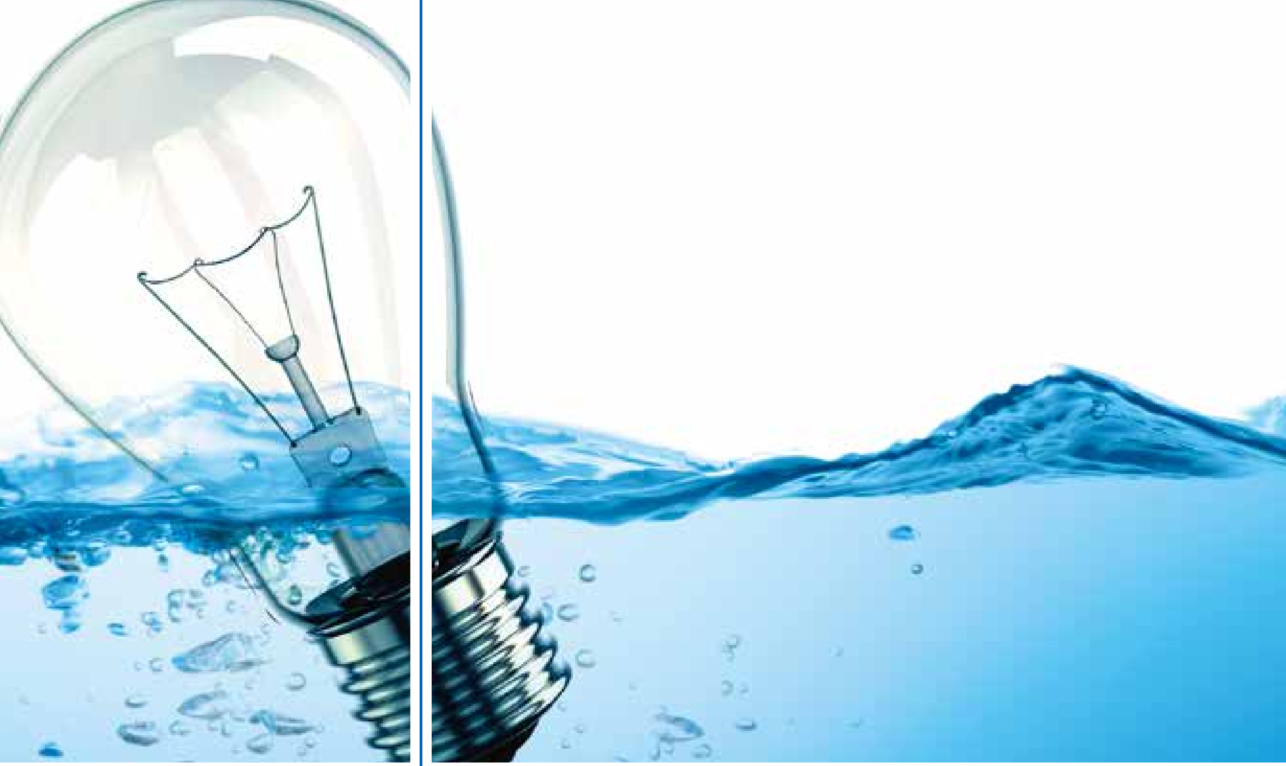

This report has been prepared as input to the 2014 World Water Week and its special focus on Energy and Water.

Energy and Water:

The Vital Link for a Sustainable Future

WORLD WATER WEEK

SIWI

REPORT 33

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Energy and Water:

The Vital Link for a Sustainable Future

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Welcome

When we look ahead and envisage a future where coming generations will thrive, we see one threat overshadowing all others: a silo mentality, every sector acting on its own, would effectively cripple any effort to build a sustainable future. Energy and water make a very good example. Water and energy are interdependent in more ways than not. We need energy for pumping, storing, transporting and treating water, we need water for producing almost all kinds of energy. An increase or decrease in one will immediately affect the other.

The arguments for tighter links between the two communities are abundant, as you will find in the contributions to this report, and become all the more important as a raised living standard in many countries lead to a higher demand for both water and energy.

It is a fascinating fact that water and energy challenges are very similar all over the world, although solutions often need to be local. The opportunities to learn from each other and cooperate are endless.

This urgent need for a closer relationship between the energy and water communities will be discussed and encouraged during World Water Week in Stockholm, and it will remain an important part of SIWI's work in the years to come. It is an issue going well beyond the water and energy communities. It is central in the global efforts to eradicate extreme poverty and a concern for all of humanity.

Our intention with this World Water Week report is that it shall act as a take-off point for increased collaboration between professionals in the energy and water communities, building on some encouraging signs we are already witnessing. We hope that it will help inspire some future-minded thinking, uninhibited by sectoral boundaries and old truths.

Torgny Holmgren

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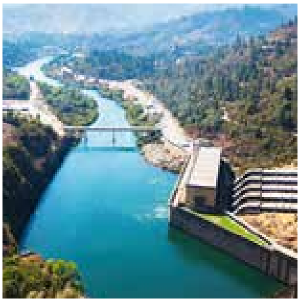

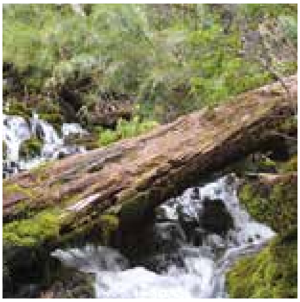

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Introduction

By Torkil Jønch Clausen, Anders Jägerskog, Torgny Holmgren and Karin Lexén

The theme for Stockholm World Water Week 2014, – Energy and Water – is a logical next step from the previous themes "Water and Food Security" (2012) and "Water Cooperation" (2013): water is a critical resource for development, and the water community needs to connect with make the connection to vital water-dependent societal sectors of society in order to properly manage this resource. We need to do that by interacting actively with the food security and energy communities, rather than by talking about them. This also implies that the Week will continue to address the "water, energy and food security nexus" as an important topic, and attempt to actively include stakeholders from the food security and energy communities in the Week.

The flow of the Weeks will continue towards the theme "water for development" in 2015, the year when the global community will adopt a set of Sustainable Development Goals (SDGs) for the Post-2015 development agenda and negotiate a new climate change agreement at COP21 in Paris.

2014 World Water Week in Stockholm takes place a few weeks before the UN General Assembly begins negotiating the SDGs, and a few weeks after the UN Open Working Group published its report with recommendations for SDGs.

Looking at the current discussions among member countries and institutions, and within the private sector, we have come a long way since the outcome document of Rio+20 in 2012, "The Future We Want". The document failed to recognise water in the energy chapter and energy in the water chapter. Since then, the connection is increasingly addressed and discussed. However, in the formulation of the SDGs, it remains a challenge to make the connection clearly and forcefully.

Why is it important? An estimated 1.3 billion people lack access to electricity, some 800 million get their water from unimproved sources and over 800 million are undernourished, largely the same underprivileged poor. If we are to reduce poverty and human indignity, if we are to achieve sustainable economic development through "green growth", we need to establish this vital connection. In Stockholm, we try to contribute to this endeavor by bringing together key stakeholders from a wide spectrum of professions in academia, civil society and the private sector , this year with particular focus on the "water and energy" link. Our success depends on making the Week attractive to both our traditional water constituency, and to participants from the energy and other communities.

There is considerable interdependency between the energy and water sectors in all societies. However, we find huge institutional, technical and economic asymmetries between the two sectors. To a large extent, the energy sector is market based and run by private, often big companies acting on global, regional or national markets. The water sector, on the other hand, is dominated by small public utilities acting on regulated markets at the local municipal level. Energy efficiency is a driving force for development in the energy sector. We use less and less energy per unit produced although even greater efficiency is warranted if we want to stave off the climate change challenges ahead. Water, on the contrary, is largely characterised by inefficient use or overuse, even if changes are starting to take place. Incentives for technical advancements are insufficient. Energy makes up a major part of the production costs in the manufacturing industry while water does not. Energy is priced on the market and there is a high awareness about energy prices among customers. In the water sector, marginal cost pricing or cost-recovery pricing is common, and there is a low customer awareness of water prices.

No one can remain in doubt about the enormity of the challenge facing us, and the need to connect our communities: it takes large amounts of energy to pump and treat water, and large amounts of water to produce energy, whether for biofuels, for extraction by e.g. fracking, or as withdrawals for cooling. If water is in short supply during droughts, energy

Photo: SXC

crises may follow. We share these challenges and must find joint solutions to them. The Thematic Scope for the Week sets the stage: we aim to address the societal opportunities for and challenges to making this connection, and do so with a range of cross-cutting issues in mind (see the Thematic Scope on page 10).

With this publication we want to raise the discussion about the energy-water connection to a new level by letting a number of key experts take on urgent issues such as renewable energy for green growth, the role of hydropower for sustainable development, the looming urban water and energy challenge, the inevitable trade-offs between carbon storage and water use, the hot issue of shale gas and the trade-offs needed between the water and energy sector etc . To conclude the report we look ahead to the importance of these issues for the Post-2015 development agenda.

In the first chapter, James Dalton and Mark Smith of the International Union for Conservation of Nature (IUCN) focus on water, energy and ecosystem resilience and how they are interconnected. Critically discussing Integrated Water Resources Management (IWRM) they claim that it may not be the best approach when discussing energy. Furthermore, they highlight the importance of ecosystems in the water and energy nexus which is a perspective that is sometimes forgotten in today's debate.

Kimberly Lyon and Jean-Michel Devernay of the World Bank and Jian-Hua Meng of the World Wide Fund for Nature (WWF) discuss sustainable hydropower in the context of water and energy security. The article highlights the potentially positive as well as negative aspects of hydropower development and argues for the necessity do to the right thing, i. e. maximising positive effects while holding the negative to a minimum. They note the key interlinkages between energy production, water security, environmental flows and healthy ecosystems and argue that they are all interdependent. If one fails the others will suffer. Being both a controversial topic as well as an area in need of debate – not least in light of the fact that one out of five people in the world still lack access to electricity – this is a welcome contribution to the discourse.

Fracking for shale gas is an area of intense public debate, primarily from a climate change and broader environmental perspective. Michael Oristaglio of Yale University and Andreas Lindström of Stockholm International Water Institute (SIWI) address the link between fracking and water. Fracking is a major consumer of water. Furthermore, there is a risk that fracking fluid (of which water is a major part) used in the extraction of shale gas could leak and contaminate groundwater systems. Thus, from a water perspective, it is a question of both water access and availability as well as one of water pollution. The authors describe the challenges and risks from a water perspective and note the lack of thorough scientific research in the area..

Turning to climate change, green-house gases, carbon storage and water Phillia Restiani of SIWI, Anders Malmer of the Swedish University of Agricultural Sciences (SLU) and Berty van Hensbergen of SSC Forestry discuss the need to balance trade-offs between forest, water and ecosystems in view of climate change. Showing the role that forest can play in the equation contributes to the report by highlighting the need for a holistic and integrated thinking. Silo perspectives are not an option and harmonisation of adaptation and mitigation measures are imperative. The authors conclude that since people make decisions on how to use land based on what will provide them with livelihoods, it is clear that unless the value allotted to forests increases, it is unlikely that the goal of providing livelihoods, sequestering carbon, conserving biodiversity and maintaining water services can be upheld.

Kalanithy Vairavamoorthy, Jochen Eckart, George Philippidis and Seneshaw Tsegaye of the Patel College of Global Sustainability and the University of South Florida offer yet another perspective on the issue of water and energy. They discuss the challenges in the urban setting and the need to address trade-offs between water and energy. Capturing the dynamics between water and energy in the urban setting, they argue for an integrated energy and water demand management perspective. They highlight the need to view wastewater as a resource, and the need to address water leakage in cities. These measures would save both energy and water, and the authors point to concrete steps that need to be taken.

Jens Berggren from SIWI focuses his contribution on the intimate linkages between water and energy and how the energy sector is dependent on an increasing share of the world's water. While the lion share of the freshwater use globally today is for irrigated agriculture a much larger share will be used by the energy sector. The challenges that this posits for the water and energy sectors are vast and in need of more attention.

In the final chapter, Karin Lexén and Torgny Holmgren link this year's energy and water theme to the 2015 theme on water and development. Water and energy considerations are key to the achievement of the Millennium Development Goals (MDGs) and likewise important components of the ongoing discussion on Sustainable Development Goals (SDGs). The contribution points to some of the linkages in need of attention as we move into 2015 and beyond.

In conclusion, it is clear that the articles in this volume as well as the debate and discussions to be held during the 2014 World Water Week will offer important suggestions for policy directions in the coming years. As has been highlighted in this report, the need to build strong links between the water and energy agendas are more important than ever. The cases being made in the contributions strengthen this argument as we move into intensified discussions, debates and finally decisions by the UN General Assembly on the future development agenda during 2015.

