ADVANCES IN HYDRO-ENVIRONMENT RESEARCH
the Water–Energy–Food–Environment nexus

Prof Arthur E Mynett
UNESCO-IHE Institute for Water Education
Delft, the NETHERLANDS

a.mynett@unesco-ihe.org

Water and food are tightly related: some 70% of the world water consumption is used for food production (20% for industrial use and 10% for human consumption). Water and the environment are tightly related: in order to cope with water abundance and water scarcity, blue-green solutions are nowadays more commonly being explored.

Water and energy are tightly related as well: the year 2014 is the United Nations Year on Water and Energy. Under the coordination of the World Water Assessment Programme (WWAP), with contributions from several leading UN-Water Agencies and published by UNESCO, the World Water Development Report (WWDR) 2014 focuses on facing the challenges of Water and Energy. In this paper some drivers and needs for rapid advances in hydro-environment engineering and research are presented hereafter, with a focus on water and energy.

THE INTERDEPENDENCY OF WATER AND ENERGY

Water is required for producing nearly all forms of energy: for the development of hydropower, for thermal electricity generation, and for biofuel production. Decisions on energy production need to take into account the availability of water resources, the water requirements of other users (agriculture, industry, human consumption) and the need to maintain healthy ecosystems (WWDR2014). Inversely, energy is needed at all stages of water extraction, treatment and distribution. Water supply and sanitation services, as well as irrigation, flood protection and drought relief are all critically depending on affordable and reliable sources of energy.

There is an increasing potential for conflicts between (hydro)power generation and environmental considerations. Thermal power generation accounts for roughly 80% of the global electricity production and is responsible for one half of all water withdrawals in several developed countries. Hydroelectricity, which also requires abundant water supply, provides an additional 15%. Technological advances can sometimes reduce trade-offs, but may carry additional trade-offs of their own. The evolution of the global energy mix (the distribution of the various energy sources being used) will have an unprecedented impact on water resources and other water users. Decisions made today on how to increase energy production will determine the sustainability of freshwater resources tomorrow.

More than 1.3 billion people worldwide are lacking access to electricity. More than 95% of them are located in sub-Saharan Africa and developing Asia. Roughly 2.6 billion people rely on the traditional use of biomass for cooking (IEA, 2012*a*). An estimated 400 million people rely on coal for cooking and heating purposes; together with wood, charcoal, peat or other biomass, this causes air pollution and has serious potential health implications when these are used in traditional stoves. The map in Figure 1 shows the access to electricity in developing countries as a percentage of their population (WWDR2014). It is no coincidence that the figures concerning lack of access to water services and energy align so well: the same people are often missing out on both. The close correlation between respiratory diseases caused by indoor air pollution due to coal/wood stoves, and waterborne diseases like diarrhoea caused by lack of safe drinking water and sanitation, is just one point of evidence.

