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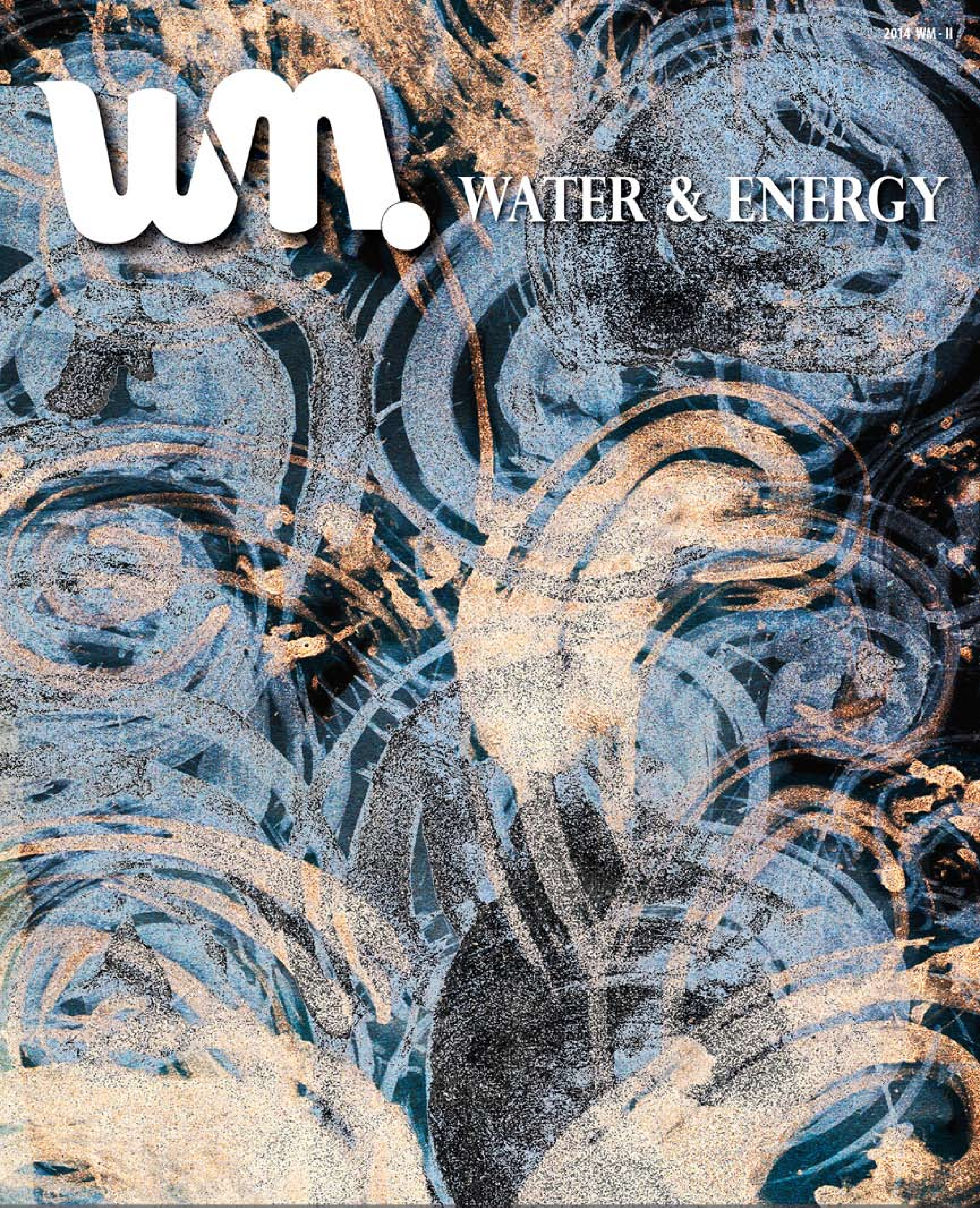

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Water Monographies

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WATER & ENERGY

WATER & ENERGY **WM 2 - 2014**

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EDITORIAL

A year ago, in the first issue of these Water Monographies, we stated that the water problem was not one of scarcity but rather one of its access. And such access depends on the availability, we said, of appropriate technologies, maybe yet to come, result of human cooperation sublimated into intelligence. Technologies which need energy like ourselves. We are water, but we live on energy. Such rebel water needs an intelligent energy management.

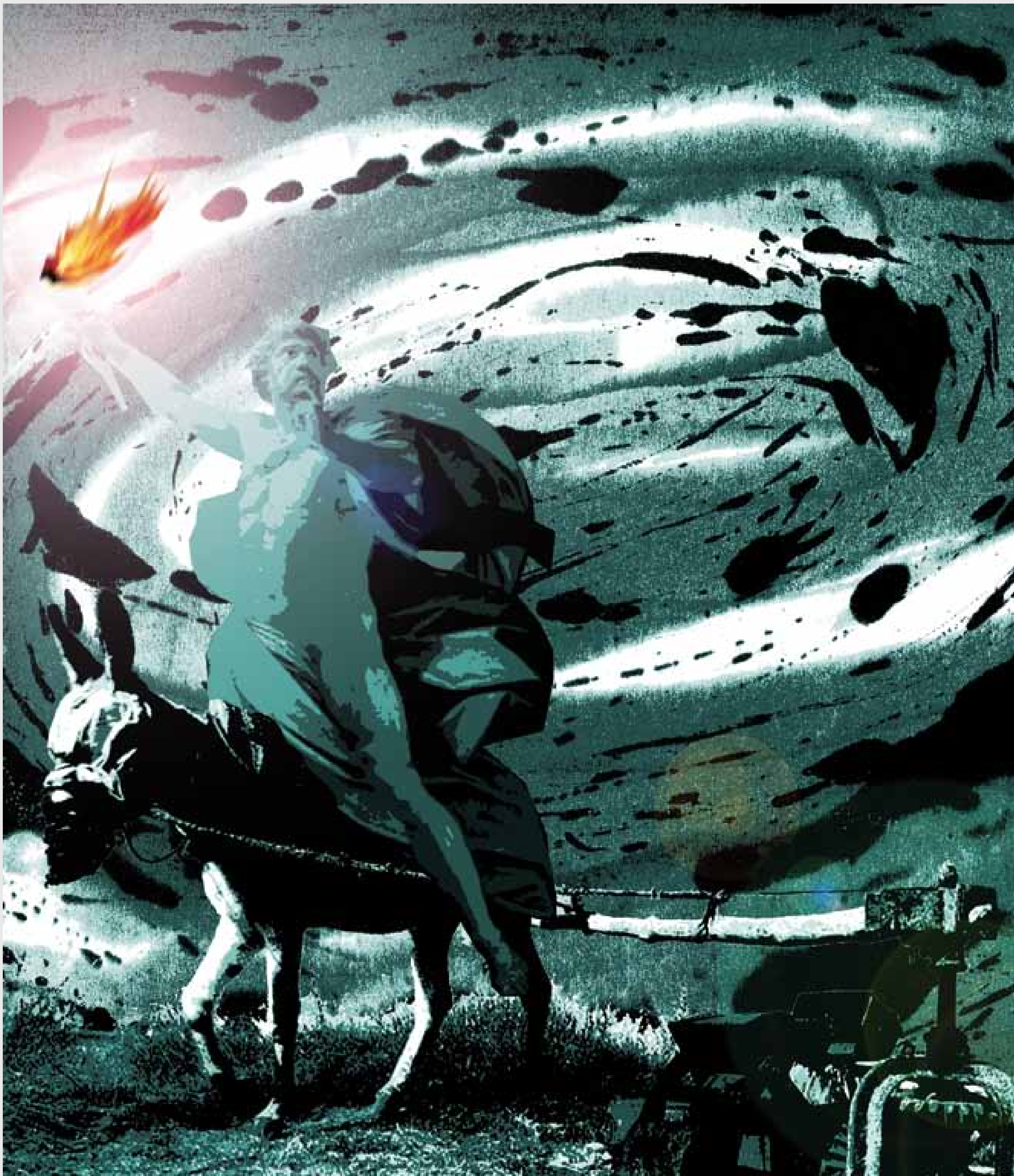
In quantum mechanics, the energy of an open system is not fixed, but is a random variable with a probability of having a determined value. It is possible to obtain the energy needed to make for our water needs. There is no precedence, no prevalence. Not for us humans, pure chance, nothing more than quantum.

The term energy (from Greek ἐνέργεια [enérgeia] "activity", "operation"; of ἐνεργός [energós] "active force" or "force in motion") relates to the ability to act, transform or launch set in motion. An energy excess can also destroy. Water humanizes energy; cools it down, tempers it, leashes it, renders it. Also stores energy and delivers it when in motion. We are energy transformed and water in the making. Energy provides the possibility, and water makes life come true. Male and female are of the same coin. Not heads and tails, but two parts that together bring life. Ours, too. Nature shows the way to the need for indispensable cooperation.

Available water for energy, energy available for water, and intelligence's cooperating role planning overall.

So here we are again, a year later, in Water Monographies recalling that such link is not voluntarily adopted, but one that precedes us and is eternal. Although sometimes, we may enjoy swimming upstream.

Ramiro Aurín



Human is the most important power to move the world. (© Illustration: Hiroshi Kitamura)

WATER AND ENERGY NEXUS:

CHALLENGES, SOLUTIONS AND UNITED NATIONS INITIATIVES

Josefina Maestu and Carlos Mario Gómez

KEYWORDS:
UN-WATER CONFERENCE
WATER
ENERGY
EQUITY
SUSTAINABILITY
COOPERATION

INTRODUCTION

On January 2014, several agencies, programmes and organizations of the UN system met with practitioners in the UN-Water Annual Zaragoza Conference to discuss the Water and Energy Nexus in preparation for the World Water Day. The Conference motivation comes from the key importance of securing equitable access, efficiency and sustainability of water and energy as a pre-condition for sustainable development. Emerging from the 2012 Rio+20 Conference, the Water and Energy Nexus rapidly got to the top of the Post-2015 international sustainable development agenda once its importance as both driver and constraint of human development was recognized. The agenda is planned to be agreed in the General Assembly of the United Nations in 2015 and its implementation would require developing appropriate responses, managing the multiple trade-offs, identify the synergies and maximize the co-benefits of managing together water and energy.

The UN-Water Zaragoza conference organized in the context of the UN International Decade for Action "Water for Life" 2005-2015, was a stepping stone in this Agenda. The Conference served to the aims of the decade of fostering efforts to fulfil the international commitments made on water and water-related issues by 2015. The focus is on furthering cooperation at all levels and engaging women, so as to achieve the water-related Millennium Declaration goals, the Johannesburg Plan of Implementation of the World Summit for Sustainable Development and the Agenda 21. This article presents some of the main discussions and proposals made in the conference.

THE NEXUS CHALLENGES

Participants in the Zaragoza Conference discussed the different interlinked water and energy challenges. Among them, The World Bank, the OECD and the World Water Assessment Programme of UNESCO, explained how securing access to both water and energy is a social challenge. This is particularly true for the poorest level of society, where fulfilling the Millennium Development goals is still pending and the lack of adequate access to water, sanitation and energy sources to cover basic needs is still the main barrier to overcoming poverty and exclusion.

Fig. 1. UN-Water Annual Zaragoza Conference. Preparation for the World Water Day 2014.

In fact, the organizations in the UN system argued that economic growth and demography has been and will remain as the main drivers of water and energy demands in the near future and will push further the trends towards water and energy scarcity. The transition towards a developed society requires secure and adequate access to water and energy for the people, for practically all the goods and services in which water and energy intervene as essential production inputs and for the environment on which the continuous provision of freshwater and many energy sources relies on.

Under the OECD (2012) baseline scenario, by 2050 the world economy will grow to four times its current size. This is expected to result in a less than proportional increase in water demand but will still require 55% more water. Households' water demand is expected to grow by 130% due to the combined effect of higher population with better living standards. The higher increases in water demands are expected to come from manufacturing (+400%) and from thermal power plants (+140%).

These projections are in line with those developed for energy demand and consumption that by 2035 are expected to be 35% higher than in 2010 and will result in a more than proportional 85% increase in water consumption (EA, 2012).

With the total annual sustainable freshwater supply remaining static at 4,200 billion cubic meters, the annual deficit for 2030 is forecasted to be 2,765 billion m3, or 40% of unconstrained demand, assuming that present trends continue. India and the People's Republic of China (PRC) are forecasted to have a combined shortfall of 1,000 billion m3 reflecting shortfalls of 50% and 25%, respectively (2030 WRG).

In many areas of the world, the development of the most common forms of energy (electricity from coal/thermal and hydropower) is limited by the availability of water. In water stressed regions, in both poor and transition economies, this is now a well-known reality. But the lack of future resources did not prevent the building up of electricity generation facilities that can only currently work below their designed capacity.

A more water-constrained future will impact reliability and costs in the energy sector. In fact, water scarcity is mostly the unanticipated consequence of many endeavours in areas such as agricultural, manufacturing, electricity or land development that are appraised and accepted by using the same critical assumption: that the water available in the future will basically be the same as today.

Fig. 2. Nigerian Child facing drought and rising of food prices. Bargadja, Niger. © UN Photo/PMA/Phil Behan.

The Energy Industry already faces water related risks

- In the *U.S.,* several power plants have had to shut down or reduce power generation due to low water flows or high water temperatures.
- In 2003 in *France* an extended heat wave forced EdF to curtail nuclear power output equivalent to the loss of 4-5 reactors, costing an estimated €300 million to import electricity.
- In 2012 a delayed monsoon in *India* raised electricity demand (for pumping groundwater for irrigation) and reduced hydro generation, contributing to blackouts lasting two days and affecting over 600 million people.
- The 2011 drought in *China* limited hydro generation along the

Yangtze River, contributing to higher coal demand (and prices) and forcing some provinces to implement strict energy efficiency measures and electricity rationing.

- Exposure to recurring and prolonged droughts are threatening hydropower capacity in many countries, such as Sri Lanka, China and Brazil.

SOLUTIONS FOR A SUSTAINABLE FUTURE

A sustainable future is possible within the range of the existing resources. The inventory and the evaluation of best water and energy technologies available, show that there is room for improvement in human development. Many alternatives do exist that are compatible with growth and development and also make possible reversing natural degradation trends and the building up of a more adaptable and more resilient society. However, the relative optimism of this conclusion cannot shade the magnitude of the challenge of transforming the promise into a reality.

One essential condition to take advantage of these opportunities consists of recognizing how the world's water and energy systems are inextricably linked. Significant amounts of water are needed in almost all energy processes (from generating hydropower, cooling and other purposes in thermal power plants, to extracting and processing fuels). Conventional energy generation requires the mobilization and utilization of considerable water resources, particularly for cooling for nuclear and thermal energy, and reservoir storage and driving turbines for hydroelectricity. Power generation is particularly sensitive to water availability and several power plants have been forced to shut down due to lack of cooling water or high water temperatures.

Conversely, the water sector needs energy – mainly in the form of electricity – to extract, treat and transport water. The degradation of water sources implies increasing amounts of energy to pump the same amount of water from deeper aquifers or farther sources. Any alternative to reallocate water to its more productive uses might require energy for transport and to adapt water quality to its new uses and places.

Water needs energy, energy needs water and human development needs both. One of the main risks in the search for a sustainable development path comes from ignoring the basic fact that there is no other option to handling the water and energy challenges in an integrated manner. These risks are already present in some of the most relevant alternatives to face water and energy challenges.

Water stress might put additional pressure over to energy. Going further and deeper to obtain water as water becomes scarce requires more energy for transport and pumping. The non-conventional sources that may compensate for the lack of freshwater may require energy intensive transformation processes such as desalination of sea and brackish water or regeneration of wastewater.

Growing demand for limited water supplies puts increasing pressure on water intensive energy producers to seek alternative approaches, especially in areas where energy is competing with other major water users (agriculture, manufacturing, drinking water and sanitation services for cities) and where water uses may be restricted to maintain healthy ecosystems.

Access to energy might worsen the water crisis. Uncertainties related to the growth and evolution of global energy production (e.g., via growth in unconventional sources of gas and oil, or bio fuels), and the price of energy can create significant risks to water resources and other users. The increasing momentum in the production of bio fuels has created a growing demand on water resources. Even a modest 5% share of bio fuels in road transport demand (as predicted by the International Energy Agency for 2030) could increase the water demand for irrigation by as much as 20% (WWDR, 2012).

The multiple interdependencies between water and energy mean that any response needs to tackle the two

Fig. 3. A view of solar panels on the UN Interim Force Base in Lebanon (UNIFIL). Naqoura, Lebanon. © UN Photo/Pasqual Gorriz.

sectors in an integrated way. Ignorance of these basic facts may lead to responses that try to adopt alternatives that fix one problem at the expense of worsening the other and that might fail in the end.

Coordinated responses can take advantage of the synergies between water and energy. Instead of ignoring the interdependencies, coordinated responses can take advantage of the synergies between water and energy. Saving energy means saving water and vice versa. Enhancing the efficiency in the way that water is used translates into lower pressures over freshwater sources but also into a reduced demand of energy for water treatment, pumping and transport and then into even less water required to produce energy. Moving towards less water intensive energy sources and less energy intensive water sources, saving water and energy in any production and consumption process and reallocating water and energy to their more valuable uses are all alternatives that take advantage of these synergies in opening the option of producing more with less.

Nexus solutions can and should be implemented by building partnerships to allow a joint action and *support in the search and implementation of effective measures.* Building partnerships consists of making agreements to reap the benefits of cooperation in the water and energy sector. Not only are the challenges involved in the Water and Energy Nexus beyond the scope of any individual public authority, business or stakeholder but actions can be coordinated in such a way that the whole is greater than the sum of its parts.

Partnerships *might involve different actors* from the energy and water community including businesses, different levels of government, civil society, academia and all those with a stake in finding the way towards a sustainable social response to the water and energy challenges. While recognizing the diversity of perceptions, interests and roles all partnerships are in agreement to cooperate in reaching a mutual benefit.

Mutual benefits are essential to make partnerships work for sustainable development. For instance, a

credible policy to increase water security in the long term can reduce the risk of investments in the energy sector. In addition, the simultaneous increase in both water and energy security can result in important competitive advantages for the entire national economy. A long term water and energy strategy with clear targets on the water and energy portfolio, a prospective role for renewable energy and non-conventional water sources, might speed up the diffusion of the best available technologies and foster innovation. These are only some of the synergies that partnerships can create in order to ensure a sustainable development.

But partnerships *require an enabling environment.* Institutions and technologies still favour the mutual ignorance of water and energy issues both in business and policy making. Water risks are not adequately considered in the assessment of energy projects and plans and energy issues still play a marginal role if any in water projects appraisal and river basin management plans.

Partnerships might have *multiple functions.* They may serve to integrate policies and broaden the scope, enhancing the effectiveness of both water and energy planning as well as to coordinate different sectorial policies, such as land planning, rural development, nature conservancy, manufacturing, etc., all within a sustainable use of water and energy.

Effective partnerships are social constructions that *advance through mutual commitment and trust* and when successful might make important contributions to both water and energy governance. They favour transparency, inclusive and legitimate decisions and help providing better regulations and enabling institutional frameworks, among other advantages.

Partnerships are also knowledge alliances. They allow Identifying opportunities to improve water and energy access, efficiency and sustainability as well as finding the way to implement win-win solutions that are more sustainable. They allow learning from the water and energy communities; they enhance the ability of anticipating risks and learning from failure as well as improving the chances of success. On a broader scale, partnerships allow building a shared vision of the challenges involved in the joint management of water and energy and pave the way to enhancing the acceptability of the tough decisions that need to be made in the short term to come back to a sustainable trend in the medium and the long term.

THE NEXUS IN THE UN INITIATIVES

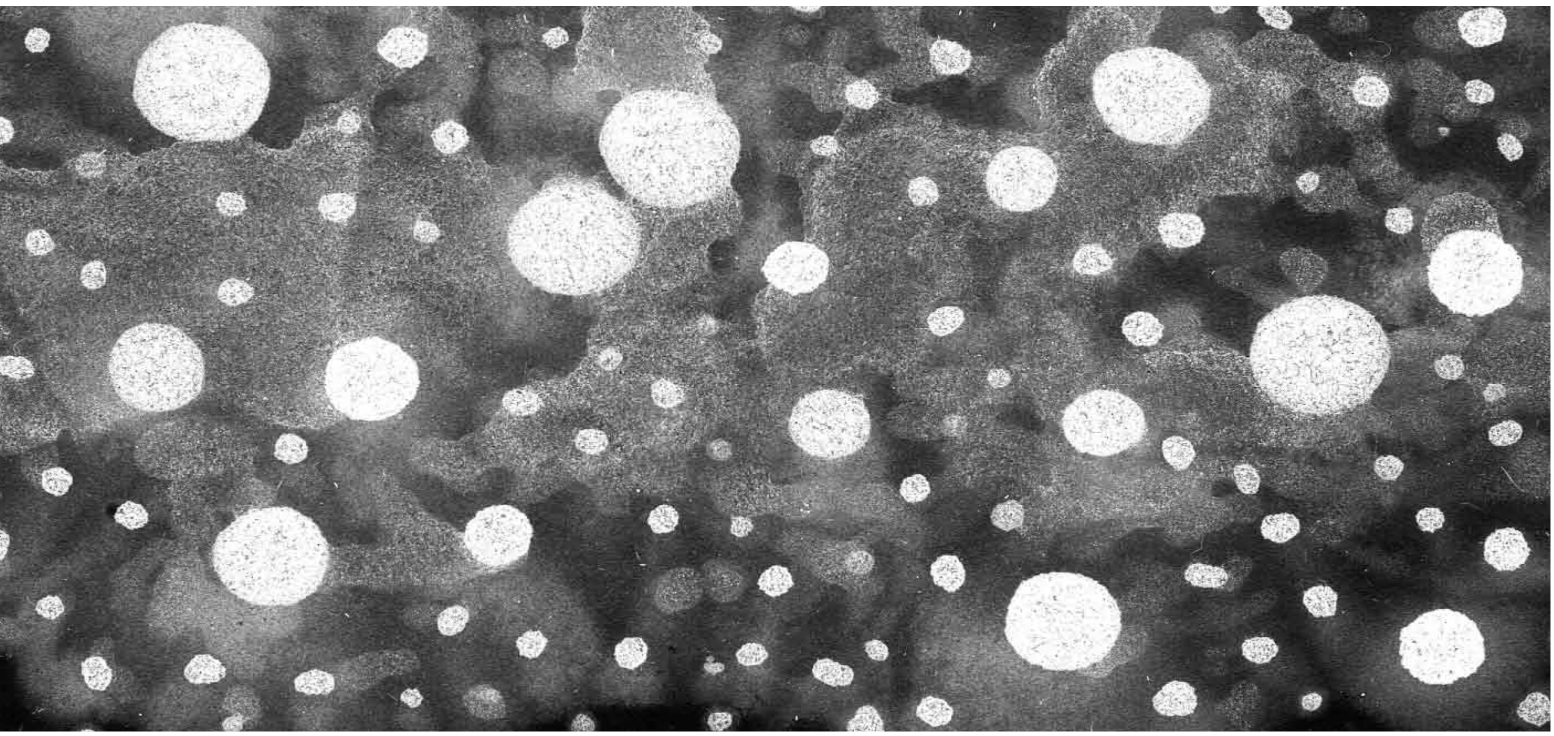
Since the Bonn Nexus Conference *(The Water, Energy and Food Security Nexus: Solutions for the Green Economy, 16-18 November 2011),* the United Nations has triggered the dialogue to promote finding sustainable development pathways by increasing the policy coherence between the areas of water and energy.

The UN system – working closely with its international partners and donors – is collectively bringing its attention to the Water-Energy Nexus. Particular attention is being paid to identifying best practices that can make a water and energy-efficient 'Green Industry' a reality: several methodologies are at play to improve industrial productivity while reducing water and energy use.

The United Nations Conference on Sustainable Development, held in Rio de Janeiro, in June 2012, marked an important milestone. The UN brought together governments, international institutions and major groups to agree on a range of smart measures that can reduce poverty while promoting decent jobs, clean energy and a more sustainable and fair use of resources. Under this basis, securing water and energy is now seen as a key priority within the new and emerging agenda for the Sustainable Development Goals and the Post-2015 development dialogue.

To pursue these objectives, the UN has organized the following actions:

- *Decade of Sustainable Energy for All (2014-2024).* Through Resolution 67/215, the United Nations General Assembly declared the decade 2014-2024 as the Decade of Sustainable Energy for All. The Decade underscores the importance of energy issues for sustainable development and for the elaboration of the Post-2015 development agenda. It highlights the importance of improving energy efficiency, increasing the share of renewable energy and cleaner and energy-efficient technologies. Enhancing the efficiency of the energy models would reduce the stress on water.
- *Sustainable Energy for All initiative.* The Sustainable Energy for All initiative is a multi-stakeholder partnership between governments, the private sector, and civil society. Launched by the UN Secretary-General in 2011, it has three interlinked objectives to be achieved by 2030: (1) Ensure universal access to modern energy services; (2) Double the global rate of improvement in energy efficiency; (3) Double the share of renewable energy in the global energy mix.
- *UN-Energy.* Established in 2004, UN-Energy was initiated as a mechanism to promote coherence and inter-agency collaboration in the field of energy and to develop increased collective engagement between the United Nations and other key external stakeholders. UN-Energy's work is organized around three thematic clusters: (1) Energy access; (2) Renewable energy; and (3) Energy efficiency.
- *United Nations Industrial Development Organization (UNIDO).* UNIDO's primary objective is the promotion and acceleration of integrated and sustainable industrial



development in developing countries, using sustainable practices primarily focused on water and energy security, and countries with economies in transition and the promotion of international industrial cooperation towards sustainable development.

- *United Nations Environment Programme (UNEP).* UNEP coordinates United Nations environmental activities, assisting developing countries in implementing environmentally sound policies and practices. The Water-Energy Nexus, its interdependencies and best practices related to energy and water security have been highlighted in its wide range of publications. UNEP has played a significant role in developing international water, energy and other international conventions, promoting environmental science and information and illustrating the way in which those can be implemented in conjunction with policy, working on the development and implementation of policy with national governments and regional institutions in conjunction with Non-Governmental Organizations (NGOs).
- *World Bank's Thirsty Energy initiative.* To support countries' efforts to address challenges in energy and water management proactively, the World Bank has embarked on a global initiative: Thirsty energy. Thirsty Energy aims to help governments prepare for an uncertain future, and break disciplinary silos that prevent cross-sectorial planning. With the energy sector as an entry point, Thirsty Energy quantifies trade-offs and identifies synergies between water and energy resource management. Thirsty Energy demonstrates the importance of combined energy and water management approaches through demand-based work in several countries, thus providing examples of how evidence-based operational tools in resource management can enhance sustainable development. This created knowledge will be shared more broadly with other countries facing similar challenges. Thirsty Energy tailors approaches depending on the available resources, modelling experience, and institutional and political realities of a country. In order to ensure client ownership and successful integrated planning, Thirsty Energy focuses on building the capacity of relevant stakeholders and leveraging existing efforts and knowledge. The energy-water challenge is too large for any organization to tackle alone.
- *The 2014 World Water Development Report.* The 2014 World Water Development Report (WWDR) provides answers to key questions such as: what are the implications of the Water-Energy Nexus for SDGs? How can we make better policies for integrated management and governance? How can we make a business case for Water-Energy Nexus? How do we create enabling environments – public/private, pricing, improving joint access – urban vs. rural? Finally, how do we guarantee the long-term sustainability of water and energy system?

Fig. 4. Geothermal energy is converted into electricity and used to heat green houses. Taupo, New Zealand. © UN Photo/Evan Schneider.

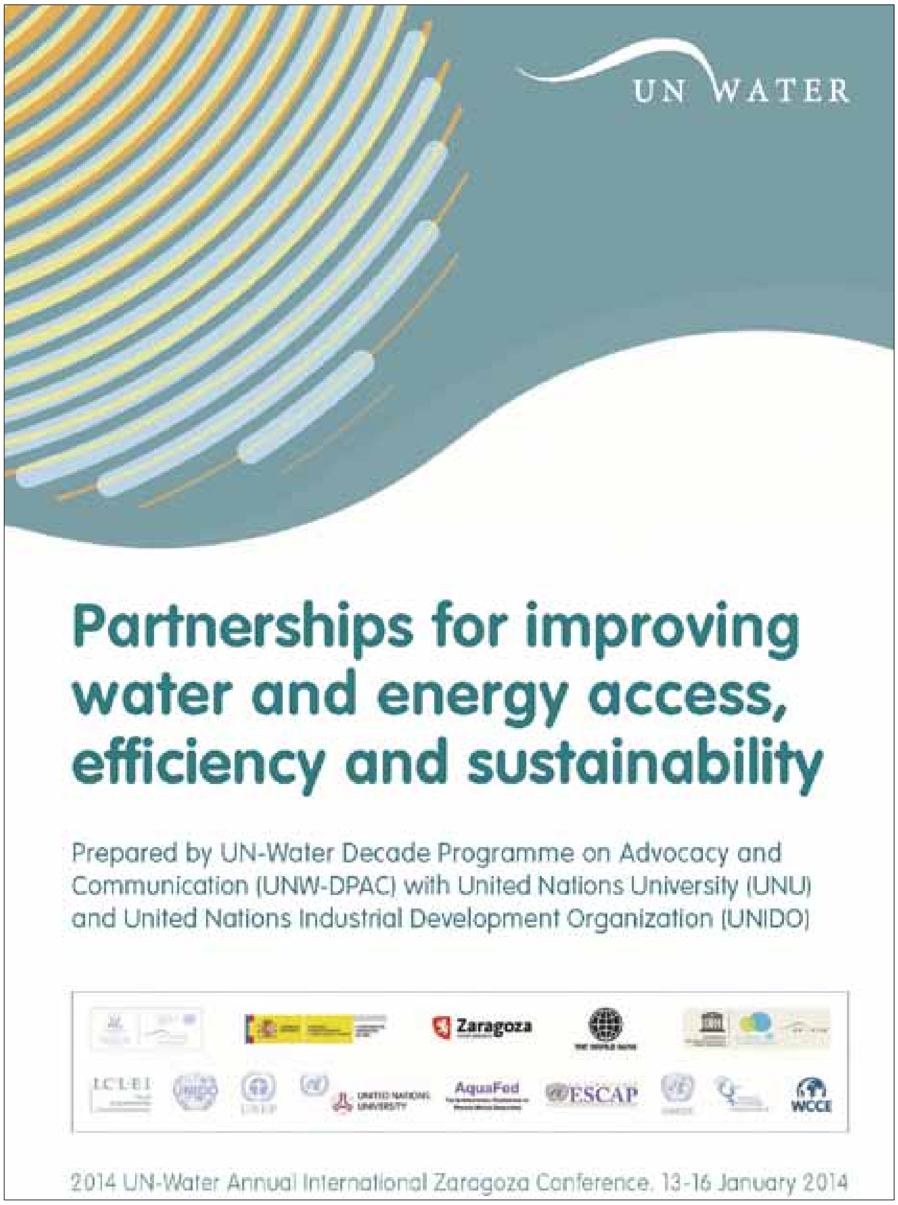


Fig. 5. Front cover of the final report of "Partnerships for improving water and energy access, efficiency and sustainability".

FINALLY

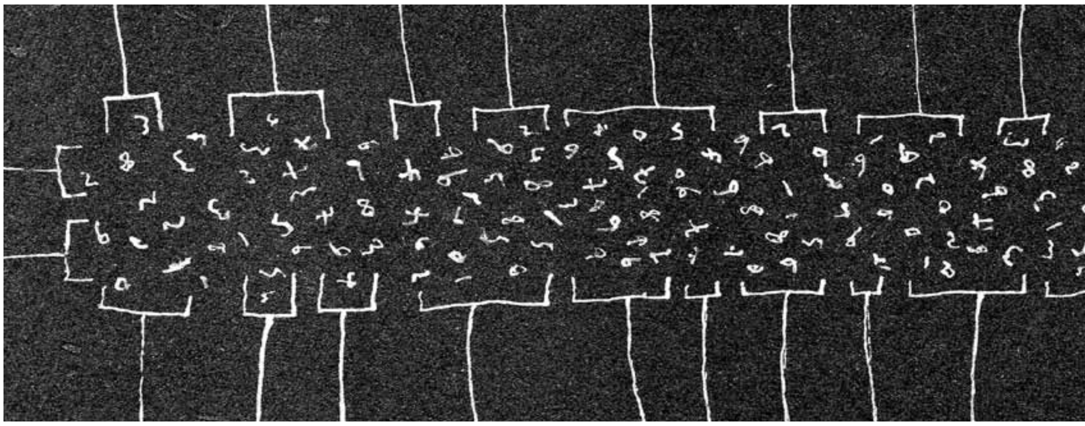
World Water Day (WWD) is held annually on 22 March as a means of focusing attention on the importance of freshwater and advocating for the sustainable management of freshwater resources. Each year, World Water Day highlights a specific aspect of freshwater. This year 2014 the focus is on water and energy issues. The United Nations University (UNU) and the United Nations Industrial Development Organization (UNIDO) lead the official celebrations.

The World Water Day (WWD), held in Tokyo, Japan, the 20-21 March 2014, addressed the Nexus of Water and Energy in the context of sustainable development. The WWD aimed at raising awareness across a broad range of business domains and government sectors to solve water and energy challenges in a cohesive way.

On the occasion of the WWD, the UN-Water 'Water for Life' Best Practices Award was presented. The International Water Management Institute (IWMI)-Tata Water Policy Programme (ITP) in India and the 'NEWater programme' in Singapore have been the 2014 Award winners. ITP successfully filled the gap between research and policy action to improve groundwater use in India through energy infrastructure and policy improvements. NEWater wide uses water reclamation. While this is not a new concept, what is significant is the successful wide-scale implementation and public engagement plan of NEWater along with its participatory practices and public education programmes, which have allowed delivery of an exponentially successful service. Both are inspiring examples on how the Nexus approach can help improved water and energy access, efficiency and sustainability.

As explained, the Zaragoza Conference addressed the challenges, relationships and partnerships that make possible to implement solutions for ensuring access, efficiency and sustainability in the provision of water and energy. During the conference, successful initiatives were presented that are paving the way towards addressing the Nexus. Some of these from UNIDO, Greenpeace, the World Bank, and the United Nations University are presented in the first part of this publication, coordinated by UNW-DOAC. They provide examples on the way ahead.

In the first part of this publication Diego Rodríguez from the World Bank addresses the challenges in the public sector for integrated water and energy planning ; Zafar Adeel, Director of United Nations University Institute for Water, Environment and Health (UNU-INWEH) addresses the knowledge challenges for integrated policy design and implementation on water and energy; Christian Susan and John G. Payne from the United Nations Industrial Development Organization (UNIDO) present the challenges and developments in Water and Energy Efficiency in Industry and the role of UNIDO in this regard; Annukka Lipponen and Mark Howells, Environmental Affairs Officer at the United Nations Economic Commission for Europe (UNECE) address how the UNECE is promoting Policy Responses on the Water and Energy Nexus.



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WILL WATER CONSTRAIN OUR ENERGY FUTURE?

Diego J. Rodríguez and Antonia Sohns

KEYWORDS:
THIRSTY ENERGY
INTEGRATED PLANNING
ECONOMIC ANALYSIS
CLIMATE CHANGE
RISK AND UNCERTAINTY

BACKGROUND

Our water, food, and energy resources are under ever-growing pressure from increasing populations and economies, and many already struggle to obtain access to these resources. In 2012, 2.5 billion people had unreliable or no access to electricity (EIA 2012), and 2.8 billion people lived in areas of high water stress (WWAP 2012). As economies grow and diversify, competing demands for water broaden to include more intensive municipal and industrial uses, as well as increased demands for agriculture. By 2050, emerging economies, such as those in Africa will generate 7 times more electricity than today, and in Asia, primary energy production will almost double, and electricity generation will more than triple by that same year (see Figure 1) (World Energy Council, 2010).

Rapid urbanization and climate change will compound challenges to provide adequate supply and access across sectors. Further, climate variability and related extreme weather are already causing major floods and droughts putting populations, livelihoods, and assets in danger. This variability is likely to worsen under current trends. The number of people affected by climate-related disasters doubled every decade in the last 40 years (World Bank 2010). Diminished water quality also impacts growth as it degrades ecosystems; causes health-related diseases; constrains economic activities; and increases wastewater treatment costs. Scarcity due to availability or quality is caused not only by physical factors, but also the political and economical aspects that affect the allocation, availability, and use of water.

Such variability in the supply and quality of water resources is becoming increasingly recognized as a chief constraint for energy companies with inherent risks associated (see Figure 2).

In 2013, CDP's Global Water Report found that 82 percent of energy companies and 73 percent of power utility companies indicate that water has become a substantive risk to its business operations, and 59 percent of energy companies and 67 percent of power utility companies have experienced water-related business impacts in the past five years. This report adds to the mounting evidence that energy and water resources must be planned in an integrated manner. In 2012, the International Energy Agency (IEA) published a chapter in its World Energy Outlook centred on water and energy issues; and the UN's Stockholm World Water Week focused on the intersection of energy and water in September 2014.

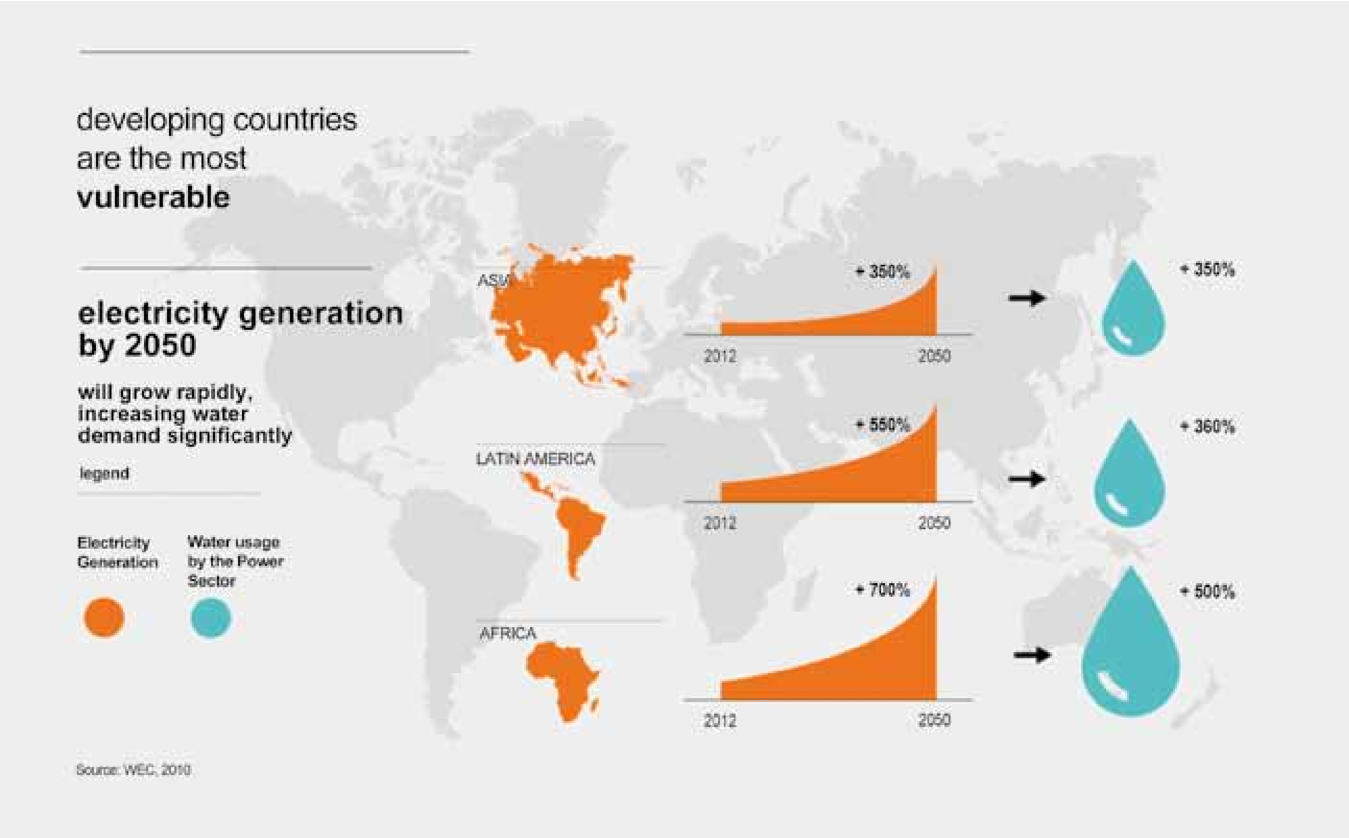

Fig. 1. Growth in Electricity Generation by 2050.

