Water for Energy Vulnerability
In North America

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FOREWORD

The immediate background publication by WEC is the *Study on Energy Policy Scenarios to 2050*[1], after which it was decided that four vulnerabilities were to be analysed in detail between 2008 and 2010. After consultations with WEC Member Committees, NGO's and IGO's throughout the world and as agreed during the Executive Assembly meetings held in Rome during the 20th World Energy Congress in November 2007, the 2008-2010 WEC Studies Committee has committed to focus on a limited number of major global studies in the coming work cycle leading to the 21st World Energy Congress in Montréal in 2010.

During the preparation of the present report, together with representatives of several WEC Member Countries and officials, the Study Committee concentrated efforts on four vulnerabilities' studies and one policy assessment. One of those study groups is devoted to "Water for Energy Vulnerabilities", or W4E-V. The present report is a rough draft of the North American contribution to this study.

Each Member Committee was asked to reply to six specific questions that would lead WEC to gather the basic information to perform the present study on W4E-V. These questions were stated as:

1. What are the quantifiable water requirements of the region in the next 40 years? How is this divided among energy, food, drinking water and other essential uses?
2. What technological improvements are needed to assure adequate supplies of water and what is expected to be available in a business as usual situation?
3. What is expected to be the relative importance of water in rivers, oceans, hydropower, desalination, groundwater, wastewater treatment and recycling?
4. What policies are needed (by region) to assure adequate water for energy? For food?
5. What levels of investment are needed? And where? And on what? And when?
6. What metrics are available (if any) for assessing water for energy requirements e.g. units of water required per kWh electricity generated (by source: coal, gas, oil), etc?

[1] WEC Study on Energy Policy Scenarios to 2050, http://www.worldenergy.org/

Hence, the present draft examines the key issues and solutions surrounding water and energy, and attempts to depict policies and investments required for a sustainable water-energy-food system. Since different regions have variable degrees of water availability and development, and therefore variable future needs, it is vital that this draft takes these differences into account.

Key questions include the quantifiable water requirements of a region over the next 40 years, how this is to be divided among energy, food, drinking water and other essential uses (e.g., manufacturing), what technological improvements are needed to assure adequate supplies of water, what is the relative importance of water from rivers, oceans, hydropower, desalination, groundwater, wastewater treatment and recycling, what policies and levels of investments are needed to assure adequate water for energy and for food, for what and by when.

A report is planned for late 2010 at a session at the World Energy Congress, in Montreal.

The strength of the world study is that it uses the bottom-up process integrating WEC's network of Member Committees. As usual in WEC studies, the world was divided into five regions:

Africa - defined as the African continent, including Madagascar and the Cape Verde Islands.
Asia - including East and Southeast Asia, Oceania, Central Asia, and the Middle East (Gulf States).
Europe - includes the European Union (EU-27) and EFTA nations (Norway, Iceland, Switzerland, etc.), the Balkan countries, Turkey, Russia, Ukraine, and Belarus.
Latin America and the Caribbean - South America, Central America, and the Caribbean nations.
North America - Canada, Mexico, and the United States of America.

The North American Region has decided to submit its reply as a region, not as the addition of independent countries, which will allow a quicker detection of challenges and opportunities towards the end. Hence, the attention to the basic questions posed above is not given on an individual country basis, but on the general analysis contained in this report. However, the basic characteristics of each country are presented and discussed separately in the first part of the report.

In writing the present draft, it has been very clear that the subject of energy has drawn the attention of innumerable expert institutes and individuals over the last decade, and international cooperation on the subject has produced excellent and most relevant documents and recommendations. The same and even more can be said on the subject of water. Hence, the present exercise cannot and doesn't attempt to compete with any of those studies and proposals; on the contrary, it pretends to build on the extraordinary data base on world wide energy and water to contribute with a simple approach that allows for the promotion of the very basic recommendations that will be included towards the closure.

1. WATER FOR ENERGY IN THE WORLD

Water availability at the global scale

Estimates of ground water values vary widely amongst sources. It constitutes approximately 30% of all fresh water, whereas ice (including ice caps, glaciers, permanent snow, ground and permafrost) constitutes approximately 70% of fresh water. With other estimates, groundwater is sometimes listed as 22% and ice as 78% of fresh water.

Present time challenges have turned the whole energy business into turmoil, and energy prices as well as energy value chain parts are very volatile. On top of that, the changed outlook for water availability affects both hydro-electricity and thermal electricity generation, and has lead to price volatility in wholesale electricity markets. Ongoing drought conditions and lower water inflows in some parts of the world, and indeed of North America, have the potential to reduce water available to electricity generators (both hydro and thermal, including nuclear), and in the longer term, continued growth in electricity demand will require additional investment in power stations that need water for electricity generation.

