Renewable Energy for water supply and treatment – experiences, costs and competitiveness

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Water and energy are two of the most important topics on the international environmental and development agenda. Unfortunately, though, international aid and development agencies and programs often treat the two as isolated issues. Here, Ole von Uexküll explains how fossil and nuclear energy systems exacerbate the global water crisis, while many renewable energy technologies alleviate it, and that the world water woes cannot be solved until we make a complete shift to renewables.

In 2001, the Executive Director of UNEP, Klaus Töpfer, opened the International Conference on Freshwater in Bonn with the words: "Indeed, there are only two issues that are so intensively inter-related and important for development and they are water and energy." While water and energy have, each in its own right, become well-established as top development priorities, this inter-relation between the two fields is very rarely mentioned.
Since the beginning of the 1990s, a series of international conferences has been held on the use of our global water resources. Their recommendations rank from the recognition of water as an economic good over rather vague development jargon ("new partnerships, identifying best practice, increased efficiency, improved management") to the "Millennium Development Goal" of halving the number of people without access to safe drinking water by the year 2015. However, none of the conferences conclude that energy questions are linked to water problems—except for questions of hydro-power, where the connection is obvious. Not even the 2002 World Summit on Sustainable Development in Johannesburg, which recognized energy and water separately as top development priorities, established the link. A look at the scope of the global water and the global energy crises and their connected problems and connected solutions shows that the two issues are, in fact, far more related than only via hydro power.

The global water crisis

Water has always been Earth's most valuable resource. All ecosystems and every field of human activity depend on water. In contrast to other resources, there is no substitute for water in most of its applications. The availability of this clear gold has determined the fate of empires, and wars have been fought over its access. Only 2.5 percent of the world's water is freshwater, and only a tiny fraction of this is accessible for human use. In principle, this should be a self-generating resource, but today many aquifers are tapped at a rate exceeding their natural regeneration capacity and many rivers are polluted. At the same time, the water retention capacity of the landscape is constantly decreasing because natural vegetation is cleared and soil surfaces are sealed. As a consequence, the amount of freshwater available for human use is dramatically decreasing in many regions. Currently, at least one billion people have no access to safe drinking water.

The global energy crisis

The world energy system depends largely on finite fossil and nuclear energy sources, which require long and complex resource chains—from mining and extraction to transportation and processing to conversion to energy in the power plant and disposal of waste (Scheer 2002). Along these chains the energy system causes adverse socio-economic and environmental problems such as armed conflict, economic inequality and dependencies, the poisoning of the environment, and global climate change. Particulate emissions from the burning of fossil fuels annually cause roughly 800,000 casualties worldwide, corresponding to a 1.4 percent share of global mortality (World Health Organization 2002), and nuclear radiation is still causing much suffering around Chernobyl and elsewhere. It is evident that if the poor countries of the South were to copy the energy consumption patterns of the North, there would be a global ecological collapse.

Connected problems

Our present energy system consumes and pollutes water along its entire resource chain. For oil extraction, water is pumped into the wells to increase the pressure. Refining consumes additional water. Coal production and transportation, gas processing and transmission, and the nuclear fuel cycle also consume large amounts of water. At the same time, water is polluted by oil spills and tanker wrecks, and contaminated by radioactive emissions from reprocessing plants. Table 1 shows the water consumption of different electricity production technologies. Thermoelectric power generation, with its large evaporation losses, consumes most water. In the United States in 1995, thermoelectric power generation accounted for 39 percent of total annual water withdrawal and 3.3 percent of annual consumptive water use, which is more than any other industry (U.S. Geological Survey 1998). (Because of massive irrigation, industrial water consumption is still outnumbered by the agricultural sector with 85 percent.) The numbers in Table 1 reveal the inefficiency of common energy-water operations, for example boiling water to make a cup of tea (see boxed text).

How much the water evaporation of power plants disrupts the natural water balance depends on the climate of the region and the source of the cooling water. Most power plants use freshwater, although the use of seawater would not compete with human water needs. In arid regions, where freshwater availability is a limiting factor for agriculture, industry, and human health, a competing power plant has disastrous consequences. To make things worse, the burning of fossil fuels prevents rainfalls. A study of satellite data in the journal *Science* (Rosenfeld 2000) shows that particulate matter from urban or industrial sources like fossil power plants can completely shut off precipitation from clouds. The likely explanation is that the small particulates act as cloud condensation nuclei forming many small droplets that inefficiently merge into raindrops. Besides local climate effects, the burning of fossil fuels is changing the global climate. It is widely expected among climate experts that climate change will bring about an increase in extreme weather conditions (i.e. more heavy rains as well as more droughts). This can cause dramatic changes in the water balance of whole regions, which so far are poorly understood and highly unpredictable. During the August 2003 drought in Europe, many nuclear power plants had to reduce energy production or even shut down because rivers simply did not carry enough water to ensure their cooling. Obviously, droughts can also hit hydro-power, an energy source that many countries are highly dependent on, very hard.

Connected solutions

To solve the world energy crisis, a complete transition to renewable energy sources (RES) is inevitable and technically possible, as has been shown by many projections and feasibility studies (see Scheer 2002 and references therein, as well as studies at www.eurosolar.org). Table 1 shows that two of the most important technologies for solving the world energy crisis—PV and wind power—consume practically no water during operation. The same is true for small hydro power plants. In light of the global water crisis, it is astonishing that this fact is not regularly brought forward in favor of RES as opposed to nuclear and fossil energy sources.