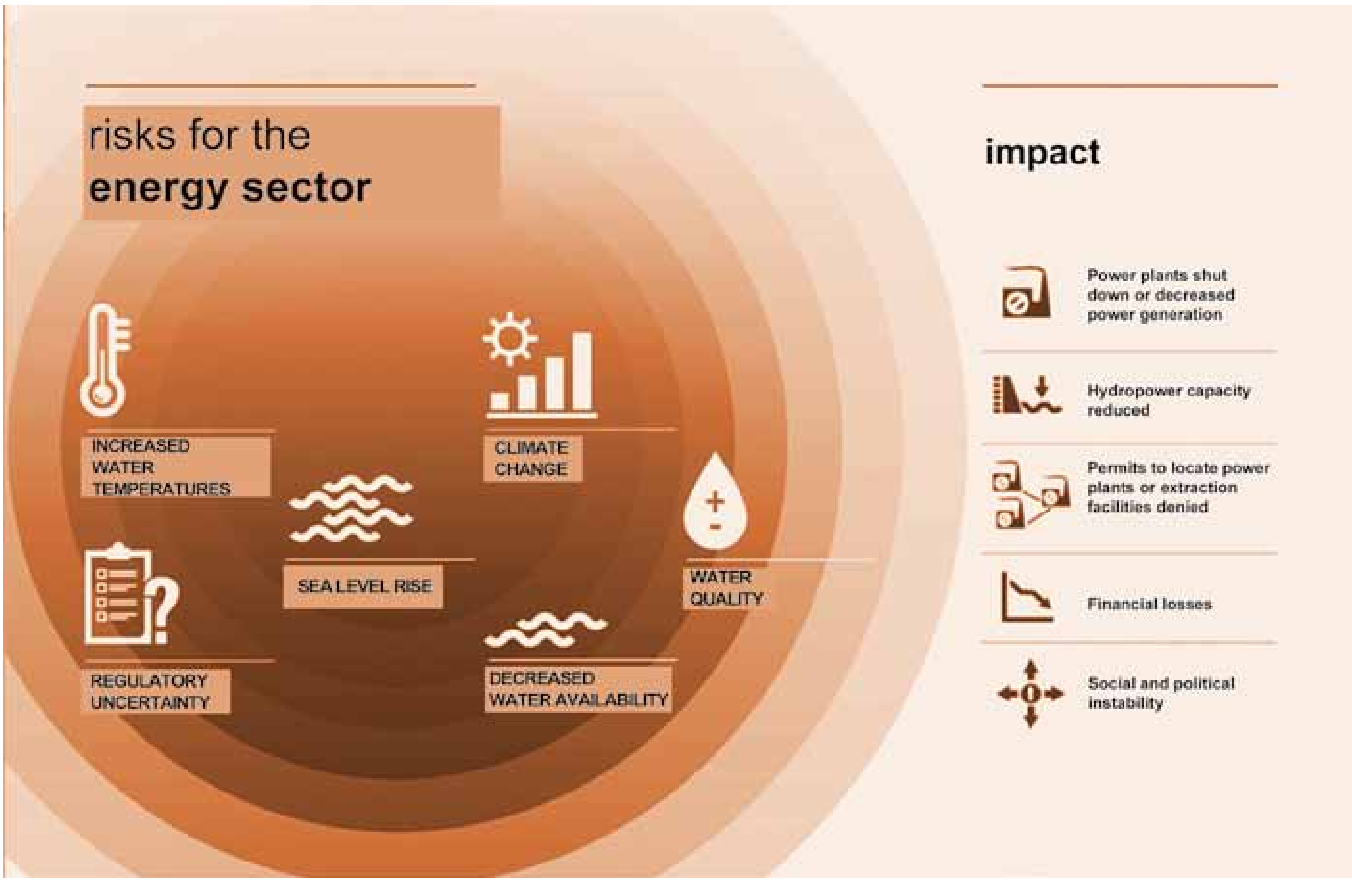

Fig. 2. Risks for the Energy Sector.

Ensuring that energy and water demands are met has profound implications on the other respective resource, as water is needed to generate energy (hydropower, thermoelectric cooling, fuel extraction and refining, irrigation for bio fuels) and energy is needed to extract, treat and distribute water and to clean the used and polluted water. No matter what the source, energy and water are inextricably linked, and must be addressed.

Despite the inherent interconnectedness of water and energy resources, natural variability and climate change's impact on the resources is made more complicated by inadequate institutions and capacity. Despite the importance of energy and water, and the close relationship between the two, funding, policy making and oversight of these resources in industrialized and developing countries are performed by different people in separate agencies in many governments. Thus, integrated energy–water policy is rare. Furthermore, the current internal incentives system still favours independent sectorial outcomes over cross-sectorial results.

In order to ensure we are investing in climate-smart infrastructure and integrated water and energy resource management, it is necessary to develop better tools and institutions to assess and manage cross-sectorial implications and the potential magnitude of water and energy stresses for the energy sector.

FRAGMENTATION IN PLANNING AND INVESTMENTS

Current planning tools at the regional or country levels make projections based on economic and population growth, while there is a limited body of analysis to inform decision makers about the consequences of changing water availability due to growing demand or the impacts on climate change, both in the aggregate and across sectors, particularly at the basin level. Thus, models today lack the capacity to address the wider social, economic, and environmental impacts of the Energy-Water challenge, and are not able to identify the implications of potential water and energy policies and investments intending to address water constraints. This is of particular concern for countries with strong energy demand growth, or significant declines in per capita water supplies.

In the context of conventional water supply planning, analysis is primarily concerned with developing water resource systems to manage the distribution of water in time and space in order to allocate the water supplies to meet a specific set of objectives or demands. Most water allocation modelling assumes that there are always adequate energy supplies available to facilitate the catchment, pumping, and treatment of water. Few, if any, of the water allocation models quantify the imposed energy consumption associated with different water demands. This approach does not adequately reflect the dynamic interplay between energy and water, especially when considering the large energy demands that may be incurred as a result of transporting (pumping) and treating water to meet an end use.

Water models typically require a high level of hydrologic detail on a particular watershed, making them data-intensive as well as complex.

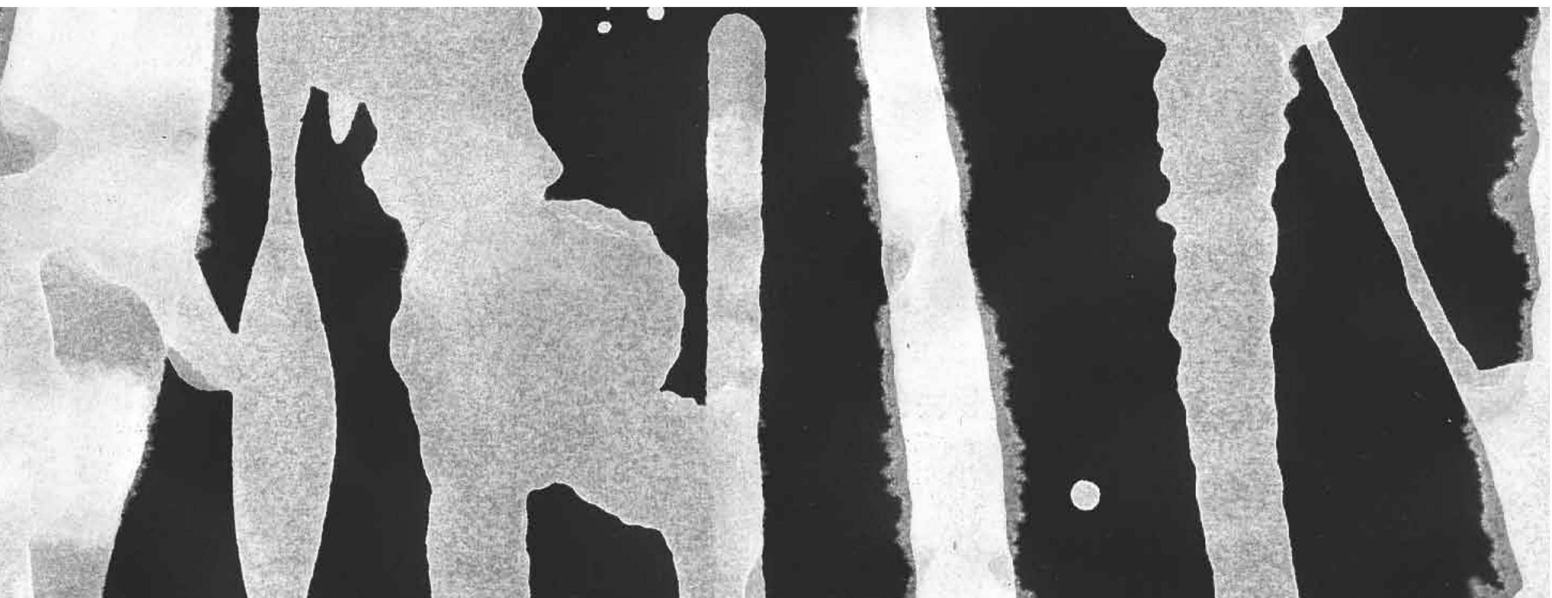

**Fig. 3. The expansion of food production through irrigation groundwater in Sauth Korea.
Cheju Island, Sauth Korea. © UN Photo/M Guthrie.**

These models can provide a high level of detail on water circulation in the watershed (stream flows, evapotranspiration, return flows, exchange between surface and ground water), which is valuable for considering the pros and cons of e.g. a specific new hydropower investment. On the other hand, scaling-up the use of such models for water budgets at a country level with multiple watersheds imposes a large data and analytical burden to maintain a level of detail that may not be needed for first-cut resource assessment and the broad implications of changes in water utilization, including for energy sector development. In addition, while economic parameters can be combined with hydrological modelling to analyze the costs and value of output for a new hydroelectric investment, economic analysis of water allocation at a national level requires more economic detail on competition among alternative water uses.

Similarly, energy planning rarely takes into account water concerns in the development of their growth and management frameworks. Conventional energy planning is primarily concerned with siting and cost requirements for energy generation in the context of transmitting the produced energy to population centres. Except for hydro-power-dominated systems, the availability of water supply necessary for power generation at the upstream planning stage is typically assumed to exist and is often not considered to be a limiting factor in operations although it is accepted that potential constraints will be an important factor. The consumptive use of water necessary for the generation of energy production required by water infrastructure is not considered dynamically within models. In these situations, there is an inherent multiplier on both energy and water demands that may be overlooked when employing the traditional approach to modelling and analysis. While this effect may be quite marginal in regions with ample supplies of both water and energy, it could become a central cross-sector constraint in regions with resource scarcity and will require accurate evaluation and analysis.

Energy sector models have advanced substantially over the past four decades, and these can also incorporate estimates of water demand for energy production through simple coefficients of water utilization per unit of output, mainly for electricity, but can include water for bio fuels, mining and refining as well. A wide range of models is available, from fairly basic electricity capacity expansion models, to very detailed electricity network models to economy-wide general equilibrium models with representations of various types of energy supply and demand. However, the energy models do not address total water availability and its dynamic nature or (economic as well as volumetric) tradeoffs among water uses. In some advanced models, water availability and variability is taken into account as it affects hydropower production and with that, other supply options to the system. The linkages of such water availability and variability with other sectors are usually handled by incorporating exogenous constraints or parameters in the energy models (e.g. minimum environmental or navigation outflows, quotas for irrigations, among others).

Projected climate change and impacts on water availability are not commonly factored into conventional energy planning and operations. Global warming will likely cause increased competition for water resources among economic sectors (e.g. Industry and agriculture) and to supply water to increasing populations and maintain healthy ecosystems. One of the greatest challenges when assessing impacts of climate change is to do so in an integrated way so as to fully take into account the many complex inter-relationships not only within the energy sector, but also in other sectors.

Assessing the multi-dimensional synergies, trade-offs and risks are of increasing relevance given the future challenges, such as by leveraging the existing modelling capacity of the client countries and building on their energy and water planning models and capacities. To contribute to this effort, the World Bank has launched the Thirsty Energy initiative, which leads in this effort by working with developing countries to integrate dynamic water variables into energy modelling and development plans.

Robust planning frameworks must be accompanied by governance structures that harmonize policies across major economic sectors and eliminate perverse incentives across water and energy. For example, energy policies that provide subsidies that promote overextraction of groundwater resources and/or water policies that do not allow for proper pricing. These policies are usually in place in countries where there is also a severe institutional fragmentation in which each sector plans their investments in a siloed approach. As such, when contemplating integrated planning, it is imperative that the proper institutional, regulatory, and legal reforms are also performed.

THIRSTY ENERGY INITIATIVE

The World Bank's Thirsty Energy Initiative (TE) encourages building a framework that provides interactive environments to explore trade-offs and evaluate alternatives among a broad list of energy/water options and objectives (see Figure 4). In particular, the modelling framework needs to be flexible in order to facilitate tailored analyses over different geographical regions and scales (e.g., national, state, county, watershed, interconnection region). It attempts to optimize the combined system (to both minimize cost and consumption). Based on Thirsty Energy's research, it was found that the most effective way to improve Energy-Water modelling is by incorporating water resources and uses into existing energy modelling frameworks.

Strengthening any modelling framework and capacities will require a more robust treatment of risk and uncertainty. Resource cost and availability are typically defined by supply-cost curves, which are inputs to the model, and uncertainty in the cost or availability of specific resources is traditionally handled through scenario or sensitivity analyses, which can determine how much the model results change when these parameters are changed. Examples of when it is

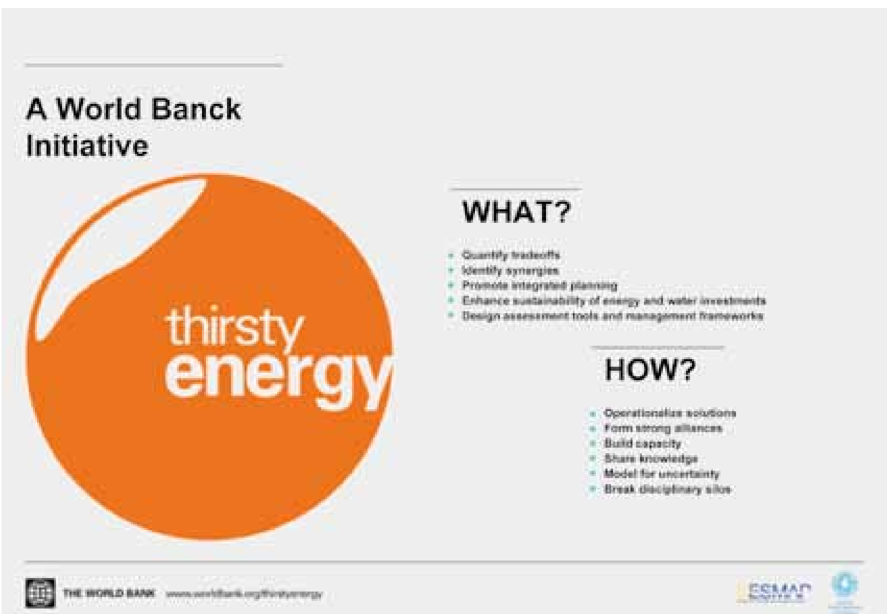

Fig. 4. The Thirsty Energy Initiative.

important to investigate uncertainty in this area include situations where the energy system is dependent on a significant amount of imported fuels, or where environmental or technological concerns may significantly alter the cost or availability of extracting or processing certain resources, and where weather/climate unpredictability may have extreme impacts on water for power generation.

Uncertainty in demand projections is typically only investigated through scenario analyses, where specific changes in future energy demands are postulated based on specific changes in underlying assumptions behind the original demand projection, such as a change in GDP or population growth rates. With the introduction of water into energy models, new areas of uncertainty are introduced. The biggest of these is the variable nature of the underlying weather data projection and its correlation to the energy service demand projection. Energy system models do not normally deal with this kind of variability. Water models are often used to determine the resilience of the water system to extremes of weather in a simulation framework. Energy system models are more often used to identify economically optimal investments out of a large variety of possible options. Integrating water systems into energy optimization models will require careful design of the input data sets to avoid or minimize inconsistencies. Precipitation levels and temperature data are primary drivers of water availability, and they also directly drive the levels of energy services required for space heating, space cooling and many other energy services. Integrated models will require development of a coherent set of weather and energy demand projections.

FROM PLANNING TO INVESTMENTS

Integrated planning is a necessary but not sufficient condition to address the challenges of the Nexus. It is also important to increase institutional capacity, and employ efficient technologies and solutions supported by the client country, and to invest in infrastructure. Infrastructure is an efficient means of increasing resiliency to climate change and improving water and energy management, yet there are key funding gaps that threaten economic growth and could lead to an increase in the number of people living in poverty. Estimates suggest that developing countries will require US$1.1 trillion in annual expenditure through to 2015 to meet their growing demand for infrastructure (World Bank 2011) – this is more than double their US$500 billion annual spending (Qureshi 2011).

The International Energy Agency (IEA) has estimated that nearly $1 trillion in cumulative investment ($49 billion per year) will be needed to achieve universal energy access by 2030. If investments are not made, 1 billion people will remain without access to electricity in 2030. Even greater is the need for investment in water infrastructure. For developing countries alone, it has been estimated that US$103 billion per year are required to finance water, sanitation and wastewater treatment through to 2015 (Yepes 2008). All of these estimates are even higher if climate change mitigation and adaptation strategies are incorporated.

In order to overcome the funding gaps and achieve resilient infrastructure for a sustainable future, private investment, together with public financing, should be encouraged to promote sustainable service delivery, especially in the poorest countries. Moreover, regulations and policies will be required to incentivize efficient and integrated infrastructure for a more sustainable future.

Traditionally, most infrastructure services have been provided by the public sector. It is estimated that 75 percent of water infrastructure investments in developing countries come from public sources (Rodríguez *et al.* 2012b). Nevertheless, given the infrastructure financing gap, the public sector alone cannot provide enough funding to satisfy the needs of the increasing demand for services.

Private capital must be involved to close the gap, and yet, private investors are usually reluctant to invest in infrastructure projects, including those relating to water and energy, due to the risks involved such as the long payoff period and sunk nature of the investment. When they do invest, they prefer to work in middle income countries where the risk is lower and capacities are high, leaving low income countries dependent on volatile public budgets and donor commitments. This environment should coordinate efforts by the private sector, governments and international institutions; enhance capacity-building of local institutions; improve public spending and its monitoring; and reduce investment inefficiencies and help utilities to move towards cost recovery.

As the lifespan of most water and energy infrastructure is more than 30 years, decisions being made today are locking rivers, cities, ecosystems, power systems into particular consumption patterns. Recent work by the IEA (2010) suggests that in 2008, energy consumption subsidies added up to more than US$550 billion globally, but much of it was not properly targeted and provided limited benefits to the poor (Toman *et al.*, 2011). In order to ensure a sustainable infrastructure legacy, we need regulations, policies and financing mechanisms promoting sustainable and integrated planning so that future infrastructure is lower in maintenance, less expensive, and more efficient.

SOLUTIONS EXIST BUT...

There is a vast literature presenting different solutions to the integrated investments of water and energy and as such there are many other opportunities for the joint development and management of water and energy infrastructure and technologies that maximize co-benefits and minimize negative trade-offs (see Figure 5). Economic analysis can allow countries to decide if such models are viable in their context. Combined power and desalination plants, combined heat and power plants, using alternative water sources for thermal power plant cooling, and even energy recovery from sewage water are just a few other options that can provide income for one operation and make a waste a resource. It is even possible to save energy and water more simply, through leakage reduction in the water sector, improving energy efficiency, or increase awareness of the issue to change the consumer behaviour and decrease energy and water waste.

Besides the pursuit of new technical solutions, political frameworks need to be designed to promote

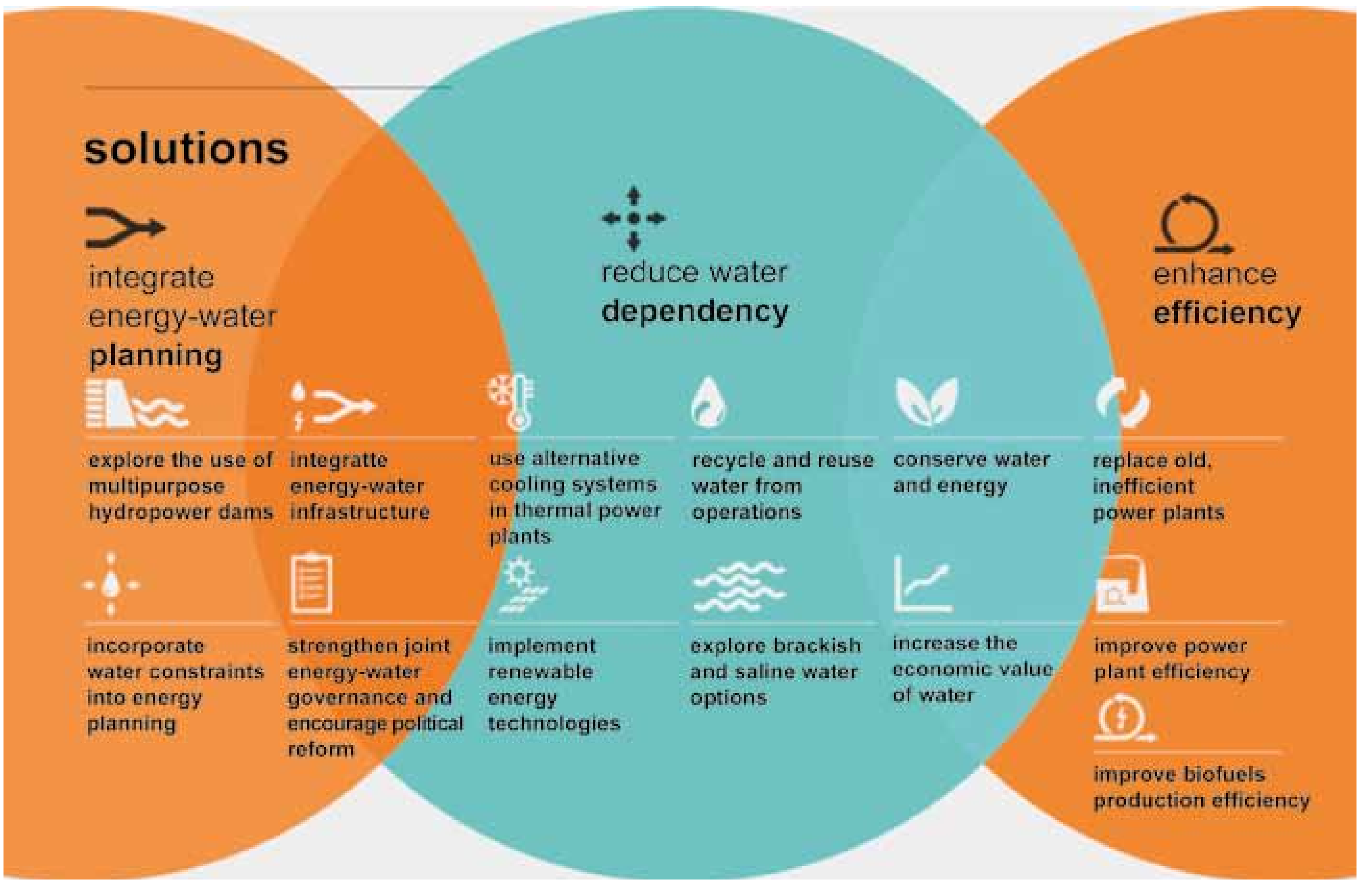

Fig. 5. Solutions to Address the Nexus.

Fig. 6. Treatment Plant Wastewater. Danbury, Connecticut, USA. © UN Photo/Evan Schneider.

cooperation and integrated planning among sectors as well. Current management frameworks are developed based on risk avoidance and control of resources as the paramount considerations in traditional electrical utility planning and water resources planning. Yet, the success of planning can be best met through the participation of all units of government and stakeholders in decision-making through a process of coordination and conflict resolution. Integrated resource planning of the Energy-Water challenge emphasizes the importance of establishing a more open and participatory decision-making process and coordinating the many water institutions that govern water resources. Therefore, Energy-Water planning approaches should encourage the development of new institutional roles in addition to new analytical tools. It also promotes consensus building and alternative dispute resolution over conflict and litigation.

Reforming existing management frameworks, from modelling, economics, and political, countries will be able to develop a more systematic approach to consider the complexities of water and energy issues, and the existing interactions and relationships between sectors. But this is easier said than done. Reforming political and institutional process is not an easy task. Transferring technologies either, as this process is highly correlated with existing capacities and regulatory and legal environments in the countries. Furthermore, many of these technologies are quite costly and difficult to implement. Understanding the local contexts becomes essential if we are to ensure that many of the existing solutions can be fully implemented in the developing world. And quantification of potential tradeoffs and synergies is essential.

Economic analysis can help capture tradeoffs in Energy-Water management decisions. Water and energy are crucial inputs into economic production. Tightening constraints may introduce the potential for reductions in economic activities. Increasing water demand and scarcity have potential to increase market prices for water and energy and lead to redistributions of these increasingly scarce resources between sectors. In the case of water for example, increasing scarcity in one area is likely to result in the increased purchase of food products from another area. When this occurs, significant structural adjustment can occur and needs to be managed with sensitivity in order to ensure that overall economic activity and employment is not reduced in the short term. Actual outcomes will depend on the capacity of a community to adjust, rates of technological progress in development of water efficiency in energy and food production, rates of knowledge provision, institutional, governance, and planning arrangements to facilitate efficient investment and synergies in water and energy planning.

One of the more difficult issues to manage is the fact that the economic value of water to the energy sector, at the margin, will generally be greater than its economic value to agriculture, while the implicit political power of the agricultural sector can sometimes be greater than that of the energy sector. This implies that the energy sector will generally be willing and able to pay more for water than competing agricultural uses – with the associated risk that some agricultural groups may seek to use their political power to redress this difference in economic power, such as by portraying the energy sector as damaging agricultural interests and threatening food security.

CONCLUDING REMARKS

Meeting future demands for water and energy resources requires innovative approaches that encourage cross-sectorial cooperation and improve analysis of water and energy tradeoffs at the national and regional levels. Furthermore, as organizations and experts go forward, creating Sustainable Development Goals and other targets, it is critical to cut across sectors in analysis because improvements for one goal may have negative impacts on another. Such as increasing the share of bio fuels in renewable energy generation may have a greater impact on water resources than other renewables. Or establishing emissions caps can promote the use of more water-intensive energy producing technologies with potential negative impacts on the sustainability of water resources and imposing negative environmental externalities.

As governments and institutions globally consider goals of the future, best practices of today can be employed to enhance efficiency, resiliency, and integrated planning. These approaches will help governments and companies avoid financial losses in energy and power investments, infrastructure prone to risk in the wake of climate change, and unstable economies.

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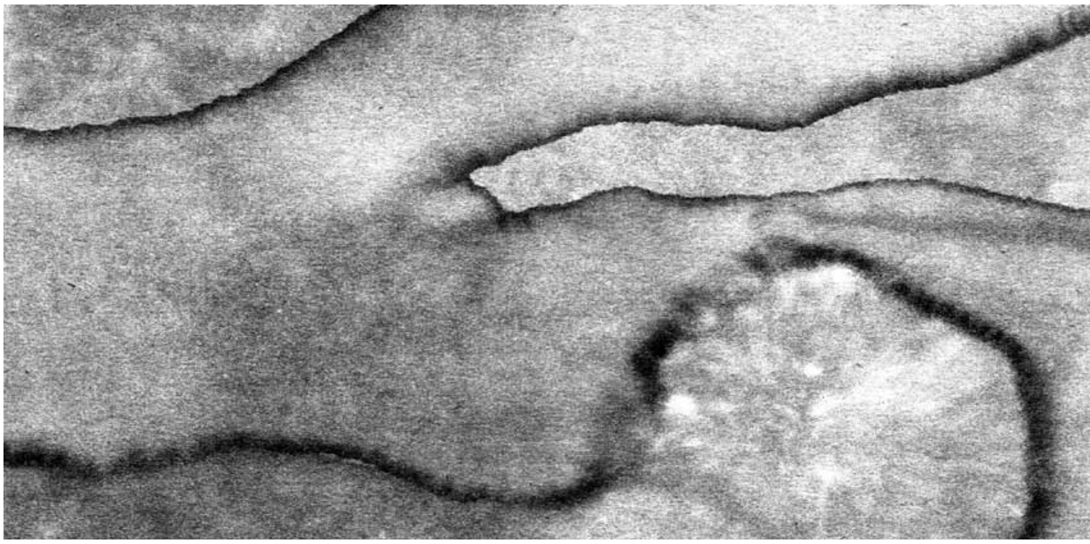

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KNOWLEDGE CHALLENGES

FOR POLICY INTEGRATION OF WATER AND ENERGY DOMAINS

Dr. Zafar Adeel

KEYWORDS:
WATER MANAGEMENT
ENERGY GENERATION AND SECURITY
WATER-ENERGY NEXUS
POLICY INTEGRATION
KNOWLEDGE AND DATA GAPS

AN INTRODUCTION TO THE WATER-ENERGY NEXUS

Water and energy have always been closely associated, and in many ways, have been the defining element in industrial and economic development. The notion of a "Nexus" of these sectors –that is a focal point at which the management, planning, and resource allocation intersect– is not new either. A number of conferences and meetings in the last decade have expounded on the notion of this decade, and with some variance have included a number of other elements also, including food, urbanization, health, etc. (Hoff, 2011; WEF, 2011; ADB 2013). The idea that the Nexus approach can help bring down vertical silos separating historically distinct sectors, and thus achieving greater efficiency, is a major consideration in the ongoing dialogue on this topic. The idea, however, is not without its detractors who claim that such mergers across sectors and governmental bureaucracies are not feasible, and given some major disparities amongst the respective sectors, may even prove to be counter-productive.

Energy generation, regardless of the technology or resource used, requires some form of water –either to move turbines in hydropower generation configurations, to cool energy generation thermal and nuclear plants, to irrigate bio fuel crops, or to serve as a drilling/pumping fluid in hydraulic fracturing (or fracking) systems (WWAP, 2014). Some forms of energy utilize water in a consumptive pattern, making it unavailable for subsequent use because of quality degradation or evaporation. Other forms, like hydropower are non-consumptive and may be further linked to water management and irrigation schemes. Conversely, water pumping, treatment, desalination, delivery, and wastewater management all require significant amounts of energy (Hoffman, 2011). Globally, it is estimated that about 8% of all energy generated is consumed for water management, making it a sizable energy consumer (WWAP, 2012).

There is yet another societal nexus in which the lack of water and energy becomes a significant detriment to human, social, and economic development. The poorest of the poor –the so-called bottom billion– are people in developing countries who are without access to water, modern forms of energy, or adequate sanitation (Sumner, 2010; WWAP 2014). The consequences are devastating in terms of a circular cycle of poverty, illness and deprivation. The author has publicly argued that addressing the global social development crisis

requires a consolidated approach, in which combined solutions for water, energy and sanitation are provided to the bottom billion people on a priority basis (UN-Water, 2011).

As the United Nations collectively declared the World Water Day for 2014 to focus on the Water-Energy Nexus, a number of dialogues focused on the essentials, opportunities, and challenges of the Nexus. The author, being responsible for organizing such dialogues, was able to review a broad range of perspective and synthesize some key points presented in this paper.

In order to better understand the nature of the "Water-Energy Nexus", a more fundamental analysis of the disparities, knowledge gaps, and policy roadblocks is needed. This paper aims to explore these underlying challenges, which may hinder the adoption of the Nexus approach, and offers some recommendations about ways to overcome them.

Fig. 1. The search options for addressing the water tightness has driven companies to favour above all one: the construction of desalination plants. Egypt.

KNOWLEDGE CHALLENGES FOR THE WATER-ENERGY NEXUS

1. *Identifying and Quantifying Tradeoffs:* The competition for capital and financial resources for water and energy sectors is significant and often not neutral (Bizikova *et al.*, 2013). In other words, policy formulation at national level must account for some tradeoffs. Many national development processes are oblivious of these tradeoffs or do not possess the tools to adequately quantify these tradeoffs for rational policymaking (Hoff, 2011).
   For example, switching to air-cooled or water-efficient thermal power plants requires a higher capital investment up front but could lead to long-term cost savings, particularly in terms of the water delivery costs (ADB, 2013). Such higher initial capital investments can be more readily justified in situations where water scarcity or water pricing have resulted in water becoming a major cost component in energy genera-

Fig. 2. Dam power plant Ruzizi One. Democratic Republic of Congo.© UN Photo/Marie Frechon.

tion. Similarly, many developing countries have shied away from investment in large-scale dams; the common arguments offered in opposition are societal impacts through displaced population, environment and ecosystem impacts of reservoirs, perturbation of water sharing amongst riparians, etc. However, these dialogues often become politicized and polarized; it is rare to have an unbiased discourse that would also account for savings in energy costs, creating of economic opportunities, increase in food security, and flood protection (Baghel and Nüsser, 2010). A major hurdle is that the full range of benefits associated with these elements cannot be easily monetized or quantified.

The asymmetries between the water and energy sectors also feed into the difficulty of rational quantification of tradeoffs. Globally, energy sector is estimated at about US$ 6 trillion, where as the water sector is estimated to be less than a tenth of that (WWAP, 2014). In many countries, the energy sector is greater in its financial mobilization by one or two orders of magnitude when compared to the water sector. That also implies that the respective interest lobbies are also disproportionate in size and wield asymmetric influence in policy formulation processes.

2. *Leveraging Benefit and their Sharing:* As noted earlier, it is often difficult to conduct quantitative

tradeoffs between the water and energy sectors, but it is even more challenging to quantify knock-on benefits. For example, more efficient energy generation could have beneficial impacts on human and ecosystem health, but they might accrue in the medium- to long-term; direct attribution and accounting of ecosystem benefits poses a major scientific challenge. Similarly, better provisioning of water and energy at the household level could drive the public health costs associated with acute and chronic health problems. Accurately projecting these indirect benefits, such as reduced health care costs, is often beyond the financial planning capacity available in developing countries.

This situation becomes progressively more challenging when water and energy are shared across jurisdictions and/or boundaries. Mechanisms for transboundary sharing are typically aligned to work on either energy or water, and very rarely both. From a rational standpoint, one might argue that mutually sharing conjoined water and energy-related benefits would create more options and opportunities for reaching compromises. The geopolitical realities and historical resource conflicts often intercede and interrupt the likelihood of mutually agreeable benefit sharing formulas.

3. *Undertaking Meaningful Risk Analyses:* From first principles, it stands to reason that ineffective management of water and energy resources exposes societies to a range of risks (Kumar, 2005; Wüstenhagen, 2007). These include impacts of extreme events like floods and droughts, social unrest caused by energy and water shortages, economic destabilization by disruption in flow of critical resources for industrial and agricultural activity, reduced agricultural production and impacts on food security, and increased costs in public health. Some researchers are claiming, for example Gleick (2014) in the case of the ongoing Syrian civil war, that a combined realization of these risks can cause major societal disruptions.
Even when adverse impacts can be quantified, the results of such

Fig. 3. Hellisheidi geothermal power plant in Iceland. Located in the Hengill area, an active volcanic mountain range in southwestern Iceland.
Hengill, Iceland.
© UN Photo/Eskinder Debebe.

meaningful risk analyses are often trumped by short-termed political expediencies. While governments are hampered by political exigencies, the private sector has recently stepped up and taken on the task of quantifying risk based on scientific evidence. Foremost amongst these is the reinsurance industry, which has invested considerable resources in understanding and quantifying risks, and exploring risk mitigation approaches (Mills, 2005). More generally the World Business Council on Sustainable Development has also taken on a more forward-looking stance towards understanding and addressing these risks (Sandhu *et al.,* 2012; WBCSD, 2002).

4. *Assessing Resource-Efficient Technologies:* It remains a challenge to assess the efficiency of existing and new technologies in terms of water consumption, and somewhat less so for assessing energy generation and transmission efficiency. In most developed and developing countries, the notion of energy efficiency is relatively well established and does not require expenditure of political capital to demonstrate success. Water efficiency, however, becomes a factor only in extreme water-scarcity situations, but is otherwise ignored. A key reason for this is the inadequacy of water pricing, allowing excessive water consumption with little financial consequence. At the same time, pricing of water services and supply remains a politically and emotionally charged issue –most politicians tend to shy away from that topic, as a consequence.

5. *Disparity in Energy-Water Data Availability and Access:* As the energy sector is commercialized to a much greater extent, streamlined within economic flows, and retains considerable private sector engagement and interest, pertinent data are readily available at sub national, national and international scales. In contrast, the availability of water data suffers from considerable gaps, particularly for larger units such as transboundary shared river basins or aquifers. Water and related data are often characterized as state secrets and guarded as such. This unavailability and limited access to data translates directly or indirectly into the challenges outlined in terms of knowledge gaps presented in earlier sections.

CREATING PARTNERSHIPS FOR POLICY INTEGRATION

In order to overcome some of the challenges identified in the previous section, out-of-the-box and innovative thinking is required. One might argue that policy integration around the Water-Energy Nexus can break down knowledge barriers and create enabling environment for demonstrating achievement of higher benefits. Such opportunities are often accompanied by risks, both of which are discussed in this section.

1. *Opportunity – Driving Development Agenda:* The Water-Energy Nexus offers a fresh policy perspective in which emerging notions like the green economy and triple bottom lines can be easily incorporated (UN-Water, 2011). The "newness" of the concept, on its own, can create space for policy dialogue, and the ability to define the nexus in specific national contexts. As the international community gears up to define the Post-2015 development agenda in terms of Sustainable Development Goals (SDGs), this agenda needs to be further translated in national terms, identifying approaches for implementation and resource allocation. Recent reports have argued that the Water-Energy Nexus offers a stable platform for this development agenda formulation (UNU and UNOSD, 2013).
2. *Opportunity – Promoting Sustainable Consumption Patterns:* Many researchers in the recent years have explored the notion of planetary boundaries and whether our current consumption patterns are crossing irreversible thresholds (Rockstrom *et al.,* 2009). Whether one agrees fully with these global expert assessments or not, it is apparent that consumption patterns and consumer behaviours need a major re-think to achieve sustainable economic and industrial development. A dialogue around the Water-Energy Nexus offers a new opportunity to engage the general public and elicit its interest into a forward-looking dialogue. Many of the benefits achieved from improved water-energy security accrue in the short-term, making the notion tangible and digestible to the general public.
   The same argument could also apply to consumptive sectors of the economy, most notably manufacturing and agriculture. Creating a space for policy dialogue offers the opportunity for these sectors to look outside the 'box' and determine how increased water-energy efficiency can drive towards improved bottom lines.
3. *Risk – Enhancing Skewed Public Perceptions:* Considerable negative opinions and suspicions exist around the private domains of the water and energy sectors. Examples abound. The hydraulic fracturing energy sector is viewed as a major pollutant of aquifers and even causing minor local earthquakes. The hydropower sector is deemed to be a destroyer of aquatic and land-based ecosystems, and a disruptor of communities impacted by water reservoirs. Coal-based power generation is deemed to be a major contributor towards global climate change, a cause of negative impacts in local health and ecosystems. Nuclear energy sector, impacted by recent disasters in Japan, is viewed with great suspicion.
   The water sector does not fare much better in public perception. Many view engagement of the private sector as a recipe for unbridled exploitation and depletion of water resources. In the Canadian context, many are concerned about the potential transport of water resources by the shiploads by the private sector to other countries (Barlow, 2001).

Fig. 4. View of a coal plant. Mpumalanga, South Africa. © UN Photo/Gill Fickling.

As a consequence of pre-existing and persistent notions of malfeasance on part of the private sector, there is a significant risk that the Water-Energy Nexus may be viewed as a further collusion to deprive the general public of its wellbeing. This notion is further exacerbated by the misconception that the United Nations General Assembly has now declared water as a human right, and hence, it should be available to everyone free of cost. Those aiming to support the Water-Energy Nexus in the public-opinion space thus face an uphill battle for gaining the trust and favour of a suspicious audience.

4. *Risk – Lobbies Over-riding Public Interests:* The concerns outlined in Section 3 may become a reality in some countries. In most cases, the energy sector lobbies exert considerable influence over politicians and policymakers –being driven by large-scale elements of the national economies. The same is often not true of the water sector, which is in contrast hampered by over-legislation or regulations. Nonetheless, proponents of the Water-Energy Nexus have to pay considerable attention to how abusive lobbying may be prevented and its potential negative impacts minimized.

RECOMMENDATIONS FOR THE WAY FORWARD

1. *Exploring New Modalities for Partnerships:* Mitigating some of the risks outlined in the previous section would require newer forms of collaboration between the scientific community, governments, the private sector, and the civil society. It is essential to build coalitions that bring together traditionally antagonistic entities to sit across the table. The "newness" of the Water-Energy Nexus can be presented as the argument for creating a new narrative around joint management and resource planning. Notions of social equity can be instrumental in the formulation of these partnerships, particularly when framed in the context of poverty reduction and social empowerment.
   Such partnerships can empower the research community to offer evidence-based solutions that address the knowledge gaps described earlier in the paper. Effective warehousing and dissemination of this knowledge would also need to be a central element of these new partnerships.
2. *Creating Cross-Scale Policy Instruments:* New policy instruments that cut across traditional geographical and sectorial boundaries may facilitate early adoption of the Nexus concept. Bringing together water and energy ministries, other than in the context of hydropower generation and management, may require creation of apex level bodies within governments; e.g., at the ministerial level. Many examples exist, in Thailand and Japan for instance, in which creation of apex bodies allows for develop-

ment of more effective policymaking apparatus around environmental issues (Adeel, 2003).

A new discourse may need to be started in transboundary situations in which water and energy must be shared across national, or sometimes sub national, borders. Traditional water sharing platforms, like conventions, treaties, and commissions, are focused exclusively on water management and often exclude energy. Prior examples suggest that combined management of these resources can actually open up new vistas for cooperation.

3. *Connecting with the Post-2015 Development Agenda:* Formulation of the SDGs offers an interesting opportunity for re-shaping the future of national development planning. By linking together some of the targets underlying the SDGs, it is possible to mobilize the resources for jointly addressing water and energy problems in both developed and developing countries (UNU and UNOSD, 2013). Creation of dynamic, interlinked models can enable rational analysis of development scenarios.