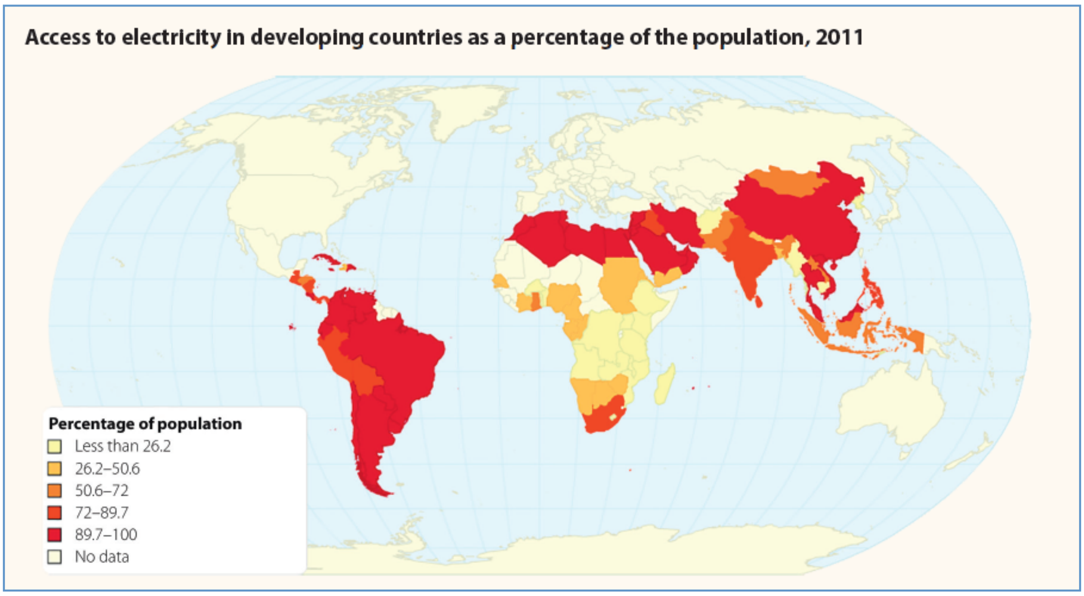

Figure 1. Access to electricity in developing countries
(red > 50% access; yellow and white < 50% access)

With a growing world population (from 6.5 bn at present to 9.0 bn by the middle of the century) the demand for freshwater will increase significantly over the coming decades. This already puts major strain on available resources in nearly all regions, but most critically in developing and emerging economies.

RENEWABLE ENERGY RESOURCES

Worldwide energy demand is projected to grow by more than 1/3 over the period until 2035 – and 90% of global power generation is water-intensive. This growth will occur almost entirely in non-OECD countries, with China and India accounting for more than half that growth. The greatest increase in energy demand in both OECD and non-OECD countries is expected to come from renewables.

Hydropower is expected to account for the largest portion of the renewable increase in non-OECD countries, whereas wind is predicted to dominate within OECD. In the absence of sturdy energy policies, the capital cost of powerplant development is by far the most important driver in the evolution of nuclear power and renewables. Relative costs, which are very much influenced by government policies, are the primary driver of the projected changes in the types of fuels and technologies used to generate power. Thermal power plants (coal, natural gas, oil and nuclear) are providing roughly 80% of the global energy production. And together they put a major strain on the water resources required to produce this energy.

Solar photovoltaic and wind are the most sustainable sources for power generation. However, in most cases the intermittent service provided by solar photovoltaic and wind needs to be compensated for by other sources of power (which do require water) to maintain load balances. Support for the development of renewable energy will need to increase dramatically before it can makes a significant change in the global energy mix, and by association, in water demand.

WATER SECURITY

There is clear evidence that groundwater supplies are diminishing, with an estimated 20% of the world's aquifers being over-exploited. Globally, the rate of groundwater abstraction is increasing by 1–2% per year, adding to the water stress in several areas and compromising the availability of groundwater to serve as a buffer against local supply shortages. Water quality is also a key determinant of water availability. Polluted (or saline) water cannot be used for several crucial purposes such as drinking and hygiene. The energy required to produce 1 m^3 of water varies among the water sources: seawater requires 2.5~8.5 KWh/m^3, wastewater 1.0~2.5 KWh/m^3 (desalination); abstracting water from aquifers requires ~0.5 KWh/m^3 while the least energy intensive water production comes from lakes or rivers at ~0.4 KWh/m^3.

The annual average monthly blue water scarcity in the world's major river basins was calculated by equally weighing the twelve monthly blue water scarcity values per basin. Water scarcity and decreasing availability of water for agriculture constrain irrigated production overall, and particularly in the most hydrological stressed areas and countries. As many key food production systems depend on groundwater, declining aquifer levels and the depletion of non-renewable groundwater put local and global food production at risk (WWDR2014).