Although water scarcity affects hydro-electricity generators, as has been evident in western NA in recent years, the impact on coal and gas-fired generation and the emerging geothermal and solar thermal technologies has been the most critical at this time. Constraints on water supplies and the need to reduce water use in coal and gas-fired power stations, in particular, are important for long term investment decisions but also have implications for carbon emissions.

The North American Region of WEC (NA) is presently consuming about one fourth of total world energy, of which Canada represents about 8%, USA close to 88% and Mexico 4%. The regional expectation for the next forty years is of a total growth of only 25%, although the total energy requirements on a global scale are expected to multiply by a factor close to 2.5, propelled basically by the impressive growth of Asia. The NA region will then represent a global energy requirement of about 13%. At the same time, a very important factor is that the most developed regions (i.e., Europe, Australia and NA) are registering great energy (and often, as well, irrigation water requirements) savings, while developing nations are demanding ever increasing amounts of energy and water.

Energy and water are intimately linked in almost all processes and in almost all countries, as will be seen in this progress report several times. However, they are not interchangeable goods. If there are large amounts of cheap, good quality energy, all other society requirements (food, water, housing and transport) can be readily met. But abundant amounts of water do not necessarily result in the solution of all energy demands, at least under the present technological paradigms.

Furthermore, in the larger countries on earth, India and China, it is often found that there are regions battling floods and other water excesses, while at the same time other regions suffer from acute draught.

An interesting insight can be gained from the water to inhabitant ratio for the WEC regions:

Region	m^3/inhab yr
Africa	236
Asia	590
Europe	539
LA & Caribbean	417
NA	1 422

It is a known fact that the figure for NA is grossly increased by the Canadian water figures. Otherwise, there is not a clear correlation between water available and the degree of development. On a closer inspection of water data, it can be seen that as a higher level of development is attained, the water required by irrigation diminishes, since industrial, urban and other water uses compete more successfully with agriculture than in developing countries. In NA, estimates of water use in agriculture in Mexico vary between 75% and 90% of all clear water available, while that figure is considerably lower in USA (41%) and Canada (12%), as is usually in developed countries. Development, it seems, is a promoter of water efficiency in food production.

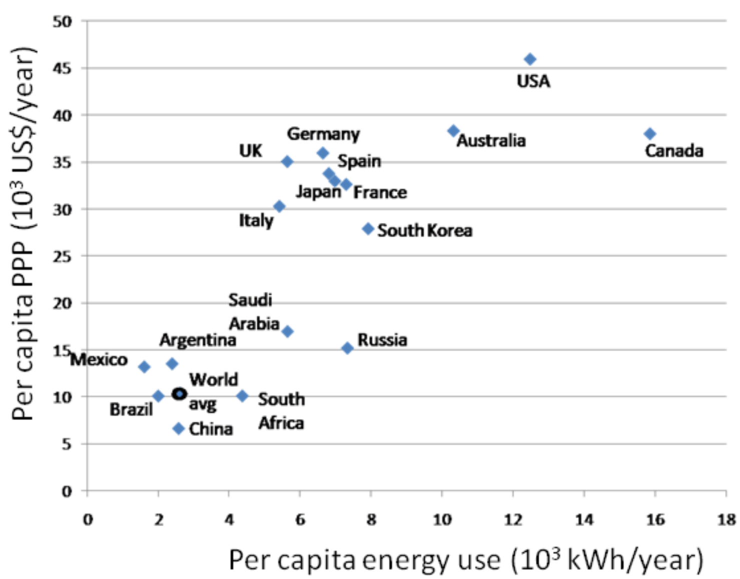
Energy consumption

World's energy availability and use is well documented in several reliable documents such as WEC's studies[2]. A summary of most relevant figures is found in the Annex. Some interesting numbers can be reproduced as follows. The power available related to its primary energy is found in the following table:

2 WEC Survey of Energy Resources 2007, http://www.worldenergy.org/publications/survey_of_energy_resources_2007/default.asp

Fuel type	Average power in TW		
	1980	2004	2006
Oil	4.38	5.58	5.74
Gas	1.80	3.45	3.61
Coal	2.34	3.87	4.27
Hydroelectric	0.599	0.933	0.995
Nuclear	0.253	0.914	0.929
Geothermal, wind, solar, wood	0.016	0.133	0.158
Total	**9.48**	**15.0**	**15.8**

The availability of energy is generally perceived as a good indicator of the degree of development of a country or a region. Energy available on a per capita basis is seen to increase as available cash is increased in any country. Access to purchase power can be determined by means of the purchase power parity (PPP) that the CIA publishes annually and is readily available online[3]. Development is alternatively measured by the economy on a per capita basis, such as yearly gross domestic income per capita (GDP/capita). The relationship between individual accesses to energy related to the per capita purchase power parity is seen in the figure below:



There is a general trend toward a higher national degree of development with energy available, as is generally perceived, and the data for the countries chosen

3 CIA World Factbook 2009

reveal a tendency toward a higher level of wellbeing (measured by PPP) with access to more energy (in kW h/y). However, as it can be seen, the relationship is not unique. Some countries seem to provide better comfort with a lower energy bill, as Mexico when compared with Argentina and Russia, or Germany when compared to Australia and Canada. In North America, Canada and the USA are attaining a very high living standard ($38 000 and 46 000 respectively) with an energy expenditure of between 13 000 and 16 500 kW h/y per capita while Mexico is well behind, with a GDP of $13 000 per capita and an energy bill of 1 800 kW h/y capita.

Increasing water demand

Global consumption of water is doubling every 20 years, more than twice the rate of human population growth, while population and over extraction in many regions of the world has reduced the ability of suppliers to meet the demand. During the last 70 years the global population tippled, but water withdrawals have increased over six times. Since 1940, the population growth averaged 1.5 to 2%, while at the same time water withdrawals have increased globally by an average rate of nearly 3% per year, although at a reduced rate of only 1.5% to 2% in the last decade.

According to United Nations, more than one billion people on earth already lack access to fresh drinking water. The demand for fresh water is expected to rise to near 60% more than the currently available amount.

Six billion people in the world are at present using about 54% of all accessible fresh water. By 2025 the human's share is expected to be 70%. If, however, the per capita consumption rises at the current rate, humankind would be using over 90% of all available fresh water within 25 years. These trends are obviously unsatisfactory, probably unrealistic and clearly unattainable.

Major water uses

Agriculture

About 70% of all available fresh water is used for agriculture. Pumping of ground water by farmers of the world exceeds natural replenishment by at least 160 billion cubic meters (160 km^3) a year.

One to three cubic meters of water is required to yield just one kilo of rice and 1 000 tons of water to produce one ton of grain. Current water withdrawals for irrigation are estimated at about 2 000 to 2 500 cubic kilometres per year.

Poor drainage and irrigation practices have led to water logging and saline pollution of approximately 10% of world's irrigated lands (30 million hectares of world's 255 million hectares of irrigated land) as per FAO. Saline pollution and water logging have dragged another 80 million hectares. Agriculture is responsible for most of depletion of ground water, along with up to 70% of pollution. Both are accelerating.

Most of world's important grain lands consume groundwater at unsustainable rates. Collectively water depletion in India, China, United States, North Africa and the Arabian Peninsula add up to 160 billion cubic meters a year- an amount equal to the annual flow of two Nile Rivers.

Industry

Water withdrawals for industry vary with the level of development:

World: 22% of total water use
High-Income countries: 59% of total water use
Low- Income countries: 8% of water use.

The annual water volume used by industry is estimated to rise from 752 km^3/year in 1995 to 1170 km^3/year in 2025, when the industrial use component is expected to represent about 24% of total use. Some 300-500 million tons of heavy metals, solvents, toxic, sludge, and other wastes accumulate each year from industry. Industries based on organic raw materials are the most significant contributors to the organic pollutants load with the food sector being the most important polluter.

Contribution of the food sector to the production of organic water pollutants:

High Income countries: 40%
Low-Income countries: 54%

More than 80% of the world's hazardous waste is produced in the United States and other industrial countries. In developing countries, 70% of industrial waste is dumped untreated into waters where they pollute the usable water supply.

Energy

World energy demand, especially for electricity, will increase greatly during the 21st century. Hydro power is the most important and widely- used renewable source of energy. It represents 19% of total electricity production. Canada is the largest producer of hydroelectricity, followed by the United States and Brazil.

Built to provide hydropower and irrigation water and to regulate river flow to prevent floods and droughts, they have had a disproportionate impact on the environment. There are now about 45 000 large dams in operation. In 140 countries they account for 19% of world's electricity generation and supply, and through irrigation almost 16% of world's food.

Hydro power plays a major role in reducing green house gas emission, although several critics have found that methane emissions from the embankments are too large.

Dams and the environment

The large water bodies created by the construction of dams are mainly meant to regulate the intrinsic variable river flows; whereas there are other site related dams, which depend on their management for recreation, fishing, power generation, water quality, etc. The very obvious site related effect of a reservoir is submerging of land consisting of vegetation, forest wild life and human settlements. Thus, besides natural factors influencing the hydrological system in a river basin, man's activity based on water-related needs resulting in creation of large water bodies interfaces in certain distinct ways with hydrosphere. Man attempts to modify certain natural constrains regarding water availability in time and space, carries out different land based activities which involve manipulation with run-off formation process. All these manipulations of the hydrological process are caused by the following:

(a) Use of surface and ground water which is returned either to the atmosphere as evaporation or to the river system as polluted waste water.