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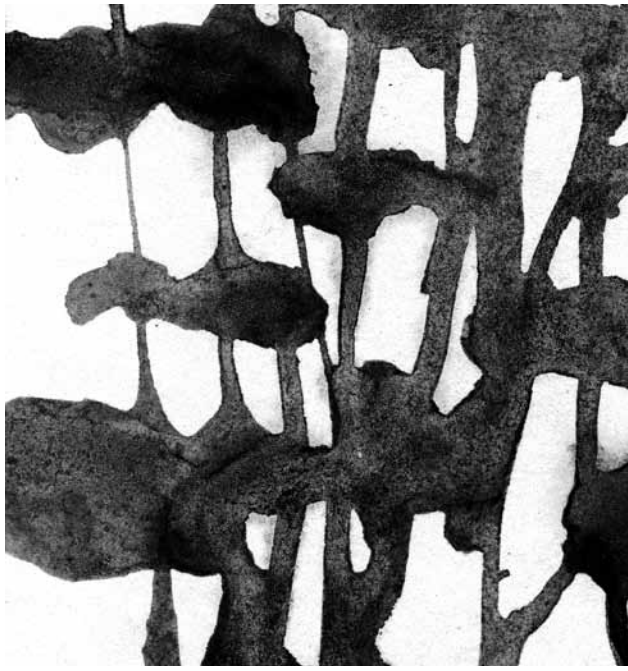

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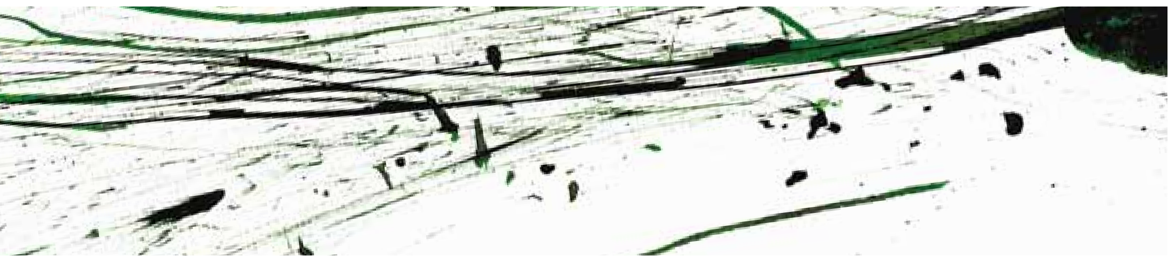
CHALLENGES AND DEVELOPMENTS

IN WATER AND ENERGY EFFICIENCY: ROLE OF THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO)

Christian Susan and John G. Payne



KEYWORDS:
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ISID
TEST
GREEN INDUSTRY
RECP

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BACKGROUND TO THE FUTURE

In the ongoing process to define the Post-2015 development agenda and agree on Sustainable Development Goals (SDGs), the international community finds itself at a critical juncture. Poverty is still the central challenge of our world: the SDGs, currently being formulated to succeed the UN Millennium Development Goals (MDGs), must succeed in addressing this challenge.

Over the past three decades many countries have reached higher development levels in all dimensions – economic, social and environmental– for the benefit of their people. Analyzing the drivers for this trend demonstrates that countries with steady economic growth, driven by industrialization, international trade and related services have managed to reduce poverty most effectively. In fact, there is not a single country in the world that has reached a high stage of economic and social development without having developed an advanced industrial sector (UNIDO, 2014*a*).

This observation has been recognized by the UN General Assembly's Open Working Group on the SDGs, which considers structural transformation through industrialization to be a key driver of growth in

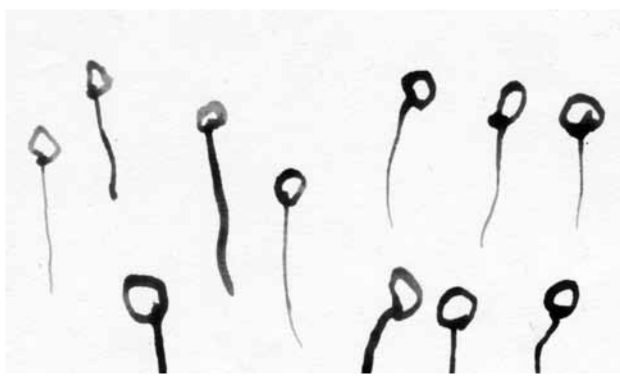
productivity, employment creation, improved living standards, economic diversification and technological upgrading. Thus, industrialization was selected as one of the Focus Areas for further consideration in the framing of the SDGs and Post-2015 development agenda.

Fig. 1. An important natural resource, seabuckthorn is used for the prevention of soil erosion and the production of food and medicine. Uvs, Mongolia. © UN Photo/Eskinder Debebe.

Inclusive and Sustainable Industrial Development

UNIDO will contribute to the Post-2015 development agenda by promoting Inclusive and Sustainable Industrial Development (ISID) (UNIDO, 2014*a*) to harness the full potential of industry's contribution to the achievement of sustainable development, and lasting prosperity for all. This new vision, as enshrined in UNIDO's landmark Lima Declaration (UNIDO, 2013) adopted by the organization's member states on December 2, 2013, will shape the future operations, spirit and direction of UNIDO for many years to come.

The pursuit of ISID includes several key elements such as creating shared prosperity by promoting decent employment opportunities, particularly for women and youth, such producing a multiplier effect for households (UNIDO, 2014a). Working conditions are improved by involvement in international trade which requires compliance to standards and gives exposure to new technologies. Measures to safeguard the environment are promoted through innovation and process optimization towards cleaner production, waste re-



duction, chemicals management and less pollution. Renewable energies and energy efficiency are targeted, as energy represents a significant cost, affects competitiveness and impacts climate change. Overall, these elements have become the driving forces for the promotion of more competitive and environmentally sustainable production – "Green Industry" - rather than a choice between industrial growth and sustainability.

Fig. 2. This photo was part of an exhibition with pictures of people who depend on the Mau Forest, one of the largest reservoirs in the country. Anabkoi, Kenya. © UN Photo/Riccardo Gangale.

Green Industry

In keeping with its mandate, UNIDO "coined the concept Green Industry, to place industrial development in the context of global sustainable development challenges" (UNIDO, n.d.*a*). The Green Industry Initiative provides a core component of ISID by ensuring that industrial production and development, while remaining economically viable, does not come at the expense of ecosystem health or produce adverse human health impacts. It thereby helps to decouple economic growth from increased resource consumption and pollution, which is essential in satisfying the needs of a growing global population in light of our planet's finite resources. Furthermore, it will allow societies to reap the full benefits of economic development without detrimental social and environmental impacts.

The momentum surrounding the Green Industry Initiative was carried forward to the UN Conference on Sustainable Development (Rio+20) in 2012, where the high-level Green Industry Platform (UNIDO, n.d.*b*) was launched as a vehicle to scale up and mainstream Green Industry policies and practices throughout global manufacturing. The Platform serves to catalyze action by bringing together government, business and civil society leaders around a set of core engagements. Since the launch of the Platform, it has reached 193 members including 30 governments, 96 businesses and 68 international business and civil society organizations.

Resource Efficient and Cleaner Production (RECP)

Resource Efficient Cleaner Production (RECP) lies at the heart of the Green Industry Initiative. RECP promotes the efficient use of natural resources (raw material, energy and water), and the minimization of wastes, such as effluents discharged to water (UNIDO, n.d.*c*). Water and energy figure prominently, being key and fundamental inputs into any industrial process. UNIDO, in collaboration with UNEP, established National Cleaner Production Centres (NCPCs) that execute projects in various countries (UNIDO, n.d.*d*). Their work promotes pollution prevention in production, emphasizing its short- and long-term economic gains, and includes the transfer of environmentally sound technologies related to water and energy as well as raw material (Chart 1).

Chart 1

National Cleaner Production Centres NCPCs
Selected Achievements

Kenya	Peru	Sri Lanka
Chandaria Industries Ltd.	Metalexacto – Small lead foundry	Rathkerewwa Desiccated Coconut Mill
• Paper and tissue products	• Reduced lead content in waste by 19%	• Decreased waste output by 18 tons
• Programme to increase waste water recovery & recycling	• nabled recovery of nearly 350 tons lead p.a.	• Achieved considerable reductions in water & energy
Achieved:	• Decreased water & energy consumption	• GHG emissions reduced by almost 1,000 tons p.a.
• 25% reduction in energy consumption	• Total GHG emissions reduced by 270 tons p.a.	
• 50% reduction in water consumption	• Investment costs low & recovered within months	• Annual savings > $315,000 from an investment <$17,000
• 60% reduction of waste & waste water		
• Annual savings > $600,000 with negligible total investment		

Source: UNIDO, n.d.*i*.

Water-Energy Perspective

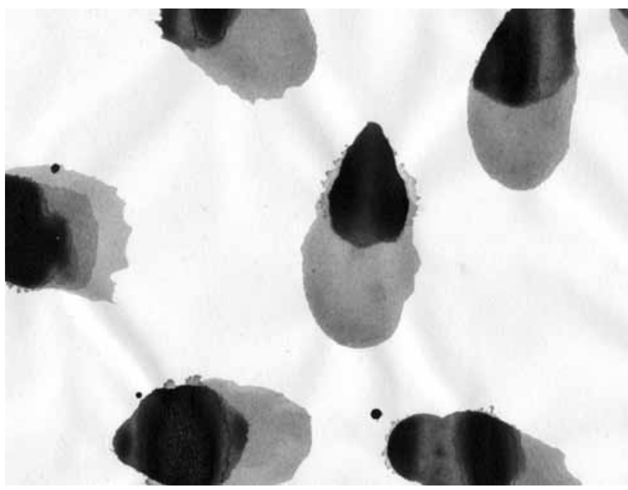
The focus of the 2014 World Water Development Report (WWAP, 2014) is on water and energy. It states that demand for both freshwater and energy will continue to increase significantly over the coming decades to meet the needs of growing populations and economies, changing lifestyles and evolving consumption patterns.

Industry accounts for approximately 37% of primary global energy use (UNIDO, 2008). Global energy demand is expected to grow by more than one-third over the period to 2035, with China, India and the Middle Eastern countries accounting for about 60% of the increase. Electricity demand globally is expected to grow more than 70% by 2035 mainly in non-OECD countries, with half of this growth in India and China (IEA, 2012). It has been estimated that, by using proven technology, manufacturing industry can improve its energy efficiency by 18 to 26% and reduce its CO_2 emissions by 19 to 32% (IEA, 2007)

In terms of world water withdrawals, industry uses about 19% (FAO, Aquastat, n.d.). Global water demand (withdrawals) is projected to increase by some 55% by 2050, mainly because of growing demand from manufacturing (400%), thermal electricity generation (140%) and domestic use (130%) (OECD, 2012).

With the projected increase in demand for water in manufacturing, it is clear that the efficient and effective use of this limited resource in industrial processes will become of utmost importance if present and future generations are to benefit from sustainable development. In meeting this demand, the strong global Nexus between water and energy must be taken into account to minimize trade-offs. Energy consumption is a main driver behind climate change, which, in turn, affects water resources, and huge amounts of water are used in the generation of electricity. This relationship between water and energy is likely to become tighter against the background of climate change and efforts involving its mitigation and adaptation.

Meeting growing water and energy demands will be the challenge for the future and increased levels of collaboration and coordination will create positive outcomes in nearly all situations (WWAP, 2014). Meeting the future challenges will require concerted actions allowing all stakeholders and development partners to make the best possible use of their individual strengths and comparative advantages. UNIDO will continue to contribute to this process by further promoting ISID.



UNIDO AND THE TASKS AHEAD

Developing countries have increased by nearly double their share of manufacturing value-added from 18% in 1992 to 35% in 2012 (UNIDO, 2014*a*). With a mandate to promote ISID in developing countries and countries with economies in transition, UNIDO is dedicated to tackling the challenges of industrial growth and to develop and execute the required responses.

Shared Challenges of Water and Energy

While there are specific challenges to water and to energy, there are also shared or common challenges to efficiency in both domains. These challenges are at the economic and human interfaces and primarily include:

- *Technology Implementation:* There is a wealth of new ideas and innovations for the more productive use of water and its improved treatment, as well as for energy efficiency and generating power from renewable energy sources. The difficulties are purchasing and installation costs, and getting innovative ideas to the market and implemented. Incubating new technologies takes much time and investment and many good ideas fail along the way. Investors and venture capital sources want returns within certain timeframes or they will look elsewhere to place their funds. Moreover industry needs reassurance about the effectiveness and reliability of technology. It is naturally sceptical to invest in untried innovations without a track record, yet more than two thirds of the growth in developing countries results from catching up on technology (UNIDO, 2014*a*).
- *Governance and Policy:* Robust, thoughtful and sound policy will lie at the centre of enabling ISID, with different approaches for individual countries. Long-term strategies are needed to help ensure stable economic and political environments and create incentives to invest in the necessary solutions. It is important to ensure institutional strengthening of the government ministries in charge of water and energy policy and this is a prominent goal in UNIDO projects. Moreover, there is a strong call for coordinated approaches by decision makers involved in water and energy policy (WWAP, 2014). Based on policy, well-crafted laws and regulations combined with compliance and enforcement are necessary to push industrialization in the desired directions. The regulations must be clear and based on the latest sound science. Energy regulation (through Greenhouse Gas (GHG) and Carbon Capture (CC) requirements driving efficiency) affects manufacturing more indirectly than water regulation, which is usually targeted directly at the amount and quality of effluents and discharges. Yet water regulation, amongst others, has an influence on hydropower development.
- *Finance:* The ability to secure investment for water, renewable energy and energy efficiency is a function of investment priorities. There are competing needs for outside investment funds and for company budgets to invest internally. Good business cases must be made to show the short and long term investments, payback periods, cost-benefits and measures needed to increase production (as water and conventional energy are

Fig. 3. Tebikenikora, a town on the Pacific island nation of Kiribati, affected by climate change in low-lying lands. Tebikenikora, Kiribati. © UN Photo/Eskinder Debebe.

inexpensive in places). Inadequate legislation may make it cheaper to keep paying the fines than to address a pollution problem. Frequently progress comes down to navigating trade-offs.

- *Partnerships:* To leverage the advantages of ISID, partnerships, knowledge exchange and networking are essential. They must occur at all levels between industry and the private sector, government, civil society, academia, intergovernmental organizations and NGOs. International partnerships facilitate access to a variety of resources and expertise. Building partnerships is challenging, especially between water and energy stakeholders, where there are vested interests and separate agendas. Business-as-usual results in "institutional lock-in" despite the disadvantages. The same is true for industry which can often be oblivious to the needs of others and assume supplies of water and energy will always be available. Though difficult it is essential to penetrate these barriers to gain visibility and make collective, beneficial decisions.
- *Climate Change:* Repercussions from climate change have affected energy use in industry for some time, such as decreasing carbon footprints by reducing GHG emissions achieved through energy efficiency and renewable energy efforts. Using less energy and water reduces energy demand, which in turn decreases the production of GHGs through electricity generation from fossil fuels. Industry may emit GHGs directly if it generates its own power or from its production processes. The pressure on GHG targets is increasing and will rest more and more on industry, power generators and others. An adequate water supply is important to industry and is increasingly uncertain due to the effects of climate change. Industry may be forced to relocate from presently industrialized countries to those that are less industrialized but have better water supplies.

Water – Frequent Challenges

Growth in consumer demand for goods is increasing with population growth, which is occurring especially quickly in non-OECD countries. As it increases its production to meet this demand, industry will need more water. To reduce stress on limited fresh water supplies and ensure an adequate water supply, industry will have to improve its water productivity (value of product for each unit of water used) in order to keep pace with growing demand for goods and, at the same time, reduce its discharges.

In the water domain, the frequent challenges are persistent but accentuated in some countries, particularly developing ones.

- *Quantity – the exact figure:* In facing the increasing demands on freshwater resources, industry is challenged to find ways of reducing total water withdrawals and consuming less. In developed countries, where the price of water has traditionally been low, there is little incentive to conserve. This is changing and will likely lead to increasing motivation for industry to use water more wisely and improve water productivity. This will also extend up industrial supply chains where, in most cases, industry's supply chain water footprint is much larger than its operational one (Hoekstra *et al.,* 2011).

Fig. 4. Mother and son carry jerry cans to collect water. Khor Abeche, Sudan. © UN Photo/Albert González Farran.

- *Quality – matching use, reducing effluents:* Industry does not need water of a consistently potable quality to conduct many of its manufacturing processes. However if it relies on municipal supply, this is what is delivered.
  If industry uses surface water or groundwater, it may be using good quality resources more suitable for human consumption. In a few cases, industry requires high water quality and has to rely on in-house treatment.
  Effluent discharges are infamous for polluting water bodies. Industrial contamination is often more toxic and harder to treat than more common pollutants and can persist in the environment. Industrial effluents are doubly damaging because the contamination can affect the environment and human health and, by polluting source waters, also reduce the quantity of good quality water available or mean that it has to be treated (more energy use) before it can be used again.
- *Availability – scarcity and allocation: security and disputes:* Even in a location where sufficient water is available, competing demands for its use may result in allocation for specific users. In China, India and Indonesia lack of water is already a major constraint to industrial growth (Pacific Institute, 2007). It is easy to foresee how water availability issues can escalate to water security (reliable and safe supply) disputes, particularly of a transboundary nature.
  In developing countries, population growth and the demand for products by a growing middle class are big water demand drivers. One of the biggest challenges for ISID is to bring the prosperity of industrialization while also managing water resources that become increasingly challenged by the externalities, such as increasing population, which this prosperity creates. In countries where water is scarce it must be given priority as basic human right: improved water supply is essential to overcoming poverty.
- *Pricing – what's fair and what's right:* Pricing water is a very difficult issue. Industry's historical background sees water as essentially free with the corollary that efficient use is neglected. The wide variation in water prices is influenced by subsidies that often

result in a lower price than the actual cost to pump, treat and deliver the water. The trend for increasing water prices to reflect the actual cost is likely to stimulate conservation and efficiency. The other side of this issue concerns water as a basic human right and how this can be properly accommodated. This relates directly to poverty and, particularly in areas of scarcity and developing countries, basic water supplies need to be affordable or free.

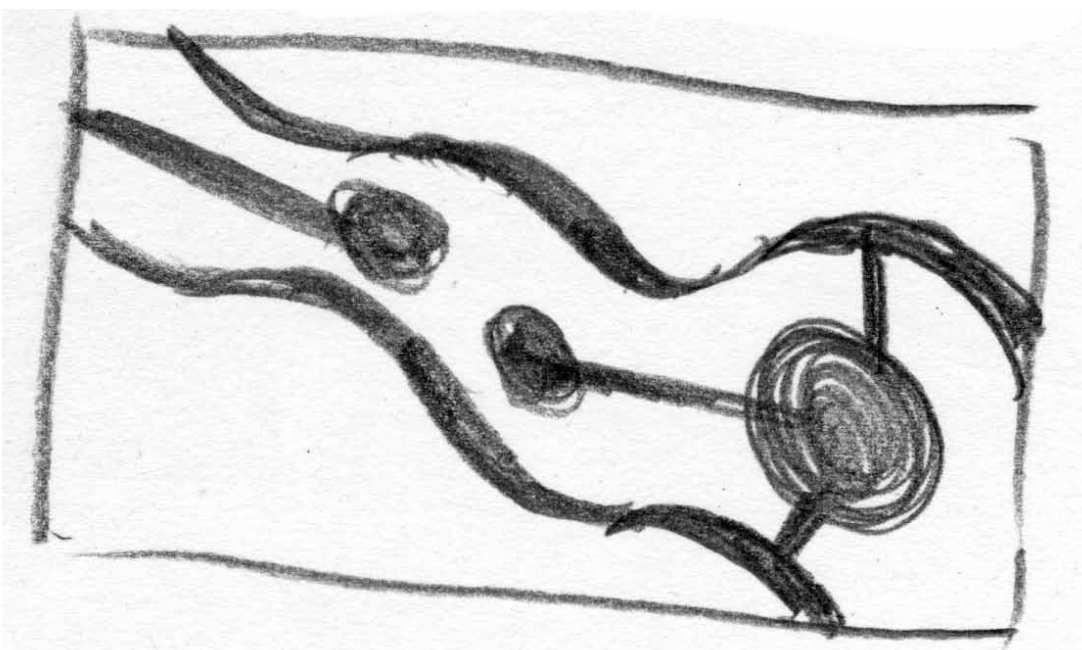
Fig. 5. Afforestation Project. Lima, Peru. © UN Photo/Eskinder Debebe.

Energy – Broader Challenges

Energy has a larger economic dimension than water: it is bigger business and its challenges, such as access and price, are more widespread. Moreover, energy generation and use is strongly influenced by GHG reduction and climate policies driven by laws and regulations which often promote energy efficiency. In industry, energy has a direct connection to water: it is needed to pump, treat, heat and cool water. Yet, it is also non dependant on water when it is used to drive machinery, heat or cool plants and transport goods. As with water, there can be ripple effects up the supply chain of companies and their energy use.

The challenges facing the energy sector that spin off to industry are broader than those related to water, in that water issues are frequently limited to watersheds whereas energy has no such limitations.

- *Security – Access:* Industry needs a constant and reliable energy supply. Energy security is comprises its access as well as its supply (WEF, 2012). There are obvious supply risks with fuels, such as coal and oil, but increasingly water may be a bigger risk, as in the well-known cases in the US, France and India where power generation was stopped for lack of sufficient cooling water. Moreover, access to power depends on transmission and distribution systems, which frequently cross regional and international boundaries often with inherent risks as a result. Again there is a relationship to poverty: it is well-known that more people lack access to electricity and clean cooking energy than water and the challenge is to balance their needs equitably with those of others.
- *Price - Volatility:* For industry volatility in energy prices is more of a problem than the availability of energy. This affects energy intensive industries and may drive relocation. However, in major fossil-fuel producing countries, such as Russia, where local energy is cheap there is little incentive to reduce energy use (UNIDO, 2010).
- *Renewables – Integration:* Renewable energy has the potential to strengthen energy systems and trigger technological innovation for increased competiveness and reduced environmental impact. However, a number of obstacles need to be overcome to increase its market, including high risk perception, lack of technical know-how, and the need for financing to facilitate its integration into the existing energy mix.



UNIDO ON THE GROUND

UNIDO, in delivering its mandate in the context of ISID, has developed and implemented responses by sector and geographically in developing and transition countries. The focus is mainly on small- and medium-sized enterprises (SMEs) to improve their competitiveness and market access by simple and practical approaches to meet productivity and environmental requirements (UNIDO, n.d.*a*). The projects are frequently at the plant or factory level in collaboration with local government institutions to produce enabling environments. This is primarily achieved by targeting cleaner and sustainable production and water management through RECP techniques. Cleaner production addresses production efficiency, environmental management and human development, with techniques shown in Figure 6.

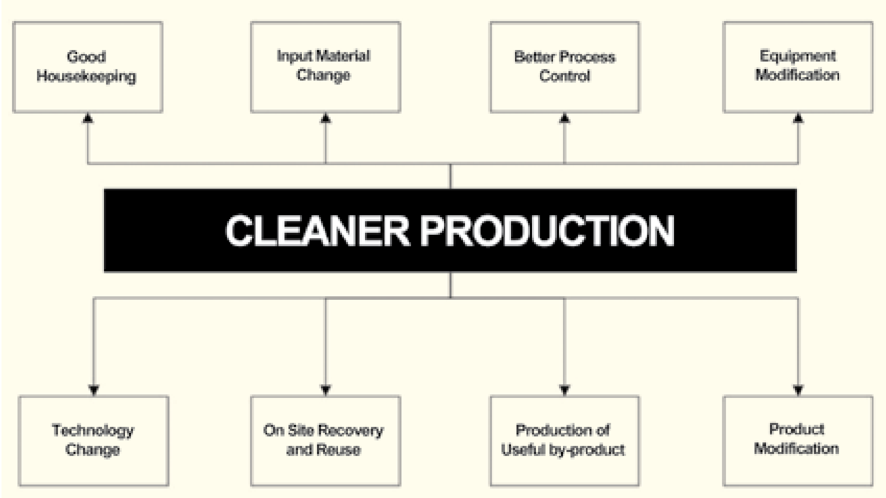


Fig. 6. Techniques of Cleaner Production. Source: UNIDO, n.d.*j*.

MED-TEST

MED TEST is a UNIDO green industry initiative supported by the GEF, the Italian Government and the "Strategic Partnership for the Mediterranean Large Marine Ecosystem (LME)1" of UNEP-MAP. The program addresses land-based sources of pollution within priority industrial hot spots of the Mediterranean Strategic Action Plan (SAP-MED). A pool of 43 manufacturing sites, mostly SMEs, across 7 industrial sectors in Egypt, Morocco and Tunisia actively participated in MED TEST during 2010-2011.

A total of 765 measures were identified; 76% were implemented, 14% retained for further technical and economical investigations and only 10% discarded. About 54% of the measures have a return on investment of less than 6 months. In the three countries, the project identified total annual savings of about $17 M in energy, water, raw materials and increased productivity corresponding to a portfolio of around $20 M of private sector investments in improved processes and cleaner technology which do not include end-of-pipe solutions.

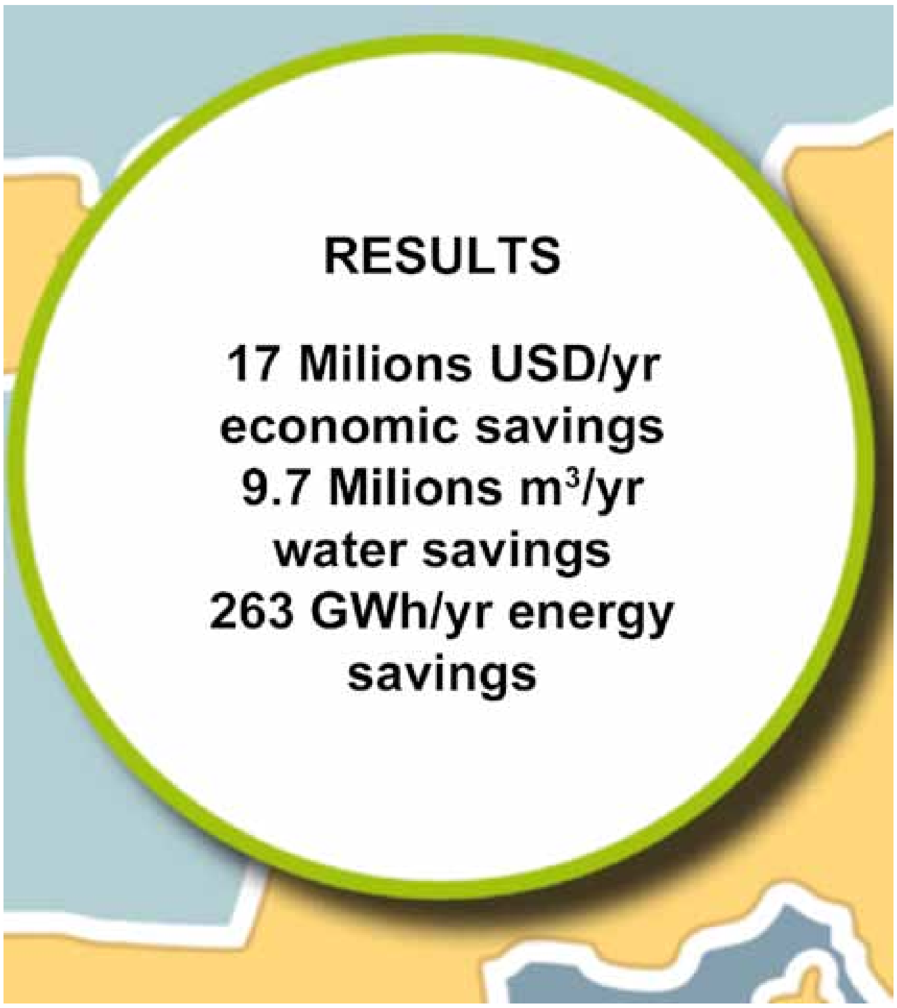


Fig. 7. MED-TEST. Source: UNIDO, 2012.

Water Efficiency at Work

Broadly, UNIDO focuses on reducing water consumption, increasing water productivity, and protecting water resources from discharges. The related measures include improving water-use efficiency, extending wastewater treatment, water recycling and reuse, enhancing effective water governance including catchment area based integrated water resources management (IWRM) and transboundary co-operation. The main vehicle for these initiatives is UNIDO's Transfer of Environmentally Sound Technologies (TEST) Programme, which has been successfully implemented in a number of countries (Figure 7).

The TEST integrated approach (UNIDO, n.d.*e*) has three areas of intervention:

- *Process Level.* Pollution prevention rather than pollution control (end-of-pipe) solutions.

TEST – MANAGEMENT TOOLS				
• Resource Efficiency & Cleaner Production (RECP)	• Environmental Management Systems (EMS)	• Environmental Management Accounting (EMA)	• Environmentally Sound Technologies (EST)	• Corporate Social Responsibility (CSR)
Source: UNIDO, 2014*b*.				

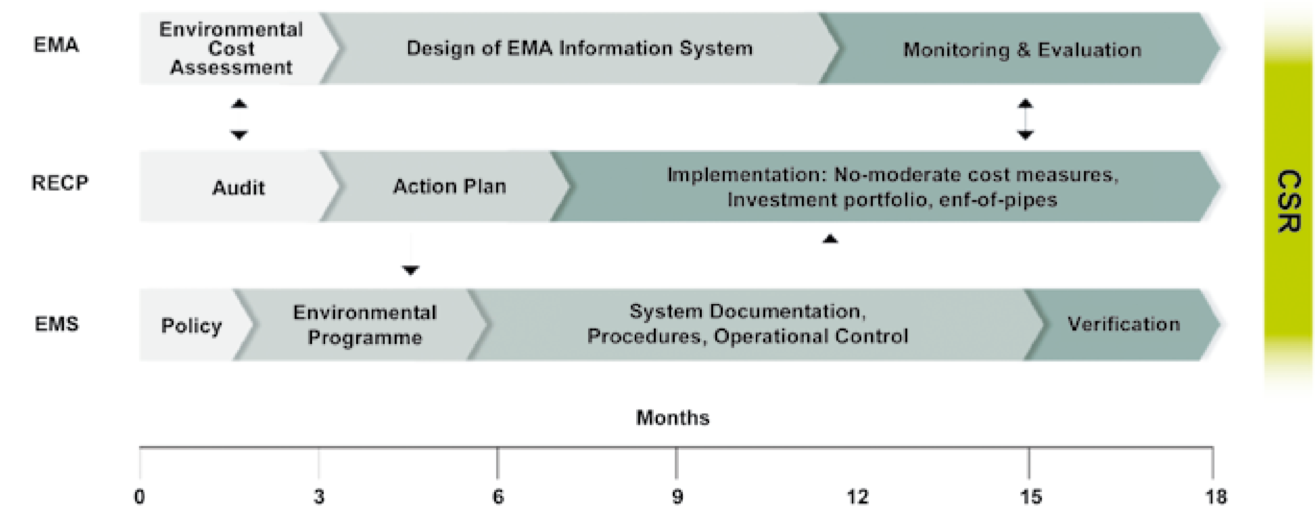


Fig. 8. Implementation Workflow in a company. Source: UNIDO, 2012.

- *Management Systems.* Preventive environmental management using an information system on relevant material, energy, water and related financial flows necessary for linking the strategic and operational levels.
- *Strategic Level.* Environmental and corporate social business responsibilities (CSR) and sustainable enterprise strategies (SES).

The TEST integrated approach has five management tools (Figure 8) aimed at changing practices in a comprehensive way to ensure adoption of environmental practices and initiation of a continuous improvement process.

Energy Efficiency and Renewable Energy in Action

Energy-intensive SMEs currently using electricity generated from fossil fuels are being encouraged to move to renewable energy for environmental reasons, to increase productivity, and prepare them to handle unreliable supplies from national grids. At national and regional planning and decision making levels, UNIDO assists with strategy on renewables, including technology and financial schemes, with three prongs (UNIDO, n.d.*f*).

- Mainstream the use of renewable energy in SMEs.
- Support innovative business models to promote renewable energy as a business sector.
- Create business development opportunities through increasing access to energy.

An example relating to the Water-Energy Nexus is the promotion of small hydro-power (SHP) generation which has little or no environmental impact (UNIDO, n.d.*g*). UNIDO's goal for the development of SHP is to provide energy access for productive uses and industrial applications, especially in rural areas. SHP has proven to be a suitable renewable energy technology in the context of rural electrification efforts, energy diversification and industrial development. In regions with hydropower potential, this is very cost effective and can supply motive power to small industry. In 2013, UNIDO, in cooperation with the International Centre on Small Hydro Power (ICSHP), based in China, launched the first global assessment on SHP, the World Small Hydropower Development Report 2013 (WSHPDR 2013) and knowledge platform. It contains compiled data on installed capacity and potential of SHP for 149 countries and 20 regions.

In its industrial energy efficiency and climate change activities, UNIDO targets energy efficient operational practices over and above energy efficient equipment. Production systems change during a facility's life and the energy systems may become less efficient. Simply having energy-efficient components does not ensure energy savings within a system. Evidence from programmes indicates that such components may result in about 2% to 5% gains in efficiency, whereas systems optimization can produce 20% to 30% with short payback periods (UNIDO, n.d.*h*).

Fig. 6. Geothermal energy is converted into electricity and used to heat green houses. Taupo, New Zealand. © UN Photo/Evan Schneider.

PROGRESS MOVING FORWARD

The world is undergoing a new industrial revolution (UNIDO, 2014*a*), ranging from changes in developed countries using high technology and knowledge based initiatives, to those in transition and developing economies defined by structural change towards prosperity. The question is not choosing between industrialization and sustainability, but how to transform industry and business, using the right approaches and technology, to resolve environmental challenges and achieve sustainable industrialization. It is widely accepted that industrialization is a development priority: therefore the task ahead is to determine how this will be achieved to blend with reaching the SDGs and prosperity for all.

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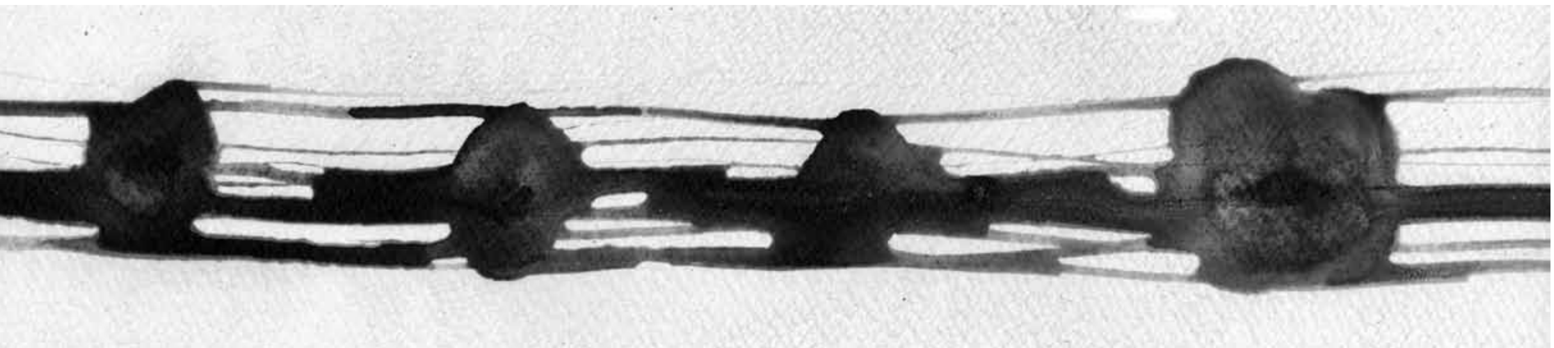

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PROMOTING POLICY RESPONSES

ON THE WATER AND ENERGY NEXUS ACROSS BORDERS

Annukka Lipponen[1] y Mark Howells

KEYWORDS:
TRANSBOUNDARY COOPERATION
ASSESSMENT
WATER CONVENTION
INTERSECTORAL COORDINATION
NEXUS

HUMAN CHALLENGE – DEVELOPMENT IN A FINITE WORLD

Population growth, economic development, increased water, energy and food needs all exert increasing pressures on natural resources –as noted by (Bazilian *et al.,* 2011):

- All three areas have many billions of people without access (quantity or quality or both).
- All have rapidly growing global demand.
- All have resource constraints.
- All are "global goods" and involve international trade and have global implications.
- All have different regional availability and variations in supply and demand.
- All have strong interdependencies with climate change and the environment.
- All have deep security issues as they are fundamental to the functioning of society.
- All operate in heavily regulated markets.
- All require the explicit identification and treatment of risks.

The provision of water-services, energy-services and food are provided through chains of physical activity. These chains include the use of technology, artificial and natural infrastructure. Those in turn rely on primary supplies of land, energy and water resources. Of special importance is natural infrastructure. That includes ecosystems.

Those resources, chains of activity and services are inexorably interlinked. Selected linkages are noted in Chart 1.[2]

Further, those interlinkages are significant. To give a sense of scale, (UN, 2014) notes that "at a global level, 7 per cent of commercial energy production is used for managing the worlds freshwater supply, including for extraction, purification, distribution, treatment and recycling. About 70 per cent of human water use is for irrigation and 22 per cent is for industry, most of which is for thermal cooling in power plants and manufacturing. Roughly 4 per cent of final energy use is in agriculture, food processing and transportation adding an increasing additional energy amount. About half demand increase for maize and wheat

Chart 1				
Selected Nexus linkages				
Impacts of the issues below on those listed on top	Climate	Land/Food	Energy	Water
Climate		Climate change and extreme weather affect crop productivity and increase water demand in most cases.	Climate change alters energy needs for cooling & heating and impacts the hydropower potential.	Climate change alters water availability and the frequency of droughts and floods.
Land/Food	Greenhouse gas emissions from land use change (vegetation and "soil carbon") and fertiliser production.		Energy is needed for water pumping, fertiliser and pesticide production, agricultural machinery and food transport.	Increased water demand due to intensification of agriculture, and effects on the N/P cycles.
Energy	Fuel combustion leads to GHG emissions and air pollution.	Land use for biofuels and renewable energy tech. (solar, wind, hydro, ocean), crip/oil price correlation.		Changes in river flow, evaporation in hydropower dams, biofuels crop irrigation, fossil fuel extraction (esp. unconventional).
Water	Changes in hydrological cycles affect local climates.	Changes in water availability for agriculture and growing competition for it affect food production.	Water availability for biofuels, energy use for desalination but also storage of renewable energy as fresh water.	

Source (UN, 2014).

has been due to bio fuel production. Energy use for desalination and pumping for irrigation constitutes a large share of energy use in some developing countries."

Further, sectoral management framework only functions and supports development as long as human societies live in conditions of abundance of resources. The current, commonly uncoordinated and often noncoherent, policies to support food, water and energy security have often had adverse consequences tending to disproportionately affect the poor, as they depend the most -and spend the largest share of their income- on basic needs in the form of water, food and electricity.

Looking at the interlinkages between water and energy in pan-Europe and North America demonstrates the importance of taking them into account in policy development.

TARGETED CHALLENGES - ENERGY AND WATER CHALLENGES IN THE UNECE REGION

While the challenges at the interface of water and energy differ across the United Nations Economic Commission for Europe (UNECE) region,[3] a few major issues are highlighted in the Fifth World Water Development Report (WWDR) (UN-WWAP, 2014), "Water and Energy".

It demonstrates the importance of hydropower in Europe that hydropower generated 16% of the electricity in 2008 and there are currently about 7,000 large dams. There is at present time renewed interest in hydropower as it may allow capacity expansion of other renewable energy sources, reduce carbon dioxide emissions and, in some cases, better cope with the predicted increase in variability of flows. One specific driver increasing development of renewable energy sources, including hydropower, is the energy policy. The Renewable Energy Directive[4] lays down legally binding targets; notably, a 20% share of renewable energy in the EU by 2020.

There are also concerns related to the hydropower development. In many areas, hydropower generation is in conflict with other water uses, notably irrigated agriculture. Hydropower is one of the main drivers of hydro morphological alteration, loss of connectivity and change in the flow of water and sediment.

Another trend is that freshwater supplies are increasingly augmented by highly energy intensive methods (e.g. desalination), especially where water scarcity prevails.

WWDR also illustrates the vulnerability of energy generation to changing weather and climatic conditions: Cooling water scarcity during recent warm, dry summers led several thermal (nuclear and fossil-fuelled) power plants in Europe and the south-eastern USA to reduce production. Thermoelectric power plants produce the majority of total electricity in the USA (91%) and in Europe (78%).

An increase in and spread of water scarcity and stress is predicted to affect about half the river basins in the EU by 2030 (EC, 2012c).

THE VALUE OF TOOLS FOR PROMOTING SUSTAINABLE DEVELOPMENT AND THE REALITY OF LOW INTEGRATION IN AVAILABLE TOOLS

At a global level, the need for Nexus toolkits has been established (UN, 2014). Not being the least to meet the recently proposed United Nations Post-2015 'Sustainable Development Goals' (SDGs). In a flagship assessment discussed later, the multi-faceted impact of a Nexus approach will be demonstrated[5] A Nexus (intersectorial) approach to resource management –also across borders– would significantly facilitate progress towards many of the SDGs proposed by the Open Working Group, including (but not limited to) those on hunger and food security, availability and sustainable management of water and sanitation for all and on access to energy for all.[6]

The tools that support sectorial policy making are becoming increasingly integrated. So called, Integrated Energy Planning (IEP), Integrated Water Resource Management (IWRM), Integrated Land-use Assessments (ILUA), etc. have been developed to study, plan and develop policy for resource management. However, there are examples of these approaches that have been shown to be inadequate, especially where resources are tightly interwoven (Welsch *et al.,* 2014, Herman *et al.,* 2013). Each approach examines future development scenarios of one sector, yet no account of consistent and concurrent scenarios of other sectors are normally made. Integrated management processes make inter-sector linkages explicit. However, they typically assume that the related sectors are static, or that their development is not fundamentally changed by the same 'shocks', scenario assumptions or induced effects. This can result in important feedbacks being ignored or overlooked. New approaches are needed and promising methods are being developed (Howells and Rogner, 2014).