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THEMATIC SCOPE:

ENERGY AND WATER

Several years ago, in the Asia-Pacific Water Development Outlook 2007, the Prime Minister of India stated that "...if all members of society can have adequate access to energy and water, many of the societal problems can be solved". That statement is as true today as it was then. Energy and water are inextricably linked – we need "water for energy" for cooling, storage, biofuels, hydropower, fracking etc., and we need "energy for water" to pump, treat and desalinate. Without energy and water we cannot satisfy basic human needs, produce food for a rapidly growing population and achieve economic growth. And yet, today, 1.3 billion people lack access to electricity and some 800 million people get their water from unimproved sources. Many more consume water that is unsafe to drink. These are mostly the same billion poor, hungry and underprivileged human beings. Over the coming 30 years food and energy demands are expected to increase dramatically, yet we will depend on the same finite and vulnerable water resource as today for sustaining life, economic growth and our environment.

When addressing the "energy and water" theme during 2014 World Water Week in Stockholm we shall take an overall "systems view" of how we develop and manage energy and water for the good of society and ecosystems – at local, national, regional and global levels – and avoid unintended consequences of narrow sectoral approaches. The "water, energy and food security nexus", underpinning the green growth approach, will be central to the agenda.

The energy and water theme will be addressed from two overall perspectives: the societal opportunities and challenges, and the cross-cutting issues.

Societal opportunities and challenges

Demography and economy driving energy and water demands

Efficient production and use of energy and water is essential in the national context to ensure basic needs and development opportunities for people. However, both energy and water transcend national boundaries, physically through transboundary waters and power grids, and economically through regional economic cooperation. Cooperation between nations increasingly focuses on sharing benefits, rather than water per se, with both food and energy as the primary, water-dependent goods to share. At the global level recurrent crises – energy, food, financial – illustrate systemic inter-dependence. Developing countries have serious challenges in achieving the Millennium Development Goals (MDGs) by 2015, and the close water, energy, and food interconnections need to be considered in formulating Sustainable Development Goals (SDGs) to follow the MDGs from 2015.

> *"…if all members of society can have adequate access to energy and water, many of the societal problems can be solved"*

Balancing societal uses of energy and water

Energy and water are critical factors in urban development. Rapidly growing cities depend on reliable energy and water supply, but must try to reduce demands, manage trade-offs and optimise resource use by reuse, recycling and generation of energy from waste, all in an integrated urban management context. For industrial development improved efficiency in the use, and reuse, of energy and water is essential to save on increasingly scarce resources and costs, for both production and waste management. An added driver is to strengthen corporate social and environmental responsibility through sustainable production. Research, innovation and technology development for improved energy and water efficiency are essential for such efforts. The energy-water linkage is not only about quantity, but also about water quality and pollution, related to pollutant discharge, to significant quantities of heated cooling water affecting surface waters, or to potential groundwater pollution due to energy-related geo-engineering activities, including fracking.

Energy and water in a vulnerable and changing environment

Sharply accelerating demands for food and energy production place increasing pressure on the availability of water for vulnerable ecosystems and the biodiversity and human livelihoods they sustain. Energy production, be it hydropower development, biofuel production, shale gas exploitation or other forms of energy production, may have serious environmental and social consequences that need to be properly assessed and addressed. Climate change may affect the water system through increased variability, long term temperature and water balance changes and sea level rise, and is in many cases an added driver to be considered. Climate adaptation is primarily about water and land, but water resources are also critical for climate change mitigation, as many efforts to reduce carbon emissions rely on water availability. Because the water cycle is so sensitive to climate change, and because water is so vital to energy generation and carbon storage, we need to recognise the coherence between mitigation and adaptation measures. In ensuring this, and managing variability and environmental flow requirements, storage of both energy and water becomes a critical issue, including water as a medium for storing energy. Storage may be required at all levels, from the household and village levels to major infrastructure in transboundary settings, not least in developing countries. Such storage may be provided through investments in conventional infrastructure and/or in the restoration and management of natural systems.

CONTINUED: THEMATIC SCOPE: **ENERGY AND WATER**

Cross-cutting issues

Coordinating energy and water policies and governance

Unintended consequences of energy development for water, and vice versa, often have their roots in fragmented policies, e.g. energy subsidies in some parts of the world contributing to unsustainable groundwater overdraft through excessive pumping. The energy and water worlds seem to be divided between those who focus on technical solutions, and those who assume that the challenge is rather one of politics and governance. In taking a "systems view" energy and water policies need to be coordinated. In developing effective energy and water governance different characteristics and traditions prevail: while energy production most often is centrally managed, good water governance needs to include local, de-centralised planning and management in dialogue with affected stakeholders. For both, top-down needs to meet bottom-up governance. As evident when addressing the water, energy and food security linkages, real engagement of actors from other sectors is a pre-condition for success. For water the implementation of the Integrated Water Resources Management (IWRM) approach includes energy, but its role has not been sufficiently examined. In the energy sector policy choices, whether conventional or alternative, must depend on water resources availability and vulnerability. Both require stakeholder involvement in the entire chain from resource exploitation through regulation to consumption, including consideration of both energy and water in the food chain from "field to fork". Poor and vulnerable stakeholders in developing countries require special attention, as does improved gender equality and youth participation.

Addressing the economic and financial aspects of water and energy

The economic value of energy varies in a changing market and may be difficult to assess for long term investments. For water, assessments of economic value must accommodate the fact that water is a public and social good, and access to safe drinking water has been declared a human right by the United Nations. At the same time, assessment of costs and benefits for different water uses needs to address gaps in knowledge of values linked to biodiversity and ecosystem services. However, when addressing benefit sharing, and likely energy and water markets, not least across boundaries, acceptable and reliable estimates are required. When it comes to financing and pricing the situation is equally complicated, due to the asymmetry, volatility and inter-linkages of energy and water prices, with energy mainly being priced on the market and water as a public good. Understanding of these inter-linkages, and their economic and financial implications, are necessary for both public and private decision-makers.

Developing information and decision support systems for energy and water

Access to, and sharing of data and information, not least across jurisdictions and boundaries, is in itself a major challenge for water resources management. In transboundary settings it is often considered an issue of national security. The data and information challenge does not become easier when energy and water is combined. However, assessment of the inter-linkages and trade-offs for water from energy development, and vice versa, is strengthened greatly by an environment of dialogue, trust and full sharing of data and information between decision-makers and affected stakeholders, both public and private. It must also be flexible and adjustable to rapid change. Energy and water data and information may be made more accessible through mobile technologies. The complexity of decisions on energy and water development often calls for combined energy-water modeling as a basis for developing integrated decision support systems. In both sectors advanced models have been developed, and efforts to further combine and apply integrated energy and water modeling systems are underway. Such developments include hydro- and energy economics, ecological and hydrological effects, social criteria and economic tools to quantify trade-offs.

Bridging the science-policy-people interface for energy and water

In the final declaration "The Future We Want" from world leaders at the Rio+20 Summit in 2012 the chapter on energy contained no reference to water, and the water chapter did not mention energy. Clearly, whilst a lot of information about the water-energy linkages has been developed, awareness and knowledge have not transcended sectoral boundaries at the administrative and political levels. The science-policy-people dialogue on energy and water needs to be improved based on increased "energy and water literacy" and a genuine effort to communicate advances in science and good practice, as well as innovation in technology and management, to our political decision-makers. Meanwhile, political decision-makers need to set the agenda and framework for the science and technology to become policy relevant. In the developing countries in particular such efforts need to be associated with efforts to develop capacity at all levels to address these inter-linkages.

Chapter 1

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Water and Energy: A Necessary Evolution from Dialogue to Partnership?

By James Dalton and Mark Smith, IUCN

Introduction

Eleven years ago the World Bank, in their 2003 Water Resources Sector Strategy, highlighted the nature of water flowing through the economy and the need for a cross-sectoral perspective in managing water (World Bank, 2004). In a more recent document, the Bank highlights that "... except for systems dominated by hydropower, the supply of water necessary for power generation is typically assumed to exist and is often not considered to be a limiting factor in operation"' (Rodriguez *et al.*, 2013). It is from these assumptions that water management challenges often arise. With effective coordination and collaboration between sectors, however, resolutions to such challenges should, in principle, be achieved. The key questions are: why are there disconnections between water resources management and water needs for energy production? How can these be overcome?

The case for water-energy coordination

Energy generation requires water in large volumes. This is clear for hydropower, where water is the fuel for energy generation. Beyond hydropower, large amounts of water are required for cooling thermal power plants, which generate 75 per cent of global electricity supply (IEA, 2012). Conventional thermal plants account for 43 per cent and 39 per cent respectively of total annual freshwater withdrawals in Europe and the US (Rodriguez *et al.*, 2013). In the UK, predictions to 2030 suggest that water risks and environmental impacts will constrain electricity production (Byers *et al.*, 2014). The impact of water shortages on the Australian National Electricity Market in 2007 saw generation capacity reduced and a three-fold increase in the wholesale price for electricity (Hussey and Pittock, 2012). Whether recognised or not, energy companies play an important role in water management.

Looking forward, procurement of water by the energy sector – as either a "fuel" or a "coolant" – will rise as energy production expands in response to increasing demand for electricity (Dalton *et al.*, 2014). This trend is emerging as water management turns increasingly to strategies for demand management - strategies that will hopefully ease competition among sectors and allow for more optimal water allocation. For energy companies to succeed in procuring the water they need, workable mechanisms for them to join these efforts must be found. Energy and water needs can be addressed alongside growth in water use by industry, in irrigation to meet food security priorities, coping with inefficiencies in water usage systems, combined with climate change impacts (Dalton *et al.*, 2014).

Challenges to water managers' expectations

Energy system developments provide benefits *beyond the river*[1](Sadoff and Grey, 2002), driven by electricity needs and commercial opportunities at national and regional scales, increasingly through "power pools" (World Bank, 2008). The Brazilian Ministry of Energy, for example, intends to expand hydropower in the Amazon basin (MME, 2007) mainly to serve users in other regions of the country, outside of the basin. Thailand is backing development of water resources in Lao PDR to fuel industrial growth and development at home in Thailand – a strategy with the added effect of externalising any environmental and social concerns (Matthews, 2012) – in response partly to historical civil society opposition to "home grown" hydropower (Hirsch, 1995).

Could it be argued that for the energy sector the basin is irrelevant, or at least subordinated to priorities at national level (Dalton *et al.*, 2014)? For electricity provided across borders, wider economic growth and development corridors are critical drivers, with regional opportunities shaping investments. In the Mekong region, some argue that this focus on wider economic growth marginalises the role that the Mekong River Commission (MRC) plays in transboundary water governance (Suhardiman *et al.*, 2012). Indeed, this may be fuelling calls – made predominantly from a water perspective – to expand the mandate of the MRC to include energy and food security issues to better manage the challenges of the water-energy-food nexus (Bach, *et al.*, 2012).

The concept of Integrated Water Resources Management (IWRM) is based on the premise that the basin is the management unit for water. If the energy sector is disengaged from the basin, the development of river basins will at times (or in places) remain disconnected from the economic distribution of the full benefits – for example electricity – that river basins can provide (Dalton, *et al.*, 2014). IWRM has, perhaps as a result, struggled to gain recognition beyond the water sector (World Bank, 2010). While water managers believe that a *water-centric* approach brings cross-sectoral benefits, other sectors are less convinced. Practically, water managers may then be left out of water requirement assessments by other sectors. It is not always clear, therefore, whether water management that is integrated – under the name IWRM or otherwise – can successfully reconcile sectoral demands.

The nexus of incoherence

Greater realisation and connection of cross-sectoral challenges and opportunities has developed since the 2003 World Bank Strategy through the reframing of water resource management challenges predominantly as the water-energy-food nexus (see Hoff, 2011). Alongside this, recognition has emerged of the role that river basins and their ecosystems play in the nexus as natural infrastructure (Krchnak *et al.*, 2011). Recommendations from the Berlin 2013 Nexus Policy Forum made clear that '*investing in natural infrastructure is a cost-effective way of improving water, energy and food security*'. However, with the energy sector poorly aligned to river basin management, it will not likely see its own interests reflected in the case for investing in natural infrastructure. This makes it more difficult in the case of electricity to make the link between healthy ecosystems and the distribution of economic benefits related to well-managed river basins. Benefits *from, because of,* and *beyond* the river hence lack coherence with *benefits to* the river[2].

This incoherence can multiply when disconnection beyond water, energy, ecosystems and river basins are considered. Water and energy intersect with and have impacts on agriculture, forests and carbon stocks. Each in turn impacts ecosystems. And each must contend with costs from trade-offs made – implicitly or explicitly – among water and energy security and

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[1] Benefits *beyond* the river include greater trade opportunities, integrated and regional infrastructure development and investment opportunities, linked markets for agricultural produce, biodiversity and river flow benefits, regional improvements in water quality.