(b) Dam construction to facilitate on site use and to regulate its use.

(c) Manipulations of land-soil-vegetation system thereby modifying the ground water and run-off processes.

Thus all water resources' developments have environmental implications. The benefits of water schemes are obtained at the expense of certain natural assets, defined as environmental impacts, which primarily affect the population and cause ecological changes. These implications of water developments extend well beyond a river basin, and as such, to predict the overall effects with certainly has not been easy even by ecologists. For those engineers who have been in charge of the traditional method of development of water resources, it is not until very recently that the awareness of the public perception has crept in. It is now quite common to find that a new water resources project is unacceptable to a certain section of society while another segment fights for its implementation. This conflict has provided further opportunity to consider the water resources projects from the point of view of their environment impact.

The social and environmental impacts of dam activities have been broadly divided into three categories of sub-systems, namely, physical, biological and human.

The Aswan Dam in Egypt, one of the major dams, is a good example of impact on the physical sub-system. The project, which was conceived primarily for generating hydropower, has reportedly resulted in a reduced fish population, and at the same time has lowered the fertility of Nile Valley and increased the salinity in middle and Upper Egypt. These effects could have been examined at the planning stage and appropriate measures taken to reduce them to a minimum. The 1967 Koyna dam disaster in India drew the attention of the engineers to the possibility of inducing earthquakes by building large dams. It is reported that in general the seismic disturbances can be traced to the existence of inactive faults and the heights of the water column is probably more of an important parameter than the total volume.

Evolution of water quality

Irrigation schemes have created favourable ecological environments for parasitic and waterborne diseases that can be caused by protozoa, viruses, or bacteria, many of which are intestinal parasites. These diseases are not new but with stabilized perennial irrigation, the diseases have been introduced into previously uncontaminated areas. The number of cases from all parts of the world has now come to light where society has had to pay heavy prices for irrigation schemes in terms of the overall health of the region as well as ecological deterioration. A determined effort is thus necessary to minimize these prices and maximize the benefits of such development.

The above mentioned effects naturally have impacts on human beings, as a direct impact displacement of local inhabitants due to irrigation projects have resulted in serious problems. It is very difficult to put in words the complex relationship between tribal population and their land. It is experienced that resettlement of tribesman causes great cultural shocks when their new environment is altogether different from their own. The dislocation of people for the Aswan High Dam and Volta Dam and Ghana had created famine conditions and major catastrophe had to be averted by a World Food Program.

There are also many other water disruptions that affect directly the energy issue. Just to mention a few, the economic losses from the great floods of the 1990s are 10 times those of the 1960s in real terms. Floods account to about one third of all natural catastrophes and cause almost one half of all casualties and one third of all economic losses. In addition, the number of disasters has increased by a factor of five. There has been a 37-fold increase in insured losses since the 1960s. Given the trend towards multiple risk insurance cover, which normally includes flood losses, insurance losses will go up even more. Yet the majority without flood insurance will continue to suffer more.

On the other hand, the impacts of agriculture on water quality are less visible but over time as least as dangerous, because many of the fertilisers, pesticides, and herbicides used to boost agricultural productivity slowly accumulate in groundwater aquifers and natural ecosystems. Their impact on health may become clear only decades after their use, but their more immediate impact, through eutrophication, is on ecosystems. These problems accumulate in fresh and saltwater bodies, such as the Baltic and Black Seas.

Biodiversity losses have been only partly detected and measured. Just a few larger organisms are monitored or considered. But more than 100 freshwater-associated vertebrates (birds, amphibians, fish) became extinct after 1600, 55% of the extinctions for these three classes. Worldwide, 20% of freshwater fish are vulnerable, endangered, or extinct; 20% of threatened insects have aquatic larval stages; 57% of freshwater dolphins are vulnerable or endangered; and 70% of freshwater otters are vulnerable or endangered. About 75% of freshwater molluscs in the United States are rare or imperilled. With the possible exception of North America and parts of Europe, nearly all inland fisheries show signs of overexploitation. Cichlid fisheries in Lake Victoria have been replaced by Nile perch catches, but many of the endemic cichlids are extinct. Many stocks of salmonids in western North America have been lost.

In closing this section, however, it must be recognised that North America is faring much better in terms of its local and regional water for energy tensions than most of the world. The obvious immensity of water reserves in Canada, as compared with the growing water needs in USA, have sparked rough discussions among groups that prefer a national versus international situation preserved. The fact that water can be negotiated away from NAFTA reserves, has produced, in the past fifteen years, a heated debate in Canada and USA northern states.