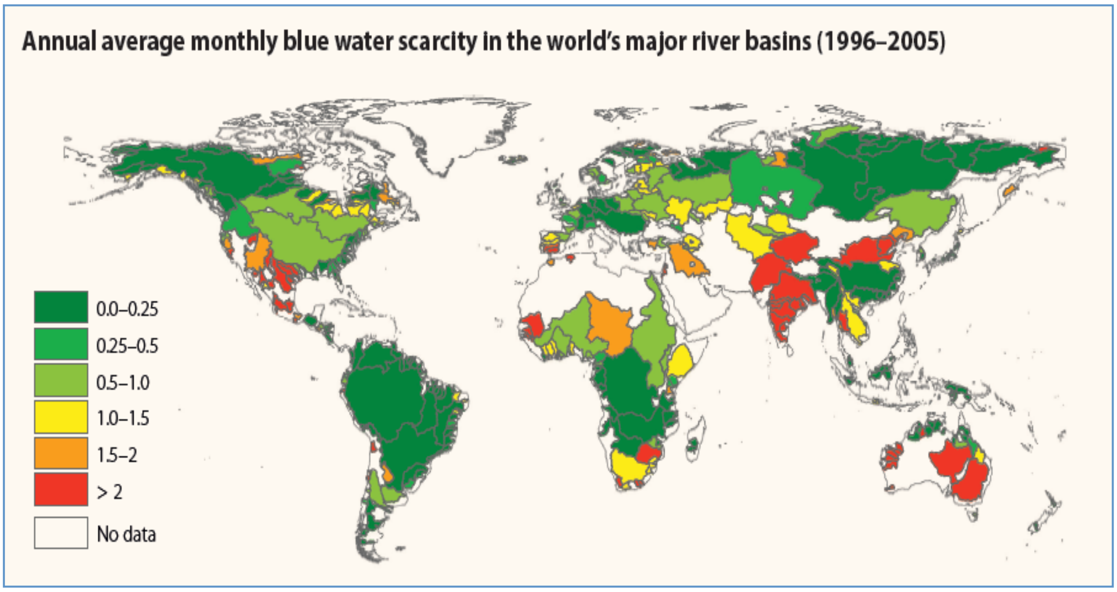

Figure 2. Annual average monthly blue water scarcity in the world's major river basins

Energy efficiency measures are important at all stages of the agrifood chain. Efficiency improvements through technological or behavioural changes can lead to direct cost-savings, or to indirect benefits by adjusting to agro-ecological farming practices. For both large and small systems, any means of avoiding food wastage should be encouraged and can result in considerable savings in energy as well as in land and water used to produce food that no one consumes. Water and energy consumption in urban environments can be reduced by investing in systems for integrated urban water management during the early stages of urban planning. Examples of conservation of water sources are (i) the use of multiple water sources (including rainwater harvesting, stormwater management and wastewater reuse) for different needs; and (ii) performing treatment of water as needed rather than requiring all water to comply with the potable standards.

INTEGRATING THE HYDRO-ENVIRONMENT

An integrated approach to water and energy requires in-depth understanding of synergies and trade-offs in the use of natural resources, taking into consideration the role of ecosystem services for the energy and agricultural sector. Ecosystem services are being compromised worldwide, and energy production is one of the drivers of this process. Different forms of energy have, to different extents, an impact on water resources. Most energy production heavily depends on readily available water resources, which impacts water-related ecosystems in a number of ways: if adequate water resources are not available at the right place at the right time and in the right quantity and quality, ecosystem functions and services can be negatively affected.

There are many opportunities for the joint development and management of *water and energy infrastructure and technologies* to maximize co-benefits and minimize negative trade-offs. There is the possibility to co-produce energy and water and to exploit the benefits of synergies, such as combined power and desalination plants, combined heat and power plants, using alternative water sources for thermal power plant cooling, and even energy recovery from sewerage systems. In addition to pursuing new technical solutions, also new political and economic frameworks need to be designed that promote cooperation and integrated planning among sectors. Innovative approaches to increase efficiency by cross-sector cooperation, and integrated planning for water and energy to decrease costs and ensure sustainability, are just two examples.

THE WATER NEXUS IS AT THE HEART OF SUSTAINABLE DEVELOPMENT

Achieving the Millennium Development Goals (MDGs) critically depends on achieving major progress in providing access to safe drinking water and sanitation, reliable sources of energy, adequate food supply and preservation of the environment. Separate sustainable development goals dedicated to water, food, energy and environment may sometimes be viewed independently of each other, but should always be considered in close inter-relation and coordinated in order to maximize their co-benefits in the most cost effective way.

Freshwater and energy are crucial for human well-being as well as for sustainable socio-economic development. The essential roles of water and energy in achieving all MDGs are now widely recognized. Major regional and global crises on climate, poverty, hunger, health and finance that threaten the livelihood of especially the three billion people living on less than US$2.50 per day, are interconnected through water and energy (WWDR2014). For those reasons, advances in hydro-environment engineering research are needed now more than ever.