Shortcomings in inter-sectorial coordination are a major challenge both on the national and transboundary levels, in developing countries, economies in transition and in developed countries. In transboundary basins the impacts potentially propagate beyond state borders, therefore calling for cooperation between riparian countries in the management and use of shared water resources, including on water infrastructure. In such settings, the trade-offs and externalities may cause friction between the riparian countries and different interests. The development of an approach to assess the Water-Food-Energy-Ecosystems Nexus in order to enhance inter-sector coordination and transboundary cooperation can therefore be helpful.

While all sectors are important, in the context of transboundary basins, water provides a useful point of entry to a Nexus analysis. The physical link it creates between countries calls for transboundary coordination. It is increasingly obvious that different sectorial policies and development plans that significantly impact on the status of water resources is outside the domain and influence of water management, underlining a need to cooperate closely with different economic sectors. As such, the 'Nexus' approach can be seen as a subsequent (or even parallel) step to IWRM. It is made for the purpose of strengthening transboundary cooperation by actively involving all sectors whose action can improve synergies.

Fig. 1. With few vital resources, migrants have called for the help of UN agencies and NGOs. Dar al Salam, Sudan. © UN Photo/Albert González Farran.

DEVELOPING POLICY RELEVANT INTEGRATED TOOLKITS

Several case studies have been developed and are designed for policy relevance. These have included:

- At the sub national level (Chart 2A), developing tools that assess integrated water and energy efficiency policy.
- At the national level challenges associated with meeting concurrent goals under threat by climate change (Chart 2B), and developing coherent security and mitigation policies.
- At a global level (Chart 2C), a first open toolkit to analyze development in the context of the Nexus.

These Nexus approaches aim to improve the situation by developing integrated assessments to strengthen the knowledge base, working across sectors and for development of coherent policies that support co-optimization. Bazilian *et al.* (2011), based on (IAEA, 2009) conclude treating the three areas of the water-energy-food Nexus holistically would lead to a more optimal allocation of resources, improved economic efficiency, lower environmental and health impacts and better economic development conditions. In short, overall optimization of welfare.

Water is an important entry point, with water resources being used by almost all economic sectors and the society for different purposes and by different users.

When it comes to water resources, friction and potential conflicts may result from tensions between sectorial objectives, unintended consequences of resource management and trade-offs between sectors, both at the national and the international level. A classic example of a water use for energy which may affect other water uses is hydropower which –if developed unilaterally without adequate consideration to downstream co-riparian's' needs and to intersectorial impacts– may degrade transboundary relations.

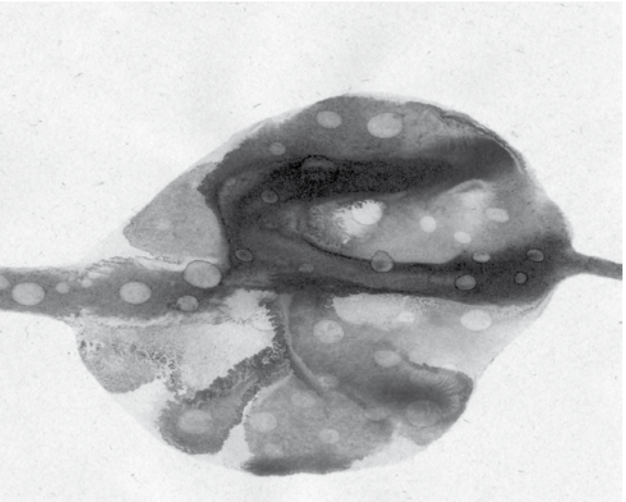
Chart 2
Policy relevant Nexus tool development
A. Moving towards more integrated governance is not trivial. It requires new skills, tools and motivation. This is where (Bartos and Chester, 2014) (2014) in their paper "The Conservation Nexus: Valuing Interdependent **Water and Energy Savings in Arizona**" make an addition. Using a recently completed integrated water-energy model, they illustrate how the water and energy systems are intertwined in Arizona. Yet the state policies are not. The authors show that measures to reduce water use can indirectly reduce energy supply needs. This results not only in savings on state-wide water bills but also (indirectly) on energy bills - and vice versa. For the socio-economy, this could translate to cheaper services and more efficient resource use (Howells and Rogner, 2014).
B. In **Burkina Faso** analysis indicates that increasing energy use and GHG emissions directly, disproportionately and indirectly, improves energy security and reduces GHG emissions. (Hermann *et al.*, 2012). Essentially the work shows that by intensifying agriculture (requiring more mechanization, oil, and GHG intensive fertilizer) less agricultural land is required. Lower land requirements, slow deforestation. With more forests there is a greater carbon stock. This provides more fuel wood, the major energy supply in the country. More forests sequester and reduce GHG emissions. In **Mauritius** (Howells *et al.*, 2013), show that a policy designed to reduce energy import dependence, reduce GHG emissions and improve economic performance is counterproductive under potential climate change. The policy, to move from sugar to bio ethanol production, neglected inter-sector links. Taking them into account, shows that with drops in rainfall, more energy is required for water pumping and desalination – to maintain crop levels. This is expensive and requires the import of coal to fuel power stations that meet the increasing electricity demand. Water prices increase, and so too does the cost of cropping. In turn the price of the ethanol produced goes up, making it less competitive on the international market. The increased burning of coal (the cheapest option for the island) increases the island's GHG emissions. These compounding interactions had previously gone unnoticed, though so called 'integrated' planning practice was employed.
C. At a **global level** (UN, 2014), the UN has developed the first open source Global Nexus model (called GLUCOSE). This was developed to show, amongst other things, if sector development plans are consistent. It indicated that this is not the case. For example, there is not enough land to provide food and bio fuel requirements - if current dietary trends and agriculture productivity trends continue. Yet, a large number of global GHG mitigation outlooks indicate that large scale adoption of bio fuel is needed.

Chart 3
Water and Energy Nexus in a transboundary context: hydropower development and the international law
Development of hydropower potential provides opportunities for economic development and poverty reduction, but also has potential impacts on the environment and on other water uses, including by co-riparian countries.
Key principles of international water law –i.e. equitable and reasonable utilization, prevention of significant transboundary impact, and the obligation of cooperation– apply well to the construction of new hydropower facilities as well as operation and maintenance of existing ones. More specific obligations that international law imposes on States in this area are to take all necessary measures, i.e., to exercise due diligence, in order to maintain and protect installations, facilities and others works at international watercourses, and to notify and consult on the planned measures.
The UNECE environmental conventions, in particular the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention, 1992) and the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention, 1991), provide strong legal frameworks for cooperation on planned measures on transboundary watercourses. The recent developments with the UNECE Water Convention becoming a global treaty, the entry into force of the Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Watercourses Convention, 1997), and the prospective opening of the Espoo Convention would further reinforce the legal frameworks for cooperation on shared waters and water infrastructure at the global level.

International water law and its instruments clear, transparent and consultative procedures about development projects –including energy related ones– in transboundary basins to achieve better-informed decisions, to prevent disputes and to lead to better development paths (Chart 3).

In brief, management of transboundary waters requires not only international cooperation, but as has been shown, cross sector coordination also.

So far, work on the Nexus of water, energy and food specifically targeting transboundary river basins has hardly been carried out, and there have been no toolkits specifically designed to address this challenge. The approach to assessing intersecto-



rial linkages, trade-offs and benefits, developed for transboundary basins under the UNECE Water Convention (Chart 4), identifies where significant cross-sector and cross-border relationships exist. This helps lay a foundation to develop coordinated actions to meet development needs.

Chart 4
The UNECE Water Convention
The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) takes an integrated and cross-sectorial approach to regulation of water quantity and quality issues. This implies strengthening local, national and regional measures to prevent, control and reduce transboundary impacts –one of the core principles of the Convention– and to ensure sustainable management of transboundary waters. As its other core principle, the Convention promotes equitable and reasonable use of transboundary waters. (e.g. UNECE, 2011).
The Water Convention was signed in Helsinki in 1992 and entered into force in 1996. Some 39 countries in the pan-European region and the European Union are Parties to the Convention. The Water Convention, initially negotiated as a regional (pan-European) instrument has been amended in 2003 to open it globally, to all UN Member States and these amendments entered into force in 2013 (UNECE 2013).

UNECE'S APPROACH TO ASSESSING THE NEXUS

At its sixth session (Rome, 28-30 November 2012), the Meeting of the Parties to the Water Convention included an assessment of the Water-Food-Energy-Ecosystems Nexus in the Convention's programme of work for 2013-2015. This decision was in recognition of the possibility that friction and potential conflicts in water management might result from tensions between sectorial objectives, unintended consequences of resource management and trade-offs between sectors, both at the national and the international level. By assessing the situation in transboundary basins jointly and improving the knowledge base, synergies can be achieved and potential solutions identified.

Chart 5
The Task Force on the Water-Food-Energy-Ecosystems Nexus
The work of the Task Force seeks to address, through improved understanding, problems related to low coherence and a lack of integration between sectorial policies, which result in negative impacts on the status of shared waters.
The Task Force brings together primarily representatives of the countries sharing the basins in which a Nexus Assessment has been proposed to be carried out, as well as representatives of organizations undertaking parallel initiatives, partners, experts and stakeholders. The meetings of the Task Force in April 2013 and in September 2014, allowed for consulting the countries about needs and expectations; laying the foundation for developing an approach; review, commenting and refinement of the methodology as well as sharing of experience.

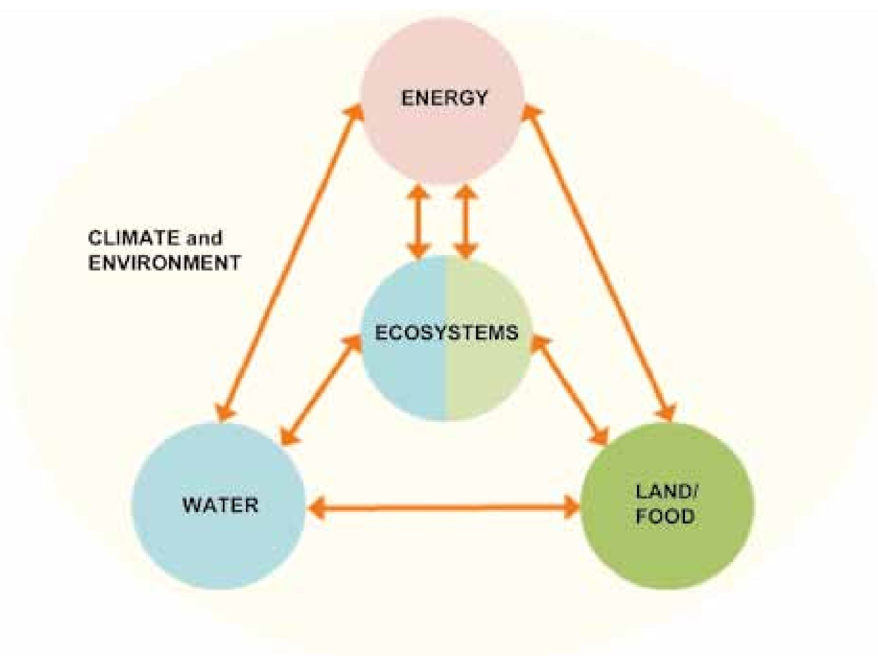


Fig. 2. A Nexus diagram reflecting the conceptual interlinking employed in this intersectorial assessment.

In the same session, the Parties to the UNECE Water Convention established also a Task Force on the Water-Food-Energy-Ecosystems Nexus to oversee and guide an assessment of selected transboundary basins for intersectorial issues and for identification (Chart 5).

The aim of the assessment is to identify intersectorial synergies that could be further explored and utilized for additional benefits in the different basins, and to determine policy measures and actions that could alleviate negative consequences of the Nexus and help to optimize the use of available resources. The assessment process should help the countries move towards increased efficiency in resource use, greater policy coherence and co-management, and build capacity in addressing intersectorial issues.

The process also looks to generate relevant information to support decision-making at different levels to move towards a more efficient use of resources and to enhance sustainability. It has been designed to support ownership by the authorities, meaningful participation by various stakeholders, learning together (developing capacity in the countries) and the exchange of experience between basins.

The participatory part of the process in particular, with an intersectorial basin workshop as a key step, involves looking at the plans of the sectors in the riparian countries' and discussing whether the plans of the different sectors are compatible. Furthermore, as it is not enough to consider the intersectorial dynamics in the present, it is explored, mainly in descriptive terms, what changing drivers and the climate outlook mean for the intersectorial links/the Nexus in the future.

Once the main intersectorial issues have been identified and the most important ones distinguished with the participants of the workshop, the focus is turned to how to better reconcile the different uses, that is, to identify what opportunities there are to reduce negative intersectorial impacts and enhance synergies.

The following analysis focuses on and substantiates using indicators the main intersectorial issues identified jointly with the riparian countries. Indicators help to illustrate aspects such as demand for resources by sector and efficiency of use, dependencies as well as resource scarcities and securities (water, food, energy and environmental).

Fig. 3. MINUSTAH and the OPC working to rehabilitate the water system. Saut d'Eau, Haiti. © UN Photo/Victoria Hazou.

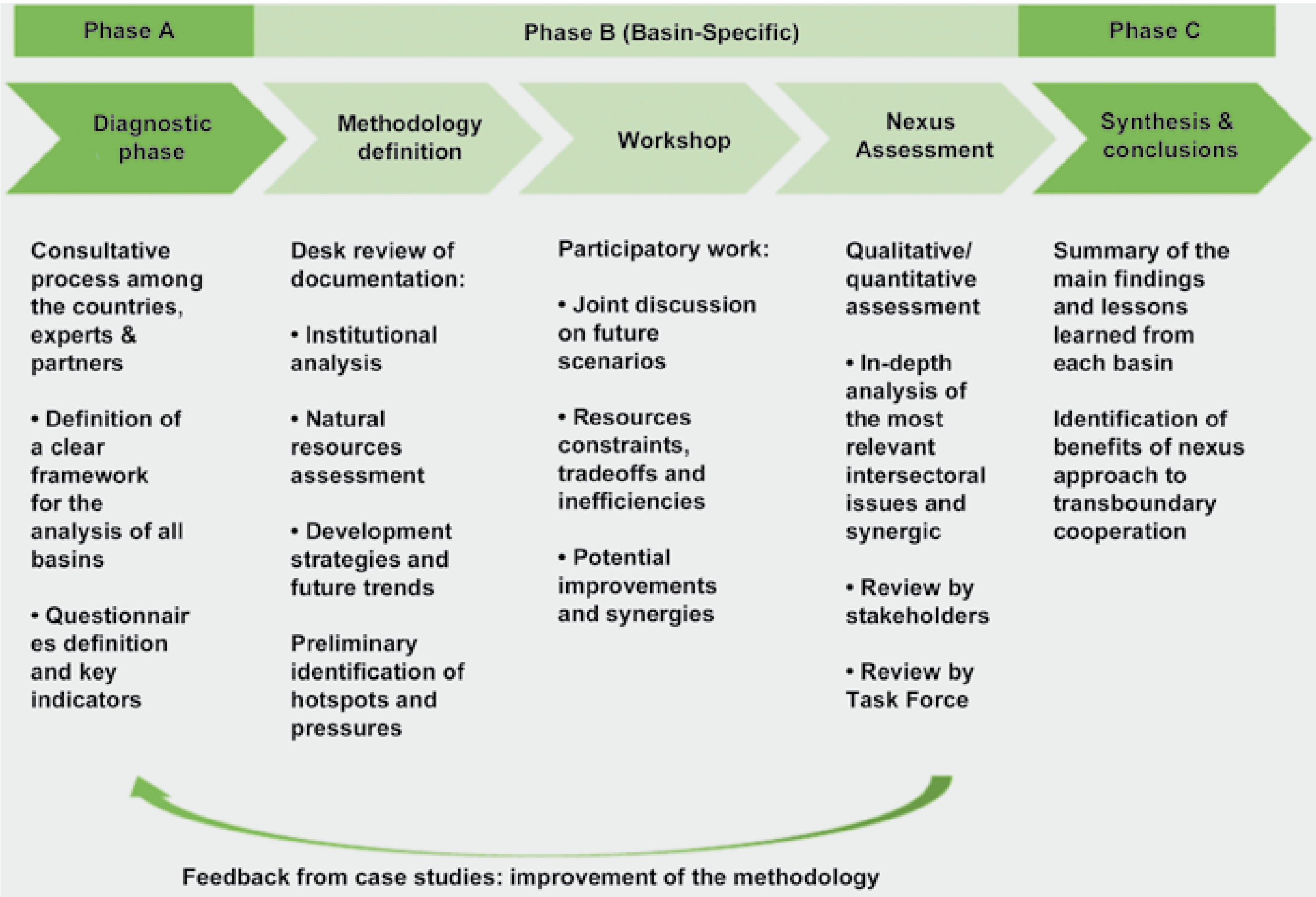


Fig. 4. Key elements of the methodology developed for assessing the Water-Energy-Food-Ecosystems Nexus in transboundary basins.

The approach, developed by the Royal Institute of Technology (KTH, Stockholm) in cooperation with UNECE, is presented schematically in Figure 4.

The application of the methodology has demonstrated that it facilitates a dialogue across sectors and resources. The representatives of the countries have appreciated the opportunity for intersectorial discussions, which are not common practice even at the national level. The general assessment framework was developed to assess diverse basins, but the methodology allows for flexibility to adjust to the characteristics of each basin.

THE TRANSBOUNDARY NEXUS ASSESSMENT OF THE ALAZANI/GANIKH BASIN – SELECTED INSIGHTS

An on-going Nexus Assessment of the Alazani/Ganikh Basin, shared by Azerbaijan and Georgia, illustrates the application of the methodology. The findings demonstrate the need and value of transboundary, inter-sector cooperation, beyond water. While the assessment in itself provides useful orientation by stakeholders in the region, their organization to adopt a Nexus approach to their future decision making processes needs to be justified.

In applying the methodology, the basin workshop is the key step, organised in the case of the Alazani/Ganikh in Georgia in November 2013 in cooperation with the UNDP/GEF Kura project “Reducing Transboundary Degradation in the Kura Aras River Basin” and the Ministry of Environment Protection and Natural Resources of Georgia. The workshop brought together ministries of environment, energy, agriculture, emergency situations, communities, state agencies, companies and civil society from both countries to identify jointly future tendencies and the main intersectorial issues (Figure 5).

Special attention is paid to inter-sector and trans-boundary links. These are later needed in order to identify areas of cooperation. And the effects between sectors are qualitatively described. This is done in general terms, considering socio-economic trends (population growth, economic development etc.), strategic directions and priorities of the countries, and external constraints, such as climate change.

Fig. 5. Stakeholders working on identifying the main intersectorial links at the Nexus Assessment workshop held in Kachreti, Georgia. Photo: Ministry of the Environment of Georgia.

Scenarios of integrated development

One such scenario, for example, in the Alazani/Ganikh, is the implication of continued fuel wood use at the household level in Georgia which highlights implications of energy policy on the ecosystems and water resources. Fuel wood harvested from a forest provides the heat needed for cooking and heating, yet its use increases pollution in the home. As the wood is free, and the opportunity cost of people's time spent collecting it is low, the trend is continued. (In Azerbaijan, alternative fuels are accessible at low cost). However, fuel wood harvesting causes deforestation (an inter-sector link). Deforestation causes the loss of ecosystem services (another intersectorial link). Amongst others these include loss of flood control service (due to rainfall runoff implications), a reduction in terrestrial carbon stock (as carbon is captured in the forest trees), and degradation of ecosystems. The lack limited of flood control and the difficulty of effectively limiting flash flooding increases the severity of effects from flooding (an inter-sector link). As Georgia is upstream, flooding is propagated downstream, and as the river forms border for a substantial part of its length, both countries are affected by the flooding and its effects on the erosion (a transboundary link). The net effect is both intersectorial and transboundary.

Intersectorial, transboundary solutions

After brainstorming and identifying needs and issues, uncovering key intersectorial issues in meeting those needs, then cross-sector transboundary possible solutions were identified. Solutions could be of various kinds –changes to policies, new policies, management and measures practices, institutional arrangements, infrastructure operation and so on–. Particularly promising may be solutions that require cross sector, transboundary actions.

Fig. 6. The UN General Assembly declared 2011 as the International Year of Forests to raise awareness on sustainable management, conservation and sustainable development of all types of forests.
Bosung, Republic of Korea. © UN Photo/Kibae Park.

In the Alazani, indoor air pollution is reduced as people abandon the use of wood fuel, in Georgia. This improves household health (a benefit). Yet, reduced fuel wood harvesting increases forest stock. Increased forest stock captures carbon dioxide as woody biomass (an inter sector co-benefit). This is entered in national GHG accounts (a local action with national implications). Further, increased forest cover improves the health of ecosystems in the region. Supporting a key economic growth sector, namely tourism (an inter sector co-benefit). The increased forest stock dampens and retains run-off, providing key flood control services. As Georgia is upstream, the effect is felt downstream in Azerbaijan.

An intersectorial action in response with a transboundary dimension could be fuel wood substitution in the Georgian side of the Alazani/Ganikh. Natural gas is already imported from Azerbaijan to Georgia.

This is just one clear indication of how the 'Nexus approach' or an intersectorial perspective adds value. It can help uncover the co-benefits (or external costs) associated with actions in one sector, provides insight at local and national level as well as across boundaries.

The potential benefits of such options of cooperation across sectors and countries are substantiated, wherever the available data is enough to support it, with explicit calculations (for example, on emissions reduction or savings obtainable, etc).

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

Linking to relevant policy processes

Ideally, once the effort is made, the thinking and dialogue should be prolonged to explore who (which sector, organization etc.) is in a position to address the identified potential solutions how this might be translated into, and what concrete actions could be undertaken by local actors, including authorities. This could benefit from linking into ongoing or planned initiatives and policy processes. For instance, in some basins the riparian countries are part of the EU Water Initiative's National Policy Dialogues, where the implications of the assessment's findings may help formulate their water policies. In some cases, organizations like basin organizations or other joint bodies, possibly with a multiple sector representation, could provide a framework for identification of beneficial future activities.

In the riparian countries of the Alazani/Ganikh, the relevant policy developments that the assessment could inform include Azerbaijan's new Water Strategy and development plan for the regions, Georgia's new Energy Strategy and the new Water Law, currently with the parliament, and finally the bilateral agreement on water cooperation which is in the process of being negotiated between Azerbaijan and Georgia.

TOWARD POLICY COHERENCE AND BETTER GOVERNANCE

Good governance, including intersectorial coordination and participation of the different interests and stakeholders, is an essential basis for putting the Nexus approach into practice.

Availability of legal frameworks in a transboundary basin including both framework conventions and specific agreements; emphasis on complementarity and coherence; joint institutions for transboundary cooperation around the world (demonstrating differing levels of success) to foster dialogue between different interests, supporting harmonization etc., are needed.

At the transboundary level, instruments/frameworks of international law, such as the UNECE Water Convention contribute to strengthening the legal and institutional basis, e.g. through the obligation for the Riparian Parties to enter into agreements on the transboundary waters they share and to establish joint bodies like river commissions for their implementation.

Among the reasons potentially behind the short-comings in addressing intersectorial issues at the transboundary level, just to mention a few, are the following:

– Missing agreements or institutions.
– Limited mandate of existing institutions.
– Composition of institutions and decision-making processes.
– Weak enforcement capacity etc.

Fig. 7. The Economic and Social Council (ECOSOC) discussion on the Contribution to the Elaboration Agenda Post-2015 Development. Geneva, Switzerland. © UN Photo/Jean-Marc Ferré.

Fig. 8. Access to water and sanitation in developing countries. Dhaka, Bangladesh. © UN Photo/Kibae Park.

Some key factors related to intersectorial aspects of transboundary cooperation can be highlighted from the principles of organization and activities that generally increase the efficiency of joint bodies and contribute to reaching a mature level of cooperation.[7] Among them, importantly, the existence of a sufficiently broad representation of national authorities in the joint body (beyond water management), to ensure that the different interests and concerns are considered while maintaining the institution's structure operational.

One component of the methodology developed under the Water Convention is an institutional assessment, which focuses on studying whether the institutional arrangements at transboundary level are conducive to intersectorial coordination. The basis is an analysis of the institutional and governance structures associated with the selected river basin helping to gain a better understanding of the context in which the different sectors of activity operate.

Chart 6
The emerging governance analysis
The methodology for the analysis of governance aspects, developed in cooperation with the University of Geneva for the Nexus Assessment under the Water Convention is divided into four main steps, listed below.
1) Identification of the main sectors of activity involved in the management of the resources concerned;
2) Analysis of the main policies and regulations at the sectorial and intersectorial levels;
3) Analysis of the configuration of the actors their nature as well as links between the actors (private actors, public actors, national actors, international actors, users associations, NGOs, etc.); and
4) Identification of specific hot spots, that is, the main rivalries at different institutional levels (local, regional, national, transboundary).

CONCLUDING REMARKS: VALUE OF INTEGRATED ASSESSMENTS FOR DECISION-MAKING AND POLICY DEVELOPMENT

It can be concluded that there is potentially much to gain for governments from integrated assessments. By sharing information and through dialogue, by applying assessment tools (including mapping and models), it is possible to find win-win opportunities.

However, diverse expectations can also lead to disappointments and limited resources constrain ambitions. Active participation and commitment from the different key stakeholders are necessary to make a Nexus Assessment into a relevant exercise that supports policy and decisions at different levels.

While an intersectorial-transboundary dialogue has value by itself already, adequate data is necessary for an accurate and meaningful analysis. Nevertheless, already a scoping level exercise with limited analysis and quantification can point at the right direction and highlight potential benefits that could be explored further - shortages raise awareness about vulnerabilities and can trigger more rationalised use of water.

Knowledge base about intersectorial impacts and trade-offs is improving, even though availability of quantified examples is limited. Also, good practices are getting disseminated and partnerships can play an important role in this. The unique situation of each river basin and aquifer as well as common context specificity needs to be recalled though. It requires careful assessment which to identify "solutions" which can be transferable.

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Notes

1. The views expressed in this article are those of the authors and do not necessarily reflect the views of the United Nations Economic Commission for Europe.
2. The Nexus term in the context of water, food and energy refers to these sectors being inseparably linked, so that actions in one area can have impacts on the others, as well as on ecosystems.
3. UNECE region cover 56 countries in the European Union, non-EU Western and Eastern Europe, South-East-Europe and Commonwealth of Independent States (CIS) and North America.
4. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.
5. Underlining the international topicality of policy coherence concerns, the High-Level Political Forum (HLPF) on Sustainable Development 2014, held under the auspices of the Economic and Social Council (ECOSOC), had among its topics of debate "From silos to integrated policy making". One of the background documents states: In the context of a universal, people-centred, integrated sustainable development agenda Post-2015, it can be expected that integration will be at the centre of policy concerns.
6. In the OWG proposal, the above-mentioned goals are defined as follows:
   Goal 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
   Goal 6. Ensure availability and sustainable management of water and sanitation for al.
   Goal 7. Ensure access to affordable, reliable, sustainable, and modern energy for all.
   For a full list of the proposed SDGs, the report of the OWG should be referred to.
7. These principles for effective joint bodies are available in document WG.1/2014/INF.2 available at http://www.unece.org/fileadmin/DAM/env/documents/2014/WAT/06Jun_25-26_Geneva/Informal_doc_2_Principles-of-joint-bodies_final.pdf/.

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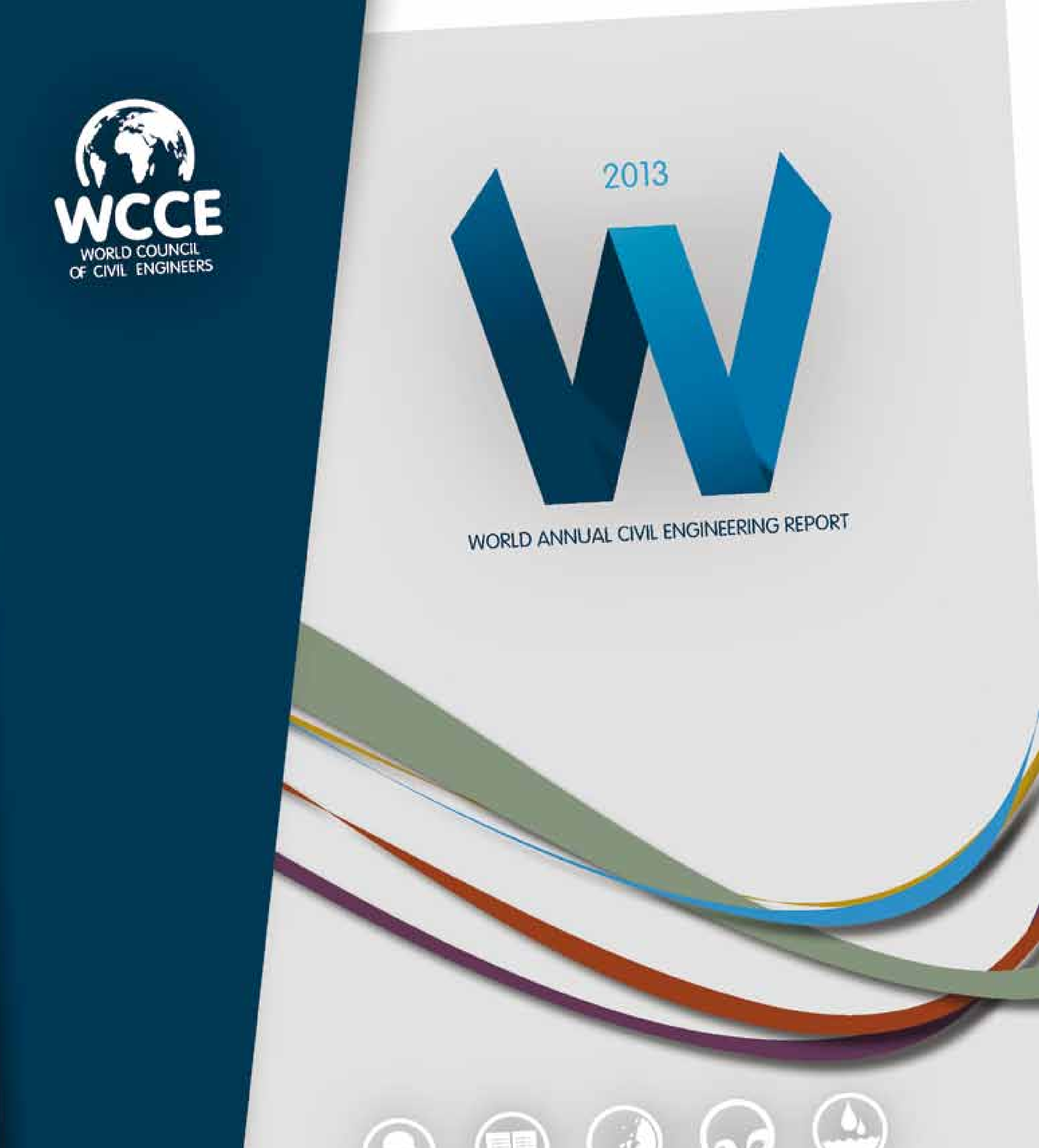
#WaterForLifeVoices



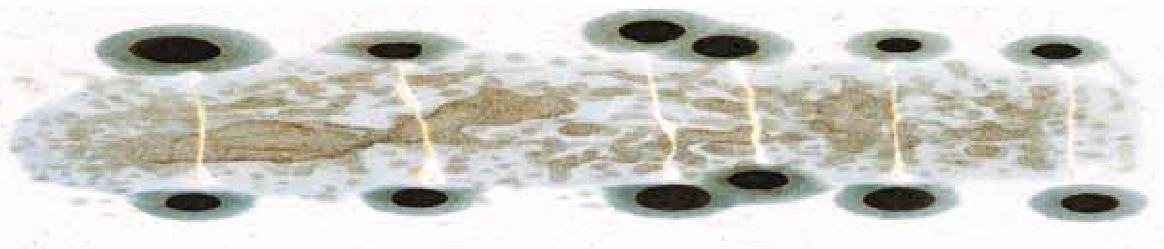
WORLD ANNUAL CIVIL ENGINEERING REPORT

WCCE
WORLD COUNCIL
OF CIVIL ENGINEERS

WATER AND ENERGY,

A CRITICAL ALLIANCE FOR SUSTAINABLE DEVELOPMENT

Ángel Simón Grimaldos

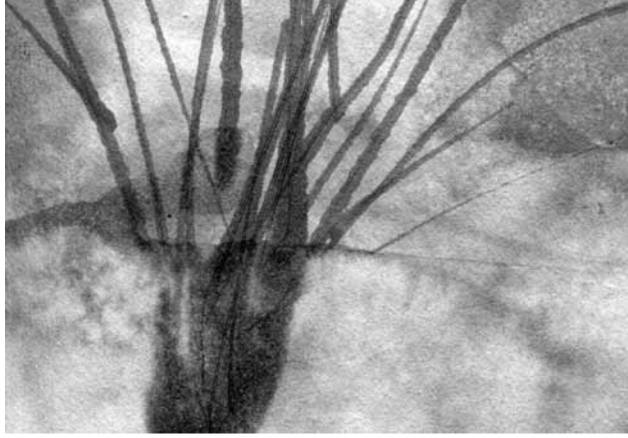


KEYWORDS:
WATER
ENERGY
FOOD
GLOBALIZATION
COOPERATION
CLIMATE CHANGE
SUSTAINABLE DEVELOPMENT

Thousands of years ago, when it was still believed that the world was flat and life flowed without haste, water, air, fire and earth constituted the basic elements which explained nature, the basis of all life. These four elements were the foundations of the human cosmogony in pre-Socratic times. Nowadays, the basis of our present and, above all, of our future has been transmuted into a triangle in which water, energy and food are the vertices of a human-centred globalization.

Water, which was already at the basis of ancient thought, is an essential element for life. In ancient Greek, Zisabrós was the word for either a treasure or a water well, and therefore water itself. Rather than a basic necessity, water is the source of life itself and is an essential element for its continuity. Water cultures were present at the beginning of the great Neolithic civilizations. The utilization of the waters of the Indus, the Euphrates and the Nile favoured a spectacular technological development in water treatment, new knowledge paradigms and even the appearance of water-linked political powers and religions. Leonardo da Vinci said that "water is the driving force of all nature." It is no coincidence that progress, water technology and its derivatives made the economy, culture and social development flourish.

We are so trapped by the hasty flow of events that we have lost the ability to focus on the tiny details that reflect the true pulse of life: the changing colour of the sky, the smell of wet grass, the sparkling eyes of a child, the changing seasons… Westerners are increasingly alienated from nature and we think, naively, that all answers to our questions are to be found in a synthetic universe that fits in the palm of our hand, in the narrow screen of our mobile phone or tablet, no matter how smart they may be. Nature, as is widely known in the East, is a compendium of wisdom and a source of inspiration. The forces that move it enclose the basis for sustainable development and a balance between all the elements. The role of water, earth, fire and air in each of their manifestations should be noted. We need to see how they interact in the fury of a volcano, the beauty of a waterfall or the sound of a storm. We need to immerse ourselves in this richness in order to understand nature and to understand ourselves, in the best tradition of Socratic thought, inspired by the words allegedly written on the pediment of Apollo's temple at Delphi: "Know thyself." The future depends on knowing how to adapt to this wonderful home that is our planet, and a better understanding of the reality of the species which inhabit it.



TACKLING INEQUALITY

I am reminded, in the twilight of 2014, of the celebration, held on March 22, World Water Day, which the United Nations dedicated this year to raising awareness about the importance of the Water-Energy Nexus. Both elements are basic pillars for balanced economic development: access to both is mandatory to eradicate poverty in vast areas of the earth's geography and meet the UN Millennium Development Goals. The discussion on the use of these resources cannot be held in isolation, as we may run the risk of finding partial solutions that do not address their natural links. It is true that there are important similarities between the two, but also substantial differences. Both elements are basic to Humanity, are global resources of heterogeneous availability, are affected by climate change, involve high infrastructure costs… Parallel to this, while energy is marketed on a global level, water has local roots; the former is expensive while the latter is objectively cheap, although often not perceived as such; Energy may proceed from different sources but water has a single source; access to water is a human right, nothing similar existing for energy; the water needed to produce energy has a scarce impact on the final price, whereas the power to ensure the water supply has a significant impact on its price…

According to the UN, it is necessary to emphasize the relationship between these elements, especially addressing inequalities, taking into account what it means for a large part of the population living in marginal areas and impoverished rural areas without access to drinking water, to adequate sanitation, sufficient food and energy services. The United Nations listed five key issues in promoting sustainable practices in the field of water and energy. Firstly, and obviously enough, water requires energy in all phases of its catchment, processing and distribution, and energy needs water to be produced in almost all its forms. According to the Spanish Energy Grid operator, Red Eléctrica, hydropower accounted for 7.6% of Spain's electricity consumption in 2012, exceeding photovoltaic, thermal renewable and solar thermal sources.

The asymmetry between the two concepts mentioned cannot hide the numerous and important examples of interaction and interdependence. We might even speak of conceptual subordination. Both sectors can do a lot together, and this is fundamental for the future of humanity: the production of energy for life at the current level of our organic growth is influenced by the availability and existence of water. Agriculture is the planet's food base, the third vertex of the triangle we must address from the sustainable development perspective. Based on a democratic logic and on respect for diversity, we must strive to find a holistic balance. The supplies of both fresh water and energy are limited and demand is increasing and will continue to grow significantly in the coming decades. A UN report, on the occasion of the 2013 World Water Day, estimates that by 2030 water demand will increase by 40%, energy consumption will double, and the need for food will grow by about a third. Once more, water, energy and food are pillars for a balance which will mould the future, with humankind gravitating at its centre. Often, the same population, without access to water and sanitation, also lacks food and energy. In this context, the choice of a circular economy seems to be the most sensible and effective way to optimize and reuse the level of resources available.

COORDINATED POLICIES

Another aspect highlighted by the UN is that saving one, whether water or energy, necessarily helps to save the other. Currently, 15% of global water consumption is used for electricity and 8% of global energy use is for the extraction, treatment and transport of water. On the other hand, it warns that the most deprived sector of the global population urgently needs access to both water services and electricity. Estimates indicate that there are 1.3 billion people without electricity around the world, 768 million lack access to improved drinking water sources and up to 2.5 billion lack sanitation. Reducing these deficits in services, which result in inequalities, is one of the priority measures to eradicate poverty worldwide. Finally, a more efficient use of water and energy requires the implementation of coordinated, coherent and concerted policies. This call is addressed to world leaders, from whom the UN requests "national innovative and pragmatic policies that can lead to greater efficiency and a better provision of cost-effective water and energy services". There will be

no sustainable development without water and energy for all.

One of the major challenges of the world, particularly regarding emerging and developing economies, is to meet the water and energy needs in the coming decades. It is clear that the most deprived require these services most urgently. All energy sources use water at some stage of their generation process, be that during the extraction of raw materials, the cooling of thermal power plants, the cleaning activities, growing biofuels or flowing through the turbines. There is a clear interconnection and, despite the short-term success of some alternatives or mitigating measures, partial responses are doomed to fail in the medium and long term.

A joint reflection and a comprehensive and coordinated response that often goes beyond the local are needed, acquiring a transnational status. The solutions cannot come from following models that solve the energy problems by increasing water scarcity in certain areas or improving water security while aggravating energy problems; or, even worse, trying to solve shortcomings at the expense of the environment. If we accept the truth of this mutual dependency, we can address a wide range of problems and solutions through an integrated approach: from the management of water supply systems to the design of efficient energy models, and including the sustainable management of the supporting infrastructures. Coordinated and parallel development of energy and water policies, rather than their isolated and independent evolution, is essential for sustainable development. The energy sector, exposed to increasing risks, must accept the increasing importance of including water issues in its strategic plans.

Poverty reduction and economic progress often lead to ecosystem deterioration. The American president, Barack Obama, has finally recognized the enormous risk posed by climate change and has established this issue as a top priority on his political agenda, so often shaken by the numerous military, religious, humanitarian or natural conflicts that proliferate at this time of global transformation and uncertainty. The Middle East, Iraq, Syria, the horn of Africa and the Sahel are the scenery of conflicts that have, in many cases, water and energy as their background, although the innocent victims are only aware of their suffering and despair. But this climate change manifests itself in natural phenomena that threaten the safety of people in many areas of the planet: polar melting causes the Alaskan coastline to be reduced by six metres per year; the population living less than one metre above sea level may suffer from an increase in this level; the North Pole ice surface is reducing, resulting in ocean warming… Examples abound; decisions to address climate change are lacking.