[2] Benefits from the river include cooperation and economic benefits from river systems that bring wider benefits than just those local to the river such as agricultural production, flood and drought management, water quality, recreation, and electricity generation. Benefits because of the river include policy change to cooperation, benefit sharing, from less self-sufficiency to more trade and security issues on food and energy supplies. Benefits to the river include improvements in water quality, river flow and ecosystem connectivity, groundwater recharge, soil conservation, biodiversity (see Sadoff and Grey, 2002).

Photo: iStock

ecosystem conservation (Sáenz and Mulligan, 2013). Clearly, information and better analytical tools will help to bring coherence to management of resources, both natural and financial. However, the greater challenge will be in getting the right people and institutions together to create ways of working jointly that suit the differing capabilities, scales of operation, mandates, and political power of each sector.

Water-energy coordination in a nexus of coherence

As King and Lafleur (2014) indicate for hydropower development in South-Eastern Africa, "divided loyalties" on the need to share regional resources and jointly invest in regionally integrated energy infrastructure, combined with the lack of information on the costs and benefits of energy integration, compound water governance challenges. The default response is to revert to the Zambezi River Watercourse Commission (ZAMCOM) as the institution to promote transboundary cooperation on water and energy – and to do so through water governance. Yet, in such contexts, the mandate or political support needed is not likely to exist in the eyes of the energy sector. Energy ministers, power companies or regional power pool operators are (usually) simply not looking at the river basin. Water governance is not the issue – but "nexus governance" may be.

Any approach to nexus governance will have to respect the mandates and institutions that exist in each sector. Constructing some new institutional architecture for nexus governance may only deepen inertia and raise the level of complication. What is required are pragmatic and flexible mechanisms that allow for cross-sector collaboration in the strategies, investment planning and operations of each sector. The better route to water-energy coordination and coherence in the nexus is likely to be the creation of platforms for collaboration where sector agencies and stakeholders can come together in developing and negotiating coordinated plans. By using the strength of sectors to implement agreed actions in projects and operations, using the mechanisms and capacities they already have in place and that are effective and accepted within the sector, better coordination and delivery for water and energy could be achieved. Incentivising the discussion is where the main challenge lies.

It can be argued that the reason why IWRM has not fully engaged with the impacts of the energy system and its demands on water has been due to a lack of joint recognition among sectors of workable means of approaching nexus governance. As a tool for improving water knowledge and allocation, IWRM has created significant and positive impact. But, to become an appropriate framework for conducting and influencing the management of water for energy needs, or other cross-sector needs, an evolution is needed in how water management that is integrated – under the name IWRM or otherwise – is organised and conducted. An approach to nexus governance that better respects the mandates and institutions of each sector could reinvigorate IWRM and increase social and economic benefits achieved from water management. IWRM could then succeed in connecting water management to the wider national and regional economic benefits that drive energy investments. The case would be made for energy companies to have a greater role, and with it responsibility, in becoming water managers.

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Chapter 2

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The Growing Thirst for Energy: Is Shale Gas Part of the Solution, or Part of the Problem?

By Andreas Lindström, SIWI and Michael Oristaglio, Yale University

Introduction

Global demand for energy will increase rapidly in the coming decades. Projections show that the world will continue to be energised by fossil fuels – coal, oil and natural gas – to an overwhelming degree (IEA, 2013). Natural gas shows the fastest relative growth among them (World Energy Outlook, 2012 and 2013). Part of the reason is the increased accessibility of so-called "unconventional fossil fuels" for the global energy mix, spearheaded by shale gas, natural gas found in tight shale formations. Large quantities located around the world, combined with advanced, efficient extraction methods, makes shale gas a comparably cheap and competitive fuel.

However, with the rapid expansion of shale-gas production come concerns – not least in connection with climate and environmental impacts. Shale gas emits less CO_2 per unit of energy than other fossil fuels during combustion, but the science of its short- and medium-term contributions to climate change is still debated. Can shale gas be part of a solution or is it part of the problem?

As the world is facing a growing water crisis, where demand may outstrip supply on an aggregated global level within decades, competition for water is increasing. Water is a key component in almost all energy-generating processes, in fuel as well as in power production. Disputes over water as a consequence of increased use for energy are becoming more evident in many regions, especially those suffering from water scarcity. Shale gas is released by a process called hydraulic fracturing ("fracking") that requires large amounts of water. Thousands of cubic meters are consumed in completing a typical shale gas well. There is also a risk that fracking could lead to contamination of freshwater sources near drilling sites. Frack fluids containing chemicals can leak if not properly handled, and natural gas poses a risk too if the well is not adequately sealed. Either form of contamination may threaten ecosystems and human health.

Environmental risks of shale gas through hydraulic fracturing – possible impacts on water resources

If leakage rates are not controlled and if shale gas leads to a longer dominance of fossil fuels during the 21st century, increased climate change will add to the world's water crisis. Droughts, floods and altered run-off patterns are all water related impacts from climate change and often constitute the most acute and direct consequence of a changing climate.

Water is the main component, 95 per cent, of the fluid used in hydraulic fracturing. Most of the remaining 5 per cent is sand, or other "proppants" used to hold open the fractures that are initiated by high pressure injection of water in the rock. The tiny propped-open fractures form the pathway for natural gas to flow from the otherwise impermeable shale to the well.

A variety of other chemicals, including biocides, gelling agents, scale inhibitors and lubricants, generally make up less than 0.1 per cent of the frack fluid. But the absolute amount of water used, literally tens of millions of litres for a single well, means that large quantities of these often toxic chemicals must be transported and handled at the drilling site.

The lack of a comprehensive standard in defining water use in fracking makes precise estimates of total water consumption from shale gas production difficult. A 2011 report by the US Environmental Protection Agency (EPA) estimated that shale gas operations would consume as much as 530 million m3 of water in the nation annually (EPA, 2011). Although this amount is small compared to water used in agriculture and electricity production – generally the two largest uses of water in any region of the US – the huge increase in shale gas production risks heightening competition for water in water stressed regions (Galbraith, 2013).

Many questions about the hundreds of different chemicals that may be used in fracking fluids need to be answered. What happens if these chemicals leak into the environment and come in contact with plants, animals or humans? What is the likelihood that these chemicals penetrate to surrounding ecosystems?

A separate concern is disposal of the wastewater that flows back to the surface after the frack job is completed; this water contains both the original chemical from the frack fluid itself plus other minerals leached from the shale formation, including naturally occurring low-level radioactive materials. Many of the known environmental problems associated with shale gas operations have been caused by improper disposal of wastewater.

Recent studies have found that some additives in the fracking process can be classified as hormone disrupting chemicals that can harm growth, reproductive functions and metabolism with possible further links to birth defects and cancer in humans (Kassotis *et al.*, 2013).

There are considerable risks of surface contamination by fracking fluids during transportation to and handling at drilling sites. Although these risks are similar to those for other toxic chemicals transported and used in manufacturing processes, the large volumes and rapid growth of shale gas activity in rural locations pose a new set of challenges, requiring strict oversight. The extent to which the fracking process itself leads to direct contamination of groundwater is a subject of intense study. The actual process of hydraulic fracturing takes place in shale gas formations that are often located several kilometers underground, separated from groundwater supplies by thick layers of impermeable rock.

Nevertheless, a study by Duke University of water wells in Pennsylvania showed evidence of higher than average methane concentrations in water wells close to active shale gas drilling sites of the Marcellus Shale in the Eastern US (Osborn *et al.*, 2011).

The methane found in the water wells had an isotropic composition similar to that of gas from the Marcellus. A similar study by the same authors, however, found no methane contamination in water wells above the Fayetteville Shale, the large shale gas play in Arkansas (Warner *et al.*, 2013) (Vengosh *et al.*, 2013) The authors concluded that a different history of drilling in the two regions, going back to the start of the oil age in Pennsylvania in the 1860s, and very different near-surface geology and hydrology might account for the different findings. Neither study found evidence of contamination of water wells by frack-fluid chemicals.

Shale gas and climate change – An uncertain future

Natural gas is the cleanest burning fossil fuel. Compared to combustion of coal, combustion of natural gas (methane, CH_4) produces about half the carbon dioxide, one fifth the nitrogen oxide, and less than one thousandth the sulphur dioxide per unit of energy released. Nitrogen and sulphur oxides are leading causes of atmospheric pollution in the form of smog and acid rain. Natural gas combustion produces essentially no mercury and few particulates, two other byproducts of coal combustion that are especially harmful to human health. Furthermore, combined cycle natural gas fired power plants have a thermal efficiency of 50 to 60 per cent, much higher than the average efficiency rate of coal plants. Lower

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raw emissions combined with higher efficiency mean that electricity from natural gas can have roughly one third the carbon footprint of electricity from coal.

For direct emissions, then, replacing coal with natural gas is by many viewed as an environmental good. The shale gas revolution has increased both the size and geographic distribution of known reserves of natural gas and, at least in the United States, has kept prices at a level that competes with coal for electric power generation. One result of fuel substitution by electric utilities is that US carbon dioxide emissions returned to 1994 levels in 2012, a decrease of nearly 12 per cent from the peak in 2007. Emissions are estimated to decrease by at least another 7.5 per cent by the end of the decade (US Climate Action Report 2014).

Still, the question remains hotly debated, is shale gas a better choice than other fossil fuels for dealing with climate change? A recent article by Harvard earth scientist Daniel Schrag summarises the controversy, which hinges on estimates of natural gas leakage to the atmosphere during its extraction from shale reservoirs by fracking, and the extent to which this leaked methane, itself a potent greenhouse gas, offsets reduced carbon dioxide emissions. Inadvertent leakage during production or transportation of natural gas is often referred to as fugitive emissions.

Starting in 2011, a series of papers by Cornell ecologist Robert Howarth and colleagues highlighted the problem with a total lifecycle accounting of greenhouse gas emissions for shale gas. In their first paper (Howarth *et al.*, 2011), the authors estimated that the standard practices and well completions used in high volume hydraulic fracturing could result, through venting and leaks, in 4 to 8 per cent of production escaping to the atmosphere over the lifetime of a typical shale gas well. This estimate was at least a third higher than the leakage rates of 2 to 6 per cent estimated for conventional natural gas reservoirs by US EPA. (Both figures include estimates of leakage from transportation in pipelines, which applies equally to conventional and shale gas reservoirs.)

Is the higher leakage from shale gas production (if correct) important for climate change? There is unfortunately no single figure of merit to conclusively answer this question. The standard definition of global warming potential (GWP) adopted by the Intergovernmental Panel on Climate Change compares the mean global forcing of temperature caused by a given amount of a gas (by weight) in the atmosphere to the forcing caused by the same amount of carbon dioxide, integrated over a specified time period. The standard time period used to compare different gases is 100 years. By this 100-year standard, methane in the atmosphere has a warming potential per kilogram 20 times higher than carbon dioxide. Integrated over a 500-year period, the global warming potential of methane falls to a GWP of about 8; over a 20-year period, it rises to a GWP of about 70. To compare shale gas with coal, Howarth and his colleagues used time periods of 100 years and 20 years, and concluded that, with leakage rates of 4 to 8 per cent, shale gas has at least a 20 per cent higher carbon footprint than coal over 20 years and is comparable to coal over 100 years.

Both legs of the original argument have been fiercely challenged. First, and most important, the controversy led to actual measurements of leakage at natural gas production sites in the United States. A large study by the University of Texas at Austin measured methane at 150 production sites and found an average leakage of 0.42 per cent of gross gas production, about ten times below the lower limit used by Howarth and colleagues (Allen *et al.*, 2013). Although encouraging, this figure itself is based on a small sampling of the tens of thousands of shale gas wells drilled in the US since 1990 (about 17,000 in the Texas Barnett Shale alone), and is likely to see further revision with more field studies. It does show, however, that leakage is controllable with modern production practices and that high rates are not an inherent feature of shale gas wells.

The practical implications of man-made greenhouse gases in the atmosphere are also subject of discussion. Model studies suggest that climate policy ought to be more concerned with cumulative emissions over the next hundred years than with emission rates over the next few decades (Allen *et al.*, 2009). Assuming that carbon dioxide emissions can eventually be reduced to (near) zero by the end of the century, the models show that it is the cumulative amount of greenhouse gases released into the atmosphere during the 21st century that is likely to determine the peak of man-made global warming. The size of the peak and its duration is not sensitive to any particular trajectory of emissions, only to the total amount. Under this scenario, as Schrag points out, the benefits for climate change if coal is replaced by natural gas – thereby reducing CO_2 emissions in the short term – are only realised in the long term if natural gas consumption itself declines relatively quickly after replacing coal, so that “clean natural gas” really does become a transition fuel to renewable and low carbon energy sources within the next fifty years.

Conclusions

Along with greater use of shale gas come risks of possible climate effects, as well as possible environmental and health impacts caused by the process of fracking.

Research suggests that shale gas might provide a bridge towards increased utilisation of renewable energy by phasing out more carbon intensive fossil fuels in the short term and by helping to turn current climate trends with their impacts on water resources. For this scenario to play out, however, incentives and mechanisms must be in place to enable the necessary expansion of renewable energy. In fact, an opposite scenario is plausible where natural gas expansion crowds out investment in renewable energy over the short term and leads to a longer term reliance on fossil fuels.

