts and interdependencies in the nexus. For six case studies, guidance documents, tools and knowledge base have been developed on various nexus issues. Economic incentives have been applied in four case studies.

Following the review of the case studies on the implementation of the water-food-energy nexus from a governance point of view, four recommendations have been elaborated in this paper. The first recommendation is to establish a high-level mandate to coordinate and cooperate between the water, energy, food and environment sectors. Coordination and cooperation across sectors (at least water, energy, food and environment), levels (local, basin, national and international) and between the public and private sector is essential to effective governance of the water-energy-food nexus. Hence, the second recommendation is to build partnerships across sectors and levels and with the private sector. Thirdly, to identify mutual benefits and coordinate planning, as well as implementation, of common solutions. Finally, capacity building on expanding the knowledge base, analytical tools and institutional development. Together, these four recommendations can help basin organisations to initiate collaboration and arrive at effectively governing the water-energy-food nexus for sustainable development.

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6. Appendix: additional case studies

6.1. Sarapiqui wetland, Costa Rica (South America)

Name: Payment for ecosystem services in Sarapiqui wetland (based on Hanson et al. 2009)

Location: Costa Rica

Scale: local

Description: A hydropower company pays US$48/ha per year to upstream landowners for forest management and restoration. The payment is based on the costs of reservoir dredging that the company avoids and the operational benefits of more reliable stream flow that can be used for hydropower.

6.2. Water and energy linkage in Austin, USA (North America)

Name: Water and energy linkage in Austin (based WWAP 2014, chapter 29).

Location: Texas, USA

Scale: Provincial watershed

Description: Texas case study illustrates how a fast growing major US city with publicly owned water and electricity utilities can craft integrative and strategic programmes and policies that help to meet the needs of the public while also helping each sector. Initiatives promoting the efficient use of water and electricity over the past two decades have allowed utilities to postpone major supply expansion efforts; although with the city's continued growth, both water and electricity utilities are expanding their supply capacity while carrying on with their demand reduction and management efforts. Several recent and ongoing projects highlight the cooperation between the two utilities and the opportunities for synergies across sectors.

6.3. River Restoration Project, South Korea (Asia)

Name: Four Major Rivers Restoration Project (4MRRP; based on WWAP 2014, chapter 26).

Location: South Korea

Scale: national, coordinating 4 major rivers.

Description: Earlier, the Ministry of Environment managed four river acts to coordinated upstream/downstream issues. Since 2008, the government has been formulating policies for green growth to reduce its carbon footprint, prepare the country to deal with the effects of climate change, and maintain its good water management practices. The Green New Deal, initiated in 2009, comes with an economic package for investment in green growth. A part of the Green New Deal, the 4MRRP aims to revitalize the Han, Nakdong, Geum and Yeongsan rivers to improve water availability and quality, control floods, restore ecosystems and promote nature-conscious development. The 16 weirs and 41 hydropower-generating units that were built during the project constitute an important part of the 4MRRP. They are designed to store optimal amounts of water for generating energy, without interrupting the natural flow of the rivers and allowing for navigation. While the amount of electricity generated is modest, the project represents Korea's firm commitment to reduce greenhouse gas emissions as a part of its low carbon green growth policies.

6.4. Lighted village scheme, Gujarat, India (Asia)

Name: *Jyotigram Yojana* scheme (based on IWMI 2011)

Location: Gujarat, India

Scale: local, village-level

Description: Innovative 'lighted village' scheme in Gujarat. The state government scheme supports massive rainwater harvesting, micro-irrigation and groundwater recharge schemes. By providing a continuous, reliable full-voltage power supply for restricted hours daily, the *Jyotigram Yojana* made it possible for farmers to keep to their irrigation schedules, conserve water, save on pump maintenance costs and use labour more efficiently. These and other benefits helped drive agricultural production to new heights while improving the quality of life for farming families. Key success factors for the introduction of the new power system were the early involvement of senior policy-makers and the support of farming community.