Also, on a global scale, it must be noted that a vast majority of human beings live under the increasing stress of lacking water of appropriate quality and suffer from a generalised supply shortage of energy. Many countries don’t even have a national electric supply system, and local and national governments are seldom conceived as responsible for their building and operation. The legal systems are in those cases defective or downright inexistent. Group politics often prevail over the social interest, with the corresponding diminished quality of the environment and increased social unrest, and occasionally the loss of life. However, for all of mankind to live in harmony, these shortcomings should be translated into challenges and business opportunities, for all countries alike.

Sustainability

Political considerations over the security of supplies, environmental concerns related to global warming and sustainability will probably move the world's energy consumption away from fossil fuels in the next few decades. The concept of peak oil is often employed to show that we have already used about half of the available petroleum resources, those that are easier to extract, and predicts in the minds of many observers a decrease of future production on a global scale.

A government led move away from fossil fuels would most likely create economic pressure through carbon emissions trading and green taxation. Some countries are taking action as a result of the Kyoto Protocol, and further steps in this direction are proposed. For example, the European Commission has proposed that the energy policy of the European Union should set a binding target of increasing the level of renewable energy in the EU's overall mix from less than 7% today to 20% by 2020[4].

The antithesis of sustainability is a disregard for limits, commonly referred to as the Easter Island Effect, which is the concept of being unable to develop sustainability, resulting in the depletion of natural resources. These considerations, although far from resulting from a scientifically proven set of scenarios, are affecting the future development of energy production, transmission and distribution, as can be seen from a changing set of rules for fixing prices and allocating subsidies in many parts of the world, which definitely can affect the energy future significantly.

Technical options

The electricity industry, as well as the energy industry at large, has a number of short and longer term technical options for reducing water requirements and reversing water use trends in the energy business . These include increasing water use efficiency, dry or hybrid cooling, saline water cooling, recycled waste water, and purified recycled water, coal seam gas water, and desalination.

Options to dramatically reduce freshwater requirements of thermal electric power plants, such as saline water cooling and dry or hybrid cooling, are mostly applicable to new power plants, as there are significant cost and logistical issues associated with retrofitting dry cooling to existing power plants. Issues to be

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4 Europe Regional Workplan 2008-2010. http://www.worldenergy.org/work_programme/regional_programme/europe/default.asp

considered with saline water cooling include the cost of transporting fuel to power plants and planning constraints that apply in coastal areas.

Energy security

More than 1.6 billion people of the world still do not have access to modern energy systems with the prospect of 400 million more people during the next 20 years to be added to this figure, as per a WEC report. These will be mostly in the rural areas of the developing countries where unexploited hydro development potential is very high. To meet this energy requirements almost 100 million people will have to be given access to modern energy sources every year for the next 20 years against 40 million people per year between 1970 and 1990 and 30 million/ year since then.

A comparison of the per capita electricity consumption shows that while Norway has 26 280 kWh/yr, USA 13 800 kWh/yr, some of the African countries have less than 100 kWh/year. As per WEC publications, 500 kWh/year per capita supplies should be taken as the minimum to aim at ensuring a reasonable quality of life. But these countries have technical and economic hydro potential which, if exploited, can enhance per capita consumption drastically.

It is clear that even the development of all available hydro potential would still be insufficient to meet the needs of many countries. But great efforts should be made to maximize the use of hydro together with other renewable sources, to minimize the use of alternative energy sources which will be detrimental to the environment

Exploitation of even these potential may not be adequate to meet the requirement of many countries.

Hydropower is the world's leading sources of renewable energy. It is emission free and offers enormous system reliability benefits. The policy and guiding principle of hydro power development must aim at ensuring recognition of the value of the hydropower resources in its energy supply portfolio. This would support a responsible balance between economic and environment concerns.

Two developing countries in Asia, China and India, together have more than one third of the world population. Both have the problems of simultaneous floods and drought in different parts of the country at the same time. Additionally, the demand for energy is rapidly increasing. In the present scenario, the preferred solution has been to take advantage of the very large coal reserves, although many experts agree that they will have to develop the hydro resources later.

The World Declaration on Dams and Hydropower for African Sustainable Development adopted for Africa in 2008 by leading international organizations like IHA, WEC, ICOLD, ICID and others, shows the way for sustainable development of Water Resources and Hydro Power. Some findings are worth noticing, as stated in the section on Dams and the Environment.

2. WATER FOR ENERGY IN NORTH AMERICA

Water requirements for fuel production

Water consumption during liquid fuel production has been evaluated[5], through major steps of fuel lifecycle for five fuel pathways: bioethanol from corn, bioethanol from cellulosic feedstocks, gasoline from U.S. conventional crude obtained from onshore wells, gasoline from Saudi Arabian crude, and gasoline from Canadian oil sands. The analysis revealed that the amount of irrigation water used to grow biofuel feedstocks varies significantly from one region to another and that water consumption for biofuel production varies with processing technology. In oil exploration and production, water consumption depends on the source and location of crude, the recovery technology, and the amount of produced water re-injected for oil recovery.