The need for more research and for strict regulatory oversight is evident. There are genuine risks posed to freshwater resources, ecosystems and human health in shale gas extraction.

Measures, already identified, that can limit negative impacts from shale gas extraction and utilisation need to be fully implemented. This means using best available practices in operations, along with continuous monitoring, impact assessment and mitigation, to avoid long term negative consequences of continued reliance on fossil fuels. Strict regulations and legislation are needed to protect air, water and land resources from new hazards of extractive processes. Strong incentives to seek other options should also be firmly in place.

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Chapter 3


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Sustainable Hydropower in the Context of Water and Energy Security

By Jian-hua Meng, WWF, Jean-Michel Devernay and Kimberly Lyon, World Bank

Introduction

Hydropower is a proven technology, capable of supplying renewable electricity at scale. It is a key component in a future global, low-carbon energy mix. It can deliver broad benefits when done sustainably: the right projects in the right places, avoiding, minimising and mitigating adverse impacts, sharing benefits and respecting societal and environmental rights and values. If done badly, hydropower projects can have significant negative impacts. The priority, therefore, must be to do it right.

Over the last fifteen years, many stakeholders have come together to improve hydropower's sustainability performance, including through the Hydropower Sustainability Assessment Protocol.

Hydropower's role in addressing poverty and climate change adaptation

Globally, one in five people lacks access to electricity. Providing electricity access to these 1.3 billion is paramount to reducing poverty, driving economic development, and improving social equality (SE4A, 2013).

The global community recognises the role of energy security in development, and under the initiative Sustainable Energy for All (SE4A), has set ambitious targets, including universal access to modern energy services and doubling the share of renewable sources in the energy mix by 2030 (SE4A, 2013). Hydropower will be an essential component in achieving these objectives; while wind, solar and other technologies are scaling up significantly and becoming increasingly cost-competitive, hydropower will remain a major and complementary source of renewable power.

Well-placed, well-designed and well-managed projects have very long lifetimes, low levelised costs[1] of electricity generation, and offer a diverse range of benefits beyond electricity. Even though hydropower technology can be deployed at virtually any scale, it is increasingly recognised that with a growing and urbanising population, decentralised systems alone will be insufficient to meet global energy access goals or the demands of growing economies.

Around the world, the poorest and most vulnerable are among those expected to be hardest hit by climate change. One of the greatest areas of concern is reduced water security, especially in Sub-Saharan Africa, where lack of investment in water-related infrastructure and highly seasonal water availability prevails (World Bank, 2013). An opportunity exists, through responsible hydropower development, to improve both water and energy security for the people in many of these countries.

Taking advantage of such opportunities, however, requires the full appreciation of the various environmental and societal risks, costs and benefits of each

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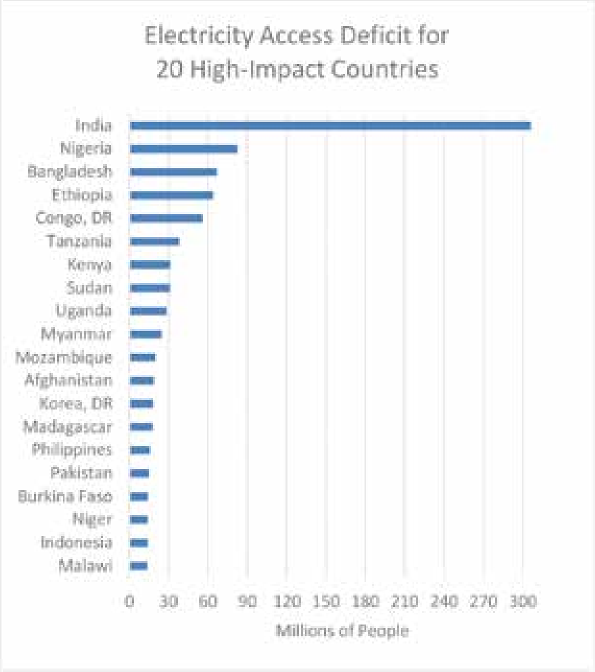
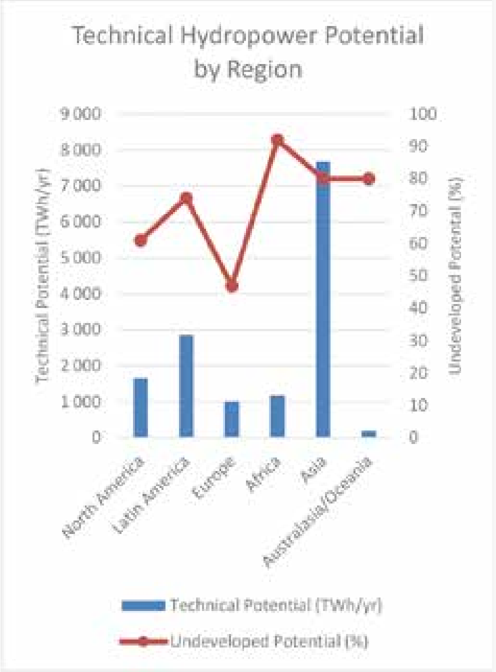
[1] Levelised costs refer to the constant cost per kilowatthour of plant building and operating and electricity generating over a the lifetime of the investment.

Figure 1



Source: Banerjee *et al.*, 2013

Figure 2



Adapted from: Kumar *et al.*, 2011

project. It should be understood that a region's technical hydropower potential (as displayed in figure 2) can only indicate the mere availability of technical hydropower development options, whereas the economically, socially and environmentally feasible potential will be lower. The performance of hydropower projects will also be affected by increased hydrological uncertainty from climate change. All these issues need to be appropriately considered before decisions are taken.

International waterways may pose specific challenges, including tensions between riparian countries which may have different water needs (e.g. hydropower and irrigation) at different times of the year. That is the case, for instance, in the Nile basin or the Amu Darya basin. Food security is linked as well, may it be by muliti-purpose projects with irrigation opportunities, or through potential impacts on fisheries, which is currently a concern for the world's largest freshwater fishery in the lower Mekong. The risk for delta recession and saltwater intrusion need also be considered. Overcoming those challenges requires rigorous assessment and a collaborative approach for minimising potential adverse impacts and equitably sharing the benefits from the creation of a reservoir.

Regional aspects: opportunities for grid integration and transboundary cooperation

Cooperation in a transboundary river basin, while complex, offers an opportunity for constructive dialogue among riparian countries on the common challenges they face.

Efforts to manage energy and water resources for hydropower at the regional scale is underway all over the developing world – from the Mekong to the Nile Basin to Central Asia – and progress is, perhaps, most easily seen in Africa. The Zambezi River Authority, jointly owned by the governments of Zambia and Zimbabwe, is one such example. It is charged with managing the Kariba Dam Complex and investigating new dam sites on the Zambezi River (ECA, 2009). These two countries join the remaining Zambezi riparians and other countries in southern Africa to form the Southern African Power Pool (SAPP), an ambitious, long-term regional engagement towards collective gains. A priority of the SAPP is to strengthen the central transmission grid to enable the hydropower resources in the northern countries to reach the load centers in South Africa (ECA, 2009). Power trading, with hydropower at its foundation, once common only in Europe and North America, is advancing in West Africa, Eastern Africa and South-East Europe.

Economics of hydropower

Reliable and competitively priced energy is critical for job creation and income generation. Hydropower is just one type of technology, but under certain conditions, it is uniquely suited to provide a range of benefits beyond electricity generation. Depending on their location, design and operation, storage projects with reservoirs offer the possibility of carrying over water from wet to dry seasons and can serve numerous other purposes, such as supplying water for municipalities or irrigated agriculture, contributing to flood protection for downstream areas, and supporting navigation and recreation. They can also provide regulating services to the electricity grid and help expansion of other, more variable, renewable technologies.

In some instances, the indirect benefits of dams can be very significant. In India, the Bhakra Dam, completed in 1963, enabled Punjab and Haryana to achieve 100 per cent electrification and facilitated a significant expansion in irrigated area. The resulting food grain surplus benefitted many urban poor and bolstered the agricultural sector, supporting jobs and higher incomes for migrant workers from regions far away from the location of the dam (Bhatia *et al.*, 2008).

Despite the potential transformative impact on the macro economy, benefits from large-scale hydropower projects do not automatically reach affected communities, who bear a significant portion of the social cost of such projects. As such, it is important to ensure that affected communities benefit in a systematic way over the long term and that these benefits are not eroded by corruption and lack of accountability. Some examples of benefit-sharing mechanisms include revenue sharing, preferential electricity rates, community development funds, and payments for ecosystem services (Wang, 2012).

Benefits to local people and the wider economy can also be undermined by delayed project implementation. In the case of the Bujagali Hydropower Project, which was initiated in 1999 with many subsequent miss-starts, it was estimated that each month beyond the original commissioning date cost Uganda about USD $6 million (AfDB, 2008) with blackouts occurring 12 hours per day on average. Now that Bujagali's five turbines are online, blackouts have been virtually eliminated, and a reliable supply of electricity has allowed schools, universities, and hospitals to offer better services such as night classes and diagnostic tests.

Sound project identification and preparation, including conducting proper assessments, earning public support and setting up a robust financing structure, can go a long way towards mitigating the risks of implementation delays, cost overruns and construction schedule slippages. In many cases, mobilising the private sector's financial resources and industrial know-how through public-private partnerships can be instrumental for hydropower development, provided an effective governance system is in place and the host country's long term interests are secured. In these partnerships, the government and private sector are jointly responsible for the development of the project, and experience has shown that a successful public-private partnership hinges upon strong government counterparts with the capacity to monitor and regulate aspects of the project.

Intact freshwater ecosystems as the basis of water security

Assessment of the viability of a hydropower project depends not only on the direct costs and returns but also on its impact on the services provided by nature. Intact freshwater ecosystems provide some of the largest ecosystem contributions to biodiversity and human welfare through provision of natural capital and ecosystem services, including commercially valuable fisheries. (Millennium Ecosystem Assessment, 2003; and TEEB, 2013). For these reasons, healthy and resilient rivers are of critical importance.

It is the rivers' flows that deliver these functions (Brisbane Declaration, 2007).

Hydropower, like almost all energy production, relies on the quantity, quality and timing of available freshwater. This water is provided by the natural hydrological cycle and is delivered by the rivers' flows. Through the manifold natural processes, which occur in healthy watersheds, floodplains, wetlands and rivers, the provisioning, regulating and supporting services for energy production are provided.

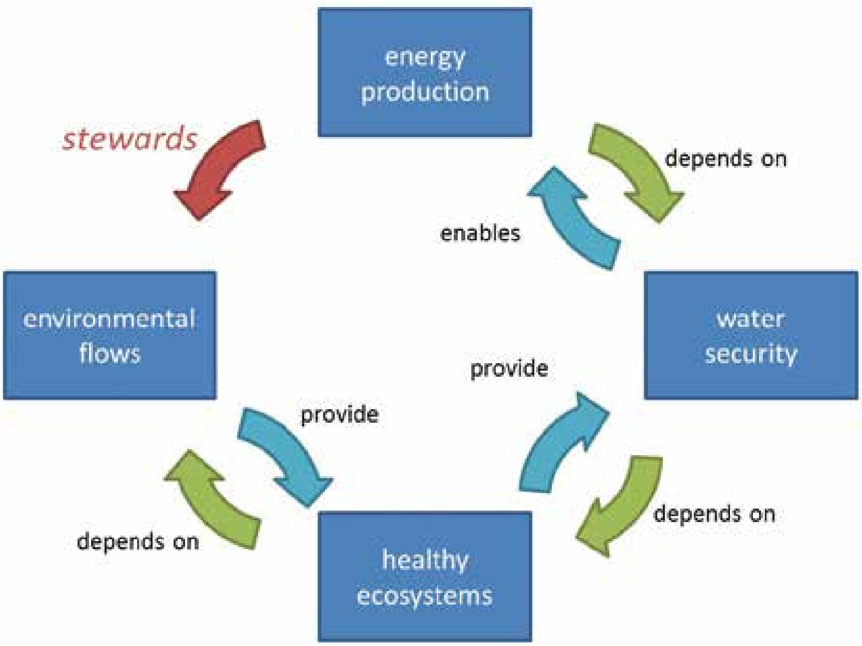
Hence, it becomes clear that the river's flows – often referred to as environmental or downstream flows – are a crucial asset, which when protected and/or restored bring enormous returns and benefits to societies, economies, and back to the environment.

As hydropower owners and operators depend on the hydrological resource, they increasingly recognise the reciprocal relationships of water security, energy production and ecosystem integrity (figure 3) and that it is in their self-interest to secure and maintain the river system's ability to provide water services. Thus, considerations of river flow, including sediment, for environmental integrity are an integral part of hydropower's sustainability performance (Hydro-power Sustainability Assessment Protocol, 2010).