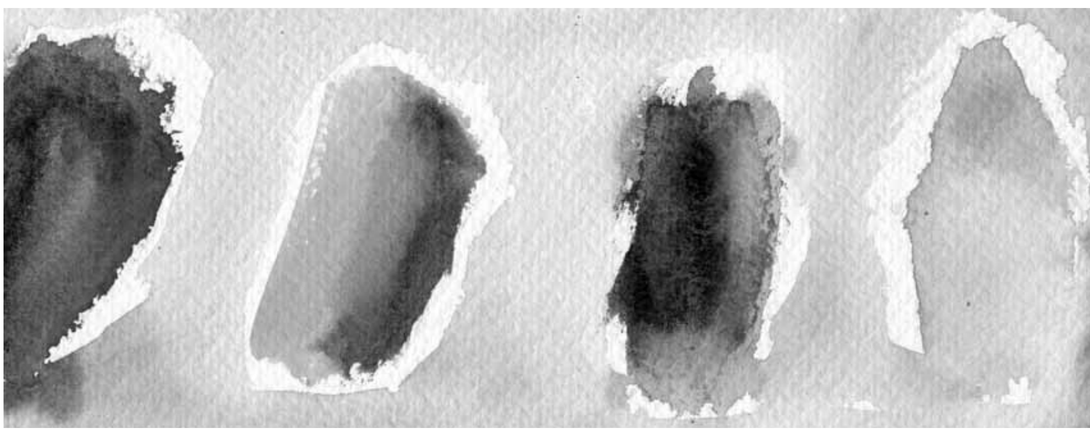
We are facing a crumbling of traditional models and alleged absolute truths. These are times of "liquid" relations between the main actors in our society. It is vital to address the effects of human activity on the climate. The shortage of raw materials and food, linked to water supply and the need for more renewable energy and resources, must be among the priorities of world leaders, international corporations and companies, which will be accountable for their decisions to future generations, which will not forgive short-term visions and delusions.

11 BILLION INHABITANTS BY THE END OF THE CENTURY

Population growth, with the emergence of cities as its most prominent symptom, is an unquestionable reality. Forecasts indicate that by 2030 there will be 400 new large cities in China, which represents a challenge for the entire planet. According to the latest predictions, the world population will reach 11 billion by the end of the century, compared with 7.2 billion today. A greedy and irresponsible use of the available resources linked to urban development's current model forces us to deal promptly with the cities' needs. An intelligent response to the Water-Energy Nexus is required to find a new economic development model that allows us to move toward the global introduction of a circular economy and a process of reducing inequalities.

Water is a human right, as declared by the United Nations in 2010 and, as we know, we do not so much face a problem of scarcity as of governance and good management of the available resources. In this regard, technology plays an important role and allows us to be optimistic about the possibility of finding breakthrough solutions which will leave obsolete formulations behind. We have made meteorical progress in information management and in new communication channels, brain research and the human genome, as well as in many other fields that will shape 21st century society. But we still have several unresolved challenges within our driving forces. Youngsters in Silicon Valley are searching for new business models which will continue to revolutionize our telecommunications, e-commerce and information that may substantially change human relations. Many of these leaps have already occurred, but the innovation setting is far from its maturity point. Surely robotics, big data and new materials will surprise us, making what we currently consider to be innovative and immovable solutions obsolescent. However, the biggest challenge is to find new ways to ensure the availability of water and energy, allowing us to abandon a development scheme that does not take into account the necessary balance between the different elements. Such challenges must be managed properly, using knowledge and technological advances as drivers for a new era of smart and responsible growth.

As has happened throughout humankind's history, our responsibility is to learn from nature, from its tense harmony, to do more with less, to achieve a new equilibrium, wherever the human being is doomed to subsistence and the future is just a dream to migrate to other areas of the world with plentiful misused resources. However, like any other system, nature has its own rhythm, achieving a balance in the medium and long term, has its own changing life, sometimes violent and even cruel in its manifestations; from drought to floods, from lack to excess, with no respite. The ability to understand, prevent and control natural phenomena is also one of our major concerns. Wealth also lies in the ability to find new ways to add value to what now seems to have none, or whose value is beyond our comprehension. Migratory waves have always existed, but never before have inequalities been so pronounced. The possibility to take a shower, use a toilet, have



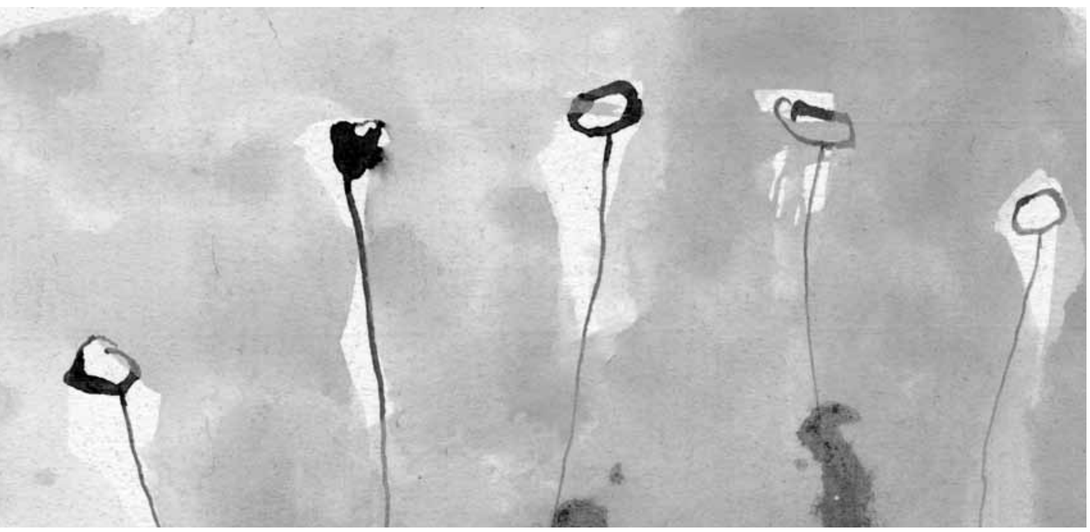
electricity, heating or air conditioning… are still amenities available to a few in this global world. Something that is just part of our daily routine is a miracle for hundreds of millions of people.

Every place, every little village and every large country has its own examples showing that the Water-Energy Nexus must be adequately addressed on both domestic and cross-border programmes and policies, in particular with a view to meeting the Millennium Development Goals and the development of the Post-2015 Agenda. At the end of the day, the industrial sector is the major consumer and efficient use of water resources for energy production will inevitably contribute to the consolidation of a "green economy", where food is the third vertex of this strategic triangle that we already mentioned as basic "food for thought".

THE THREE C'S REVOLUTION

Sustainable development must be based on knowledge, talent management and innovation. These are the foundations that will allow us to optimize the Water-Energy Nexus through management based on environmental conservation and the continuous improvement of energy efficiency. It is a question of developing the "Three C's Revolution": Comprehension, Cooperation and Commitment. In this line of action, innovation is essential to address new problems, seeking maximum efficiency to minimize the use of available resources and encouraging reuse in a circular economy. That is why all initiatives committed to empowering education and the University are so important, where new ideas are to be conceived and new generations are to be instructed, allowing us to meet our challenges ahead. Talent, the transformative power of ideas and the intelligence to integrate them, is one of our most precious assets. Cooperation, so necessary between regions, between water and energy, between the country and cities, is a new talent. Knowledge transfer is the key to a new partnership, a model in which we all win with sustainable growth which includes cities, where intelligent management and reuse are the driving forces of smart cities.

As water experts, connoisseurs passionate about our profession, we learn every day from local experiences, while maintaining a global vision. We have a daily commitment: Rethinking the present to win the future, which inevitably goes down the path of sustainable development. This requires, more than ever, collaboration between all stakeholders: governments, businesses, local and international institutions, professionals, scientists and citizens. Especially in the present circumstances, public-private partnership is a crucial practice, taking into account the role of each of the sectors, each actor respecting the role of all the others and accepting their responsibilities. The public sector should provide independent regulatory agencies and legal certainty; on our part, firms, we should be committed to service quality, excellence in management and a process of continuous improvement and innovation. This global perception based on an accurate view sensitive to the local context leads us to make a commitment to the interests of the people and the territories in which we operate. We are a local operator with global awareness, allowing us to transfer our lessons learnt. Globalization gives us a great opportunity to network: connecting territories and research institutions, moving towards a global community of knowledge on water and, therefore, an essential partner when looking for the best options regarding the energy sector. The best corporate governance has resulted in greater sustainability and good environmental practices, becoming a main indicator to be taken into account when a variety of institutions and agencies such as the Norwegian Pension Fund or the Church of England make investment decisions.



We have comprehended that the efficient use of energy is a necessary condition to ensure sustainability in our business. Maintaining supply

and sanitation services is an energy-intensive activity. General estimates indicate that between ten and twenty per cent of electricity consumption is somehow related to water. The necessary balance, optimizing internal relations within the Water-Energy Nexus forces us to think about how to generate a net energy surplus in wastewater treatment processes. Some studies suggest that the chemical energy stored in wastewater daily per person is equivalent to the electricity needed to power a hundred-watt light bulb for eight hours. We need to be creative, to innovate constantly, be committed to the development of out-of-the-box technologies, to seek greater integration of water and energy policies, to convert our premises into generators instead of consumers, always with an eye on the overbearing need to contribute to a paradigm shift in the Water-Energy relationship.

World Water Day was established to remember that water is a public commodity, essential for life and for the sustainable development of humankind. It is therefore our duty to reflect and take action on all scales, proceeding as a torchbearer in the discussion and social engagement. This is why we have reached agreements with various national and international institutions and agencies, including this publication which is the result of a joint collaboration with UN-Water and the World Council of Civil Engineers (WCCE). But we are also working with UNICEF to develop projects in the Peruvian Amazon, which will significantly improve the conditions of access to water and sanitation for 5,000 families; and with Toledo's International Centre for Peace, developing sustainable self-management of water and energy services for communities of Lebanon; or in India, jointly with the Vicente Ferrer Foundation, installing solar-powered drip irrigation systems in fourteen villages.

Nature must be our source of inspiration on the path to a more sustainable world, with a more equal distribution of wealth and a rational use of resources. Contemplating Victoria Falls, the natural border between Zimbabwe and Zambia, the Bromo volcano in Indonesia or the Great Barrier Reef in Australia may help us understand the supreme intelligence with which the forces of nature, those four basic elements of ancient civilizations, have achieved integration and understanding, a natural engineering and geothermal testimonial in which the equilibrium is not a means, but an end in itself. A lesson still to be learned.

Ángel Simón Grimaldos
Civil Engineer
Chairman of the Aquae Foundatio

WATER & ENERGY IN MEXICO:

SYNERGY FOR SUSTAINABILITY

Víctor Javier Bourguett Ortíz

Ana Alicia Palacios Fonseca

KEYWORDS:
SUSTAINABILITY
ENERGY
REFORMS
RENEWABLE RESOURCES
GENERATION
WATER
HYDRO
SMALL HYDRO
SYNERGY

INTRODUCTION

Mexico is implementing constitutional reforms in several fields, seeking to provide a feasible path to the country in a globalized world, in a period to be known as postmodernism, which needs to improve the quality of life of its citizens. That is why the Water and Power reform projects have among their objectives to create mechanisms to ensure long-term environmental sustainability, which include the reform of the Use of Renewable Energies and Financing of Energy Transition Act (LAERFTE). Such is responsible for regulating and promoting the use of renewable energy sources to generate electricity or clean technologies, as established in the National Energy Strategy 2013-2027 (ENE 2013-2027) and the National Climate Change Strategy. In Mexico the energy output from renewable sources now accounts for 15.9% of total output, exploiting only 4.76% of its potential (ENE, 2013 to 2027, SENER). As part of the efforts to address such adjustment, research funding programs have been designed, such as the Sustainable Energy Fund (ESF), managed by the National Council for Science and Technology and the Secretariat of Energy. However, these efforts have focused on Geothermal, Solar and Wind energy, leaving development and research into the hydropower sector pending. There is a high hydropower potential, mainly in the Southeast, where they have high rainfall (1,846 mm) and runoff figures (141,128 hm^3/year). The topography and conditions in the south of the country favour the development of small hydropower plants, which can be considered as a development mechanism for isolated areas, also having the advantage of being low investment projects with small negative environmental and social impacts, as they alter slightly the ecosystems in where they are to be located. However, it is necessary to build capacity for the development of such technologies. Regarding this, Mexico has research centres with expertise in such fields. This paper discusses the above in order to promote the use of water resources as a means to energy sustainability and environmental and social balance as well as the development of technology for the welfare of future generations and at a low cost.

SUSTAINABLE DEVELOPMENT IN MEXICO

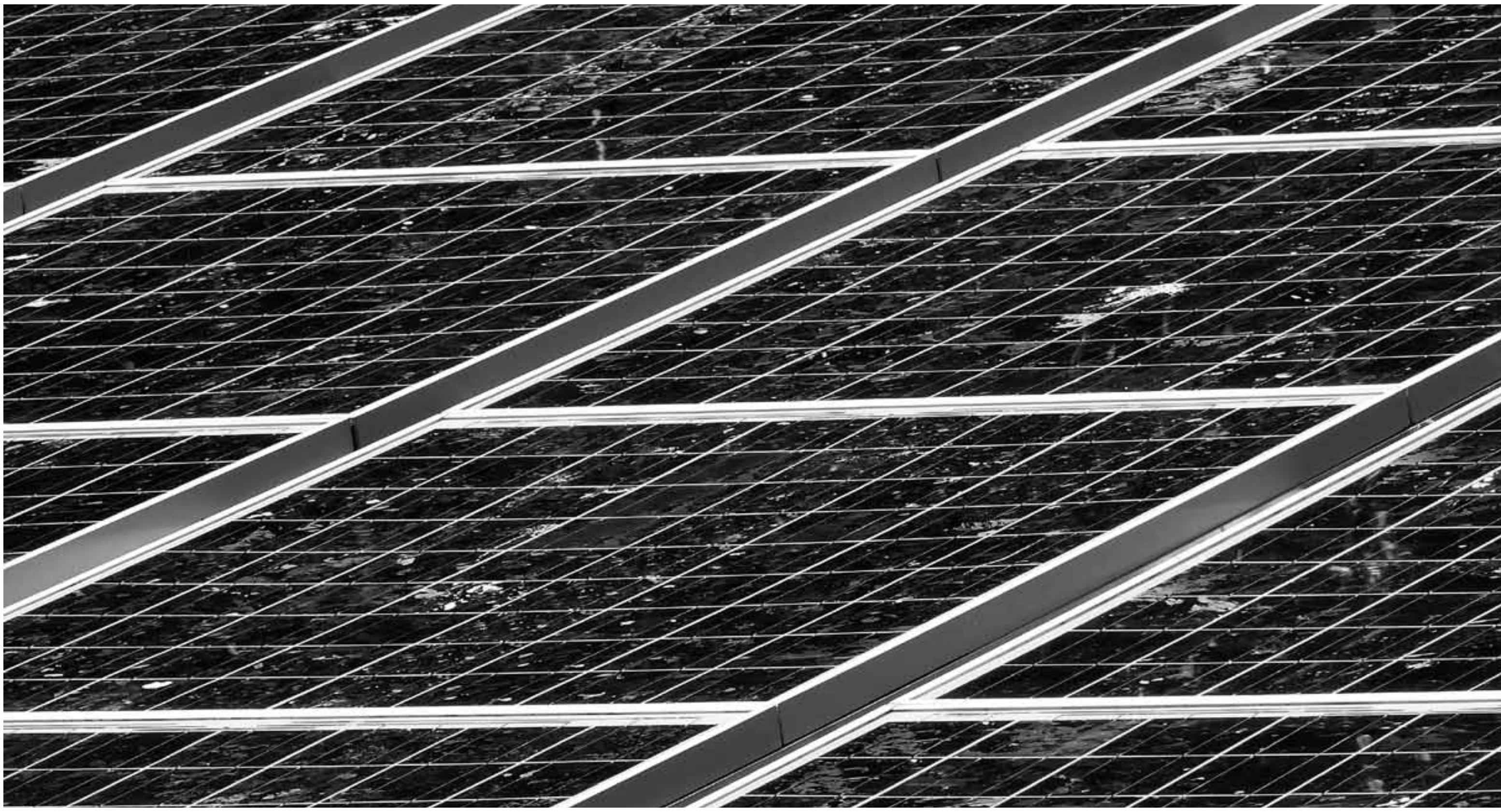
The Environment has become an element of competitiveness and economic and social development. The concept of "Sustainable Development" was first presented in 1987 by the World Commission on Environment and Development United Nations. Among the key factors required to tackle in order to achieve Sustainable Development are population growth, energy demand, climate change, water scarcity and resource and waste management elements. It will be only through efficient and rational resource management, that we will be able to deliver economic progress and welfare to the people, without affecting the quality of life to future generations.

Mexico emits only 1.5% of greenhouse gases worldwide; however, they have increased by 40% from 1990 to 2008, (Desarrollo sustentable y crecimiento económico de Mexico, Secretaría de Economía, SE). That is why the Special Climate Change Programme (ECCP) aims to reduce 50% of total emissions by 2050. To date, Mexico has signed nearly 100 international agreements related to the environment and Sustainable Development, among which are: the Convention on Biological Diversity; UNFCCC United Nations Climate Change and its Kyoto Protocol; the Stockholm Convention on Persistent Organic Pollutants; the Montreal Protocol on Substances that affect the Ozone Layer; the UN Convention to Combat Desertification; the Convention on International Trade in Endangered Species of Flora and Fauna and the Millennium Development Goals of the United Nations.

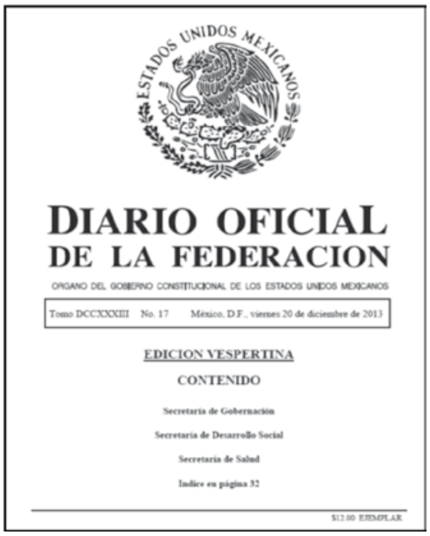
One of the great challenges of the country's Sustainable Development is to reduce fossil fuels dependence, and this can only be achieved through renewable energy output, so the Federal Government aims that by 2024, 35% of installed capacity in Mexico to come from such sources.

To achieve these goals, it is necessary to reform the legal framework so that the following options become available: a) expanding the share of national and foreign companies in renewable energy, b) opening the market to sell surplus electricity; c) assessment of the existence of economic and financial incentives for the generation of electricity from solar energy d) implementation of reforms to the legal framework for the water sector.

Within this Framework, Latin American countries are already obliged to monitor, protect and preserve natural resources, as well as protect human, animal and plant life.



ENVIRONMENT AND ENERGY REFORM


ESTADOS UNIDOS MEXICANOS

DIARIO OFICIAL
DE LA FEDERACION

ORGANO DEL GOBIERNO CONSTITUCIONAL DE LOS ESTADOS UNIDOS MEXICANOS

Tomo DCCXXXIII No. 17 México, D.F., viernes 20 de diciembre de 2013

EDICION VESPERTINA

CONTENIDO

Secretaría de Gobernación

Secretaría de Desarrollo Social

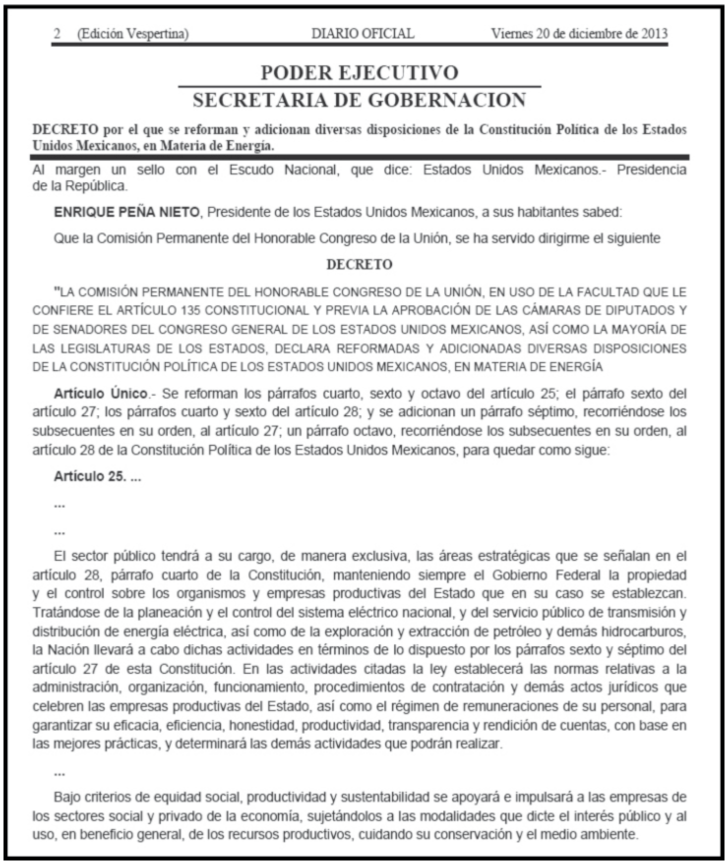
Secretaría de Salud

Indice en página 32

$12.00 EJEMPLAR

On December 20, 2013 in Mexico's Official Gazette, the Energy Reform was published with the amendment of the Articles 25, 27 and 28 of the Constitution of the United Mexican States (Figure 1). Such reform benefits the environment by promoting the use of clean fuels and renewable energy to reduce emissions of greenhouse gases.

Fig. 1. Publication in the Official Gazette of the Mexico's Energy Reform on December 20, 2013.


2 (Edición Vespertina) DIARIO OFICIAL Viernes 20 de diciembre de 2013

PODER EJECUTIVO

SECRETARIA DE GOBERNACION

DECRETO por el que se reforman y adicionan diversas disposiciones de la Constitución Política de los Estados Unidos Mexicanos, en Materia de Energía.

Al margen un sello con el Escudo Nacional, que dice: Estados Unidos Mexicanos.- Presidencia de la República.

ENRIQUE PEÑA NIETO, Presidente de los Estados Unidos Mexicanos, a sus habitantes sabed:

Que la Comisión Permanente del Honorable Congreso de la Unión, se ha servido dirigirme el siguiente

DECRETO

"LA COMISIÓN PERMANENTE DEL HONORABLE CONGRESO DE LA UNIÓN, EN USO DE LA FACULTAD QUE LE CONFIERE EL ARTÍCULO 135 CONSTITUCIONAL Y PREVIA LA APROBACIÓN DE LAS CÁMARAS DE DIPUTADOS Y DE SENADORES DEL CONGRESO GENERAL DE LOS ESTADOS UNIDOS MEXICANOS, ASÍ COMO LA MAYORÍA DE LAS LEGISLATURAS DE LOS ESTADOS, DECLARA REFORMADAS Y ADICIONADAS DIVERSAS DISPOSICIONES DE LA CONSTITUCIÓN POLÍTICA DE LOS ESTADOS UNIDOS MEXICANOS, EN MATERIA DE ENERGÍA

Artículo Único.- Se reforman los párrafos cuarto, sexto y octavo del artículo 25; el párrafo sexto del artículo 27; los párrafos cuarto y sexto del artículo 28; y se adicionan un párrafo séptimo, recorriéndose los subsecuentes en su orden, al artículo 27; un párrafo octavo, recorriéndose los subsecuentes en su orden, al artículo 28 de la Constitución Política de los Estados Unidos Mexicanos, para quedar como sigue:

Artículo 25. ...

...

...

El sector público tendrá a su cargo, de manera exclusiva, las áreas estratégicas que se señalan en el artículo 28, párrafo cuarto de la Constitución, manteniendo siempre el Gobierno Federal la propiedad y el control sobre los organismos y empresas productivas del Estado que en su caso se establezcan. Tratándose de la planeación y el control del sistema eléctrico nacional, y del servicio público de transmisión y distribución de energía eléctrica, así como de la exploración y extracción de petróleo y demás hidrocarburos, la Nación llevará a cabo dichas actividades en términos de lo dispuesto por los párrafos sexto y séptimo del artículo 27 de esta Constitución. En las actividades citadas la ley establecerá las normas relativas a la administración, organización, funcionamiento, procedimientos de contratación y demás actos jurídicos que celebren las empresas productivas del Estado, así como el régimen de remuneraciones de su personal, para garantizar su eficacia, eficiencia, honestidad, productividad, transparencia y rendición de cuentas, con base en las mejores prácticas, y determinará las demás actividades que podrán realizar.

...

Bajo criterios de equidad social, productividad y sustentabilidad se apoyará e impulsará a las empresas de los sectores social y privado de la economía, sujetándolos a las modalidades que dicte el interés público y al uso, en beneficio general, de los recursos productivos, cuidando su conservación y el medio ambiente.

One of the main goals in this Reform is to encourage the use of renewable energy on a large scale, through sustainability, environmental protection and energy security. The Energy Sector in 2013 has developed a transition strategy to promote the use of cleaner fuels, called Energy Planning (Figure 2), which includes the following programs and institutional reforms to the country.

The National Energy Strategy 2013-2027 promotes energy efficiency in the consumption and production processes, preventing and reducing environmental impacts and risks to the population and the ecosystem. Also, accelerates the transition to renewable energy sources and thereby exploit the abundant natural resources in the country. An important factor in achieving this is the mixed and private investment delivered through the development of clean energy technologies, promoted under the National Climate Change Strategy to the energy sector.

Within the framework of subordinate legislation of this reform, a decree has been issued making the National Energy Control Centre, CENACE, to become an independent public agency in charge of the national electrical operational control, which together with the Energy Regulatory Commission CRE, will be responsible for promoting the efficient development of supply, issuing standards, methodologies and other provisions governing the electricity generation from such sources and pondering the opinions of specialized research institutes, as well as national and international best practices such as the ones provided by the National Agency of Industrial Safety and Environmental Protection, through

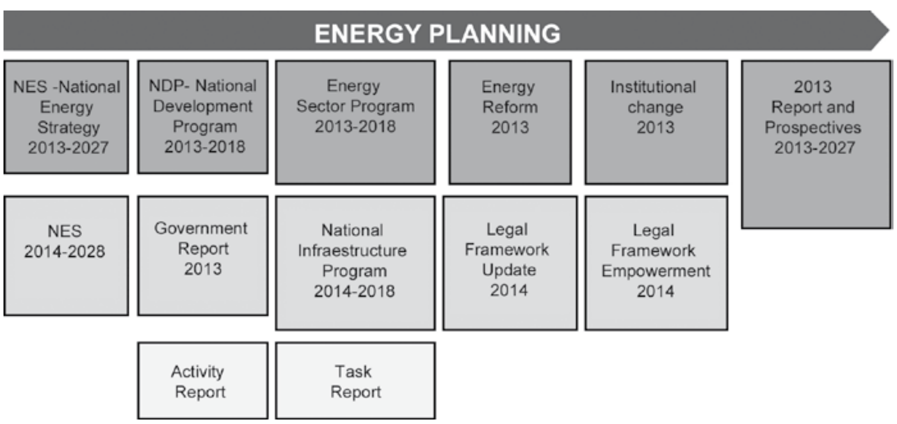


Fig. 2. Energy Planning from 2013 onwards (SENER).

the Secretariat of Environment and Natural Resources (SEMARNAT).

In addition to this, Mexico will twofold its contribution to the GEF (Global Environment Fund) to promote the implementation of high impact environmental projects, promoted in the Reform through the provision of sustainable productive infrastructure, as stated at the 5th meeting of the World Environment Fund organized by SEMARNAT.

RENEWABLE ENERGY: A PATH TO SUSTAINABILITY

In a global context, the contribution of renewable energies to the energy output in 2010 was 16%; in Latin America was 33%, while in Mexico was 10% (Figure 3).

In the same global context, electricity generation through renewable energy in 2013 contributes a 20.3% and 15.9% in Mexico (Chart 1), according to data from SENER in his paper "Outlook for Renewable Energy 2013-2027" (PER 2013-2027).

The same document states that the countries with the largest share of electricity generation from renewable sources were China, United States, Brazil and Canada, which represented more than 49% of global renewable generation (Figure 4). It is important to highlight that non-OECD countries in the Americas (Organization for Economic Cooperation and Development), are the ones who have a strong commitment on

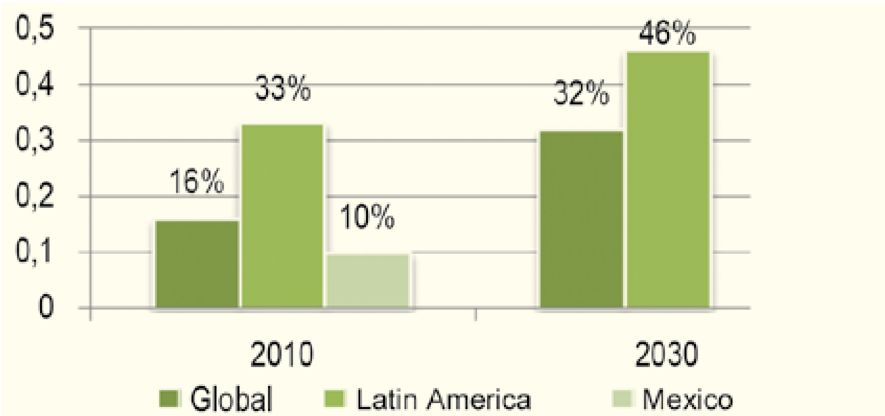


Fig. 3. Share of Renewable Energy in the World's Energy Output.

Chart 1

Electricity generation (GWh) from renewable sources Selected Economies, 2013

Country/Region	Renewable Energy Output (GWh)	Energy Output (GWh)	Renewable Energy Contribution to National's Energy Output	Renewable Energy Contribution to Global Energy Output
China	803,462	4,754,746	16.9%	17.87%
United States	551,898	4,349,571	12.7%	12.28%
Brazil	463,273	531,758	87.1%	10.30%
Canada	396,854	636,989	62.3%	8.83%
Japan	135,927	1,051,251	12.9%	3.02%
Germany	124,605	608,665	20.5%	2.77%
Spain	88,539	291,360	30.4%	1.97%
Mexico	**46,964**	**295,837**	**15.9%**	**1.04%**
Chile	26,020	65,713	39.6%	0.58%
Korea	10,712	523,286	2.0%	0.24%
Total OECD	2,130,680	10,866,959	19.6%	47.39%
World	4,495,707	22,200,994	20.3%	100.00%

Source: "Renewable Energy Prospective 2013-2027", SENER. IEA. World Energy Statistics 2013. 2013.

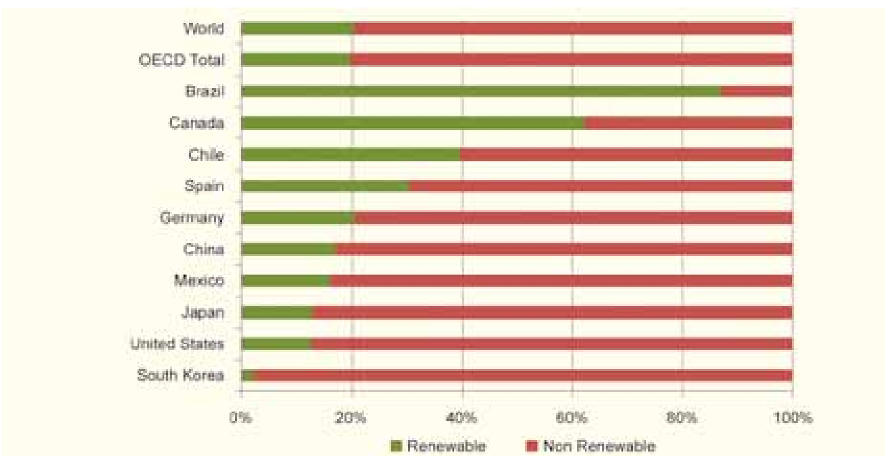


Fig. 4. Percentage of electricity generation from renewable sources from selected economies, 2013. Source: "Renewable Energy Prospective 2013-2027", SENER. IEA. World Energy Statistics 2013. 2013.

power generation by these sources, as is the case of Brazil that covers four-fifths of its domestic production by renewable energies (PER 2013-2027, SENER).

On June 7, 2013 the Use of Renewable Energies and Financing of Energy Transition (LAERFTE) Act, was amended, seeking to regulate the use of renewable energy and clean technologies to generate electricity for purposes other than the provision of public electricity service, as well as defining the national strategy and instruments to finance such energy transition and encouraging research and development of clean technologies for their use.

Within this Act renewable and non-renewable energies are classified as shown in the following diagram (Figure 5).

Concordant to the (LAERFTE) Act, SENER, jointly with the Federal Electricity Commission (CFE), has undertaken the implementation of a “National Inventory of Renewable Energies” (INER), where data on Mexico’s renewable energy potential and the feasible areas to apply these technologies may be consulted, all through an updated database of existing renewable resources. Its estimations account a current power generation through renewable sources of 39,415 MWh/year (Figure 6).

INER estimates Mexico’s Renewable Energy Potential Generation (PG) capacity according to the current situation of the country’s power generation, considering technical constraints of the technologies themselves, topographical and land use constraints and environmental risk and demand constraints in the exploit, processing capacity and transmission and resource variability.

The potential is represented by four levels of certainty (Figure 7): Resource, Possible, Probable and Tested, being Tested potential the one which has a larger number of technical and economic studies to prove its feasibility.

INER has published studies regarding Renewable Energy Potential Electricity Generation, where the most studied energy source technologies are Wind, followed by Solar.

Renewable Energy Tested Potential is mainly in the areas shown in the Figure 9.

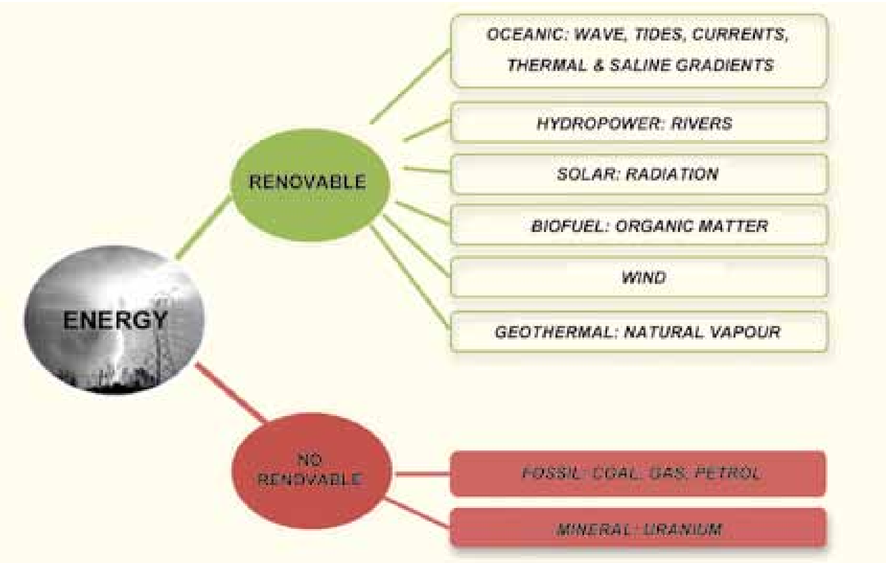


Fig. 5. Energy classification for the production of electric power and its energy resources.

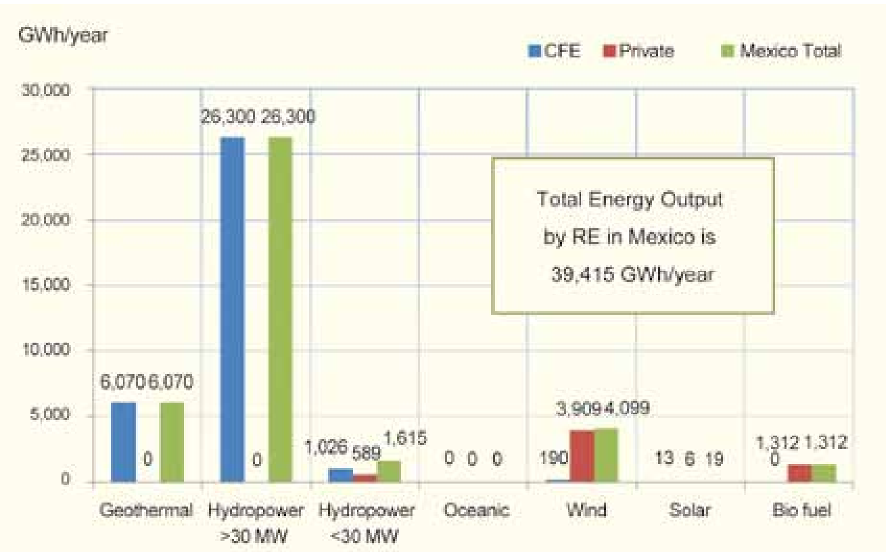


Fig. 6. Current Power Output by Renewable Energy (GWh/year).

Fig. 7. Certainty Scheme in the GP in Mexico by ER.

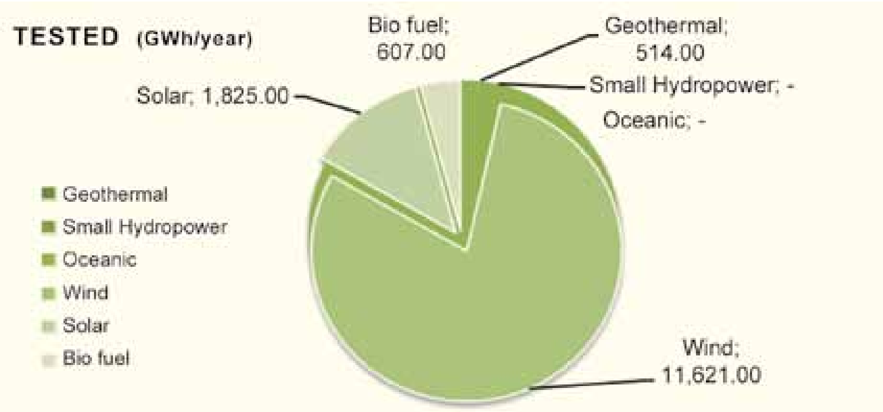


Fig. 8. Tested Potential Generation by ER.

Fig. 9. Mexico's Tested Electricity Generation Potential Location Areas by ER (INER, 2014).

Chart 2

Installed capacity of electricity generation in Mexico 2014

Power plants and Generating units

Type	Power Plants	Units	Capacity (MWh)	%
Conventional Steam	26	85	11,398.6	29.10
Dual	1	7	2,778.36	7.09
Carboelectric	2	8	2,600.0	6.64
Combined Cycle	13	68	7,566.582	19.32
Geothermoelectrical	7	38	813.4	2.08
Turbogas	30	71	1,530.01	3.91
Internal Combustion	9	58	251.305	0.64
Portable Turbogas	-	11	115.40	0.29
Portable Internal Combustion	-	19	3.11	0.01
Hydropower	**65**	**180**	**12,018.778**	**30.69**
Wind	3	106	86.750	0.22
Photovoltaic	2	2	6	0.01
Total S.D.G.	158	653	39,168.295	100
Nuclear	1	2	1,400	
Total C.F.E.	159	655	40,568.295	

Source: Hydropower Projects Coordination Unit, CFE April 2014.

HYDROPOWER GENERATION IN MEXICO

Although INER does not hold sufficient information regarding the hydropower potential, several other sources, mainly CFE, convey the growing choice of this resource as one of the most viable investment and abundant in country's Southeast.

Mexico has a long history in the construction and operation of hydropower stations: the Necaxa power plant was its first built (1905), during the rule of Porfirio Diaz, to electrify the centre of the country; becoming in those times, the world's largest hydro power plant, and has been operating uninterrupted for 109 years. Currently, three of the twelve generators installed are currently operative.

According to CFE's recent data, compiled by its Hydropower Projects Coordination Unit (CPH, April 2014), hydropower's installed effective capacity amounts to 12,018.778 MWh concentrated in 180 generating units and 65 hydroelectric power plants, being 21 of them large, and the other 44 small plants (596,278 MWh) as shown in Chart 2.

According to this data, hydropower generation amounts to 30.69% of total electricity generation in the country compared with all other sources of electricity generation, representing the main source of renewable electricity in Mexico.

In the global context (2013), China is the country with the largest hydropower generation with nearly 700 thousand GWh, equivalent to Latin America's total generation of 715,000 GWh (2011).

Overall, hydropower technologies contribute 16.1% to global electricity, with Brazil and Canada contributing over 50%, while countries like South Korea and Germany are below 5%.

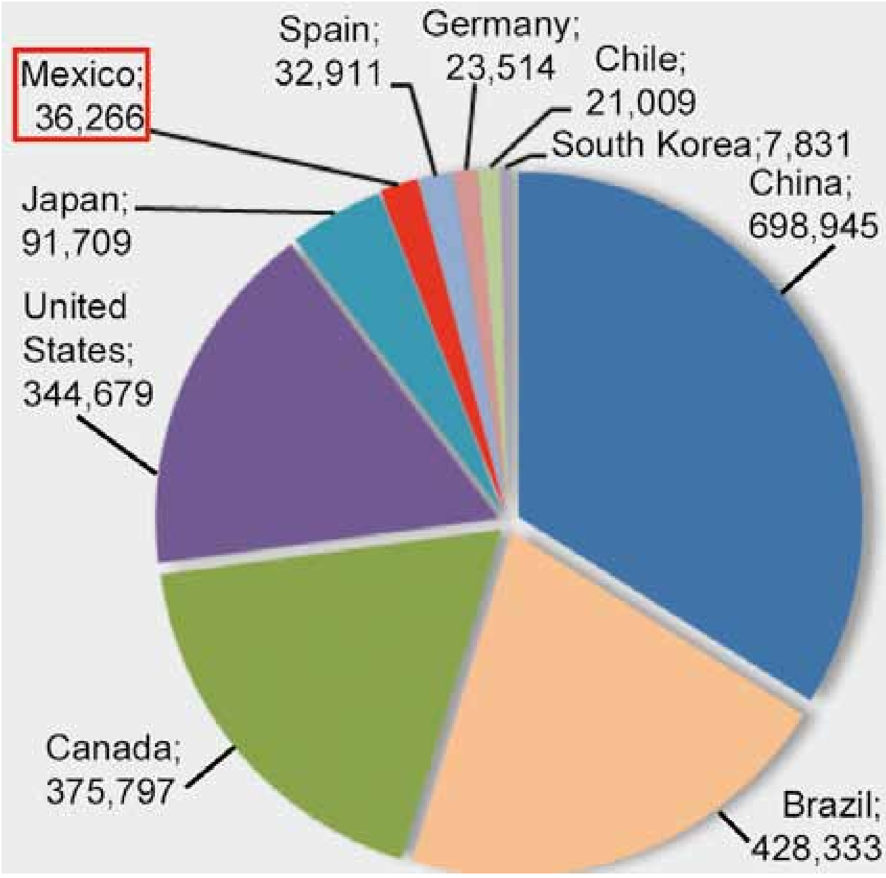


Fig. 10. Worldwide Electricity Generation Production through hydropower for selected economies, 2013 (MWh). Source: Secretariat of Energy, SENER, Renewable Energy Prospective 2013-2027.