Results also indicate that crop irrigation is the most important factor determining water consumption in the production of corn ethanol. Nearly 70% of U.S. corn used for ethanol is produced in regions where 10–17 liters of water are consumed to produce one liter of ethanol. Ethanol production plants are less water intensive and there is a downward trend in water consumption. Water requirements for switchgrass ethanol production vary from 1.9 to 9.8 liters for each liter of ethanol produced. Water is consumed at a rate of 2.8–6.6 liters for each liter of gasoline produced for more than 90% of crude oil obtained from conventional onshore sources in the U.S. and more than half of crude oil imported from Saudi Arabia. For more than 55% of crude oil from Canadian oil sands, about 5.2 liters of water are consumed for each liter of gasoline produced.

Other investigations present estimates of water requirements for future coal use in the USSR and the U.S[6]. Future levels of coal use were based on scenarios presented by IIASA in *Energy in a Finite World*. As a first step in the analysis, IIASA's coal scenarios were broken down from the scale of 'world region' to the scale of coal-producing region. This exercise revealed that American and Soviet coal targets, which seem feasible when viewed on the 'world-region' scale, may be difficult to attain on the coal-region scale due to insufficient coal reserves in some regions.

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[5] Water Consumption in the Production of Ethanol and Petroleum Gasoline, May Wu , Marianne Mintz, Michael Wang and Salil Arora, Environmental Management Springer New York Sept 2009

[6] Water and fire: Water needs of future coal development in the Soviet Union and the United States. Joseph Alcamo. Resources and Energy, Volume 6, Issue 2, June 1984, Pages 77-105

In the next stage of the analysis, an analytical model was developed, which describes on the coal-region scale the quantity of water required during different stages of coal development from mining to its final conversion to useful energy. Application of this model to each of ten principal coal-producing regions of the US and USSR suggested that roughly 1–2 tons of water will be consumed for every ton-equivalent (tce)[7] of coal-fuel delivered. However, these estimates assume a high degree of water conservation; with less emphasis on conservation, perhaps 50% more water will be required.

Water requirements for coal were then compared with competitive water uses in each U.S. coal region, as well as estimates of surface water supply in these regions. It was found that the amount of water needed for coal is small relative to other projected water uses such as agriculture and industry. However, after accounting for competitive water uses, there will probably be little or no water available for coal use during dry years in the Southwest and Northwest regions. Unless significant quantities of water can be stored for these years, coal development will have to displace other water uses in these regions.

The total amount of water used in refineries has been estimated to an average 65–90 gallons of water per barrel of crude oil[8]. The waste effluents from petroleum refineries typically require treatment before reuse or discharge. Stringent regulations on the discharge are likely to become stricter, with restrictions applying not only to industrial users, but also to municipal wastewater treatment operations. Industry faces a challenge to reduce the wastewater it generates and attain sustainable standards of operation.

Designs should incorporate economical solutions that address effluent segregation systems and the regeneration of effluents, and water scarcity is likely to force them to do so in the future. The concentration of wastewater pollutants depends on the amount of process steams, as well as the amount and the composition of the process and cooling water in the plant. Water reuse and recycling define the final concentrations of pollutants. The standard practice is to bring together contaminated wastewater into a single wastewater stream[9] and treat it further in a central treatment facility. The practice produces streams that are more difficult to treat and invariably leads to higher processing costs.

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7 One tone of coal equivalent is an energy unit equal to 29.39 GJ or 8.14 MWh.

8 W. Byers, W. Doerr, R. Krishnan, D. Peters, How to Implement Industrial Water Reuse. A Systematic Approach, vol. 1, AIChE, New York, 1995.

9 M. Sittig, Petroleum Refining Industry Energy Savings and Environmental Control, 1st ed., Noyes Data Corporation, New York, 1978.

Water requirements for electricity production

An important study analyses several scenarios that can yield specific forecasts of water requirements in this special energy sector[10]. It is included in the present report to further support the need for better overall understanding of the nexus between water and energy in the more complex environmental context and in the increased value of water as results of an increased market demand.

The first table illustrates the simple change in water demand that results from the chosen cooling process. Once-through cooling systems require some 400 more water withdrawals than recirculation systems, but result in a consumption of only about one tenth to one fifteenth.