Avoiding, assessing and mitigating the long term environmental and economic risks associated with reservoir sedimentation is an essential component of hydropower sustainability. A high sediment load may impact the life of the reservoir and the electro-mechanical components of a hydropower facility. Trapping sediment in a reservoir can also cause erosion and river bed incision downstream of the dam and reduce the amount of sediment and nutrients valuable for river deltas.

Open-eyed decision-making: planning at the appropriate scale and appropriate processes and tools
Hydropower development always involves trade-offs; there is no infrastructure project that is completely free of negative impacts, thus, the focus should be on projects where the benefits very clearly outweigh the overall costs. Since the financial, social and environmental costs – internal and external – associated with a dam or a series of dams in a river basin are strongly determined by site designation, the developers should consider a range of siting and

Figure 3. The Reciprocal Relationship between Environmental Stewardship and Ecosystem Services



design alternatives before selecting the one that offers the best benefit-cost outcome.

In determining the environmental costs, the location of the project within the river basin and its impact on the connectivity of the ecosystem is of key importance. Overall impacts and the possibility for mitigation are largely determined and limited by the siting decision; mitigation measures cannot fully compensate for a poor choice of location. By avoidance of sites that would affect valuable conservation assets , it is possible for a dam developer and operator to reduce their impacts and thereby gain broader acceptance and avoid high mitigation costs and project risks. Methods for the timely identification of high-value freshwater and terrestrial conservation assets are increasingly available.

There are no hard rules about what ecologically constitutes the least damaging site for a dam, and the level of damage also depends on the presence and management of other infrastructure in the basin.

However, some general rules can be formulated:

- Often, a few (maybe large), well-operated dams do less damage than multiple (sometimes hundreds) small dams scattered all over the basin.

- A sound mix of heavily utilised, single tributaries and remaining free-flowing river sections may balance the trade-offs between energy production requirements and conservation needs.

- The best solution, from an environmental perspective, is likely to include an undammed main stem connected with a number of the most valuable tributaries.

- In already impacted basins, refurbishment and modernisation of existing dams and hydropower stations can increase their lifetimes and improve their performance, thus reducing the need to extend infrastructure into the untouched parts of the basin. It also often constitutes an opportunity for rectifying social and environmental problems associated with the original design and/or operation mode.

Ideally, identification and prioritisation of conservation-value areas feed into basin-wide schemes that rank areas according to their conservation value and protect the most valuable ones as “no-go areas”. At the same time, other parts of a basin may be slated for development with appropriate impact management, consisting of the hierarchical approach to i) avoid impacts, ii) minimize those impacts that cannot be reasonably avoided, iii) mitigate those that cannot be avoided or minimised, and only then iv) compensate for the remaining impacts. This is a principle underpinning hydropower sustainability (Hydropower Sustainability Assessment Protocol, 2010), and a prerequisite to guiding the sustainable development and human use of rivers whilst protecting important natural assets.

From this perspective, all basin decision-makers and stakeholders actually share the objective determining which rivers or river stretches need to be kept free-flowing, and which may be developed for sustainable utilisation (WWF, 2011). The Hydropower Sustainability Assessment Protocol is a widely accepted tool to measure, and thus improve, a hydropower project’s performance. The Rapid basin-wide Sustainability Assessment Tool (RSAT) is a flexible, multi-stakeholder dialogue and participatory assessment tool to consider hydropower sustainability issues in a basin-wide context. With the RSAT, a river basin can be assessed at any point in time with multiple projects and at different stages of development.

The application of tools such as the RSAT can assist in identifying development strategies, institutional responses, and management measures that can be employed to broaden the benefits of hydropower development and reduce the risks for investors and stakeholders. The RSAT includes a framework of topics and criteria and a range of dialogue and assessment methods to achieve this.

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Chapter 4

Photo: Klas Bengtsson, SSC AB

Forest, Water, and Carbon Storage: Creating Synergies and Balancing Trade-offs in View of Climate Change

By Phillia Restiani, SIWI, Anders Malmer, SLU and Berty van Hensbergen, SSC Forestry

Introduction

Forest ecosystems are important water users and play crucial roles for both the hydrological and carbon cycles. As water is becoming increasingly scarce and less predictable under climate change, forest's role in securing water resources and services cannot be more critical.

Forests are home to at least 100 million indigenous people, whose lives are almost entirely dependent on forests, and another 800 million rural people, who rely on forests for fuel, food or subsistence income. 350 million of them are the world's poorest people. In terms of energy supply, forests provide wood energy, the most decentralised source of renewable energy, which contributes to 9 per cent of the global total primary energy supply in 2008. Tropical forests are also habitat to more than half the species on earth, and rainforest plants provide a quarter of pharmaceutical drugs (FCPF 2013, FAO 2012).

Nevertheless, ongoing deforestation occurred at a rate of 13 million hectares per year between 2000 and 2010, contributing to 20 per cent of global greenhouse gas emissions. Forest loss and degradation were estimated to have cost the global economy – in terms of loss in natural capital – between € 1.3 trillion and 3.1 trillion a year (Sukhdev, 2010), much more than the formal cash contribution of forests to developing economies at USD 250 billion (Agrawala *et al.*, 2013).

Growing awareness of the unsustainability of an economy based on natural resource depletion has led to a new thinking toward "bioeconomy"; which is a greener economy underpinned by sustainable productions of biomass across industrial sectors [1]. Forests play a vital role in this transition to a green economy by increasing the efficiency and widespread use of wood-based energy as part of renewable energy (FAO , 2012).

Increasing demand for environmental sustainability has also placed forest industries at the forefront of innovation in making use of renewable source of energy. In developed countries, the highly energy intensive pulp and paper industry have managed to decrease their energy intensity by deriving most of their energy from wood bark and black liquor from the pulping process. Furthermore, the forest industry also provides opportunities for creating innovative wood-based products such as bioenergy, biochemicals and biomaterials (FAO, 2012). The development of these bio-based industries can eventually reduce global demand for fossil-fuel based energy in the future.

In pursuing the forest's role in a greener economy, it is important to recognise that the relationships between the wide range of forest services (water, climate, biodiversity, timber and non-timber forest products, including bioenergy and food production) are very complex and forest management for a specific benefit often impacts negatively on others. These services also differ in their sensitivity to changing environmental conditions, such as climate change impacts. Water management

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[1] For examples of references on bioeconomy, please see: http://ec.europa.eu/research/bioeconomy/policy/bioeconomy_en.htm and www.formas.se/PageFiles/5074/Strategy_Biobased_Ekonomy_hela.pdf

should be an integral part of forest management, taking into account the linkages, potential synergies and trade-offs among forest, water and carbon while pursuing specific management objectives.

An understanding of these linkages has further importance in the context of climate change as forest ecosystems are important for both adaptation and mitigation efforts. This chapter aims to raise awareness about the linkages between forests, water and carbon and how they can be integrated into more resilient forest, water, and energy governance in view of climate change.

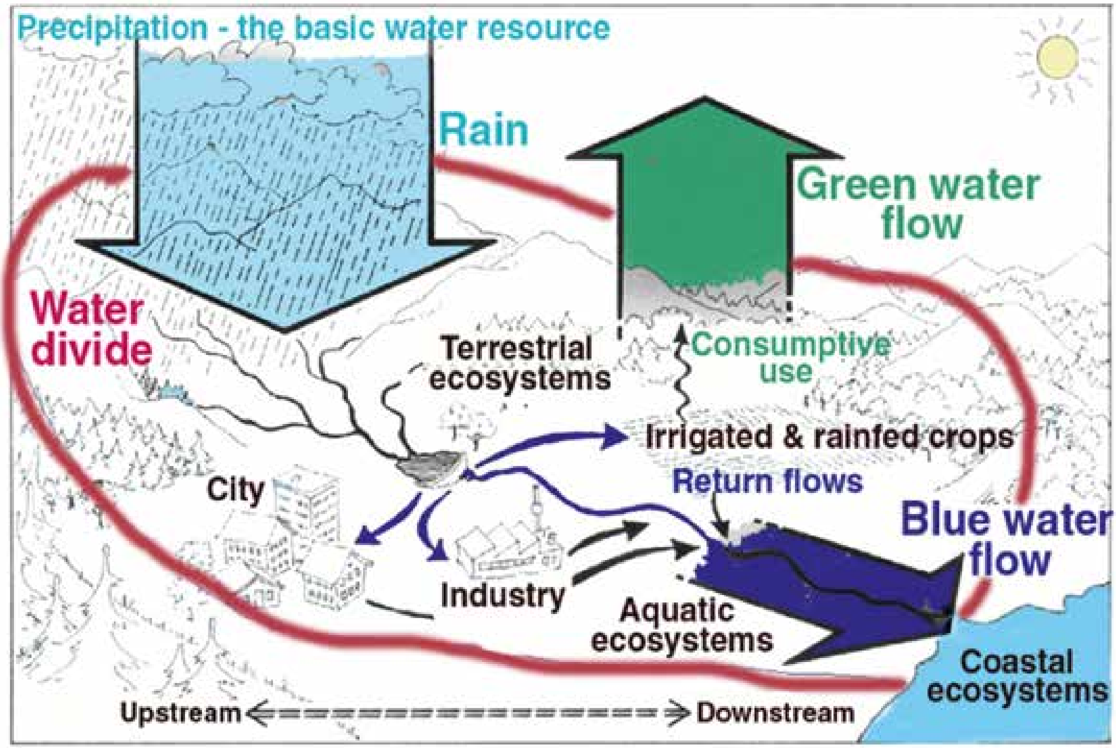
The forest and water story under climate change

Forests' role for water can be seen in three main aspects: 1) hydrological cycle, 2) Water quality maintenance, and 3) reducing water-related hazards.

In the global water cycle, forests are important water users that affect "blue water" and "green water" flow, which influence rain generation (Rockström *et al.*, 2014, Scott 2005). Trees use water for their growth, returning water to the atmosphere through evapotranspiration, improving infiltration for groundwater recharge, and allowing some precipitation to flow overland directly into streams as storm runoff.

Common perception sees forest cover as a 'sponge' for groundwater infiltration that ensures water availability for downstream users during dry periods (FAO, 2013). It may not always be valid. In tropical developing countries, the "trade-off theory" is more relevant, where trees' evapotranspiration is greater than their water infiltration benefit (Scott, 2005) as shown in Figure 2 (Malmer *et al.*, 2010b). For

Figure 1 Water Cycle in a Landscape



Source: Rockström *et al.*, 2014

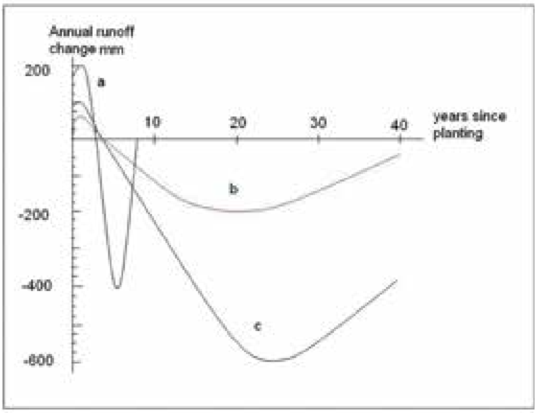
example, timber plantation in South Africa resulted in marked reductions in stream flow, prompting the government to restrict plantation expansion since the 1970s (Scott *et al.*, 2005). Forest management can improve, maintain, or reduce water supply and quality for specific uses depending on temporal and site-specific characteristics.

At the basin scale, maintenance of good water quality is the most significant contribution of a healthy forest ecosystem compared to other land uses. Forest cover reduces the rate at which water from rainfall reaches the ground due to the effect of the leaves. This allows a greater proportion of water to infiltrate and reduces overland stormflow which is quickly lost to the sea. A well managed forest cover enhances water filtration by trapping sediments and pollutants from upper catchments and by improving the river morphology and plants' root systems, which prevent siltation downstream.

Water filtration services by upstream watersheds can be more cost-effective for downstream water users. The New York City watershed management programme has generated USD 6.5 billion in cost savings. About a third of the world's biggest cities obtained a significant portion of their drinking water directly from forested watersheds and protected areas (FAO, 2013). Similarly water produced by removing alien woody vegetation from fynbos catchments in South Africa is the most cost effective method of satisfying the water needs of large cities (Marais, 1998).

Forest cover can play a significant role in reducing the risk of water-related hazards, by mitigating small and local floods, landslides, drought, desalinisation and desertification. At river basin scale, the flood mitigation effect of forests is however insignificant. In areas with saline-susceptible soils, such as Bangladesh and Western Australia, deforestation has worsened salinisation problems. Moreover, dense tree cover provides a safety margin against landslides at shallow landslips or slip-prone areas (Hamilton *et al.*, 2008). Climate change affects water availability differently across regions, including forest ecosystems. Low water availability will affect forest productivity negatively, while increased precipitation might increase the risk for floods and landslides with further implications on downstream water quality, losses and damages. Reduced and more erratic rainfall and runoff will influence the vitality, resilience, and survival of trees and forest ecosystems. This will further impact on ecosystem health, biodiversity, and the cascading socio-economic impacts on livelihoods, food and energy security for upstream and downstream areas.