6.5. Nam Theun hydropower scheme, Laos (Asia)

Name: The Nam Theun 2 hydropower scheme (RBO project). Example based on http://www.water-energy-food.org/en/practice/view__593/from-serre-ponçon-to-nam-theun-2-back-to-a-sustainable-and-multi-purpose-future-integrating-water-energy-and-food-needs.html

Location: Nam Theun and Xe Bang Fai Rivers in Lao PDR and Thailand

Scale: International, trans-boundary

Description: The Nam Theun 2 hydropower scheme in Laos is a trans-basin project (partial water diversion from Nam Theun river to Xe Bang Fai River) with 1070 MW installed capacity under 350m head. It creates a 450 km^2 and 3.5 billion m^3 reservoir by means of a 45m high dam. Power generation, irrigation, flood control, clean drinking water, access to reservoir for fishing, and boating are different benefits of the scheme, which is a major contributor to the socio-economic development of this region including Thailand. Indeed, NT2 originated in a protocol signed between the Lao and Thai Governments. A high level of public consultation and disclosure was a priority to ensure that all affected people were fully informed of the Project and that their views are taken into consideration.

6.6. Biofuels, Thailand (Asia)

Name: Changing to biofuel crops makes productive use of contaminated water (based on IWMI 2012).

Location: Town of Mae Sot, Thailand

Scale: local

Description: Ten years ago, Thai epidemiologists noticed unusual clusters of kidney disease among elderly people around the town of Mae Sot. Heavy metal poisoning was suspected. A research team demonstrated that an irrigation system dissecting an area rich in minerals was contaminating local rice. Thanks to their efforts, farmers received compensation and training so that they could switch to growing inedible crops valuable for biofuels. Loans from Agence Française de Développement, a local mining company and the government were used to build an ethanol plant, and many farmers now produce sugarcane for conversion into biofuel.

6.7. Fuelwood substitution, Alazani/Ganikh Basin

In an assessment of the water-food-energy-ecosystems nexus in the Alazani/Ganikh River Basin shared by Azerbaijan and Georgia, the main intersectoral issues and possible synergic measures were identified by applying a nexus-assessment methodology specifically developed in the framework of the Convention on the Protection and Use of Trans-boundary Watercourses and International Lakes (KTH 2014).

In the rural Georgian upstream part of the Alazani/Ganikh Basin, constraints of access to modern energy sources affordable to the population result in biomass use. The resulting deforestation aggravates erosion, contributing to sediment load of the river. A trans-boundary, nexus action in response to this problem could be fuelwood substitution taking advantage of the existing energy trade between the two countries: Azerbaijan is a natural gas producer and gas is already imported to Georgia.

The effects of the above action are felt across the border downstream in Azerbaijan but clearly benefits both countries as the river forms the border for a part of its length. Overall, reduced fuelwood harvesting increases forest stock improving the health of ecosystems with various intersectoral co-benefits:

- Reduced erosion with beneficial effects on water quality and maintenance of infrastructure
- Dampened and retained run-off, providing key (flash) flood control services
- Improved health of the population in Georgia (indoor air pollution is reduced as people switch away from using fuel wood)
- Supporting a key economic growth sector, namely tourism
- Increased carbon dioxide capture

The countries are also pursuing other paths with make energy available in the basin — developing small scale hydropower generation — but the challenge is how to do it sustainably, minimizing also environmental impacts.

An agreement on trans-boundary waters is being negotiated between Azerbaijan and Georgia. The draft agreement envisages a joint commission with a multi-sector representation from the countries.

6.8. Murray-Darling Basin Authority, Australia (Asia & Pacific)

Name: Murray-Darling Basin Authority (MDBA), RBO. Example based on http://www.mdba.gov.au/

Location: Australia

Scale: national basin

Description: The primary task of the MDBA as stated in the first clause of the agreement is to: 'promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling basin'. Several of the dams in the basin are equipped with turbines for generation of hydropower.