Fuel source	Technology	Withdrawal (litres/kWh)	Consumption (litres/kWh)
Fossil	Once-through	142.5	0.38
Fossil	Recirculating	4.5	4.20
Nuclear	Once-through	174.6	0.38
Nuclear	Recirculating	5.7	5.70

Cooling nuclear plants[11]

Apart from any difference in thermal efficiency which affects the amount of heat to be dumped in the cooling system, there is no real difference in the amount of water used for cooling nuclear power plants, relative to coal-fired plants of the same size. It has nothing essentially to do with whether it is fuelled by coal, gas or uranium. However, some US studies quote a significant difference between coal and nuclear plants, this evidently being related to the (unstated) thermal efficiency of selected examples. The studies exclude nuclear plants on the coast, which employ salt water for cooling.

A major effect of the US Clean Water Act is to regulate the impact of cooling water use on aquatic life, and this is likely to drive the choice towards recirculating systems over once-through ones for freshwater. This will increase

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10 Estimating Freshwater Needs to Meet 2025 Electricity. Generating Capacity Forecasts, by Jeffrey Hoffmann, Sarah Forbes, and Thomas Feeley. U.S. Department of Energy/National Energy Technology Laboratory, June 2004

11 Cooling power plants. World Nuclear Association, November 2009. http://www.world-nuclear.org/info/cooling_power_plants_inf121.html

water consumption unless more expensive and less efficient dry cooling systems are used. This will disadvantage nuclear over supercritical coal, though flue gas desulfurization (FGD) demands for coal will even out the water balance at least to some extent.

For the heat transfer function the water is circulated continuously in a closed loop steam cycle and hardly any is lost. It is turned to steam by the primary heat source to drive the turbine to do work making electricity, and it is then condensed and retuned under pressure to the heat source in a closed system. A very small amount of make-up water is required in any such system. The water needs to be clean and fairly pure. A US Geological Survey report in 1995 suggested 98% of withdrawal is typically returned to source.

However, a second function for water in a power plant is to cool the system so as to condense the low-pressure steam and recycle it. As the steam in the internal circuit condenses back to water, the surplus or waste heat which is removed from it needs to be discharged by transfer to the air or to a body of water. This is a major consideration in siting power plants, and in a siting study all recommendations were for sites within 2 km of abundant water - sea or estuary.

Cooling water requirements for each type of plant were calculated from NETL data[12] and are tabulated as follows for "model" plants' consumption of fresh water:

Fuel and thermal cycle	Water requirements per unit of energy
Coal, once-through, subcritical, wet FGD	0.52 litres/kWh
Coal, once-through, supercritical, wet FGD	0.47 litres/kWh
Nuclear, once-through, subcritical	0.47 litres/kWh
Coal, recirculating, subcritical, wet FGD	1.75 litres/kWh
Coal, recirculating, supercritical, wet FGD	1.96 litres/kWh
Nuclear, recirculating, subcritical	2.36 litres/kWh

The figures are puzzling in that supercritical coal should use significantly less than less-efficient subcritical coal-fired plants and for recirculating use of cooling towers the large difference between subcritical coal and nuclear is unexplained. Clearly there are significant variables which are not accounted for though they must surely be relevant to NETL's projections.

However, a useful indicator is that once-through power plants will require 0.47-0.52 litres/kWh while recirculating (cooling tower) ones will need 1.75-2.36 litres/kWh produced. The last figures are significantly lower than the ones

12

Water Requirements for Existing and Emerging Thermoelectric Plant Technologies. DOE/NETL-402/080108. August 2008. Revised April 2009 presented in the previous table, which reinforces the concept that these matters must be better studied and measured in the future so as to provide decision makers with better data to analise their options.

Water demands for energy to 2050

The preceding section allowed for the identification of water needed for fuel production and for electricity generation. The projections by WEC[13] can now be employed to foresee the water requirements per region and year. A first exercise to develop the calculation of data is shown with the figures provided for the crisis scenario, specifically for North America.

First, it is assumed that coal is processed before using in any fashion, and the water required for the whole process is estimated at 1.5 (the mean of 1 – 2) tons of water per ton of coal equivalent, which has an energy content of 29.39 GJ or 8.14 MWh[14]. A factor is thus derived of 0.277 x 10^9 ton of water needed for each unit of energy in primary production, shown in the data measured in EJ.

Water required to process oil is estimated at 65 – 90 gallons per barrel of oil. In other units, a barrel of oil produces an equivalent of 6 GJ and requires a mean of 293 litres of water. The corresponding factor is thus 0.2929 x 10^9 ton of water needed per EJ of oil.

Non-conventional oil, and some of the fuel produced from biomass, can be reported to need at least three times more water than gasoline production. Some reports are even much higher. The factor is then proposed of 0.8846 x 10^9 ton of water per EJ produced with non-conventional oil.