Figure 2 Increases and Decreases in Streamflow due to Growing Forest Plantations.



Notes: a) Acacia mangium, Malaysia, 50N; b) global mean shrubland to Pinus/Eucalyptus; c) old-growth Eucalyptus to regenerating Eucalyptus 370S
Source: (a) from Malmer *et al.*, (2010b), (b) and (c) from Jackson *et al.*, (2005)

Water in the Forest Carbon Management

Forests play an integral role in the global carbon cycle by storing carbon above-ground (in vegetation biomass) and below-ground (in vegetation roots and soils). 80 per cent of earth's above-ground terrestrial carbon and 40 per cent of below-ground terrestrial carbon lies in the forests (FPCF, 2013). The accumulation of biomass in stems, roots and mature soils lock carbon away from the atmosphere and renders forests as carbon sinks. Changes in forest cover, e.g. clearing forest for agriculture and bushfires, can return carbon back into the atmosphere and turn forests into emission sources.

The role of forests as emission sources and sinks has gained increased attention, especially through the Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanism. It is basically a performance-based mechanism that provides incentives for forest owners and users to reduce emissions and increase removals of carbon. Growing interests in the REDD+ mechanism is reflected in the pledged funds that amount to USD 3.3 trillion of bilateral and multilateral funds (GCP, IPAM, FFI and UNEP FI, 2014).

REDD+ financing has generated concerns about the pursuit of forest management for carbon sequestration at the expense of multiple benefits of forests, including water services. This has given rise to the importance of safeguard mechanisms and principles for REDD+ projects. Nevertheless, these safeguards have mainly focused on stakeholders' participation in forest governance and biodiversity, with little attention on the implications on water management. At the same time, changes to the water cycle and services can undermine the carbon sequestration objective.

Higher evapotranspiration than water infiltration in humid and semiarid regions, especially in the early period of forest growth (Figure 2), means that reforestation or afforestation[2] activities for carbon sequestration do not necessarily bring about increased dry-season flow at the downstream, as many would expect (Jackson *et al.*, 2005). In fact, these activities might not be economically viable in some water scarce regions if they were to pay the true costs of water. A number of studies indicate that water consumption by trees is directly linked to tree productivity and therefore carbon sequestration (Scott, 2005). In coastal areas, tree growing can even decrease soil carbon and undermine a carbon sequestration objective (Hamilton *et al.*, 2008). Reducing deforestation and forest degradation, along with conservation of mature or pristine forests, however, would maintain water infiltration. Restoration of deforested or degraded land can also reduce downstream stormflow (Malmer *et al.*, 2010a).

The above examples highlight the trade-offs and complexities among forest harvest productivity, carbon sequestration and water management with further implications on wildlife habitat and other water services. These trade-offs are very important in the context of increasing scarcity and competing demand for water on one hand, and the potential for using degraded forest/land for carbon sequestration and other purposes on the other hand. World Resources Institute estimates that there are two billion hectares of deforested or degraded lands globally, which offer opportunities for higher productivity if restored. The key question is how to balance the multiple benefits of forests and manage the trade-offs by taking into account water management.

Addressing Climate Change Impacts on Water through Forest and Adaptation

There are two-fold linkages among forest and adaptation (Locatelli, 2011):

1) Adaptation for forest.

Forests themselves are vulnerable to climate change. Forest managers need to design adaptation options that are necessary for forest vitality under climate change. For instance, forest managers in the Mediterranean region might need to introduce thinning operations or shift the harvesting period or change landscape design in order to reduce water competition and improve water balance. Other measures include conservation of forests in watershed areas, fire prevention and modifying forest plantation management to avoid drought conditions.

2) Forest for societal adaptation.

Since forests provide livelihoods and vital ecosystem services for poor, forest dependent communities, they contribute to societal resilience against climate change through Ecosystem based Adaptation (EbA). EbA is

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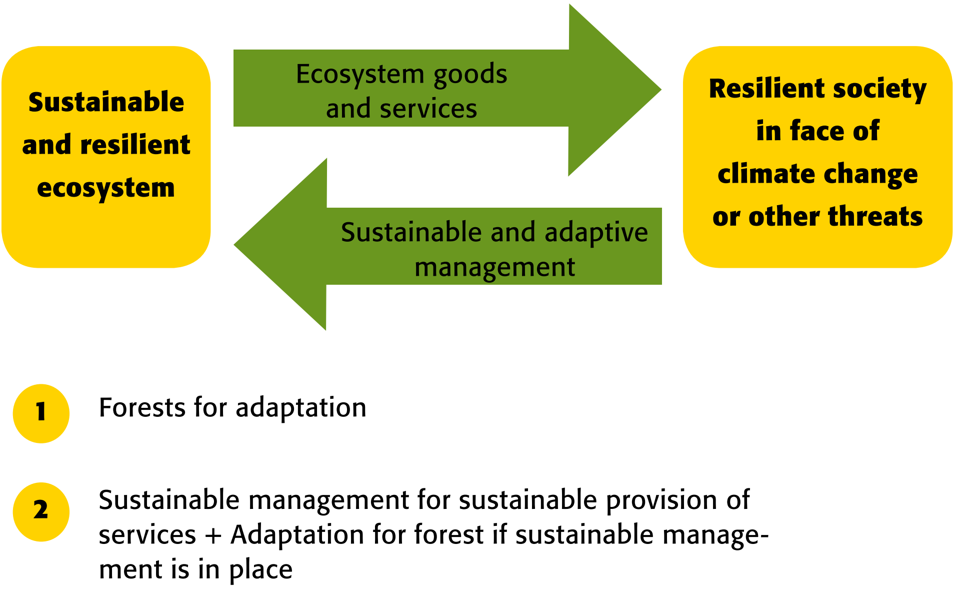
[1] Afforestation refers to planting of trees on land that has been non-forested for a long period (usually 50 years)

Figure 3 Forest and Adaptation



Source: Locatelli (2011).

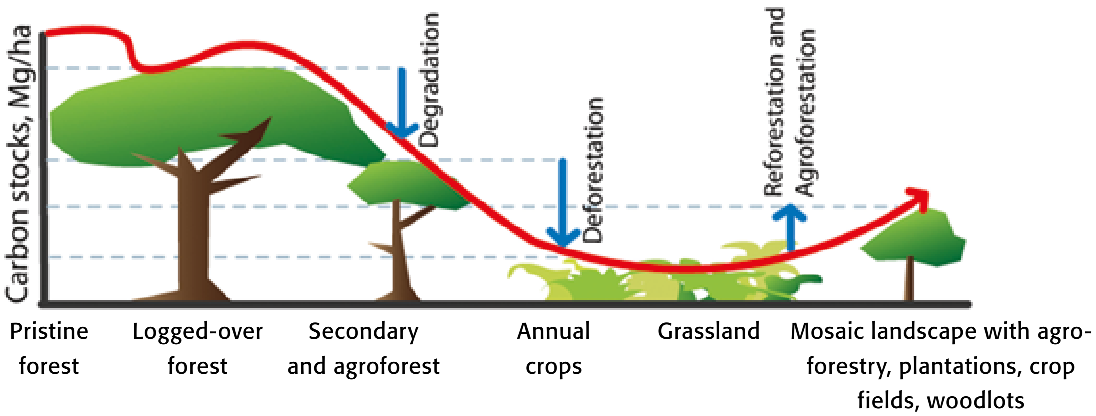
defined as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of CC". It also encourages sectors benefitting from forest services to engage in forest adaptation planning. For instance, projected increase in precipitation and soil erosion in Central America will increase sedimentation problems for hydroelectricity dams. Upstream soil conservation is part of adaptation.

Linking climate adaptation and mitigation in the forests

There are close interactions that go both directions between climate adaptation and mitigation in the forests.

- **Forest-based mitigation affects both forest and societal adaptation (EbA)**
  Forest-based mitigation projects, i.e REDD+ projects, can positively affect forest adaptation by reducing anthropogenic pressures on forests; thus reducing climate change exposures on forests (Locatelli, 2011). Mitigation projects can also have positive or adverse effects on communities' resilience. Rising demand for biofuel crops for example might even induce forest conversion and negatively affect carbon sequestration and water services. Producing wood pellets from wood residues, however, increases energy use efficiency as well as the reuse and recycling of wood product. Carbon sequestration projects can provide alternative sustainable local livelihoods and strengthen local institutions, but they can also put more pressure on downstream communities' adaptation to cope with increasing water scarcity. Forest managers and urban planners need to work together, for example by avoiding critical upstream watershed areas for carbon sequestration and improving downstream water demand management.

Figure 4 Land use change over time and carbon stocks



Source: CGIAR (2010)

- **Forest adaptation can contribute to mitigation** Ecosystem-based adaptation can also affect ecosystems' capacities in increasing or maintaining carbon stocks. For example, adaptive management of water balance to prevent fire in peatland forests is crucial to ensure the permanence of forest carbon storage. Alternatively, communities' adaptation for food security through agroforestry might compromise carbon sequestration and biodiversity objectives.

Forest adaptation and mitigation measures are closely interconnected with water management, but these interactions are rather intricate and very local-specific. It is important to recognise that these adaptations will give significant benefits by increasing system resilience and reducing risks even if climate change were not an issue.

Historically, forest cover and tree density has a strong correlation with land-based economic development (Agrawala *et al.*, 2013, CGIAR 2010). A diversified (mosaic) landscape approach can be highly relevant to meeting societies' continuously changing demands for land, water, energy and natural resources over time.

The way forward

Forest management should shift from a traditionally sectoral approach to a mosaic landscape approach that recognises forests as part of the social, environmental and economic landscape. An integrated forest, water, energy and carbon management does not only allow for the harmonisation of adaptation and mitigation measures, it also provides opportunities for meeting the competing water demands for economic growth, food and energy security, which are often the drivers of deforestation themselves. This integrated approach also provides an opportunity to address the long-standing challenges of using the natural environment as an engine of growth rather than simply as a fuel or raw input material.

Some key recommendations to advance integrated forest, water, energy and carbon management in view of climate change:

- Better communication and capacity building to decision makers and stakeholders in understanding the complexities of linkages, synergies, trade-offs between water, energy and forest carbon management, rather than a simplistic view of forest services.

- Improve research and understanding on the forest-water-carbon linkages across spatial and temporal scales under different socio-economic contexts.

- Enhanced cooperation and more integrated policy and institutional development for forest, water, energy and carbon.

- Synchronise economic incentives and mechanisms, e.g. through well-designed Payments for Ecosystem Services.

- Ensure that there is a functioning market for timber and non-timber forest products that returns real value to forest-associated peoples.

- Linking of key international dimensions for forest, water, energy and carbon, e.g. REDD+ in a transboundary basin context.

- Using integrated land use approach for forest, water and carbon management, e.g. diversified landscape approach.

It is vital to understand the social context of forests and water management. Forest industries have the opportunity to maximise energy efficiency, spur innovation, create a reliable fibre supply and contribute to local economies. However, land use decisions are made by hundreds of millions of people including the very poor. For the poor, land will be turned to whatever use that provides them with the most reliable livelihood in the short and the long term (in that order of importance). Only through increasing the value of forests (through marketing the full range of forest products and services) over the alternatives will it be possible to ensure that forest plays a significant role in future landscapes. In this fashion, forests will be able to secure the multiple goals of providing sustainable livelihoods, sequestering carbon, maintaining water services, providing renewable energy and conserving biodiversity.

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Chapter 5

Photo: iStock

Water and Energy in the Urban Setting

By Kalanithy Vairavamoorthy, Jochen Eckart, George Philippidis and Seneshaw Tsegaye,
University of South Florida

Introduction: Water and energy trade-offs in urban areas

Clean and reliable water and low-cost low-carbon energy are essential to enhancing economic development and sustaining healthy and livable cities. As urban population around the world continues to grow and cities adapt to the consequences of climate change, the water sector must manage the many trade-offs between water and energy more effectively. Water is essential for production of energy, such as extraction of fossil fuels, production of biofuels, and cooling and emissions scrubbing in thermoelectric power generation (Hutson *et al.*, 2004). At the same time energy is used for pumping and treating water/wastewater and harvesting of heat from wastewater (Rothausen & Conway, 2011). Capturing the dynamics of this interaction and the synergies it makes possible requires a systems analysis and an integrated framework for energy tracking in the urban water cycle.