Equally important—and equally ignored—is the fact that renewables offer a means to produce the energy necessary for extracting and transporting water in off-grid areas, especially in developing countries. It is more than doubtful that the Millennium Development Goal of halving the number of people without access to safe drinking water can be achieved as long as the international community goes on ignoring the crucial roll of renewable technologies in this endeavor. In a brief on the agricultural applications of solar energy, the U.S. Dept. of Energy Office of Energy Efficiency and Renewable Energy (2002) concludes: "Photovoltaic (PV) water pumping systems may be the most cost-effective water pumping option in locations where there is no existing power line. When properly sized and installed, PV water pumps are very reliable and require little maintenance." This has been proven by many successful installations around the world. For countries in arid coastal regions or regions with brackish groundwater, like many small islands, desalination is increasingly becoming an issue that links—for better or for worse—water and energy issues. The different desalination techniques (reverse osmosis, electrodialysis, vapor compression, multiple effect or multistage flash distillation) all require considerable amounts of energy. China has already offered to help Morocco with the construction of a small nuclear power plant, which should provide the necessary energy for desalinating seawater and greening the desert. Instead of abusing the water argument for advocating new fossil and nuclear power plants, countries in arid regions could utilize the renewable energy, which offers a far larger capacity for desalination. In coastal regions, solar thermal power plants could use seawater for cooling and desalinate it as a by-process in the generation of clean electricity.

Even more important is decentralized, autonomous desalination on a small scale. A 1998 U.S. DOE National Renewable Energy Laboratory survey of the possible combinations between different renewable technologies (PV, wind, and solar thermal) and different desalination technologies showed that reverse osmosis and electrodialysis have been applied successfully in combination with both PV and wind (Corbus 1998). For households without access to potable water, a simple solar still (Figure 1) can easily produce the water needed for drinking and cooking. Alternatively, PV-powered systems can purify and disinfect water by means of UV-radiation or microfiltration. Additionally, there is tremendous potential in the combination of wastewater treatment and energy production. Biomass removed in the treatment process can be turned into biogas for energy production by means of a digester. Integrated biological wastewater treatment systems can even produce biomass because they use aquatic plants to filter and purify the water and to sequester nutrients. Researchers at the Indian Institute of Science in Bangalore have demonstrated the viability of using these aquatic plants for biogas production. Similar research is being carried out at the University of Florida Center for Aquatic and Invasive Plants, as well as in other countries.

Conclusions

These are only a few examples of the interconnectedness between the energy and water crises. There are myriad other links, like the lowering of regional water tables by coal mines and the killing of fish and aquatic biota by the cooling systems of thermoelectric power plants. These connections all point to the fact that we cannot solve the global water crisis without halting the present energy system's free ride on our water resources. This requires a drastic change of the energy system, a complete transition from nuclear and fossil energy sources to renewable energies. To create a mutually supportive relationship between energy production and water use, there is an urgent need for research and development of integrated water/energy solutions like better techniques for the coupling of wastewater treatment and energy production. Desalination and water purification with renewables must be promoted because the growing scarcity of water will otherwise pave the way for nuclear and fossil energy in many developing countries. In international policy, we can no longer afford the mental blocks regarding the connection between these two top development priorities.

The United Nations Commission on Sustainable Development (CSD), which is planning to hold a review and a policy session on water in 2004 and 2005 and on energy in 2006 and 2007, should merge these efforts into a concerted water-energy session. The distance between energy and water issues is a result of the current overspecialization of environmental policy. Decision-makers become experts for certain sub-areas, but lose sight of the bigger picture. The same is true for environmental scientists and NGOs. This bureaucratic categorization contradicts basic ecological insights about the interrelatedness of nature. It is high time that national and international decision-makers overcame their over-specialization and looked at the inter-relationships. Energy and water are the sources of life on our planet, the king and queen among the great services nature provides us. Without respecting this relationship, we will solve neither our water nor our energy problems.

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Box:
The Lost Cup (or The Most Inefficient Way to Boil Water)

When boiling water for tea, you should take the water off the stove as soon as it boils, so that no water is lost. But is there really no water lost? If the water is boiled with electricity from a fossil or nuclear power plant, one has to consider the following calculation:

The specific heat of water is:	4.2 kJ/(K*kg)
Temperature difference from 20°C to 100°C:	80 K
Let's assume we boil 1 litre, so the mass is	1 kg
Water consumption of a nuclear/fossil power plant (table 1):	ca. 2 l/kWh

Boiling 1 litre of water requires ca. 0.1 kWh electric power (4.2 kJ/(K*kg) * 80 K * 1 kg * 0.000278 kWh/kJ = 0.093 kWh). Generating this power evaporates 200 ml of water at the power plant (0.1 kWh * 2 l/kWh = 200 ml).

Result: When our tea water starts boiling, one cup of water has already evaporated without us even noticing it.

Table 1: Consumptive Water Use for Electricity Production (excerpt from a table in Gleick 1994)

Energy technology	Consumptive use (m3 per 103 kWh(e))
Conventional coal combustion	
Once-through cooling	1.2
Cooling towers	2.6
Oil and natural gas combustion	
Once-through cooling	1.1
Cooling towers	2.6
Nuclear generation (LWR)	
Cooling towers	3.2
Renewable energy systems	
Photovoltaics: residential -[a]	
Photovoltaics: central utility 0.1[b]	
Solar thermal: Luz system 4.0	
Wind power -[a]	

[a] = Negligible.
[b] = Maximum water use for array washing and potable water needs.

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