Regions of electricity production

Mexico's total electricity production is split into five regions, according to 2014 CFE's data (portable plants not considered in these figures,), which highlight the areas of the Southeast and the West as the most productive.

Fig. 11. Electricity Generation Regions in Mexico (C.F.E.). Source: Installed Capacity, CFE, April 2014.

Chart 3

Hydro power capacity by Productive Region, C.F.E.

Hydropower

Nº	Power Plant	Region	U´s	Capacity MWh	Total Mwh
1	El Novillo	Northern	3	3x45	135
2	Huites	Northern	2	2x211	422
3	Bacurato	Northern	2	2x46	92
4	Humaya	Northern	2	2x45	90
5	Comedero	Northern	2	2x50	100
6	Falcón	North-Western	2	3x10,5	31.5
7	La Amistad	North-Western	2	2x33	66
8	Aguamilpa	Western	3	3x320	960
9	Agua Prieta	Western	2	2x120	240
10	Villita	Western	4	4x80	320
11	Infiernillo	Western	6	6x200	1,200
12	El Cajón	Western	2	2x375	750
13	La Yesca	Western	2	2x375	750
14	El Caracol	Central	3	3x200	600
15	Zimapán	Central	2	2x146	292
16	Peñitas	South	4	4x105	420
17	Malpaso	South	6	6x180	1,080
18	Chicoasén	South	8	8x300	2,400
19	Angostura	South	5	5x180	900
20	Temazcal	South	6	4x38.5; 2x100	354
21	Mazatepec	South	4	4x55	220

Fig. 12. Hydro Power Plants and Installed Capacity by Productive Region (CFE, April 2014). Source: Installed Capacity, CPH, CFE April 2014.

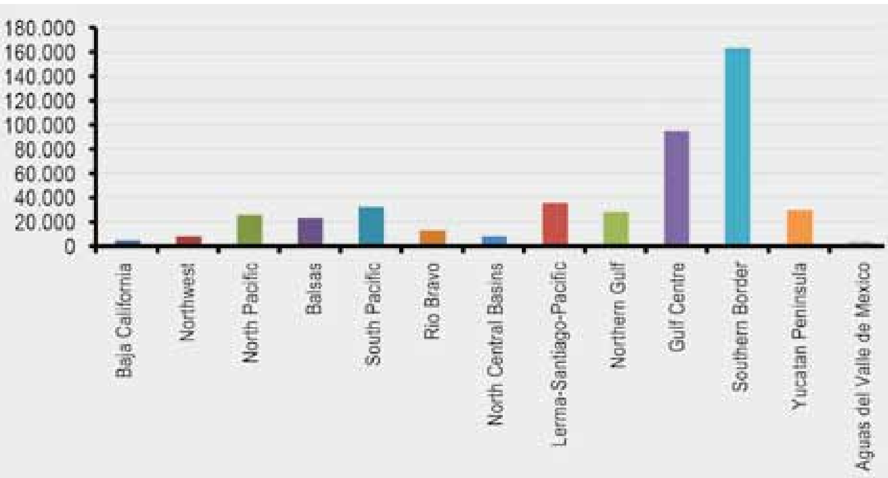
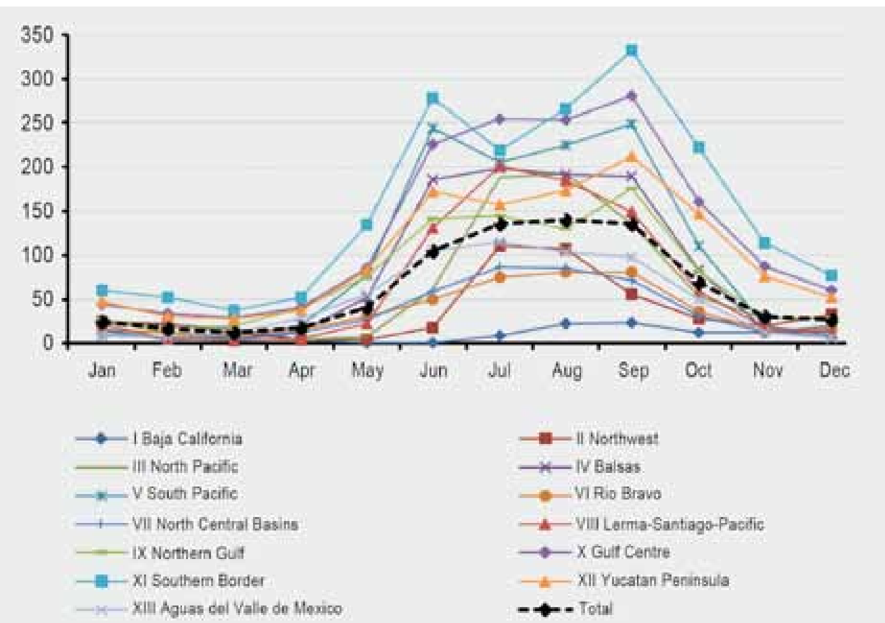


Fig. 13. Average annual volume of water per water administrative region 2011-2018 (hm^3/year). Source: Renewable water per capita per water administrative region. Mexico's Water Statistics 2013. CONAGUA, SEMARNAT.



HYDROPOWER POTENTIAL

As observed, Mexico has adequate and properly distributed hydropower resources, being its potential dependant to the storage capacity of the reservoirs, which adds up 150 billion cubic meters (Statistics on Water in Mexico, Edition 2013 CNA, SEMARNAT). Such volume depends on rainfall and runoff in different regions of the country; with 116 dams representing almost 79% of the country's storage capacity.

Hydropower development has a high return on investment and the KW/h is generated at competitive prices, whether for large plants (> 30 MW) and small hydro (<30 MW) compared to other renewable sources.

Hydrological administrative regions RHA XI Frontera Sur and IV Balsas are granted the most important water commission with 166 billion cubic meters in 2013 (Figure 13) amounting the greatest runoff and rainfall figures of the country and therefore the largest hydropower plants.

Southeast Mexico holds 35% of water in the country, with an average annual runoff of 141.128 hm^3/year, as well as the greatest rainfall, with 1,846 mm. According to this, Chiapas area holds the largest hydropower potential due to natural resource availability and area topography.

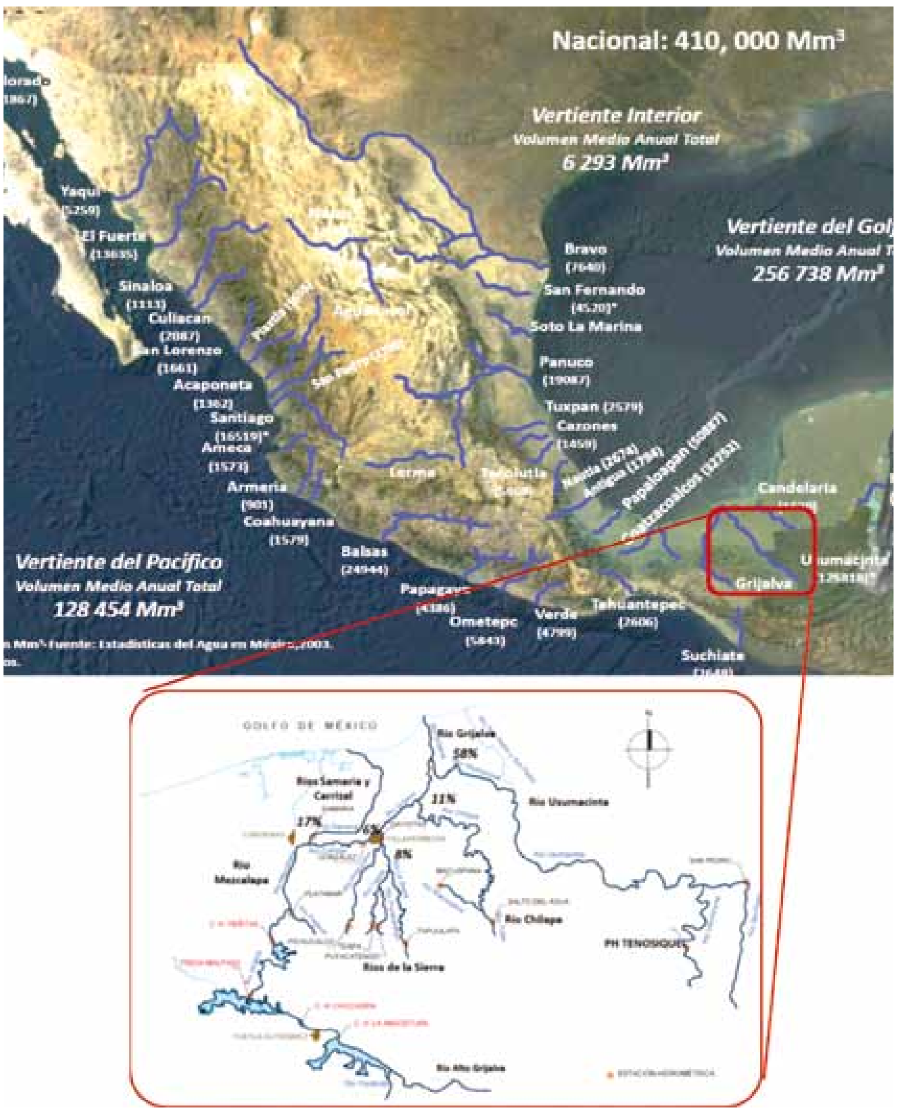
Fig. 14. Average monthly Rainfall (mm) by water administrative region 2011-2018. Source: Normal monthly rainfall per water administrative region 1971-2000. Mexico's Water Statistics, 2013. CONAGUA, SEMARNAT.

Nº	River	Water Admin. Region	Average natural surface runoff (mill m³/year)	Basin Area (km²)	River Length (km)	Maximum Order
1	Grijalva-Usumacinta	XI Frontera Sur	115,535	83,553	1,521	7
2	Papaloapan	X Golfo Centro	42,887	46,517	354	6
3	Coatzacoalcos	X Golfo Centro	28,679	17,369	325	5
4	Pánuco	IX Golfo Norte	19,673	84,956	510	7
5	Tonalá	X Golfo Centro	11,389	5,679	82	5
6	Tecolutla	X Golfo Centro	6,098	7,903	375	5
7	Bravo	VI Río Bravo	5,588	225,242	ND	7
8	Nautla	X Golfo Centro	2,218	2,785	124	4
9	La Antigua	X Golfo Centro	2,139	2,827	139	5
10	Soto La Marina	IX Golfo Norte	2,086	21,183	416	6
11	Tuxpan	X Golfo Centro	2,072	5,899	150	4
12	Jamapa	X Golfo Centro	2,066	4,061	368	4
13	Candelaria	XII Península de Yucatán	1,861	13,790	150	4
14	Cazones	X Golfo Centro	1,712	2,688	145	4
15	San Fernando	IX Golfo Norte	1,545	17,744	400	5
16	Hondo	XII Península de Yucatán	533	7,614	115	4
	Total	16	**246,081**	**549,810**		

Chart 4

Characteristics of the main rivers that shed into the Gulf of Mexico and the Caribbean Sea, ordered by their average natural surface runoff

Source: Characteristics of the main rivers that empty into the Gulf of Mexico and Caribbean Sea. Mexico's Water Statistics 2013. CONAGUA, SEMARNAT.



The Grijalva and Usumacinta rivers in Chiapas also hold the longest basin river course length (1,521 km), representing an average annual natural runoff of 115,535,000 m³, the largest in the area (Chart 4).

According to data from the Ministry of Economy in its document "Global Outlook", worldwide estimations forecast the installed capacity for electricity generation from renewable sources by 2035 as of 3,437 GW, which represent 40% of total the global electricity system, where water and wind power will become the main sources of electricity generation.

In Mexico, the Investment Program for the Electrical Sector 2012-2026 (POISE 2012-2026 CFE) estimates that by 2026 the installed capacity for hydroelectric power generation will add up to 4,631 MW capacity, from which 750 MW will belong to completed projects, in construction or tendering and other 3,881 MW will belong to future tendering projects.

CFE is currently projecting a hydroelectric dam downstream of La Angostura's dam (60 km) in the Grijalva hydrological system (Figure 15), which will be called "La Angostura II" with an installed capacity of 105 MW.

Fig. 15. Main rivers of Mexico and Hydrography of the Grijalva-Usumacinta system. Source: Water Challenges in Mexico. Mexican Academy of Engineering.

It has been observed that the development of small hydropower- SHP (<30 MW) has had and still holds great momentum in our country, being advantageous to large plants, as they do not require a large investment, and their environmental impact is reduced, not facing social problems due to the loss or modification of habitat in areas that would become underwater in its basin, the flooding of large areas of its reservoir and the possible population displacement.

Such projects began in Mexico in the early twentieth century, in the states of Puebla, Veracruz, Chiapas, Michoacan and Oaxaca, developed by the textile, paper, beer or coffee industries. Since 1960, when Adolfo Lopez Mateos nationalized the electricity industry, 60 mini-hydro plants (<5 MW) with a total installed capacity of 75 MW, became operated by CFE and LyF with public purposes. That suspended the evaluation of the national Mini-Hydroelectric potential and CFE focused its efforts on building large hydropower projects in the Grijalva, Balsas and Papaloapan rivers.

Such was until 1992, when a new Electric Service Act that allowed the production of electricity by individuals for self-supply, small producer or independent producer.

A Small Hydropower Plant (SHP) is defined as one with inferior capacity than 30 MW and can be classified as:

- Micro Hydropower Plant, if inferior to 100 KW.
- Mini Hydropower Plant, if between 100 and 1,000 KW.
- Small Hydropower Plant, if between 1 and 30 MW.

SHP has the advantage of allowing the continuity of the river without generating area flooding and turbined energy is generated by the river or circulating flow, and can become a good alternative for rural electrification. But, in order to implement this technology is important to train staff in the operation and maintenance, and also requires for hydrological studies to support its functionality during drought or extreme rainfall periods.

UNESCO, in mutual interest with other organizations has promoted the use of this source of generation for the Latin America and the Caribbean through the Major Regional Project on the Use and Conservation of Water Resources in Rural Areas, in which the following activities are promoted:

1) Identification of Scientific and Technological Research Centres
2) Identification of the hydropower potential in smaller communities and
3) Support for the design of accessible to the rural community centre.

The turbine manufacturing industry has trended globally towards small load hydropower projects “edge flow” turbines, namely horizontal turbines with low hydraulic load and high flow, and is developing adapting turbines to several flow values and different technologies, materials and experience.

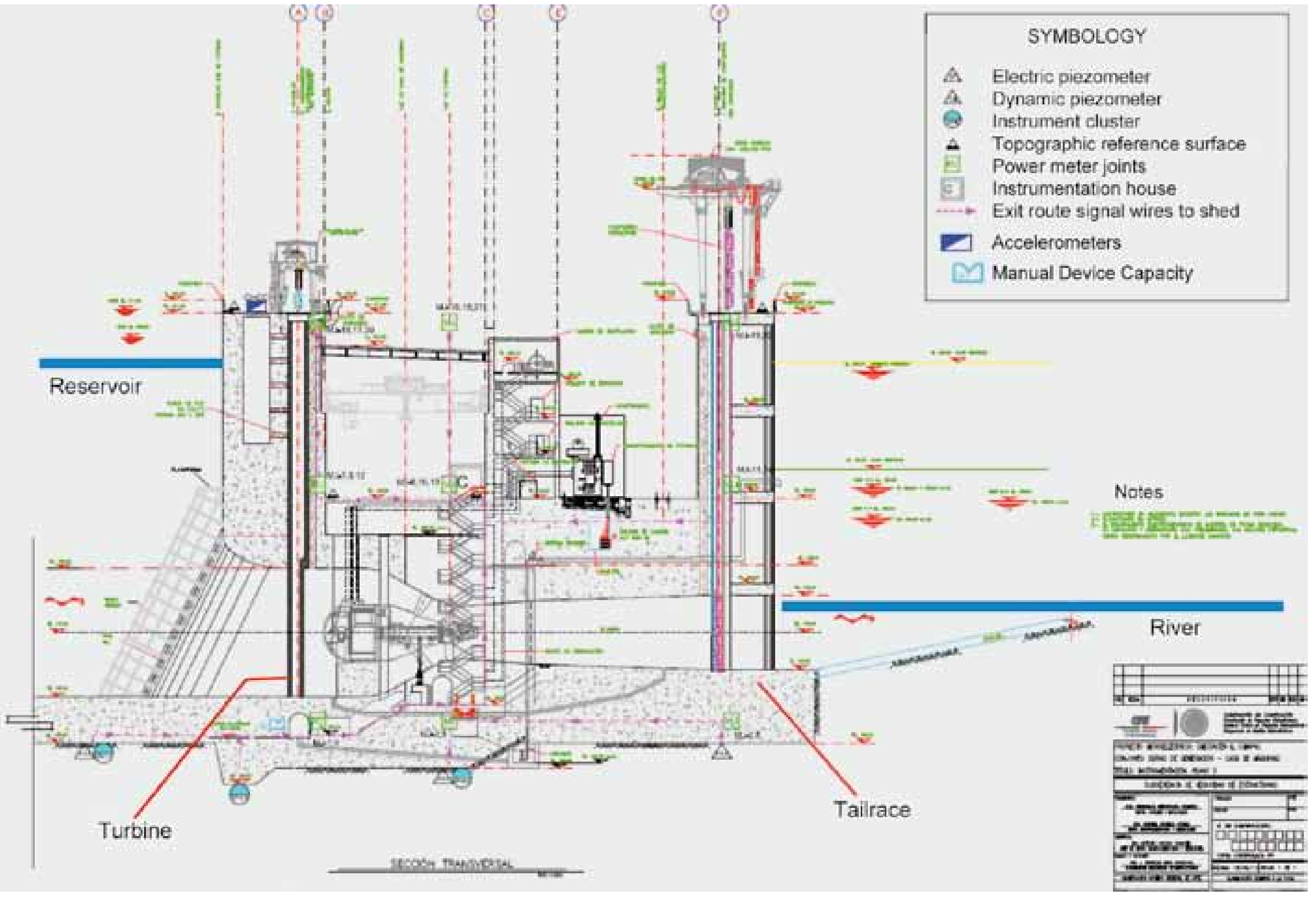


Fig. 16. Small hydropower plant cross-section project in Chiapas.

Small Hydro-power potential

The Federal Electricity Commission (CFE) estimated the generation potential of plants under 5 MW to 3,000 MW. In addition to this, the National Commission for Energy Saving (CONAE) has detected a 400 MW potential in a study of small hydro generation in 2006 in the mountainous regions of Puebla and Veracruz. Meanwhile, the Electrical Research Institute (IIE) estimated a usable 200 MW small hydro generation potential in irrigation canals in the country (USAID, Mexico 2010, "Guide for the development of electricity generation projects in renewable energy in and for municipalities").

Currently, the installed capacity of 596,276 MW is distributed among 44 small plants, most of them located in the states of Mexico, Michoacán and Veracruz. In 2012, the Energy Regulatory Commission granted 32 additional permits with a capacity of 418 MW, generating annually 1,599.1 GWh/year.

In the Grijalva system, the construction of low load power plant Chicoasén II (240 MW) is being assessed, located downstream of the Manuel Moreno Torres or Chicoasén plant (Figure 16).

CFE, through its Hydroelectric Projects Coordination Unit (CPH) has assessed the feasibility of low load projects in the area between Mexico and Guatemala and in the states of Chiapas and Tabasco. P. H. Line, P. H. On Porvenir, P. H. Isla Cayo and P. H. Yaxchilan projects are being designed on the main channel of the Usumacinta River and upstream of the PH Tenosique.

Small, mini and micro-hydro hydro power generation projects are applicable to irrigation districts, and thus help the regional sustainable development with reduced social and environmental impacts.

One option for promoting these mini-hydro projects is the implementation of development programs promoted by SENER through institutions as CONACYT and its financing schemes, such as SENER-CONACYT Sectorial Sustainable Energy Fund (ESF), which is the instrument created to promote scientific research and applied technology in the areas of energy efficiency, renewable energy, clean technologies and diversification of primary energy sources.

The ESF has been applied to projects regarding Geothermal, Solar and recently Wind Energy. It is important to push forward Hydropower through multidisciplinary partnerships such as the Renewable Energy Mexican Innovation Centres CEMIE's partnership, dedicated to the research and development of small hydroelectric plants which include research institutes participation for the development of this technology.

These financings are led exclusively by higher education institutions and research centres in the country, registered in the National Register of Institutions and Scientific and Technological Research (RENIECYT).

Thus, energy sustainability to reduce dependence on oil as a primary energy source is promoted, together with directing the development of programs dedicated to renewable energy projects established in the National Strategy and its financing instruments, mainly linked to the Kyoto Protocol targets.

WATER AND ENERGY SYNERGIES

As it can be observed, the balance on water and energy matters is crucial to global development programs and drives power generation toward using renewable energy. In Mexico, hydropower will continue to be the main renewable source, being only necessary to promote its development in areas such as:

1. Technological progress,
2. Cost reduced technology,
3. Governments' Promotion of Sustainable Development, amongst others.

It must be highlighted that, growth is dependant on the learning curve, which will reduce costs and will encourage investment in research and development. Mexico is contributing to the development of this industry by adapting its regulatory framework and allocating funding programmes focused on the development of new technologies.

Mexico has an excellent geographical location and vast potential of renewable resources and has the opportunity to manufacture the related equipment due to its extensive experience in electricity generation and supply.

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DEVELOPMENT AND APPLICATION

OF ANALYTICAL TOOLS IN SUPPORT OF WATER-ENERGY-FOOD NEXUS PLANNING IN LATIN AMERICA AND THE CARIBBEAN

Fernando Miralles-Wilhelm

KEYWORDS:
ENERGY
FOOD
NEXUS
WATER
MODELLING

INTRODUCTION: THE WEF NEXUS GLOBALLY

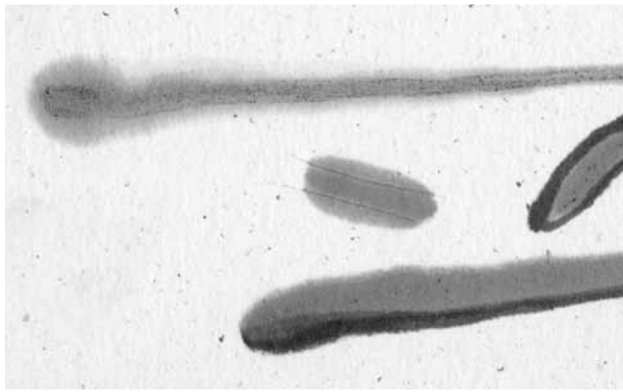
The interdependency between water, energy and food (WEF) is growing in importance as demand for each of these vital resources' security increases. Several regions of the world are already experiencing WEF security challenges, which adversely affect sustainable economic growth. In addition, there is already evidence of the effects of climate change on the availability and demand for water, energy and food, especially in fast-growing countries. At the same time, scarcity in water, energy or food is caused not only by physical factors, but there are also social, political and economic issues at play that affect the allocation, availability, and use of these resources.

Population and economic growth are expected to increase demand for food, energy, and water. Yet, 783 million and 2.5 billion people remain without water and sanitation, respectively. Stresses such as rapid urbanization and climate change are growing on all water uses. Cities in developing countries will face meeting the demand of 70 million more people each year over the next 20 years. By 2030 we will need 45 percent more water just to meet our food needs. Further, over 1.3 billion people are still without access to electricity worldwide and closing the energy gap has implications on water, such as for fuel extraction, cooling water, and hydropower.

Demand for energy for electricity generation will grow as population and economic activity expand (Shah *et al.,* 2009; Voinov and Cardwell, 2009; WWAP, 2012; Schornagel, *et al.,* 2012). Emerging economies like China, India, and Brazil will double their energy consumption in the next 40 years; by 2050, Africa's electricity generation will be 7 times as high as nowadays; in Asia, by 2050, primary energy production will almost double, and electricity generation will more than triple; in Latin America, increased production will come from non-conventional oil, thermal, and gas sources and the amount of electricity generated is expected to increase fivefold in the next 40 years and the amount of water needed will triple (World Energy Council, 2010).

Thermoelectric power plants account for 39% of the freshwater withdrawn every year in the US (USGS, 2005; see Figure 1) and for 43% in Europe (Rubbelke, 2011) almost just as much as the agriculture sector. Although most of the water is not consumed and is returned to the water source, these huge amounts of water withdrawn by the power and food production sectors have an impact on the ecosystem and on the water resources of a region.

As a consequence, there is a pressing need for integrated planning of WEF resource development and use, to avoid unwanted and unsustainable scenarios in the coming years. Although the WEF Nexus is fairly evident, these three sectors have historically been regulated and managed separately; and despite growing concern over these trends, decision makers often remain ill-informed about their drivers and ill-equipped to deal with possible outcomes. The simultaneous realization of climate change effects on WEF resources provides a window of opportunity to materialize such integrated planning in the LAC region.

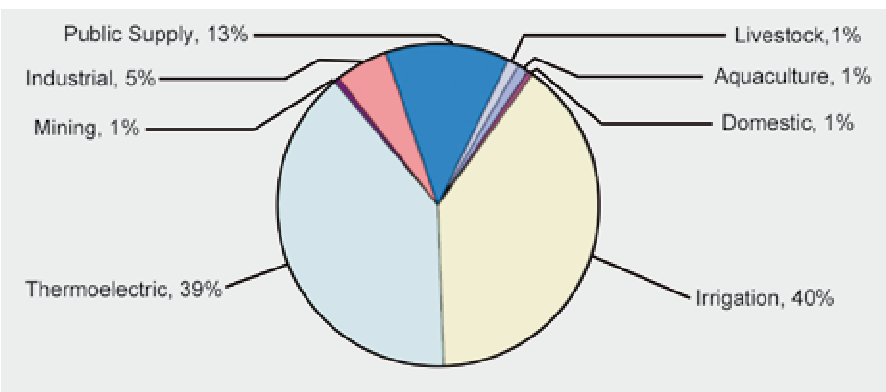


THE WEF NEXUS: CONTEXT IN THE LAC REGION

In the region of Latin America and the Caribbean (LAC), a number of key interactions illustrate the relevance of the WEF Nexus:

- *Water is needed for food production:* 90 percent of the region's agricultural land is rain-fed. In the water-constrained Andes, there is sufficient water to produce a diet of 3,000 kcal with 20 percent animal products. But changing precipitation patterns and growing demand for food are increasing the need for irrigation. Combined with urbanization, this is increasing pressures on rural landscapes and on water supplies.
- *Water is needed for energy generation:* Hydropower supplies 46 percent of the region's electricity, far above the 16 percent global average, but only 38 percent of the region's potential hydropower has been tapped. In addition, growing and producing bio fuels can require large amounts of water.
- *Energy is needed for food production:* This is the least well understood link, but food production, harvesting, transport, processing, packaging, and marketing all use up significant energy resources.
- *Energy is needed for access to water sources:* Energy is needed for desalination (which could become important mostly in the Caribbean), water distribution, and irrigation.
- *The LAC region is a net water exporter:* the water footprint (Hoekstra and Mekonnen, 2011) varies widely among countries and there are significant water exchanges within the region. For instance, Mexico is one of the major virtual water importers in the world (91 Gm^3/year; Konar *et al.,* 2011). According to Chapaign and Hoekstra (2004), the LAC regional water footprint is 1,136 m^3/person/yr. To give an idea of its variability, the country water footprints of the following countries are: Argentina (1,404 m^3/person/yr), Brazil (1,381 m^3/person/yr), Ecuador (1,218 m^3/person/yr), Peru (777 m^3/person/yr), Mexico (1,441 m^3/person/yr), Honduras (778 m^3/person/yr), Chile (803 m^3/person/yr), Colombia (812 m^3/person/yr) and Venezuela (883 m^3/person/yr).

Fig. 1. Freshwater Withdrawals in the United States (USGS 2005).



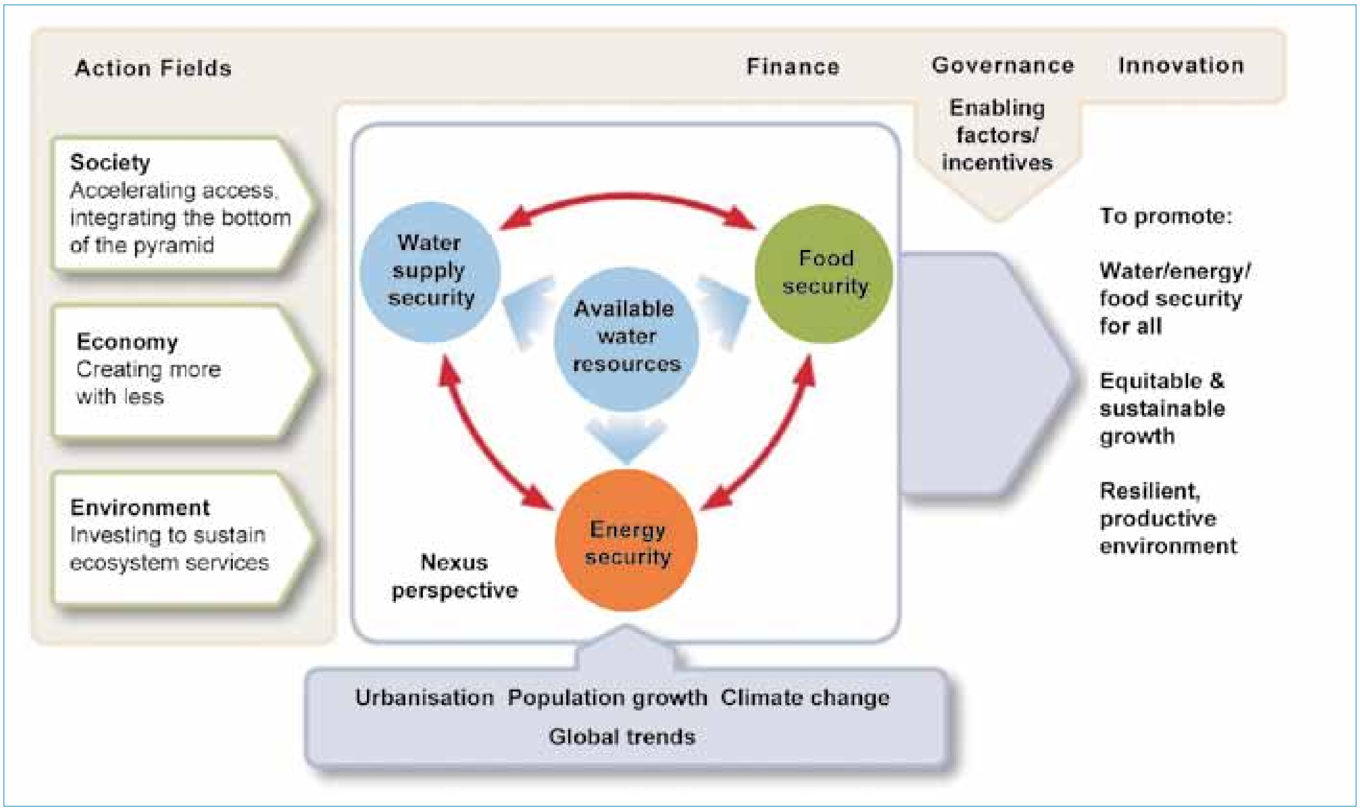
In the growing economies of the LAC region, the need to understand the interactions between water, energy and food is increasing, and in addition, planning and development challenges involve land use, urbanization, demographics, and environmental protection. These challenges and complexities can no longer be addressed in the conventional way, with each sector taking decisions independently, with separate regulations, and different goals. The complexity of the system requires a more systematic approach taking into account all the existing interactions and dependencies between sectors. As shown in Figure 2, although everything is interconnected, water plays a central role in the Nexus being in many cases irreplaceable. Therefore, a better understanding of the interactions of the Nexus is very important for smart climate and infrastructure investment planning to ensure a sustainable future.

Neglecting this interdependency has not yet had severe adverse effects, but it has already had some repercussions on the power sector. Power plants have had to shut down due to the unavailability of water for cooling purposes (low flows) or due to the high temperature of the water. Given the current and projected levels of growth of many countries in the LAC region, we can anticipate that these problems can materialize in the near future as well. The potential impacts on water pollution of unconventional sources of energy (e.g., shale gas and fracking) are still unknown and significant resources are now being explored in Argentina, Colombia and Mexico (Inglesby, *et. al.,* 2012).

PROPOSED RESEARCH APPROACH

The approach to the WEF Nexus normally depends on the perspective of the policy-maker (Harris, 2002). If a water perspective is adopted, then food and energy systems are users of the resource (see e.g., Hellegers and Zilberman, 2008); from a food perspective energy and water are inputs (see e.g., Mushtaq *et al.,* 2009; UN-DESA, 2011; Khan and Hanjra, 2009); from an energy perspective, water as well as bio resources (e.g., biomass in form of energy crops) are generally an input or resource requirement and food is generally the output. Food and water supply as well as wastewater treatment require significant amounts of energy. Of course, areas such as food-as-fuels (i.e., bio fuels) tend to blur these descriptions (see e.g., Nonhebel, 2005) due to additional impacts associated with land use, land use change and use of the available biomass resource. In any case, the perspective taken will affect the policy design. This is due to the specific priorities of the institution or ministry, as well as the data, knowledge and analytic breadth of the tools of the associated experts and support staff.

Fig. 2. The WEF Nexus Framework. Source: Stockholm Environment Institute, 2011.



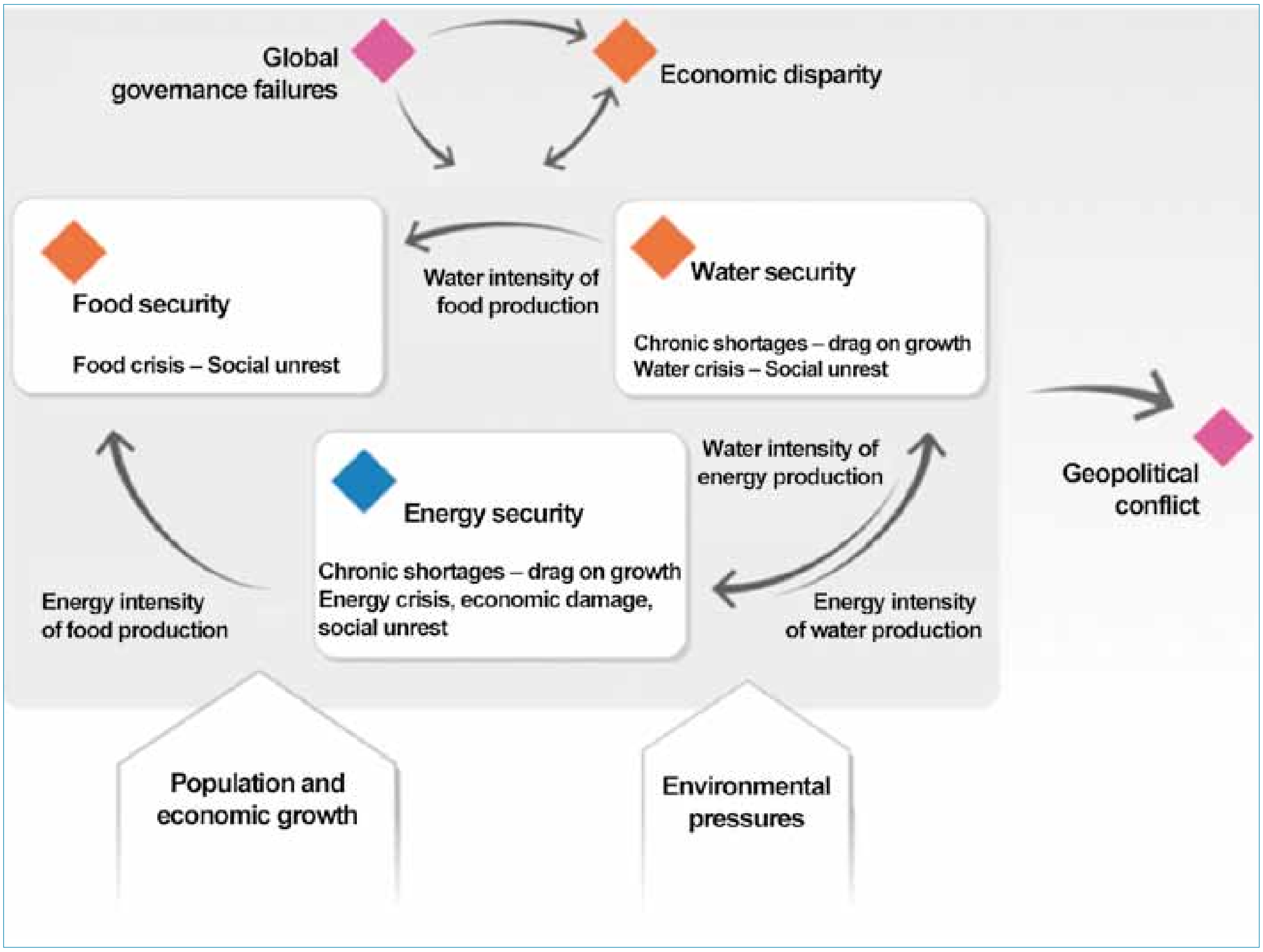


Fig. 3. Nexus schematic with a WEF security focus (Bazilian *et al.*, 2011, Energy Policy 39, 7896–7906).

Some of the descriptive elements of the WEF Nexus that are readily identifiable include:

- All three areas have many billions of people without access (quantity or quality or both).
- All have rapidly growing global demand.
- All have resource constraints.
- All are "global goods" and involve international trade and have global implications.
- All have different regional availability and variations in supply and demand.
- All have strong interdependencies with climate change and the environment.
- All have deep security issues as they are fundamental to the functioning of society.
- All operate in heavily regulated markets.
- All require the explicit identification and treatment of risks.

Figure 3 presents a schematic of the interactions with a focus on security. It is clear that each of the three "resource spheres" affects the other in substantive ways. Ignoring effects in one can have significant impacts on another. As Lee and Ellinas (2010) note, "The anticipated bottlenecks and constraints –in energy, water and other critical natural resources and infrastructure– are bringing new political and economic challenges, as well as new and hard-to- manage instabilities." Thus, the need for a systematic, coordinated planning approach is obvious.

There are very few people (and institutions) with expertise and experience in all three WEF Nexus areas; the IDB has research needs in all three WEF Nexus areas. This research initiative is the IDB's first attempt to approach this highly relevant, innovative and inter-sectorial issue.

It is worth noting that other multilateral development banks (World Bank, 2013; Asian Development Bank, 2013) have launched initiatives to finance WEF Nexus analytical work and applications.

RESEARCH OBJECTIVE AND QUESTIONS

The main objective of the IDB's research initiative on the WEF Nexus is to contribute to sustainable management and development of the water, energy and food production sectors by increasing awareness and capacity on integrated planning of Bank investments identifying and evaluating trade-offs and synergies. This is achieved by supporting client countries develop innovative approaches and evidence-based operational tools to assess the economic and social tradeoffs of constraints in water, energy and food security and their corresponding expansion plans, particularly as constrained by climate change. Designed tools may focus on upstream sector planning in order to identify primary opportunities and constraints to water, energy and food development, as well as evaluating opportunities to curb demand growth without compromising quality of service, thus indicating priorities for more detailed analysis as well as providing characterization of alternative sequences of investment in each sector. Economic tools can be employed to quantify the impact on sector investments and the economy as a whole of economic scarcity of water, energy and food as indicated by measures of their opportunity costs. This will also be an important step toward improved understanding of economic and social tradeoffs among competing uses (i.e., water for energy production versus food production, industrial and municipal uses, and environmental benefits of *in situ* water). The results of this research thus aim at helping stakeholders move in the direction of integrated Water-Energy-Food planning and of prioritization of investments.

This objective will be addressed through the following research questions:

— *What are the synergistic opportunities and constraints posed by the mutual interaction and interdependency of water, energy and food (WEF)?*

The proposed analytical tool development will focus on upstream sector planning in order to identify primary opportunities and constraints to water, energy and food security, as well as evaluating opportunities to curb demand growth without compromising quality of service, thus indicating priorities for more detailed analysis as well as providing characterization of alternative sequences of investment in each sector.

Fig. 4. Aerial view of the flood-ravaged areas near Cartagena, Colombia. © UN Photo/Evan Schneider.