The need for addressing the water and energy trade-offs

The water sector represents around 3 per cent of the world energy demand (Novonty, 2013) with huge variations among different countries and different cities (Malghan *et al.*, 2013). In most cities, the water utility consumes an average of between 0.8 and 1.3 KWh/m^3 while some cities consume up to 3.5 KWh/m^3 (PUB, 2011). The high energy demand is often driven by specific local conditions, such as energy-intensive water treatment to meet more stringent regulations, or long distance water transfer schemes with associated inefficiencies. For example the exceptional high energy demand of 3.5 KWh/m^3 of cities in southern California is mainly due to the long-distance water transfer from northern California. Water utilities use most of the energy they consume to pump water through their systems and treat wastewater. Many utilities are forced to use more energy to meet new, more stringent water quality standards for portable water, utilise unconventional water resources and meet the requirements for effluent discharge. In Singapore, for example, the energy demand of the water supply increased by 30 per cent in the period 2000 to 2007 (PUB, 2011) mainly because of the introduction of energy-intensive processes, such as the recycling of wastewater and desalination. In other cities, the increasing number of long-distance water transfer schemes has contributed to the growing energy demand of the water sector as utilities pump water over great distances (Elias-Maxil *et al.*, 2014). For most water utilities, energy costs take up to 13 per cent of the total operating cost, second only to personnel costs (Rothausen & Conway, 2011). With growing energy demand and rising energy prices, water utilities must learn to save energy and reduce their dependence on external energy sources.

The existing rise in energy use by the water sector will be exacerbated by climate change and the higher energy demands associated with adaptation. Faced with increasingly scarce and less reliable water resources, water utilities will be forced to turn to large water transfer schemes or the use of unconventional water resources such as wastewater reuse or rainwater harvesting. These alternatives may demand up to ten times more energy than conventional sources (Rocheta & Peirson, 2011). At the same time, however, there are voluntary and/or regulatory requirements for the water sector to reduce its CO_2 emissions, such as the EU carbon reduction commitments. Together rising energy demands and the need to reduce CO_2 emissions make it essential that water utilities develop integrated strategies to more efficiently manage the dynamics between water and energy.

Energy reduction strategies in the urban water sector

An integrated systems perspective can identify the potential synergies involved in managing scarce water and energy resources (Oppenheimer *et al.*, 2014; Kenway *et al.*, 2013b). Strategies available to this integrated perspective include reducing energy use, using energy more efficiently and developing new, renewable energy sources (Elias-Maxil *et al.*, 2014; Kenway *et al.*, 2013a).

Water demand management strategies that conserve water and reduce leakage can save both water resources and the energy required to supply and treat water and wastewater. The reduction in water demand achieved through the use of more efficient appliances or leakage management creates a directly proportional reduction in energy consumption (Rothausen & Conway, 2011). This synergy is especially important when utilities use marginal, energy intensive, water sources such as desalination. Furthermore, depending on the local water resources or the pumping energy required, not all water supplied in the same city has the same embedded energy. To take advantage of this disproportionate energy consumption, water demand and leakage management solutions should be prioritised in areas where the embedded energy, the total energy required to extract, treat and pump the water is high.

Just as integrated water management strategies can reduce energy consumption, better management of water pumping can reduce costs and CO_2 footprint. Traditionally water utilities pump water at night to take advantage of the lower night tariffs for electricity in order to save money. Beyond this cost saving, however, an integrated optimisation of pump scheduling can also reduce CO_2 emissions. Because of the varying mix of power plants and renewable energy sources at different hours of the day, not all electricity has the same CO_2 footprint. For example, in the US, CO_2 emission rates of the marginal energy demand for the peak hour are twice as high as the lowest one (Zivin *et al.*, 2012). With a closer integration of water and energy, the water sector could schedule their energy demand during times when CO_2 emissions of the provided energy are low.

Another opportunity to benefit from the water and energy trade-offs is to change the way people think about wastewater treatment. We should stop viewing wastewater as a burden and begin to see it as a resource. Emerging treatment technologies such as anaerobic digestion or natural treatment systems can reduce the amount of energy required for treating wastewater. The possibilities of harvesting energy from wastewater, however, open a whole new source of energy in the water sector. While biogas is already recovered from digesting sludge, emerging technologies that can produce electricity from microbial fuel cells, generate hydrogen from fermentation or recover heat from wastewater can make wastewater a valuable resource (Elias-Maxil *et al.*, 2014; Novotny, 2013). These renewable energy sources are either CO_2 free (heat recovery) or at least CO_2 neutral (biogas). By combining more energy efficient treatment technologies with the harvesting of energy from wastewater, it is possible to achieve the goal of a net zero energy wastewater treatment. An integrated perspective on wastewater treatment can convert current liabilities (energy required for wastewater treatment) into assets (energy from wastewater treatment).

Considering end-user activities

Taking advantage of the water and energy trade-offs in the water supply sector is crucial, but utilities must consider the energy demanded by their customers. End-user activities in the urban water cycle account for up to four times the energy consumed by the water supply sector (Elias-Maxil *et al.*, 2014). Reductions in end-user energy consumption can have huge impact on the whole water system.

In developed countries, the average amount of energy used to heat water is much higher than the energy consumed by water utilities and accounts for 12 per cent of the total energy demand (Elias-Maxil *et al.*, 2014). For example, in Australia it was estimated that a 15 per cent reduction in residential hot water use could completely offset the total energy use by the water utility (Kenway *et al.*, 2008). Hence integrative strategies to reduce the need for hot water (e.g. dishwashing detergents which perform well at lower water temperature), the use of clean energy for the heating of water (e.g. the use of solar collectors) or the recovery of heat energy from wastewater (e.g. heat exchanges in sewer pipes) are required. In addition, water demand management measures, such as water conservation (efficient shower heads or water saving taps) that lower the demand for hot water can create significant synergies for water and energy savings (Kenway *et al.*, 2013a). Only with an integrated perspective such as this, can water and energy trade-offs between the public water sector and the end-user activities be realised.

In many cities in developing countries the trade-offs between water and energy are even more problematic. A major problem with urban water systems in many developing countries is microbiological contamination of drinking water caused by poor or unreliable water supply. One of the root causes for the poor water service is the unreliable energy supply that frequently leaves the water supply pipes without pressure, allowing ingress of pollutants. To deal with poor water services, private consumers apply different coping strategies, such as private booster pumps to deal with low pressure, cooking of water to produce safe drinking water or carrying water from far away sources to cope with lack of access to water. All of those practices increase energy demand. This vicious cycle of increasing energy consumption can be broken by increasing the quality of water services. When a continuous water supply with sufficient pressure is provided, the

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energy for private booster pumps can be reduced. In addition, continuous water supply and high pressure in supply systems prevent the ingress of pollutants in the water supply system and reduce the need for boiling water used for drinking and cooking. An integrated perspective can bring about the synergies that will improve water services and thus reduce the energy demand of the overall water cycle.

Integrated energy and water demand management

Because water and energy are so closely interconnected, managing urban water and energy resources in the face of declining resources and increasing climate change requires an integrated perspective. Water utilities must develop the potential synergies of managing scarce water and energy resources, coordinate the activities of the water and energy sectors, and integrate the public and private parts of the urban water cycle to utilise all potential for water and energy management. Only an integrated framework that tracks both energy and water can provide the change we need.

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Chapter 6

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For Better, for Worse: The Eternal Interdependence of Energy and Water

By Jens Berggren, SIWI

Introduction: energy and water – cause and effect of climate change

Oil and other fossil fuels provide the bulk of primary energy; 82 per cent of the energy that we use has been pumped or dug up from layers deposited during earlier geological eras. However, the share of fossil energy is slowly decreasing. It is projected that one quarter of energy consumed in 2035 will come from non-fossil primary sources, but since the total energy consumption is increasing, we will still burn more fossil carbon than today in absolute terms. The energy sector's CO_2 emissions are set to double by 2030 under a business-as-usual scenario. (CADFOD, 2014)

The burning of fossil carbon is the main contributor to climate change that is leading to severe alterations to global and local hydrological cycles. It is mainly through increased frequency and intensity of floods and droughts that climate change will be experienced. In the words of Sir Nicholas Stern, author of the Stern Review on the Economics of Climate Change, "Climate change is essentially about water" (The Guardian, 2014).

Demand for freshwater is increasing and shifting

The global demand for freshwater is undergoing rapid changes. The total global demand for water is projected to grow by 55 per cent between 2000 and 2050. As a result, 45 per cent of the global population and over 60 per cent of people in the rapidly developing economies of the BRIICS[1] will be living under severe water stress. (OECD, 2012).

Up until now, agricultural production has been the main user of freshwater, accounting for over two thirds of total withdrawals. But demand from other parts of the economy and society is rapidly increasing, especially in manufacturing industries and for power production. Already in 2008 the freshwater used for cooling power plants in France and Hungary accounted for 70 and 80 per cent respectively of national total abstractions. (EUROSTAT, 2014) The demand for water for cooling electricity production outside the OECD is predicted to increase fivefold to 2050. (OECD, 2012) Over the same time, the manufacturing industries' thirst is expected to increase by over 700 per cent in the BRIICS. (OECD, 2012)

From a situation where agriculture uses two thirds of the freshwater and power production, manufacture and households together use one third – we are moving towards a world where agriculture will use only a third, with cooling of electricity production and manufacturing together demanding around half of the total abstractions.

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[1] Brazil, Russia, India, Indonesia, China and South Africa

Water is an energy resource

Our world is facing increasing water challenges exacerbated by emissions of greenhouse gases, especially from the use of fossil energy, that are changing the hydrological cycle. At the same time, water is a crucial input throughout the energy sector; "freshwater is required for each step – energy extraction and production, refining and processing, transportation and storage, and electric-power generation itself." (World Energy Council, 2010) All thermal energy conversion, from fossil fuels, biomass, and nuclear, need cooling to create the gradient that drives turbines and pistons. And cooling means water – lots of it.

In the year 2010, 22 km^3 of water was withdrawn to cool electricity production in France and 20 km^3 in Germany. (EUROSTAT, 2014) Withdrawals for thermoelectric cooling in the USA during 2005 was estimated at 265 km^3 (Kenny *et al.*, 2009), equalling more than three times the annual flow of the river Nile into the Aswan High Dam. (Sutcliffe and Parks, 1999).

The only energy technologies that are not directly dependent on water for extraction and/or conversion of energy are wind and solar photovoltaic (PV). The utilisation of these power sources has grown over the last decade, with wind producing 534 TWh in 2012 (Observ'ER, 2013) and photovoltaics estimated to produce 160 TWh in 2014 (IEA, 2014). While this amounts to around four percent of the global electricity production, they still together contribute with just a miniscule fraction of the global primary energy supply of 152,500 TWh (IEA, 2013). This means that water is a key ingredient in the conversion of practically all the global energy.

H_2O vs. CO_2

One of the key challenges for the global energy sector is to reduce its emissions of carbon dioxide before the changes in the global climate and hydrology reach unmanageable levels. As the prime emitter of fossil carbon and a large and rapidly growing water user, the energy sector is currently gnawing on the resource branch it is perched on by emitting gases that is changing water availability on our planet.
If the patterns of precipitation, snowmelt and other water events deviate significantly from the general trends of the past century, it will have serious implications for our energy supply. The flooding of the Balkans in May 2014 was expected to disrupt power supplies for at least six months (Reuters, 2014). Due to the spring 2014 drought in California, the grid operator estimated that thermal power facilities totalling 1.2 GW were at risk of having water supply curtailments and decided to write down the states hydropower capacity by 1.7 GW (California ISO, 2014). This derate is equal to the entire hydropower capacity of United Kingdom (British Hydropower Association, 2014).

There are several technological options for reducing carbon emissions; biomass, hydropower, wind, solar, nuclear and geothermal as well as carbon capture and storage (CCS). However, apart from wind and solar photovoltaic, all these technologies have high water demands (Meldrum J. *et al.*, 2013), often far higher than the high-CO_2 emitting technologies they are set to replace. CCS-systems, for instance, the only option for decarbonising fossil fuel power plants at large scale, can require more than double the amount of water per kWh compared with non-CCS systems (Merschmann *et al.*, 2013 and DOE-NETL, 2008). Biomass requires around the same amount of cooling water per kWh as other thermal electricity generation, but in addition need vast amounts of water to be grown. Driving a car on biofuels made from irrigated crops uses around 100 times more water per kilometre than conventional petroleum fuels (King and Webber, 2008). Wind and solar-PV does not need water to convert primary energy into electricity, but they face another problem – intermittency. The wind and the sun are not perfectly aligned with our electricity consumption patterns and the power output from these technologies can change rapidly. This means that the power generated from these sources needs to be balanced by other rapidly responding electricity technologies. Currently only hydropower and gas fired thermal plants can respond quickly enough to balance the grid – and both of them depend on water. To complicate the energy sector's water challenges even further: a too low water level in a hydropower reservoir would not just reduce a plant's power production capacity, it can

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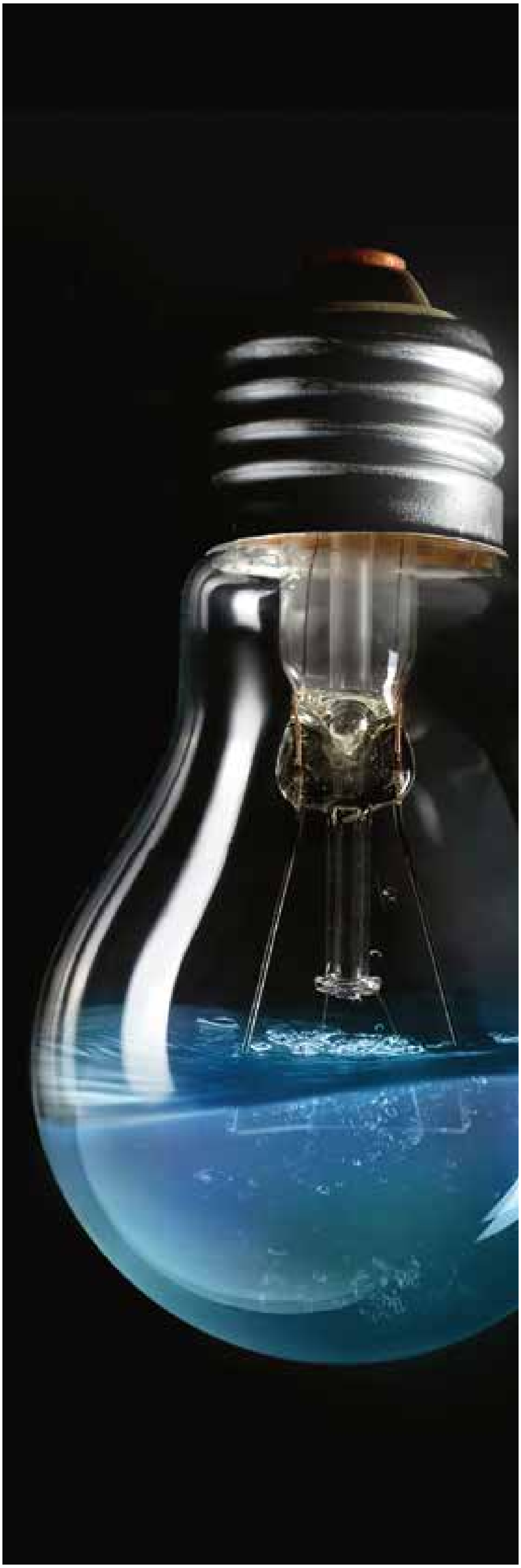
force it to shut down completely as cavitation in the turbines may destroy the entire plant.

We are hence faced with a delicate dilemma; we need to reduce the carbon intensity of our energy system – basically to save life as we know it on this planet, but also to save the energy system itself from the perils of water variability. At the same time, the available low-carbon energy alternatives are even more dependent on the increasingly scarce and fickle water resource.

Can we use less energy?

The only no-regrets solution to this water vs. carbon dilemma seems to be to use less energy, preferably by increasing efficiency. The energy use avoided since 1974 by improved efficiency in Australia, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, the United Kingdom and the United States was estimated to equal 65 per cent of their total final consumption in year 2010, mainly driven by economic incentives and energy prices (IEA, 2013b). Unfortunately, as climate change is altering the hydrology of our planet, water will no longer be available in the places, at the times and of the quality that it historically has been. One of the most dangerous effects of climate change is a risky rise in water variability. There is strong evidence for increased frequency and intensity of extreme precipitation events in the USA (Kunkel *et al.*, 2013) and further increases of both floods and droughts are highly likely with wet areas getting wetter and dry areas drier (Melillo *et al.*, 2014). In addition, water quality will deteriorate as higher flows flush out more pollutants into waterways and droughts increase the concentration of contaminants as there is less water left to dilute and disperse them.

To address this issue, the world needs to invest in water management and governance as well as in green (e.g. natural and constructed wetlands) and grey (e.g. dams and water pipes) infrastructure to build physical and social resilience. We will also need to store, move and treat water to adapt to changing



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availability. Both moving and treating water requires energy. Pumping demands around 20 percent of the world's electrical energy (Dep of Energy *et al*., 2004). In 2001, 19 per cent of California's total electricity use and 32 percent of the state's natural gas consumption was used to move and treat water and wastewater (Wilbanks *et al*., 2012). It is estimated that between one and three percent of global electricity is used for treating and transporting piped potable water, that on average has an energy intensity of 0.5-4 kWh/m^3 (Olsson, 2014). The State Water Project is the largest single user of energy in California and 90 per cent of all on-farm electricity in the state is used for pumping groundwater for irrigation (Cohen *et al*., 2004). How much more water we may have to trap, transport and treat in response to climate change is impossible to assess on a global scale, but it is clear that demand for energy for water purposes will increase.

Can energy get more water?

Another option for quenching the thirst of low-carbon energy would be to focus on increasing the availability of freshwater for the energy sector, but producing it isn't an alternative. Desalination of one cubic metre of seawater in a modern reverse osmosis plant requires around 4 kWh of energy and emits between 1.4 and 1.8 kg CO_2. (Elimelech and Phillip, 2011).

With freshwater withdrawals already unsustainably high in large parts of the world (Hoekstra and Mekonnen, 2011) and global demand continuing to rise, the only way to increase the amount available for energy is to reduce the water intensity elsewhere. The most obvious sector to start with is agriculture as irrigated agriculture currently account for more than two thirds of the total global water withdrawals (FAO, 2013). In addition, water use for irrigation is quite inefficient, with less than half of the water withdrawn contributing to plant growth. The average irrigation efficiency across 93 developing countries was a paltry 38 per cent in 1998 (FAO, 2002) albeit with high intra- and inter-country differences. Average irrigation efficiency in the Philippines, Thailand, India, Pakistan, and Mexico range between 25-40 per cent compared to efficiencies between 50 and 60 per cent in Taiwan, Israel and Japan (Rosegrant *et al.*, 2002). However, technologies exist that can increase water productivity far beyond the Taiwanese, Israeli and Japanese averages. Research in India has demonstrated that shifting from conventional surface irrigation to drip irrigation both increased yields and reduced water use dramatically, producing up to four times the crop per drop (Postel, 2011). But to reach this level of agricultural water productivity, pressurised irrigation systems are needed and pressurised irrigation needs energy. In California, pressurized irrigation systems have resulted in a 2.3 GWh per-year increase in agricultural electricity use since the 1970s (Lawrence Berkeley National Laboratory, Water and Energy Technology Team, 2014) On the other hand, for irrigation systems that use groundwater the water efficiency of drip may well mean that the reduction of the amount of water that has to be lifted from below ground more than compensates for the pressure needed in the irrigation system (Narayanamoorthy, 2007). Currently micro irrigation, the most water efficient irrigation method, is used on less than five percent of the global irrigated area, with sprinkler irrigation being used on less than 20 per cent. (ICID, 2014) This means that there clearly is a technical potential for increasing the global water efficiency of agriculture.

It is more questionable if the incentives for doing so are in place. Under the pricing regimes currently used in most parts of the world, for the 62 per cent of farmers relying on surface water for irrigation (Siebert *et al.*, 2010), investing in more efficient irrigation would mean paying for a system that uses a priced input to reduce the use of an input that has no volumetric cost.

Energy and water efficiency

As illustrated above, energy and water issues are intimately linked in a multitude of ways. In many cases the inter-linkages offer underutilised synergies that we can tap into. Saving water and reducing the water intensity of production processes can provide great savings also in the use of other resources. A water management project in the Indian textile industry reduced the use of water, energy and chemicals with a 765 per cent return on investment in a year and an average payback time of eleven days (Abdelrahman *et al.*, 2014). Unfortunately, there are also several cases where the connections between energy and water mean that hard choices must be made, e.g. between low-carbon or low-water energy technologies and between water or energy efficient irrigation.

Most of the connections in the intimate relationship between energy and water are location and time specific. This makes it difficult to provide general prescriptions on how to address the challenges and opportunities embedded between water and energy from a policy perspective. The optimal solution will depend on local conditions and political preferences. However, the complexity of the situation indicates that carefully crafted incentives rather than heavy-handed regulation and grand plans should be the way forward. To guide the local and regional decisions that must be taken on energy and water, there is a need for strong, predictable and flexible incentives, economic as well as regulatory, if we are to realise an energy and water wise world.

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Conclusions: 2015 – Charting a Course for the Future

By Karin Lexén and Torgny Holmgren, SIWI

This year's World Water Week in Stockholm takes place at the threshold of 2015, the year when the eight Millennium Development Goals are to be achieved, and when the UN General Assembly shall agree on a set of Sustainable Development Goals to guide the world from 2015 onwards and a new global climate concord is to be reached.

Although considerable progress has been made in reducing poverty and hunger, and in providing safe and affordable drinking water and adequate sanitation, we can conclude that the mission is still not accomplished.

Access to water and energy of the right quality and at an affordable price underpins poverty eradication and improved health. Water is used in energy production and energy in the provision of and treatment of water. However, if we don't manage the water resources wisely, the possibility to secure energy for all is at risk. The global demand for freshwater is under-going rapid changes and is projected to grow by 55 per cent between 2000 and 2050 (OECD, 2012). Rising demand from different users poses an increasing risk for increased competition over water, including realising the human right of access to safe drinking water and adequate sanitation for all.

The most recent reports by the Intergovernmental Panel on Climate Changes clearly point out that climate change must be taken seriously and that we are very close to reaching levels of greenhouse gases in the atmosphere that will put humans and ecosystems at risk (IPPC, 2013 and 2014). Meanwhile, it is predicted that we will continue to burn fossil fuels at a large scale and cut down and mismanage our forests (Lindström *et al.*, Restiani *et al.*, 2014). Hence, there is an urgent need for finding an alternative path and in this effort, water is central. The effects of climate change very often manifest themselves via water, too much or too little, unusable or just not reliable. However, sustainable water use is also a prerequisite for building resilience and developing climate friendly energy solutions.

We have seen a new landscape emerging with low income countries moving into fast growing economies while other countries lag behind, some of them fragile, unstable and poor. The divide between rich and poor is less a divide between countries, than it is a divide within countries. Today, the greatest numbers of the world's poor live in middle-income countries (Kanbur and Sumner, 2011).

The Post-2015 development agenda is expected to be shaped by key drivers such as growing and emerging economies, a fast growing world middle class, continued population growth, increased urbanisation, conflict and post-conflict challenges, continued rapid shift from agriculture-based economies to industry and services-production, and accelerating impacts of climate change. These drivers will pose serious challenges to water, food and energy security in terms of both availability and quality. A growing disparity in access to water, food and energy and an increasing demand from a rapidly growing global middle class calls for new ways to manage water and improve service delivery.

Our future wealth and development relies on the fundamental role of ecosystems and the planetary boundaries. Thus, the value of ecosystem services to enhance livelihoods, reduce poverty and maintain biodiversity must be recognised. Changing from a "business-as-usual" scenario to a more ecosystem-conscious development path requires a paradigm shift and recognition of the need to build public awareness and political will to make such a transition. This needs to translate into new economic incentives, changes in behaviour and lifestyles and a more efficient use of scarce natural resources. It subsequently also calls for improved governance.

In order to use the finite freshwater efficiently and share it wisely between different users, there is a need for strong commitment and smart incentives. These incentives should be of both economic and legal character. There is growing appreciation that the future development agenda must effectively value water as an asset for human development and maintenance of a productive and resilient Earth system. Properly valuing, managing and preserving freshwater and its services is fundamental to future development goals of improving livelihoods, reducing poverty, improving human health and well-being and transitioning to a viable path for sustainable development.

A dedicated Sustainable Development Goal on water would provide a unique opportunity to ad-dress these challenges in a holistic and sustainable way. The adoption of such a goal will also avoid fragmented and incoherent solutions as a result of increasing competition between differ-ent water users. Water needs also to be addressed and integrated into other SDGs, such as energy and food security, climate change and health.

There are definitely challenges ahead. But these challenges also constitute opportunities for the creation of green jobs and sustainable growth. Water plays a key role in securing the future we want.

Since the first UN Conference on Human Environment in Stockholm in 1972, millions have risen from poverty, hunger and illiteracy. The progress and vast improvements in economic and human development we have witnessed since then have been supported by transfer of know-how and financial resources, including development cooperation, as well as environmental treaties. Civil society organisations worldwide have engaged in pushing the sustainability agenda forward and over the last decade, key private sector actors have advanced to the forefront and shown leadership in words and deeds. New science and technology stand ready to be used for furthering the progress.

2015 will put the world to a test. Are we willing to commit to and act upon goals and targets that are necessary to accomplish a future for all? This question needs to be answered, not only by politicians and decision makers, but by us all. The future we want is a joint effort.

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Energy and Water:

The Vital Link for a Sustainable Future

This report provides input into the discussions at World Water Week in Stockholm 2014, held August 31-September 5 under the theme of Energy and Water. Through six chapters authored by leading thinkers in the field, it presents insightful analysis and diverse perspectives on some of the key opportunities and challenges facing the energy and water communities.

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