— *What are the impacts of the WEF Nexus interactions on policy and decision-making, particularly with respect to development investments?*

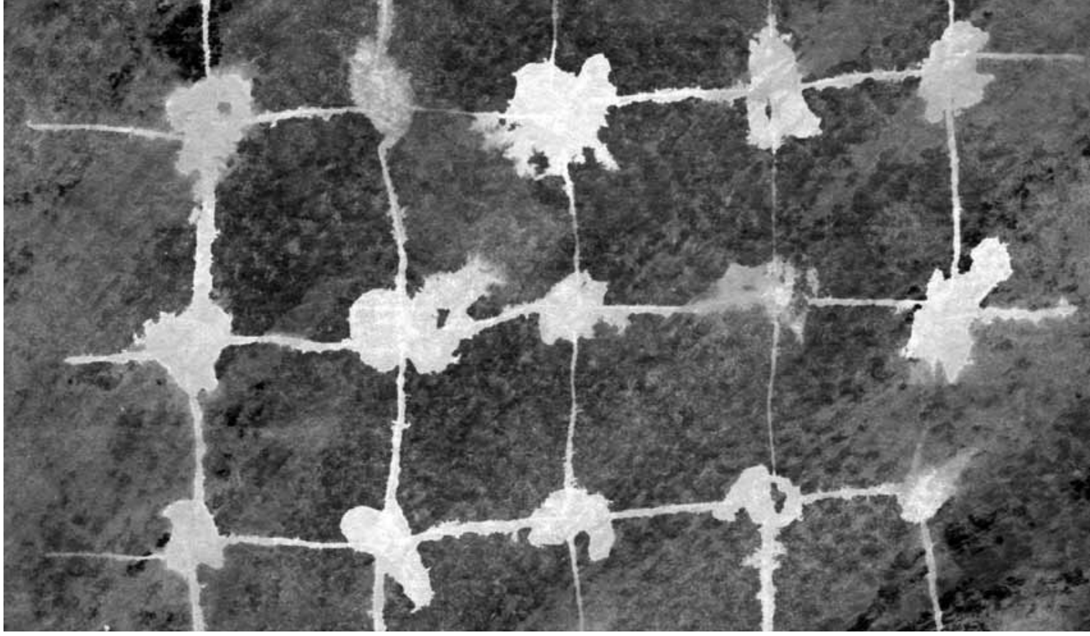
Economic analysis will be employed to quantify the impact on sector investments and the economy as a whole of economic scarcity of water, energy and food as indicated by measures of their opportunity costs. This will also be an important step toward improved understanding of economic and social tradeoffs among competing uses (i.e., water for energy production versus food production, industrial and municipal uses, and environmental benefits of *in situ* water). The results of this research thus aim at helping stakeholders move in the direction of integrated Water-Energy-Food planning and of prioritization of investments.

— *What are the threats and opportunities posed by climate change on the WEF Nexus in the LAC region?*

Although understanding of climate change impacts on the water, energy and food sectors has advanced significantly in recent years, little research has been done on the impacts of climate change on the interacting WEF Nexus. Potentially, impacts can be compounded or offset each other, posing threats and opportunities, respectively. The proposed research will use climate scenarios and projections to identify and quantify these impacts.

— *What are the institutional barriers for the utilization of WEF Nexus integrated planning tools?*

The water, energy and food sectors are planned today without much integration, e.g., water is allocated without considering energy constraints, energy generation is planned without much consideration of water sources and costs, and food production is planned without considering energy and water requirements for the most part. The case needs to be made that planning tools and institutional procedures in place need to evolve towards integrated planning approaches in order to realize synergies and manage threats identified through this research. To this end, we have identified 3 potential "test bed" applications in the region for implementation of WEF Nexus planning tools developed in the initial phase (1.5 to 2 years) of this research: Colombia (Corporación de la Cuenca del río Magdalena), Peru (Autoridad Nacional del Agua) and Brazil (Agencia Pernambucana de Agua e Clima).



LIMITATIONS IN EXISTING WEF NEXUS ANALYTICAL (MODELLING) TOOLS

A number of modelling platforms have been developed to support assessment of energy sector development under different economic and environmental policy conditions, and to support integrated resource development in the water sector. The water models include consideration of water utilization for hydroelectricity expansion versus other uses; and some energy models include calculations of water requirements for different technology investments. Typically, however, the models are designed for different purposes, and linkages between energy and water sector development are limited. Moreover, the level of technical detail and complexity in the models can preclude their application for upstream sector strategy development, a crucial analytical need in development planning. The converse is also true for the needs at river basin or sub-basin level, when models are too general and do not include the necessary level of detail.

A recent review of existing integrated resource assessment and modelling literature (Cambridge Econometrics, 2010) has shown that the analysis of individual systems (such as energy or water systems) are undertaken routinely, but are often focused only on a single resource or have often been applied on an aggregated scale for use at regional or global levels and, typically, over long time periods. Likewise, the analytical tools used to support decision-making are equally fragmented. Examples of existing tools used for energy system analysis include the MESSAGE, MARKAL and LEAP models. A commonly used model for water system planning is the Water Evaluation and Planning system (WEAP), and for water scarcity and food security planning, the Global Policy Dialogue Model (PODIUM) model is well established.

However, these and other models, in one way or another, lack the data and methodological components required to conduct an integrated policy assessment especially where these may be needed in a country/state/local policy context. Generally, they focus on one resource and ignore the interconnections with other resources; have overly simplified spatial representations; are grand policy "research" rather than short term applied "policy"/decision support models, or analyze inviable scenarios in the long term.

PROPOSED INTEGRATED MODELLING APPROACH

An integrated Energy-Water modelling system needs to address the shared needs of energy and water producers, resource managers, regulators, and decision makers at the federal, state and local levels. Ideally, the system should provide an interactive environment to explore trade-offs, explore potential synergies and evaluate alternatives among a broad list of energy/water options and objectives. In particular, the modelling system needs to be flexible in order to facilitate tailored analyses over different geographical regions and scales (e.g., national, state, county, watershed, interconnection regions).

Based on our research, there are three possible approaches for developing this system: (i) incorporate water resources and uses into existing energy modelling tools; (ii) incorporate energy production and uses into existing water resource modelling frameworks; or (iii) build a new integrated system. Building on existing modelling systems may have limitations. The test beds may prove that existing tools do not adequately address the Nexus and, as such, there may be a need to develop a new system. As such, the proposed research will analyze existing tools and their adequacy and, if needed, will explore the development of a new, more flexible Energy-Water modelling system that accounts for the wider contributions and opportunity costs of energy and water use, and allows for more integrated planning. Considering the long-term relevance of the Energy-Water Nexus, it may be deemed necessary to combine both strategies; providing an operational Water-Energy modelling tool in the short term (through harnessing existing models and capacity, implemented in the context of economy-wide water values and trade-offs), and building a more robust and flexible method over the longer term, with greater attention to cross sector linkages and impacts. An approach that can build on this existing capability should help decision- and policy-makers gain the support of stakeholders and provide an incentive for system ownership.

METHODOLOGY

The proposed analytical methodology will be based on an integrative modelling approach able to define potential synergies and constraints for the sustainable development of water, energy and food planning and investments. The outcome is intended to inform policy making at the national level.

The modelling approach will be based on system dynamics, which has been implemented in integrated assessment models (IAMs) such as those presented in references such as Hejazi *et al.* (2013) and Kyle *et al.* (2013).

This integrative modelling approach will be used to carry out the following methodological steps:

- Analyze and assess the water balances for each basin, quantifying the existing water allocation for energy generation and food production, and assess the existing models handling of basins/regions.
- Analyze the future demand for water, energy and food, and different scenarios for WEF supply based on

the existing country strategy and plans, as well as climate change scenarios (as locally available).

- Analyze the future demand for water per basin (including water for power and water for food production) by overlapping existing and future power plants/coal mining/ shale gas areas, irrigation and production of meat and other food products), focusing on those geographical areas where the energy generation and food production activities are located.
- Identify the basins where potential conflicts might arise in the future and quantify potential WEF deficits.
- Incorporate climate change impacts on water availability, energy demands, and food production outputs.
- Analyze opportunities to decrease these conflicts, by looking at different WEF management schemes and different technologies to reduce water and energy use (such as dry cooling, energy efficiency of waste

Fig. 5. A resident of the Tapajós National Forest toasted manioc. Tapajós National Forest, Brazil. © UN Photo/Eskinder Debebe.

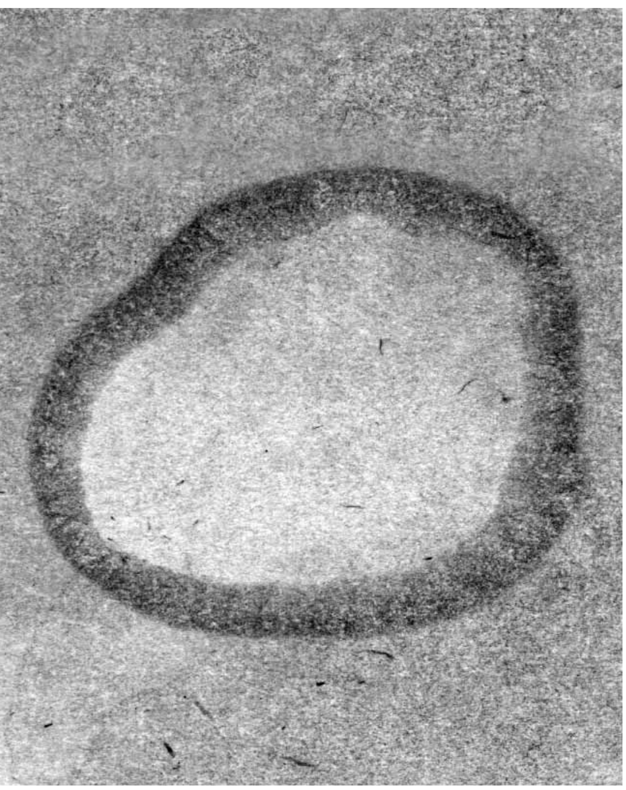
stream treatments), and looking at opportunities to curb both energy and water demand growth through demand-side actions.
- Quantification of costs and benefits (through partial or general equilibrium frameworks) of different solutions and synergies.
- Analyze the impacts of changes in WEF prices/tariffs to the water, energy and food demand and planning.

EXPECTED RESULTS

The results of the proposed research will support IDB country multi-sector dialog. In particular, this project will generate knowledge (in the form of analytical tools) that can be used for policy advice regarding the integrated planning (management of sources, production and distribution) of water, energy and food resources. The results of this project will also contribute to the identification of operations that can support public sector investments needed for the proper implementation of WEF Nexus policies in the region.

The proposed WEF Nexus modelling tools should be able to support the following capabilities:

- *Decision making:* A well formulated integrated modelling tool would help decision and policy makers assess their options in terms of their likely effects on the broad Energy-Water system. The toolkit should be able to transparently evaluate the trade-offs reflected in different options.
- *Policy assessments:* Given limited resources, it is important for policy makers to ensure that policies are as cost-effective as possible. If multiple objectives can be achieved by a single policy, it may advance development more than policies focused separately on single objectives. The toolkit should therefore provide a more complete, multi-system policy assessment.
- *Facilitating policy harmonization and integration:* There are instances of very contradictory policies, e.g., electricity subsidies that accelerate aquifer depletion –that in turn lead to greater electricity use and subsidy requirements. The toolkit should help harmonize potentially conflicting policies.
- *Technology assessments:* Some technology options can affect multiple resources, e.g., nuclear power could reduce GHG emissions, reduce the exposure to volatile fossil fuel markets, but may increase water withdrawals and use. As with other policies, the toolkit should allow a more inclusive assessment of technological options.
- *Scenario development:* Another goal is to identify consistent scenarios of possible socioeconomic development trajectories with the purpose of identifying future development opportunities as well as of understanding the implications of different policies. This is important for exploring possible alternative development scenarios and the kinds of technology improvements that might significantly change development trajectories.



KNOWLEDGE DISSEMINATION, ADVOCACY, AND CAPACITY BUILDING

As this initiative will involve a large number of stakeholders such as technical experts in countries responsible for the design and implementation of lending instruments, to sector planners, academia, high level policy decision makers, and private sector, a strategy to keep these audiences engaged throughout the process is imperative. Consultations with stakeholders, widely disseminating outputs and sharing knowledge, and developing messages and products to reach global audiences through appropriate communications platforms will all be crucial to support this initiative. There will also be a strong need to provide capacity building support of client countries, World Bank and other development partner staff on the application of the knowledge and tools implemented by this initiative.

The WEF Nexus highlights the interdependencies between different IDB units and the importance of integrated planning. Hence, it will be important to create an interdisciplinary mentality in the Bank and to foster cooperation and knowledge sharing between the different units and departments. This initiative will aim to adopt more creative and cost-efficient approaches to share knowledge among Bank task teams in all regions, as well as with external stakeholders in client countries and development partners. Audience-appropriate mechanisms will be used to share this information, such as: i) web-based social media tools; ii) interactive web-based tools; iii) learning events/workshops/meetings; and iv) cooperation with other global learning platforms.

Client ownership is crucial to ensure the success of the flagship. The team will work closely with the client governments and with the private sector in each country, engaging them from the onset. To ensure that the client governments will continue using the tools once the project is completed, the implementation will be done (i) using existing modelling and institutional structures and capacities (ii) in active collaboration with relevant government institutions in order to facilitate sustainable implementation and uptake in water and energy infrastructure planning. Moreover, the team will work only with countries where there is a clear interest demand from the government and the Bank's management in the energy sector and at the national level. In a second phase, the dissemination strategy will aim to broaden the platform of implementation of the modelling tool in other countries by encouraging exchanges between client countries within the context of a community of practice.

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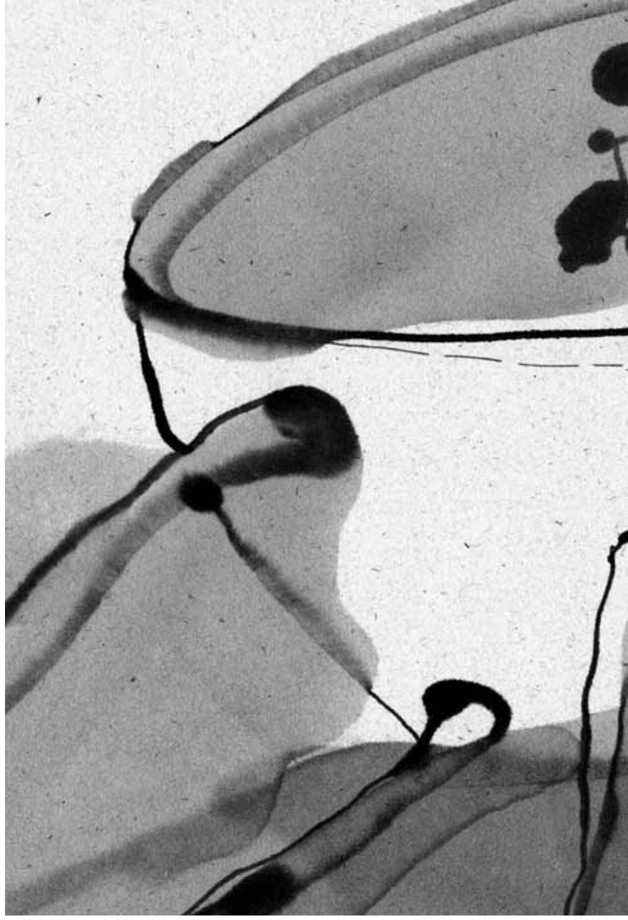

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THE ROLE OF WATER IN THE SPANISH ENERGY SYSTEM CONVERSION

MEDIUM-TERM PROSPECTS (2030)

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ABSTRACT

As in most European countries, Spain is undergoing a conversion in its energy system affecting almost whatever is relevant in this context: supply, demand, regulation, politics and economics. Such is not new. Moreover, as the panorama of the two main sectors comprising the world's energy business (electricity and fuel) have changed very significantly in Spain over the last decades, in coincidence with the democratic period and the economic modernization that the country has experienced. But the process of change is speedier due to diverse facts and with consequences difficult to predict. Regarding electricity, apart from the obvious changes of the last decade in power plant and other related equipment, as a result of its growth and adaptation to climate change conditions (decarbonization and arousal of renewable sources), the most important changes are taking place almost continuously at the regulatory level. As for the gas sector, almost irrelevant three decades ago, its development has been spectacular so far and although the current situation shows signs of uncertainty, it may be feasible for Spain to exploit in the near future fossil fuel unconventional reservoirs (shale gas and other varieties). As it is well known, apart from the foregoing opportunity, such entails risks not to be ignored.

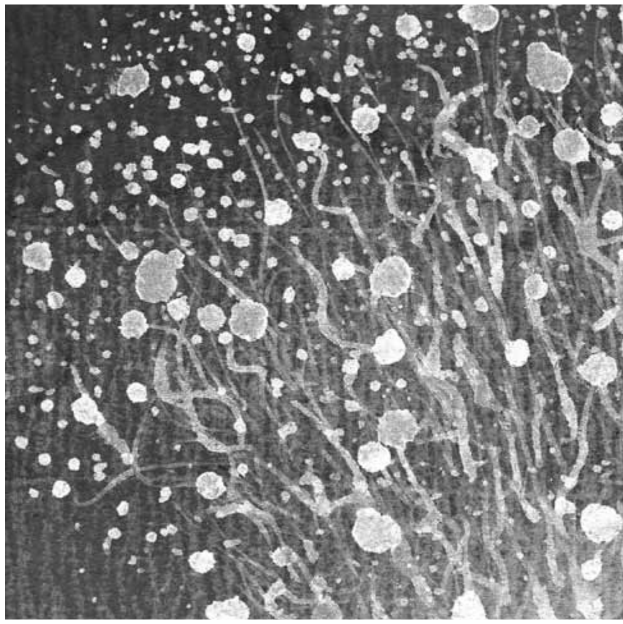
Matching apparently disparate topics in appearance, water is located in the core of this process of deep change of the energy system and complex evolution. Although it must be said, that more attention should be addressed to this role. This paper synthesizes facts and insights which, in the author's opinion, stakeholders should bear in mind while thinking out the important role which water as a resource plays in the transformation of the energy sector and the opportunities that this implies.

"There is a need to change course in a dramatic way. Gradual change will not be enough to change the track we are following."

Dr. Fatih Birol
Chief Economist
Director of Global Energy Economics
International Energy Agency

Spain is a medium sized country on the global scope and, regarding energy, shares with much of its partners in the European Union an issue which impacts largely its policy in this field: its heavy reliance on fossil fuels, especially oil. Oil and natural gas are the fuels that dominate the primary energy balance (65%) and to a very large extent must be imported. Only recently, the development of renewable energy, despite its bad planning and chaotic regulatory framework, has been capable to provide some degree of self-sufficiency (12%) to the national energy demand. The importance of energy issues has overridden the scope of its technical and economical aspects, coming to stand with notoriety within the political discussion.

Addressing energy policy comprises market, regulation, domestic issues, international relations, prosperity and conflict. The deeds that pave the way of energy are so many, diverse and of such gravitas that can hardly be accounted, let alone understood or presented with a feasible line of thought, in such a short article. And in such vast context, which is water's role? In order to answer this question about the supposedly candid Water-Energy Nexus, a brief overview of Spain's energy system should be presented. Together with this, the drivers on its futures trends on the scope of this article; short –term horizons (2020) and medium term (2030) will be below presented.



THE SPANISH ENERGY SYSTEM: KEY FEATURES

The total primary energy demand in Spain currently stands at around 33,000 ktoe/year, with a medium self-sufficiency level of 26% for all sources. The latter value varies considerably, ranging from 100% which holds hydraulic, renewable and nuclear energy, to coal's 16%, oil's 0.3% and 0.1% gas. The latter fuel is most dependent from abroad, although its supply chain may be considered safe and balanced.

From the perspective relevant to this article, which is none other than the Water-Energy Nexus, the two major Spanish energy system pillars are the electricity and gas sectors, the former biased to the end, and partly the latter. The tables below feature the most important data which define the current state and trends of both sectors in the last years from an aggregate point of view (Charts 1 and 2).

Some observations that can be inferred from the above data:

- The growth of electricity production over the last 10 years has been very low (+10% in total), result of a recessive domestic demand since the year 2008. Indeed, the demand figures of 2013 are similar to 2005, which implies stagnation due to the general economic crisis, possibly aggravated by the increase in prices of electricity supply. It is worth recalling that final consumer prices almost doubled in the 2003-2012 period.
- However, the growth in installed capacity has been extraordinarily high (+67%, 41,000 MW), which is representative of a very unbalanced and abnormal development of the electricity sector.

Chart 1

a) Electrical generation

	Year 2013	Year 2003	Δ 2003-2013
Installed power capacity	102,281 MW	61,223 MW	+67%
Installed Hydro- power capacity	19,822 MW	18,153 MW	+9%
WTG+PV+TS Installed capacity	29,484 MW	5,638 MW	+423%
NGCC Installed capacity	25,353 MW	4,394 MW	+476%
Net Total Generation	260,160 GWh	235,684 GWh	+10%
Hydro- power Generation	41,300 GWh	43,706 GWh	-5%
WTG+PV+TS Generation	66,462 GWh	12,815 GWh	+419%
NGCC Generation	25,409 GWh	14,990 GWh	+70%

Data corresponding to Spain's inland system.

Legend: WTG, Wind Turbine Generator; PV, Photovoltaic; TS, Thermo-Solar; NGCC, Natural Gas Combined Cycle.

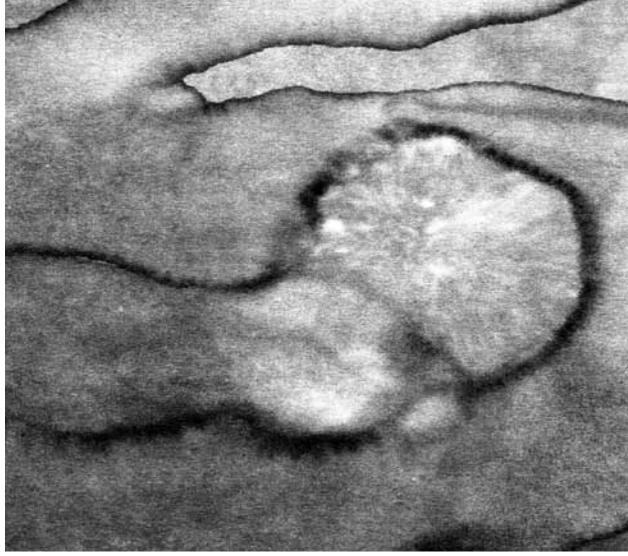
Chart 2

(b) Gas sector

	Year 2013	Year 2005	Δ 2005-2013
Natural Gas Demand	28.5 bcm	32.1 bcm	-11,3%
Gas distribution & supply Network	81,188 km	55,230 km	+47%
End user	7,470,000	6,040,000	+23,7%
Home Production	0.03 bcm	0.3 bcm	-90%

Fig. 1. The large installed capacity of currently inactive Natural Gas Combined-Cycle Plants (NGCC) is one of the most immediate drawbacks for the development of new hydroelectric projects in Spain.

- The most significant event of the decade 2003-2013 in terms of power and energy is undoubtedly the extraordinary growth of RES (Renewable Energy Sources).
- NGCC generation type assets are currently much underused (utilization factor ≈ 1,000 hours/year 2013). This is certainly relevant given the interdependence of the electric and gas sectors (about 20% of the current demand for natural gas comes from NGCC, which does not include the quota corresponding to cogeneration).
- There is a sound overcapacity in Spain's electrical system. The peak hourly demand in recent years peaked 44,800 MWh (December, 2007), while gross installed capacity is 2.3 times that value. The firm power, however, is smaller and its coverage factor reads 1.6 (still quite high).
- The gas consumption of the conventional market (consisting of industry and house and commercial sector) is currently stable, but NGCC power plants have lowered their consumption. During the last year, the domestic demand for gas has been 333,400 GWh (28.7 bcm) industry remaining the main consumer, with 64% of the total, followed by the domestic - commercial sector and NGCC power generation, with 17% in both cases.
- The evolution of the past years has enhanced the importance of the industrial sector as recipient of the gas supply in the Spanish market. In brief, the domestic and commercial sector represents 17% of the demand for natural gas, industry adds up to 64%, electricity generation holds 17% and non-energy use 2%.
- In terms of security in 2013, Spain has been supplied with nat-



ural gas from 11 different countries, among which the main supplier is Algeria, with 51% of total supply, France (12%), Nigeria (10%) Gulf countries (11.6%), Trinidad and Tobago (6%), Peru (4.5%) and Norway (3.6%).

– The domestic production of gas is irrelevant in terms (0.1% of supply). Industrial exploitation of unconventional hydrocarbons (shale gas and others) deposits has not yet begun in Spain. A first assessment of technically exploitable reserves amounts to of 2,000 bcm, which corresponds approximately to 65 years' current gas consumption. These figures should be taken with caution in any case.

FACTORS WHICH DEFINE THE ENERGY SYSTEM'S TRANSITION IN SPAIN

The energy sector, especially electricity and gas have experienced in recent years major changes in their business structure, physical plant and regulatory model. The starting point in each case corresponds to the need to adapt both sectors to the regulations that the European Union has developed for a so-called "EU internal energy market". This priority is the result of a previous process which began in the 90s, the "liberalization" of certain activities in both the fields of electricity and in natural gas sectors. It is worth recalling that, the economic integration of Spain in Europe stepped up in regulatory terms as from year 1992 (Maastricht Treaty which redefined the European Community into the European Union), while considerable political impetus was given to the member countries' objective of economic and monetary harmonization. While this has not delivered a common European Energy policy, the 1995 White Paper and following Directives concerning common rules for the electricity (1996) and hydrocarbon markets (1998) were milestones which pointed out the will of legislators towards a change of model based on the principles of open competition for certain activities (liberalization) and the promotion of sustainable energy (renewable energy policy). In Spain, this led to the 54/1997 Electricity Sector Act and 34/1998 Hydrocarbons Sector Act, the both of which landmark separating stages in the history of our energy policy along the last three and a half decades. Structural reform of the electricity and gas markets, along with the emergence of renewable energy (and its effects on the electric and gas systems, are undoubtedly the most remarkable facts of the immediate past which influence the current setting).

Currently, these two sectors are subject to structural changes rather than minor regulatory adjustments. This is due, in part, to internal reasons (supply-demand imbalances and high system costs covered in the electricity sector; infrastructure overcapacity and still uncertain development prospects on unconventional gas reservoirs). But the changes also respond to other global or specifically European external circumstances such as policies promoting progressive decarbonization in power generation and the impact of information technologies on energy grids. These issues entangle into a complex web of incentives, causes and effects that feedback each other with not always predictable effects on businesses, consumers and governments. That is why experts speak of a "new energy paradigm" that would affect not only the technical aspect of energy activities leading them towards a cleaner sustainable, but structurally different model. The traditional model of utility, settled for decades, is doomed to an identity crisis which may question its *raison d'être* as a result of the entry of alternative business models, not only on generation (distributed generation), but also in the activities of networks and even consumption. New concepts like the prosumer (producer-consumer or proactive consumer), manageable demand, and smart grid will impact the future trends in the electricity sector.

As for the gas sector, the most influencing factor in its future is the potential development or exploitation of so-called unconventional gas reservoirs, shale gas deposits and other forms of hydrocarbons that can be found in gas state or even liquid. Regarding the latter, Spain is yet to have a reliable known volume of its reserves and their known location. This knowledge affects deeply to predict the impact of this potential energy water use on each basin's water resources. Difficulties brought up by regional Governments and municipalities to prospecting have delayed this assessment compared to other neighbouring countries. Therefore, until the surveys are not properly conducted, any figures will be premature and provisional, subject to uncertainty and bias, which makes them useless for planning. This does not mean, however, that such facts and factors should not be considered as sooner or later be taken into account.

SHORT AND MEDIUM-TERM PROSPECTS FOR HYDROPOWER

The share of hydropower in the Spanish electrical system remains stable throughout the last years (almost flat evolution of installed capacity) and is quantitatively decreasing its importance in relation to other sources, especially Renewable Energy Sources, RES (wind, photovoltaic and solar thermal, specifically), also referred as clean energy. At the end of year 2013, Spain's hydropower installed capacity in the mainland was 19,822 MW (counting all types of facilities) which represents approximately 19% of the electricity system as a whole, whereas the same indicator in year 1975 read over 47%. In the last four decades hydropower has suffered a relative reduction in its share of around 30 percentage points. In terms of energy output, which can vary widely from one year to another due to rainfall, the mean result evolution has been quite similar.

The reasons for the above fact are many and can not be simplified in the hackneyed argument of the exhaustion of profitable hydraulic potential. It is true that the most profitable hydropower uses in most basins and hydraulic systems have already been incorporated into the hydro assets. But the total profitable producible that could be developed in Spain's mainland is estimated[1] at around 70,000 GWh/year, from which now is in operation an equivalent capacity of 35,000 GWh/year. Therefore there is still a significant remaining potential, if given timely conditions and interest in developing it.

In all EU, hydropower heads renewable energy sources and technologies. Its contribution towards total electricity generation is around 16% on average and is considered that so far, EU has only developed 45% of its technical, environmental and economically feasible potential. But, due to its maturity and other circumstances, authorities', investors' and technology community's interest in hydropower has faded away in favour of other alternatives. The interest in hydropower as an energy storage system has most recently rekindled due to the problem of integration of irregular sources such as wind primarily and solar. Hydropower generation in Europe is currently around 340,000 GWh/year, with an average annual growth of 1%. Our country currently ranks fourth hydroelectric installed capacity after Norway, France and Italy, and ninth in energy output.

The outlook for hydroelectric generation differs in each country, depending essentially on its potential for developing EU-28 features a remaining 380,000 GWh, which is a very significant figure. Hydropower has evolved from being the dominant source in the 70s to form a minority energy source but is unanimously considered to be the highest quality energy source to the electrical system (efficiency, flexibility, cleanliness and low variable cost). Despite this, its relative share has declined in recent decades in relation to the production of thermal energy units (conventional and nuclear) in most countries except Norway, which heads installed capacity and production (non- EU). According to Eurelectric,[2] its outlook for the short term (2020) is a moderate increase in installed capacity (+7%) and somewhat less than half in terms of energy output (+3%). In any case, it is estimated that in most countries, without exception, hydropower should be maintained as part of a balanced and flexible mix. In fact, hydropower installations remain the backbone of power plant grids. The share rate ranges across countries from 15 to 25% in installed capacity and is somewhat lower in energy output (13%-20%), a variable depending on the specifics of the country's hydrology, varying from year to year. Globally, the country in which is expected upcoming further growth in hydropower throughout the next years, is Turkey (non EU at the moment).

In Spain, the possibilities for developing new hydropower projects or refurbishing old ones is limited according to experts due to the reasons set forth below. First it should be noted that, according to Spain's electricity system regulations and legal framework, new projects development falls exclusively on business. The decision to invest in hydropower new developments solely relies on the business strategy of each company. In that sense, the prospects for development or improvement are conditioned primarily by two factors: (1) the evolution of electricity demand and system's installed capacity to match it, on the date envisaged above horizon (year 2030); and (2) the relative merit of any new hydroelectric development in comparison with any other generation technologies that may be considered to fulfil such demand.

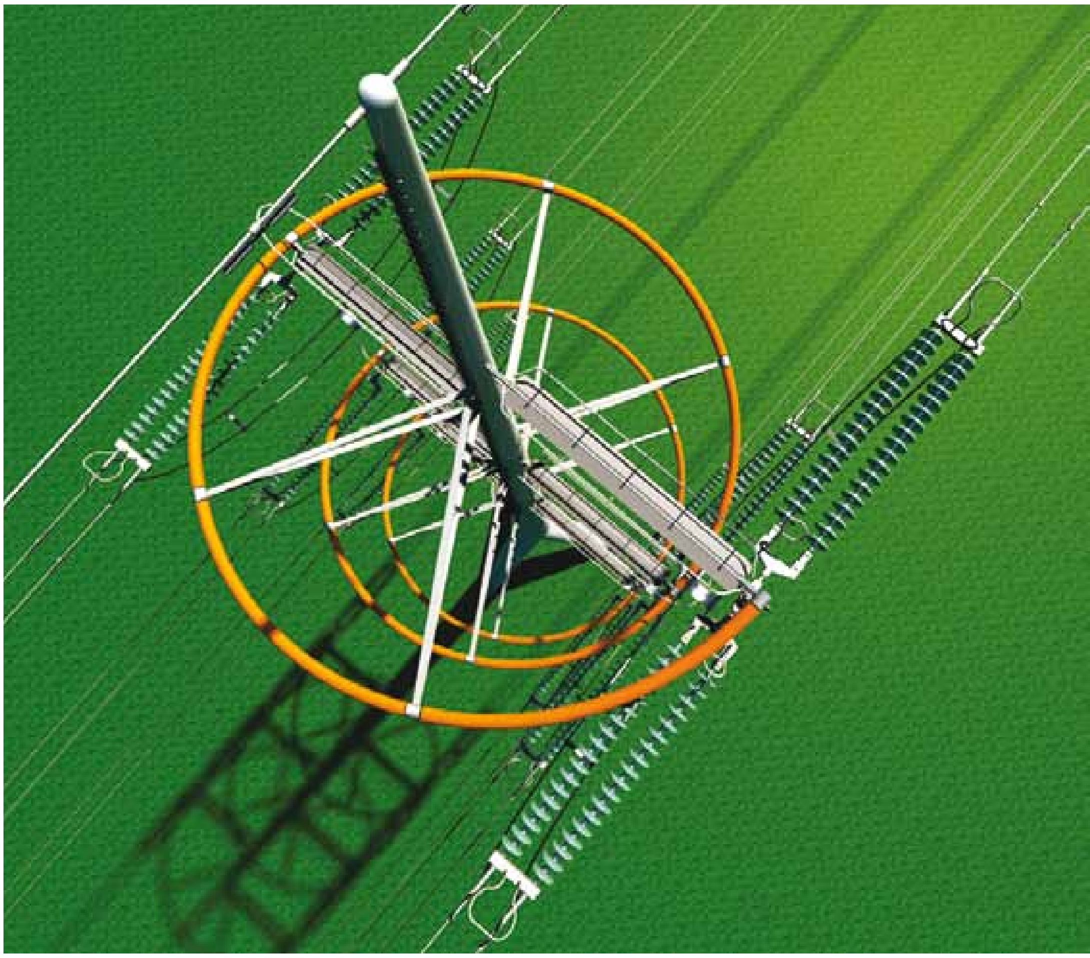


Fig. 2. Electricity grids (transmission and distribution) and especially smart grid technology play a crucial role in the evolution of the electrical system.

Leaving aside demand evolution which depends essentially on the economic cycle and focusing on the preference which investors may have on hydropower in contrast to other facilities and generation technologies (especially those that can be considered equivalent in polluting emissions), the following aspects must be taken into account in comparative terms:

- CAPEX (investment, including the cost of capital).
- Delivery and predictability (from the investment decision until the entry into operation of the facility).
- OPEX (operating and maintenance costs).
- Other variable costs (fuel, emission allowances etc.).
- Taxation.

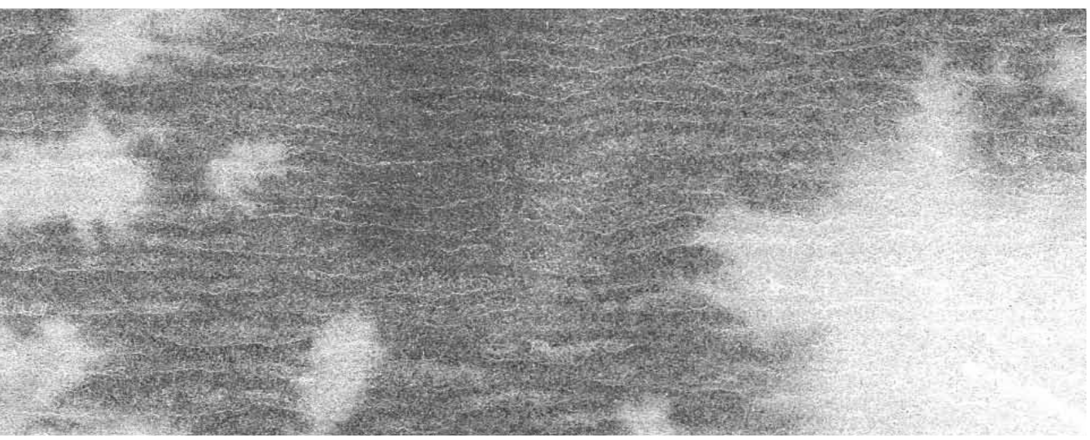
Regarding new developments, hydropower projects, in general are not usually the most competitive in the first two criteria, possibly being the most significant to investors its tax burden. Even in cases where it could be competitive (compared to PV, for example), the bulky hydro tax user fee (Article 122a Spanish Water Act), now hinders any installation's profitability with output > 50 MW. Therefore, taking into account the current regulatory framework and market situation, the likelihood of firms developing new hydropower projects appears limited.

The above drawbacks are considerably mitigated in case of the upgrading, improvement or refurbishing developments currently operative if such are possible. In such cases, the limiting factors for investment in hydropower capacity become significantly moderated and this, together with its highly positive values of this type of generation in other respects, convert such projects in a potentially attractive option for investors, usually companies who already hold hydropower assets. The actions undertaken in Spain in recent years (Belesar, San Pedro, San Esteban, La Muela) and others that planned or pending approval, are examples to this.

Special mention deserves SHP - Small hydropower (≤ 50 MW) and micro Hydropower SHP (≤ 10 MW). Such plants are user's fee (22% of energy sales income), hold the difficulty of finding new profitable sites to be developed within an acceptable timeframe SHP suffers environmentalist opposition, which places them at a disadvantage compared to other renewable energy sources, particularly wind and PV, subject to a now extinct incentives scheme. In fact, over the last 10 years only SHP's 600 MW have been installed in Spain, all of which were assigned to micro hydro power, whereas wind generation has increased in 18,000 MW and PV in 4,000 MW. Such figures concur with the former statement.

Finally, the problems and prospects of hydraulic energy storage, i.e. its role, and even probably in the future, the role of reversible hydropower stations equipped with pumping units/turbines, and their ability to store energy reserves as potential energy into the electrical system, are to be assessed. The baseline situation in Spain is sufficiently known: existing RHS are owned by power generators and serve essentially two functions: valley peak/price arbitration by temporary energy shifting, and on the other, contributing to the energy demand according to electricity grid operator designs. Both functions are developed together with some other technologies, among which are hydropower and NGCC.

Fig. 3. Water-Energy Nexus features high impact aspects, as metaphorically shown in this picture.



WATER'S ROLE IN THE EXPLOITATION OF UNCONVENTIONAL HYDROCARBONS RESERVOIRS

Water plays several important roles in the field of energy, all of which help strengthening the link between both. Regarding water uses as energy resource, the most notable is undoubtedly associated with hydropower, may it be through electricity generation or its storage as energy potential production of electrical, both of which have been mentioned earlier. In addition to these, several other functions are to be considered. These following functions are currently or may become significant in the medium term on the industrial sector: (1) the use of water as coolant in the thermodynamic cycles of thermal and nuclear power plants, which in Spain comprise an installed capacity of 55,234 MW, or 54% of generation, and an annual output of 162,220 GWh 66% of the whole country;[3] and (2) the use of water resources in the processes related to the exploitation of unconventional oil reservoirs (shale gas and others). The latter may occur when the exploitation of existing reserves begins in Spain, likely in the short term, if our country follows path what is happening elsewhere.

Of the two subjects identified, the first is an ongoing reality and although it is a rather limited consumptive use of water, the truth is that the demands associated with the cooling of thermal power plants hold whole others aspects not to be ignored. Two issues in this regard are, on one hand, improved efficiency in the industrial use of water, which affects the modernization of refrigeration and effluent treatment and secondly, the effect of disturbances or irregularities that may cause climate change on the hydrology of the country and therefore on ensuring availability of water volumes needed in thermal generation. It is in any case, a well-established energy use of water on which major changes are not expected in the time horizon covering this article. Contrary to this, the exploitation of shale gas and other unconventional oil reservoirs operations requiring or fracking processes are still nonexistent, although reasonably likely, prospects for such activity will start soon. At the moment, any forecasts may only rely on expert's estimations, and through them, the water demand for such processes is to be defined together with the treatments necessary due before reintegrating such water to the environment. The issue of fracking processes is certainly controversial, but nevertheless should not be overlooked as sooner or later, the latter will be taken into consideration by the water authority and its use regulated and planned accordingly.

Within the hydrocarbons sector (oil and gas), a global growth on water management services and related technologies is expected, according to market analysts at an annual rate of 6%.[4] This fact highlights the increasing economic interest for energy uses of water in the sectors considered, probably due to the sound development of the shale gas industry and other varieties of gaseous and liquid hydrocarbons located in unconventional gas reservoirs, susceptible of profitable operation. Water industrial and energy uses globally add up to, according to industry expert estimations an annual economic revenue around 85,000 million USD. Water shortage has moved up in the world's leaders declared priorities, as presented in World Economic Forum's Davos meetings. Thus, during the last three years (2012-2014) water problems have occupied one of the top three concerns of the world leaders. Economic activities directly related to water (not only with their energy uses) accounts for a global market of 550,000 USD million a year, with a steady growth rate of 3.5%, over the past years. This gives an idea of the importance of the value chain organized around the water resource.

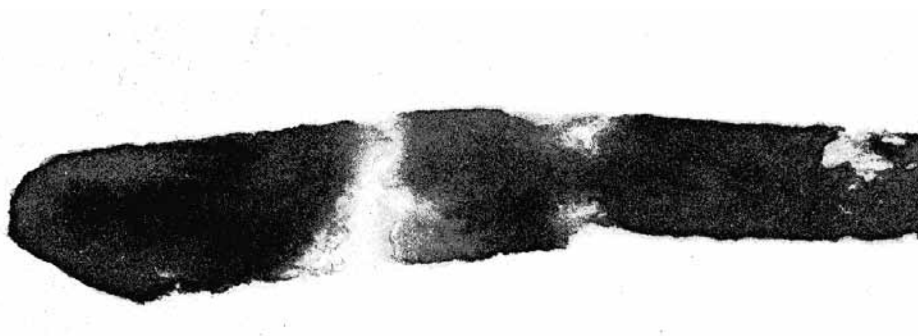
Global water shortages (60% of fresh water is concentrated within six countries) are magnified as a result of regulatory and technical inefficiency in water management in several countries. But also, and this affects new energy uses, the detraction of significant volumes to the hydrological cycle seems inevitable if US's model of exploitation of unconventional oil reservoirs becomes the standard all around the globe. Consider Russia or China, where reserves are potentially more important than those currently exploited in North America and which are usually located in arid areas. If International Energy Agency's[5] estimates are correct, the volume of US's shale gas deposits are just under 10% of the reserves estimated in the 10 countries with the highest abundance of the resource. In the case of oil (do not forget that there are also non-conventional liquid hydrocarbons) reserves in the U.S. comprises about 15% of the top ten countries with most reserves.

Spain does not have a reliable estimate of the volume of these reserves and its exact location. Such data has a critical impact on water's demands for such activity and how this demand may affect water resources in their respective basins. Difficulties brought up by regional Governments and municipalities to prospecting have delayed this assessment compared to other neighbouring countries. Therefore, until the surveys are not properly conducted, any figures will be premature and provisional, subject to uncertainty and bias, which makes them useless for planning. This does not mean however that such facts and factors should not be considered, as sooner or later be taken into account.

Act 17/2013, regarding the supply security and competition increase for Spain's electrical system, solved the regulatory loophole that Act 34/1998, regarding hydrocarbon's sectors, could not. Because of this, last year regional regulations from Cantabria, Rioja, and Navarra prohibiting the prospecting and exploitation of any shale gas or other hydrocarbons unconventional reservoirs located in their respective territories. Act 17/2013 makes exclusive to the national government, any regulation regarding prospecting and exploitation, concurrent to the constitutional's state competence of Spanish Act. Act 17/2013 states that, notwithstanding subsequent regulatory developments, European law provides the appropriate legal framework for environmental protection in relation to such aspect, and both regional and local governments are hindered its capacity to regulate this matter. Act 21/2013 on environmental assessment includes these projects as required to undergo standard environmental assessment.

Apart from the regulatory issue, it is interesting to know in light of the information currently available what can be expected of shale gas in regards to water and the influence which their exploitation may affect water policy, water basin planning and water resource management. Let us note the fact that the most attractive reserves seem to be located in the regions of Cantabria, Basque Country and Castilla y León and affect the corresponding basins of rivers Ebro and Duero. Prospects are currently being carried out in the provinces of Burgos (137,000 ha.), Alava (140,000 ha.), Cantabria and some others, in contrast with Europe's reserves are estimated in 25,000 Bcm (Billion cubic metres), Spain's exploitable shale gas reserves, according to ACIEP,[6] add up to 2,000 Bcm. 70% of such figure would be located in the Southern side of the Cantabrical mountain range and Western Pyrenees. Regarding this, a new assessment on shale gas deposits location and volume has been presented by the Spanish Mining Engineers' Council.[7] The volume of water required per well and fracking site varies in a very wide range (10,000 - 20,000 m^3) if the data obtained from the U.S. sites may be extrapolated to the European sites. This demand should be borne in mind in the future evolution of the Water-Energy Nexus in the coming years.

SUMMARY AND CONCLUSIONS



Water plays several important roles in the field of energy, all of which help strengthening the link between both. Regarding water uses as energy resource, the most notable is undoubtedly associated with hydropower, may it be through electricity generation or its storage as energy potential production of electrical, both of which have been mentioned earlier. But in addition to these, several other functions are to be considered which are related to world most important energy sectors, electricity and hydrocarbons. From an industrial perspective, a relevant function is the use of water as coolant in the thermodynamic cycles of thermal and nuclear power plants, main share of the systems' energy output. In a near future, the use of water resources in the processes related to the exploitation of unconventional oil reservoirs (shale gas and others) is to be considered in future water demand management. On these grounds, the energy perspective on water is crucial for the good running of Spain's energy system and extensively, to Spain's welfare.

From a water policy perspective and its relative action by public authorities, water uses in the fields of energy require similar care to that provided to supply the population (full cycle) and to the coverage of agricultural and environmental needs. However, unlike the above uses, this uses face a much less favourable support or even opposition to the exploitation of water resources for energy production. Being the cleanest source within the different power production technologies throughout an overall assessment, hydropower has increasingly become a target for the most warring fronts of environmental activism. Without attempting here the delegitimization of such attitudes, in this issue environmentalism mistakes its conservationist reserves. Such is a complex problem, with underlying prejudices of the current society, in contrast with his benevolence towards other renewable energy sources and technologies, which in an overall assessment are much less impact-free than normally considered. Public authorities and regulators should ensure the balance of the potential drawbacks of the use of water with its advantages, not just in the short term but in the medium term, and focus on a concept of value creation may seem less obvious today than before, they deliver a sound potential of social welfare.

It may be appropriate to recall here some wise words of that brilliant humanist and hydraulic engineer who was Juan Benet. In a lecture at the Spanish Centre for Hydrographical Studies in 1981, he declared: "… (regarding the water sector) today's luxury was yesterday's wit and will be tomorrows' ordinary". It is precisely the awareness of society on the value of water, which should help to recover the particular spirit and way of working in this area, not only banishing vulgarity but inaction as an ideological reference on hydraulic thought.

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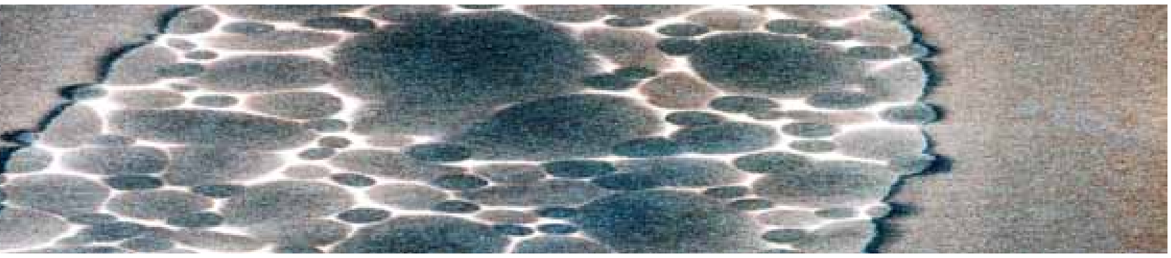
ISSUES IN THE USE OF WATER

FOR ELECTRIC ENERGY GENERATION AND STORAGE

Frank Hamill and Angelos Findikakis



KEYWORDS:
WATER STORAGE
ENERGY STORAGE
ENERGY STABILITY
COOLING SYSTEMS

The two major uses of water for energy production are for hydropower generation and the cooling of thermal power stations. Major challenges in both these uses are their potential ecological and other environmental and socioeconomic impacts. In areas of limited water resources and increasing competition for their use driven by population and economic growth the consumptive use of water is a major concern. Technology is called on to contribute to solutions that would minimize these impacts while optimizing the efficiency of energy production. Two major trends in the last few decades are the increasing use of water as a means of indirect energy storage through the construction of pumped storage hydro projects, and the reduction of water used for cooling per unit energy produced.

CONVENTIONAL HYDROELECTRIC POWER

Conventional hydropower development in the United States has been limited in recent years to relatively small and run-of-river schemes due to the fact that most of the best suited large hydro sites are already developed. Moreover, there is often environmental opposition to new large reservoirs that makes the development process a long and arduous one. Nevertheless, water storage in the western United States continues to be of considerable interest, particularly in view of the present severe drought. Should California elect to construct new storage reservoirs, there will be significant opportunities for both conventional and pumped storage hydro in conjunction with them.

Other hydro development in the United States has mainly centered on upgrading existing generating units and adding hydro generation to dams that have no power plants. Recent developments in the design of hydraulic turbines have made it possible to increase efficiency and reliability while reducing operating costs and extending useful operating lives.

Fig. 1. Red Rock Dam. Pella, Iowa.

Although conventional storage hydropower is capable of following load, supplying spinning reserve, and assisting with frequency control and power factor correction, it cannot assist with taking surplus renewable energy (mainly wind) that occurs in many grid systems in off-peak hours. Only pumped storage hydro can accomplish that to avoid curtailment ([1], [2]).

PUMPED STORAGE HYDRO

Utilities define a generating resource as “dispatchable” if it is available to meet load at any time. Resources which are limited by conditions such as streamflow, wind velocity and solar radiation are considered non-dispatchable. Thus, thermal based generation and storage hydro are considered dispatchable, while run-of-river hydro, wind and solar generation are not.

The typical load profile of the electrical grid in developed countries, which includes both industrial and domestic loads, displays strong diurnal variations. Large peak loads tend to occur during the day, while late night loads tend to be much smaller. These conditions are described as a base load, that is expected to exist 24 hours per day, and a peak load superimposed on it, that occurs for only a few hours per day. For reasons of economy and efficiency, generating resources are usually dispatched in the order of increasing cost of production. The lowest cost resources are first in line and tend to be assigned to the base load, and the highest cost resources are the last to be dispatched and cover the peaks. Non dispatchable resources are utilized when they are available and economical.

Certain types of generating resources are efficient only at full load output. These include both large nuclear generating units and large-scale fossil fueled thermal units. These types of resources fit base load conditions best, and are usually thus dispatched. Moreover, these large thermal resources are not capable of accommodating rapid load changes due to the thermal conditions of steam generators and turbines.

By contrast, hydro units are inherently capable of accommodating quite rapid load changes with only very modest efficiency penalties. Normally, such load changes are constrained only by environmental regulations and other non-hydropower uses of the water. Thus, hydro units are very flexible from a dispatch viewpoint [2].

Pumped storage hydro has been developed as a practical grid-scale energy storage technology [3] by pumping water from a lower reservoir to a higher one during the off-peak hours and allowing it to flow back down from the upper to the lower reservoir passing through

Fig. 2. USACE Kinzua Dam downriver. @ Margaret Luzier.

turbines to generate electricity during peak load hours. In this case, the stored water in the upper reservoir represents stored energy [4].

When used in conjunction with conventional thermal power stations, the benefit of using pumped storage is derived from the price differential, between off-peak and on-peak energy. When that price differential is large enough, it becomes possible to use pumped storage hydropower facilities to store off-peak energy for use in on-peak hours. This results in a sort of energy arbitrage, which can be cost effective and beneficial to the electricity consumer [5] and permits large base load resources, such as nuclear and large fossil plants to operate at their optimum loads at all times of the day. Used in conjunction with renewable forms of energy such as wind, solar, or tidal generation, pumped storage offers a means to store energy produced in off-peak times that could not have been used otherwise.

Pumped storage technology has evolved significantly since the first application of the concept in the 1890s and the introduction of reversible pump turbines and the use of a single machine as both motor and generator in the 1930s. Today's technology is largely based on the use of reversible pump-turbines directly connected to generator-motors [6]. Modern pumped storage units are capable of operating at an efficiency of between 75 and 80 percent over the pumping and generating cycle. The development of variable speed units which can operate at peak efficiency over a larger load range than fixed speed units has made it practical and efficient to deal with intermittent power sources, such as wind and solar. The increasing addition of new units of such forms of renewable energy production creates the problem of balancing the grid, to which pumped storage offers a solution.

In much of the United States (e.g. California), thermal generating resources have been moved away from regulated investor-owned electric utilities and into the hands of independent generating entities who sell their output to the utilities (or state agencies) in an auction context. The intent of this approach is to minimize the cost of energy to the consumer through open competition [7].

Independent solar and wind generators have entered this market in large numbers in recent years. This has complicated the operation of electrical grid systems since neither wind nor solar resources are fully dispatchable.

Solar generation takes place only in the daylight hours. In addition such generation is necessarily curtailed in inclement weather. Although the daylight hours tend to coincide with the peak load hours (excepting very early mornings and late evenings when solar radiation is limited, but loads are at their maximum), cloudy and rainy weather tend to be predictable only in the short term. From a dispatch view, some backup is often required, even though large solar plants tend to be sited in desert areas. Of course, distributed photovoltaic solar panels on rooftops are subject to the vagaries of local weather [5].

Wind generation is very erratic, even in areas with normally high winds. There are variations in wind output which, in the aggregate, amount to very significant up and down ramps. In this way, wind generation may be taken to resemble negative loads on the grid. Something, somewhere, needs to be able to follow these "load" changes so as to stabilize the grid and maintain tight frequency control [5].

Large electrical grids include a large quantity of rotating machinery among their generating resources and their loads. Most generators and many motors are synchronized to the electrical frequency so that load changes are resisted initially by the rotating inertia of the machines themselves. In effect, the grid acts

Fig. 3. USACE pumped storage Seneca. @ Margaret Luzier.

like an enormous rotating flywheel. Thus, small load changes tend to be absorbed in the short run by the inertia of the system. When changes become large enough to affect the rotating speed of the entire system to a perceptible extent, governing mechanisms must come into play to match power produced from the prime movers to power required by the load. Thus, if a large load is connected to the system, one or more generating units must increase output to prevent the whole system from slowing down. Similarly, if a large load is disconnected, generation must decrease to match, or the system will speed up. Complex governing systems have been developed to balance loads with resources in such a manner as to hold frequency variations to tiny fractions of one Hz. This balancing depends on the connected prime movers having available unused capacity, i.e. they are not operated at “full throttle”. In addition, these units must be capable of accommodating relatively rapid changes in load without damage or severe loss of efficiency. Such units are dispatched with the specific intent of being able to “follow load”.

In large grid systems that produce power mainly from large thermal and hydro sources, the generation is controllable and mostly predictable. The hydro plants can follow load changes fairly quickly, as can certain types of thermal generation – most notably small and moderately-sized oil or gas-fired combustion turbine generators and engine driven equipment. Large high temperature steam generators can accommodate load changes only quite slowly (over many hours) and at high cost.

Relatively predictable large scale load changes, such as the daily transition from off-peak to peak conditions, are accommodated by bringing large generating resources on line in advance, and loading them as the grid load increases. It is also necessary to be able to tolerate unexpected large load changes, such as when a large generating unit trips off line due to a mechanical or electrical fault. This is accomplished by having a certain amount of “spinning reserve,” or generating capacity connected to the grid but carrying only a minimum load. Such units stand ready to spring to the aid of the grid quickly. Some hydro units are ideal in this use. Most such units have an optimal operating point that is somewhat less than the maximum capacity of the unit. Thus, hydro units normally have a built-in capability for “overload” under abnormal conditions, which means that there is a certain amount of spinning reserve inherent in most hydro plants [3].

As older large thermal and nuclear units are retired, and renewable resources such as wind and solar generation replace them in a grid, the balancing of loads and resources becomes more complex and unpredictable. At the same time, the historical arbitrage value of pumped storage hydro has been diminished by significant increases in the production costs of large-scale fossil and nuclear power. Nevertheless, the services offered by pumped storage plants are needed to supplant similar services sourced from combustion turbine generators and similar flexible units as the use of fossil fuel fired generation (even the use of natural gas) continues to be discouraged ([7], [8], [9]).

Pumped storage plants also offer ancillary services, which the Federal Energy Regulatory Commission (FERC) of the United States defines as: “those services necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system.”[10]. FERC has identified six such services: scheduling and dispatch, reactive power and voltage control, loss compensation, load following, system protection, and energy imbalance.

Pumped storage hydro units are ideally suited for providing load following services, and, since they comprise heavy rotating machinery, they automatically contribute to the inertial stability of the grid [3].

It is worth noting that as much renewable generation depends on electronic inverters (DC to AC) and contribute nothing to system inertia, the value of rotating inertia to frequency control is increasing [3].

The importance of a strong interconnected transmission system cannot be overemphasized. With greatly increasing reliance on wind and solar generation, and the growth of wind farms and centralized solar stations in remote areas, strong transmission links are necessary to reliably serve electrical loads that are distant from the generators. Similarly, pumped storage hydro plants must be located where site conditions are favorable, and this is usually at some distance from electrical load centers.

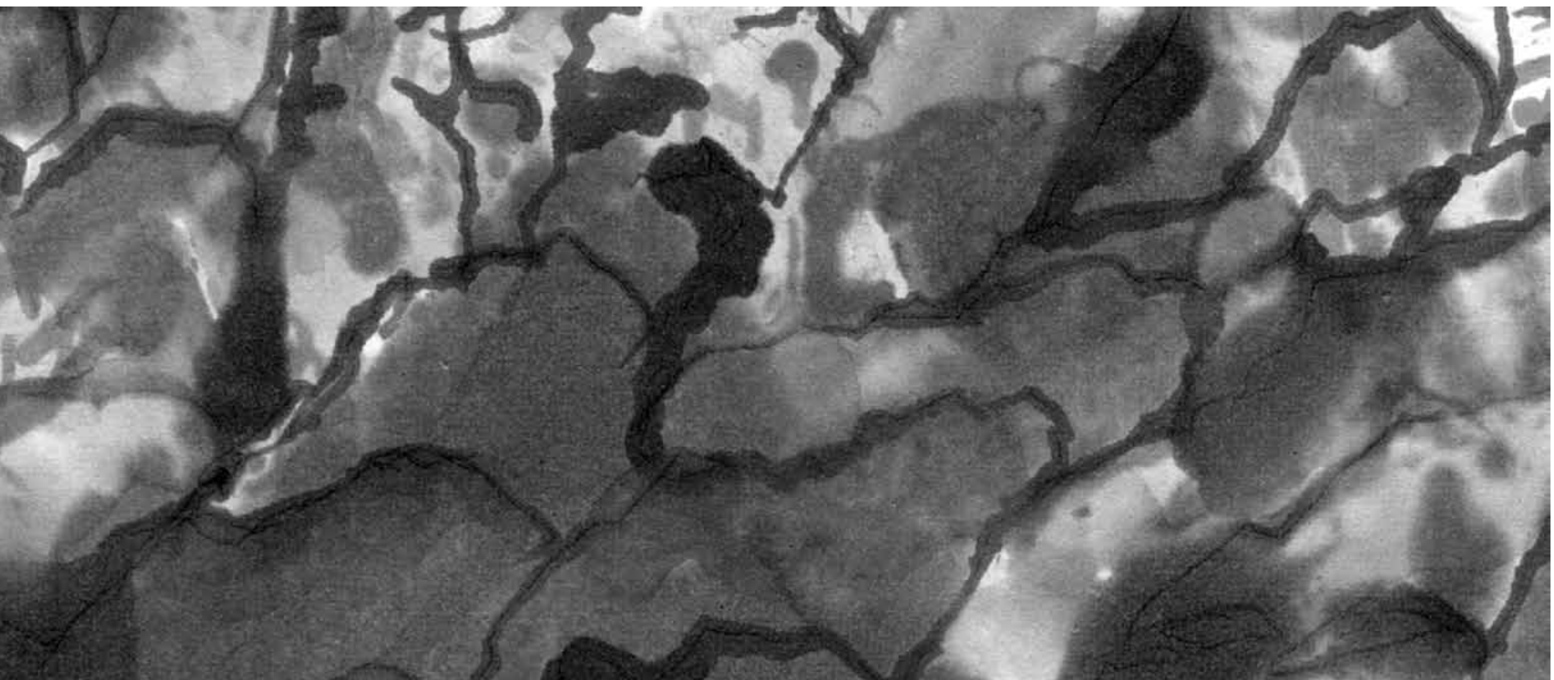
Energy storage is becoming necessary in a grid to be able to manage varying loads and varying generating resources. Despite a great deal of research devoted to various types of energy storage, with a heavy emphasis on battery systems that can be located close to load centers, so far, no such technology that could be applied at a large scale has been developed. Thus, pumped storage hydro remains the only technically and economically feasible energy storage alternative.

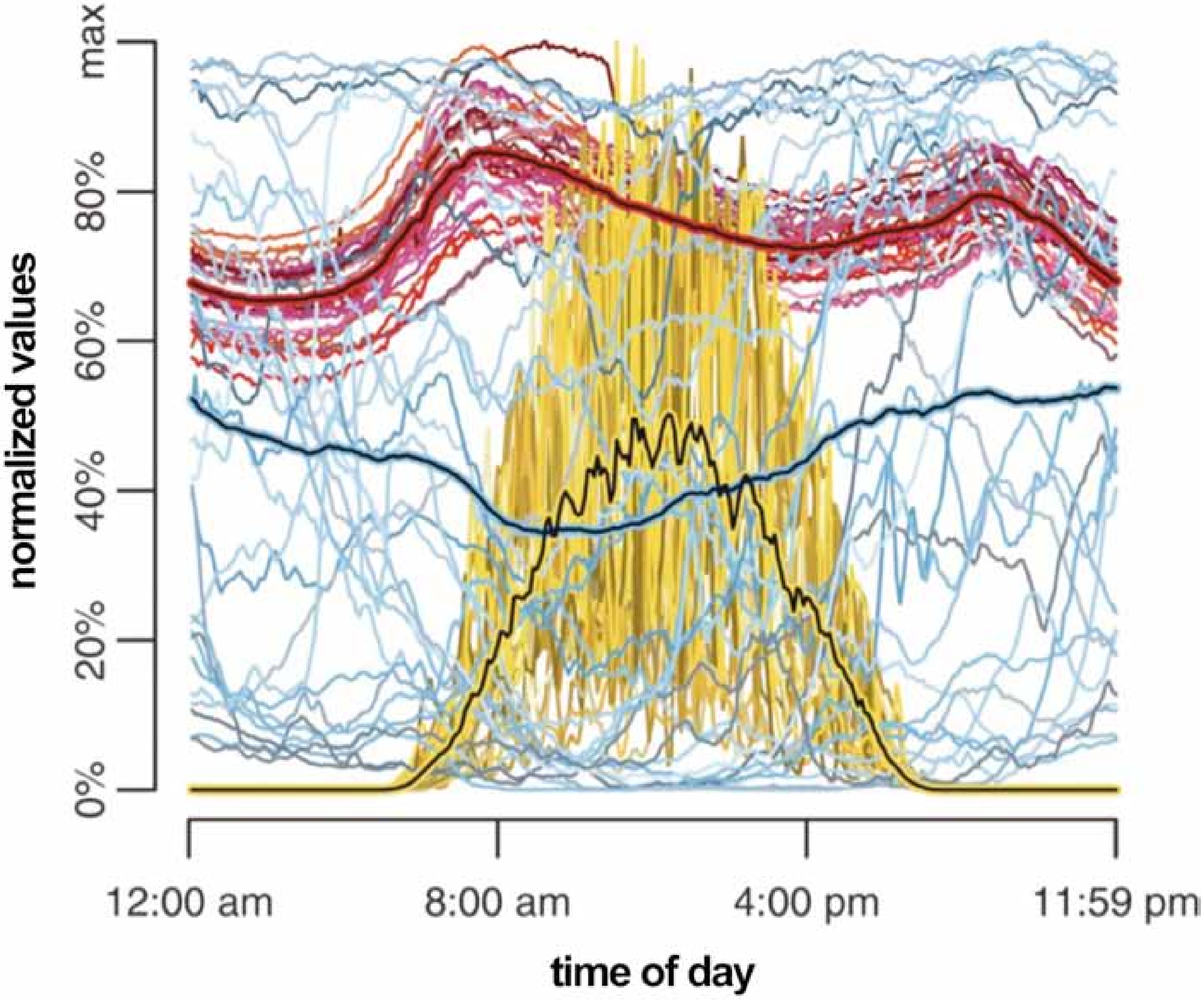
Approximately 22,000 MW of pumped storage hydro capacity have been built and operated in the United States over the last 25 years. These facilities have been able to deliver grid stabilization services such as frequency regulation, spinning reserve, non-spinning reserve and fast ramping for load following, as well as the inherent benefits of rotating inertia [3].

A comprehensive modeling study of the impacts of pumped storage hydro on the interconnected grids comprising the Western Interconnection in the United States and Canada was published in June 2014 by the Argonne National Laboratory under the sponsorship of the US Department of Energy [5]. The study modeled the expected conditions of 2022, as planned by the Western Electricity Coordinating Council. Two cases of renewable generation capacity were modeled: a baseline scenario reflecting the mandated 14 percent of total generation from renewable sources, and a high wind scenario reflecting some 33 percent renewables based on the Western Wind and Solar Integration Study, Phase 2.

This study looked at existing fixed-speed pumped storage units and planned advanced adjustable-speed units. The conclusion drawn was that the three currently planned new pumped storage plants in the western United States (Iowa Hill, Eagle Mountain, and Swan Lake North) that are expected to be of the adjustable speed technology, will be economically and financially feasible, and, coupled with the existing units, will provide much-needed services to the grids in the region. The adjustable speed units have the important advantage of adjustability of electrical load and water flow rate in the pumping mode. Conventional fixed speed pump-turbines are either operated at full load in pumping, or are shut down. Thus, adjustable speed units are able to provide load balancing services in both generating and pumping modes [11].

The study found, as others have, that without storage facilities in the





grid, renewables (mainly wind) will be expected to produce power well in excess of off-peak nighttime load requirements (see Figure 4). This will require curtailment, i.e. shutting down generating resources that could otherwise produce power [1]. Since renewable generation requires no fuel, the operating cost of energy production is near zero. That means that curtailment becomes pure waste of a resource. If that surplus power were to be used to pump water, it could be used to meet peak loads on the following day, much as pumped storage plants were originally designed to do in the mid-20th century. In addition, the plants will supply the needed ancillary services to stabilize the grid and provide for unexpected events. The values of all the services were modeled, and the plants were shown to be attractive for development in both the base and the high wind scenarios.

There is one additional potential application for large scale pumped storage in some grid systems. This is where there is the potential for tidal power development, such as at the Bay of Fundy in North America, and in the Severn Estuary in the United Kingdom. Although tidal power is very predictable, since it follows a lunar cycle, it is not very dispatchable. Pumped storage could be used to balance a grid that has tidal power in its generating portfolio. Tidal power has had only very limited development to date, but there are tidal lagoon schemes in the conceptual stage in several locations.

Fig. 4. Distribution of wind-power generation (blue), insolation (gold), and power demand (red) around the day illustrated through the superposition of 30 days of data from April 2010 obtained from the Bonneville Power Administration of the U. S. Department of Energy. Color-highlighted black lines represent average values. (reproduced with permission from Reference [1].

WATER FOR COOLING

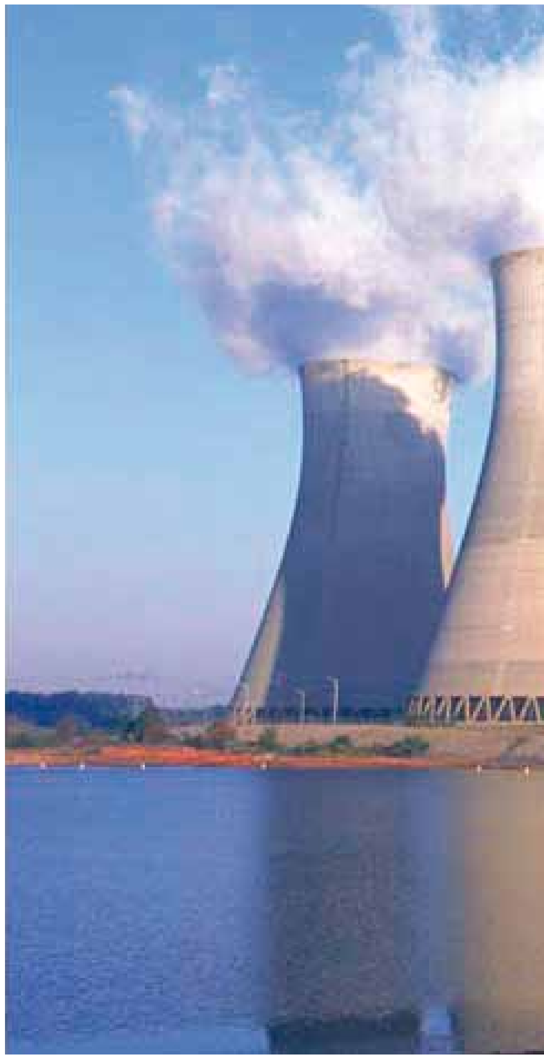
Most electric power is generated in thermoelectric power plants, which account for over 80 percent of all electrical generation worldwide [12], and for about 90 percent of generation in the United States [13]. Typical thermoelectric units use a heat source (fossil fuel, nuclear fuel, or solar energy) to produce high-pressure steam that passes through turbines driving electric generators. The majority of thermoelectric plants circulate water through heat exchangers to help condense the exhaust steam from the turbines. For example, in the United States only 1 percent of electric power generation capacity uses dry air cooling, while the rest depends on water for cooling [14].

Water cooling systems are either once-through, in which the water leaving the heat exchangers is returned back to its source at a higher temperature, or closed-loop (recirculating), in which the water from the heat exchangers is cooled and reused. Closed-loop systems include cooling ponds, and/or wet cooling towers, where the hot water is brought to the top of the tower and is cooled by the ambient air as it is let flow downwards. In these systems a portion of the water is lost to evaporation. Water consumption in these systems is between 180 and 1,200 gal/MWh (0.7 to 5.3 m^3/MWh). Once-through cooling systems withdraw very large volumes of water, of the order of 7,500 to 60,000 gal/MWh (28 to 227 m^3/MWh), depending on the type of power plant [15]. The consumptive water use in these systems, however, is of the order of one percent of the withdrawn water, or less, in the range of 100 to 400 gal/MWh (~0.4 to 1.5 m^3/MWh). In coal-fired plants part of the waste heat is lost through the stack which means that, in general, less water is needed than in nuclear power plants where practically all the waste heat is dissipated through the cooling water. For example, the consumptive use in once-through cooling systems for nuclear plants is about 400 gal/MWhe, for fossil fuel is 180 gal/MWhe and for natural gas combined cycle plants is 100 gal/MWhe [15].

Power plants with once-through cooling systems are located either next to relatively large rivers or lakes typically using freshwater, or along the coast, using seawater. Power plants in inland dry climates use closed-loop cooling systems. In some cases water-related constraints, such as low flows, high water temperatures or other environmental concerns, have caused disruptions in electric generation and/or have been the subject of permitting challenges ([15], [16]). Recognizing the water availability and environmental constraints of once-through cooling systems, in the 1970's the industry started shifting towards closed-loop cooling systems. This shift led to a progressive decrease in the average water use per unit energy produced.

In the United States the use of once-through cooling systems in new power plants does not seem feasible since the introduction of the Clean Water Act rule 316b by the US Environmental Protection Agency [17]. The intention of this rule is to prevent the removal by cooling water withdrawal of aquatic organisms, including fish, larvae and eggs, crustaceans, shellfish, sea turtles, marine mammals and other aquatic life.

Under rule 316b new facilities must ensure that their cooling water intake flow is at a level commensurate with that achievable with a closed cycle recirculating systems, through screen intake velocity is less than or equal to 0.5 feet per second, meet location and capacity based limits on proportional intake flow and that design and construction technologies for minimizing impingement mortality and entrainment are selected and implemented if certain conditions exist where the cooling water intake is located.



The final regulation issued in May 2014 requires that new units at existing facilities either reduce actual intake flow, at a minimum, to a level commensurate with that which can be attained by the use of a closed-cycle recirculating system, or demonstrate technological or other control measures for each intake at the new unit achieve a prescribed reduction in entrainment mortality of all stages of fish and shellfish that pass through a sieve with a maximum opening dimension of 0.56 inches [18].

Because of the high water volume used in once-through cooling systems the total quantity of water withdrawals for thermoelectric power generation is high. For exam-

ple, in the United States in 2005 thermoelectric power generation accounted for 41 percent of all freshwater withdrawals [19]. In 1995 the average consumptive use for all thermoelectric power plants in the United States was about 2 percent of the water withdrawals [20].

A potential solution for power plants located near cities in areas with limited water resources is the use of treated municipal wastewater for cooling. A database of power plants using treated wastewater developed in 2007 identified 57 such facilities [21]. Among them the largest and one of the first to use municipal reclaimed wastewater for cooling is the Palo Verde nuclear power plant in Arizona, which uses 55 Mgd (76 Mm3/yr) of tertiary treated water. It has been estimated that three quarters of all existing power plants and nearly all proposed plants in the United States are within 25 miles from a source of secondary treated wastewater [22]. Research is under way to address some of the issues associated with the use of treated wastewater, such as biofouling, scaling and corrosion.

In addition, the industry is adopting increasingly more air cooling and wet/dry hybrid cooling systems. These systems are particularly attractive for concentrated solar electricity facilities, which otherwise would require between 0.75 and 0.9 gal/kWh that is not available at most premium solar energy locations. Use of such systems can reduce water use by 80 to 90%. To achieve this reduction in water use the industry pays a penalty of increased electricity production cost of the order of 2 to 10%, depending on the location of the plant and several other factors [23].

Fig. 5. Plant Scherer, a coal power plant in Georgia, uses a closed loop cooling that removes significantly less water than a one-step system.

Research and development in different areas help reduce water use for power generation. Advances in metering technology make it possible to know the quantity and quality of the water used in different parts of a plant at any time, and to optimize water use and reuse. Recovery of the moisture lost through power plant stacks and cooling tower plumes and the use

Fig. 6. Hoover Dam releasing stored water for other uses downstream.

of heat absorptive nanoparticles to enhance the heat advection by the cooling water are examples of research projects at a new Water Research Center that was established recently by Georgia Power in collaboration with the Electric Power Research Institute to explore and study best practices for sustainable water management in the power industry [24].

WATER CONSUMPTION BY HYDRO POWER

Even though there is no water consumption in the process of power generation, as all the water passing through the turbines is available for other uses downstream, concerns and restrictions on the rate, timing and water quality of flow releases downstream of such plants may impact the amount and schedule of energy production. It has been argued that storage hydroelectric plants in effect consume large quantities of water, because of evaporation losses in their storage reservoirs. A recent study of evaporation losses in 35 reservoirs constructed exclusively for hydropower generation concluded that these losses were strongly correlated with the ratio of the average reservoir area over the installed capacity of the power plant. They also depend on the local climatic conditions. Estimated evaporation losses per unit energy produced spanned a range of more than three orders of magnitude from about 0.3 to over 800 gal/kWh (about 0.001 to a little over 3 m^3/kWh)[25]. In the United States, a state-by-state estimate of consumptive water use in the form of evaporation losses from reservoirs serving hydropower showed that it is range from about 2 to 154 gal/kWh (0.008 to 0.583 m^3/kWh) [26]. It should be noted that the estimated evaporation losses from reservoirs reported generally did not account for evaporation and evapotranspiration losses from vegetation and soil in the reservoir area that existed prior to the construction of the reservoir, although some account was made for river evaporation. In addition the reported estimates did not account for water level fluctuations which affect the water surface exposed to evaporation. Thus, the statistics quoted generally overestimate net evaporation losses from reservoirs. The reported evaporation losses from the reservoirs of hydroelectric projects can be much greater than the water consumption at thermoelectric power stations with similar generation capacity. For example, it has been estimated that the Vogtle Nuclear Units 1 and 2 in Georgia with an installed capacity of 2,865 MWe and closed-loop cooling system (cooling towers) use on the average 43.2 Mgd, i.e. a little under 60 Mm^3/yr [27]. The average evaporation losses from the reservoir of the Yacyretá hydroelectric project along the border of Argentina and Paraguay with a similar installed capacity (2,700 MW) have been estimated to be 3,280 Mm^3/yr [25]. It should be noted that the consumptive water use of these two power stations represents about the same percentage of available resources in each case, i.e. of the order of one percent of the annual flow of the Savannah River for Vogtle and one percent of the mean annual flow of the Paraná River for Yacyretá. In the many reservoirs that serve other purposes besides hydropower not all evaporation losses should be viewed as “consumptive water use” for hydroelectric energy production.

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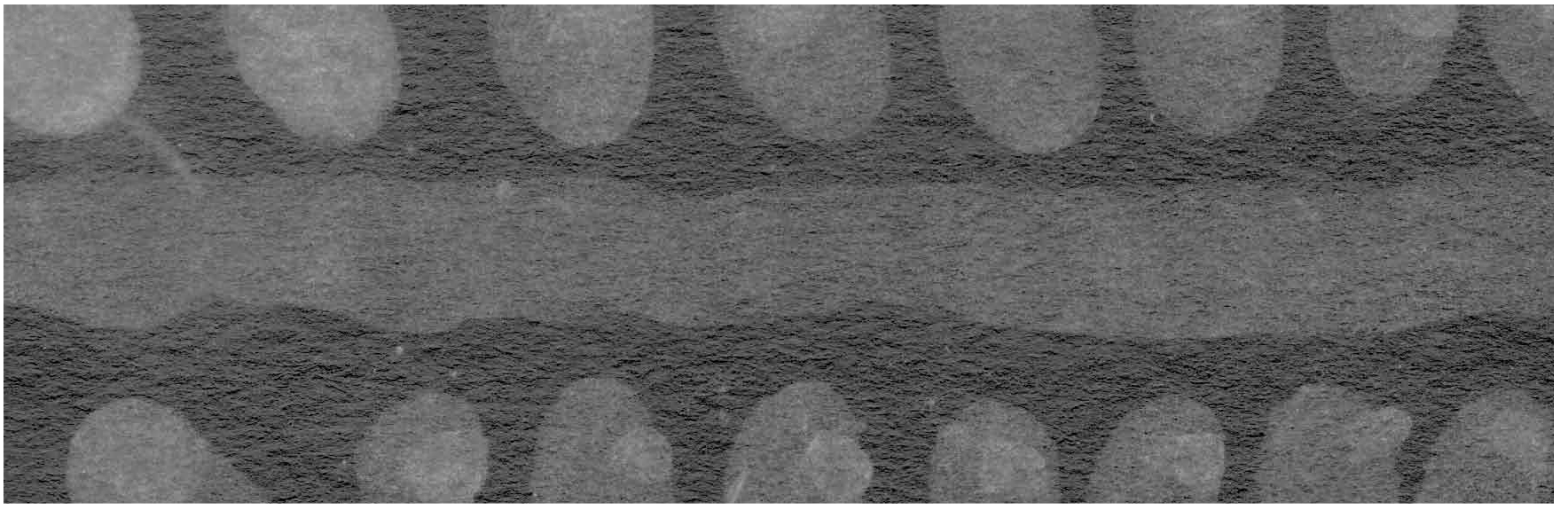

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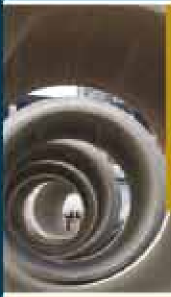

CONSTRUCTION
Chairman: Engr. Efrain Echandi

- Establish a Forum for Discussion of Construction Related Topics
- Promote the establishment of:
  - Uniform Building Codes
  - Standard Specifications
  - Model Contracting Instrument
- Promote the Use of Alternate Dispute Resolution
- Develop Ethics and Integrity in Work Execution
- Promote Use of Technology and Technology Transfer
- Certification of Academic Equivalence of Work Experience
- Corruption prevention plans
- Insurance Certification
- Promote profesional mobility

NATURAL DISASTERS
Chairman: Prof/Engr. Tügrul Tankut

- Raise awareness in the civil engineering communities of the member countries about the natural disaster issues in civil engineering applications
- Follow the advances in the civil engineering practice concerning natural disaster issues over the world
- Disseminate information about the developments in natural disaster civil engineering practice
- Foster global partnership and disaster knowledge network
- Organize an International Congresses concerning Earthquake & Tsunami in collaboration with other international organizations

EDUCATION, TRAINING AND CAPACITY BUILDING
Chairman: Engr. Martin Manuhwa

- Sharing of professional and technical information and capacities from developed countries with engineers in the developing world
- Deliver via e-learning state of the art knowledge to engineers and engineering educators in developing countries
- Strengthen engineering education in developing countries via sharing of best practices in curricular reform and in engineering practice
- Promotion and public understanding of engineering and technology
- Prepare guidelines for definition of the necessary basic knowledge and skills in engineering education, and provide them to academia and all members
- Develop policies for regional and global recognition of engineering qualifications through the strengthening of bilateral recognition of qualifications
- Develop and support policies to strengthen the mobility of engineers

WATER
Chairman: Engr. Francisco Hijôs

- Establish a Forum for Discussion for Water related topics including industry organizations, governments, NGOs, other professions and civil engineers
- Foster Integrated Water Resources Management (IWRM) policies
- Promote Use of Technology and Technology Transfer
- Training and Capacity Building in Water-related issues
- Promote transparency and full stakeholder participation as guiding principles for all aspects of water governance
- Improve fair competition and accountable implementation of water projects
- Collaborate on advancing Millennium Development Goals
- Promote water and food security in rural areas of developing countries

COASTAL ENGINEERING
Chairman: Mauricio Porraz

- Support (UPADI) (WCCE) activity in areas such as:
  - climate change and its importance within the oceans
  - the sea rise and its effects in deltas and coastlines - the melting of ice at both poles increasing Ph affecting all sea life
- Become world-wide leader in support on Ocean and Coastal Engineering.
- Raise public awareness of SCo objectives
- Promote educational programs, conferences, communications, etc… to involve all interested countries.
- Open donations for R & D funding and for SCo activities identifying and recruiting new members.
- Extend CoC activities beyond the vulnerable communities to meteorological conditions to gain external visibility
- Grow over time and create an auxiliary or associate membership.

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