Thermal electricity and nuclear electricity are considered to be the only electrical generation types that require cooling water. It is clear that once-through cooling requires about a tenth of the water consumed in recirculation cooling systems, and then the assumption is that all plants in the future will require about 0.5 litres/kWh, which results in a factor of about 0.5 x 10^6 ton of water per TWh produced in thermal power plants as well as nuclear.

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13 WEC Energy Scenarios to 2050. 19 March 2009 Crisis scenarios.

14 One oil barrel has an approximate energy content of 6.1 GJ. US Energy Information Administration (EIA), Independent Statistics and Analysis

Water requirements for several energy processes, in 10^9 tones of water[15]. Scenario crisis for North America.

Primary production source	2005	2020	2035	2050
Coal, lignite	7.95	8.52	10.3	13.2
Oil	7.50	11.5	15.6	16.7
Non-conventional oil	2.3	11.2	26.3	34.6
Thermal (combustion) electricity	1.76	2.17	2.62	3.03
Nuclear	0.46	0.43	0.46	0.54
Total	19.97	33.82	55.28	68.07

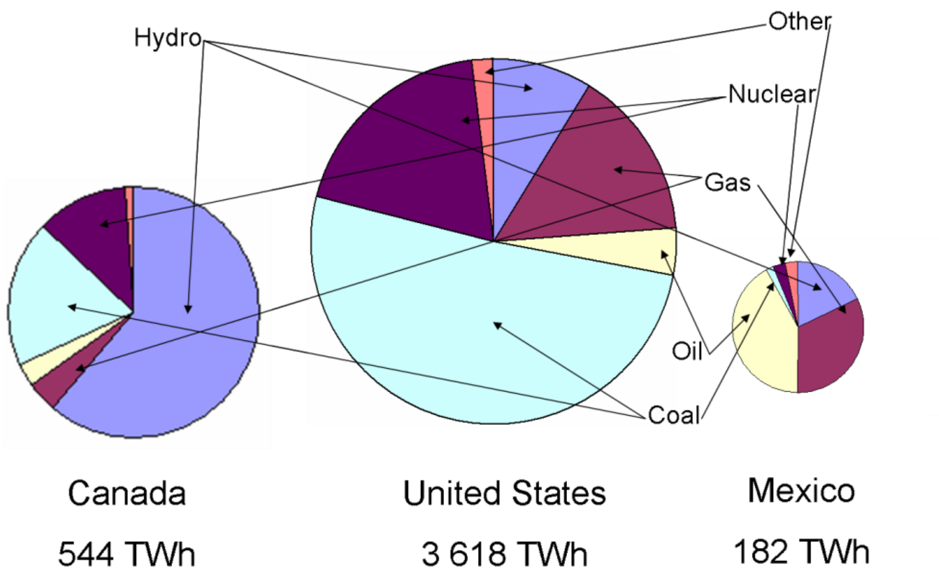
The obvious conclusion is that a very large proportion of water used in the energy sector rests with the production of fuel, although the assumptions employed in the calculation favour the lowering of the figures for electricity while using advanced once-through cooling technology. The impact of rising water requirements in cooling towers for recirculation could mean an increase of a factor of about ten in the requirements for electricity, and thus an increase in overall water for energy needs of probably 30% of those figures calculated, or even more.

The primary energy to produce electricity is also very diverse in the three countries, as the next figure illustrates[16].

In the figure, same colours are chosen for each primary fuel. Notice the small Canadian and Mexican dependence on coal as compared with theUSA, and the relatively large Canadian and Mexican fraction of hydro power. Gas and oil are very important both for USA and Mexico, but not for Canada. In the three countries, a fraction of about 2-3% of the total energy comes from other renewable sources, basically geothermal and wind. Nuclear power represents a sizeable fraction of energy supply both for Canada and USA, but not for Mexico, although the only nuclear plant in Mexico has been operating very satisfactorily and has never had any mishaps. Also, it has been awarded international recognition on safety and operation quality.

15 10^9 potable water tones is approximately 1 km^3

16 Retos y oportunidades ambientales en el dinámico mercado de electricidad de América del Norte (in Spanish), Informe del Secretariado al Consejo de conformidad con el Artículo 13 del Acuerdo de Cooperación Ambiental de América del Norte, June 2002



As stated before, there is no economic activity of importance that doesn't relate to energy and water availability. The various sectors of the economy require energy and water in many variable degrees, hence establishing overall figures of merit is very eluding. However, a certain effort in attaining them must be done if the issue of water for energy must be addressed on regional and world levels. The basic requirements and distribution of water withdrawal per NA country can be summarised as follows:

Country	*year*	***Total fresh water withdrawal km³/yr***	***Water withdrawal m³/p year***	***Domestic %***	***Industrial %***	***Agriculture %***	***Pop. (mill)***
Canada	1996	44.72	1 386	20	69	12	32.3
USA	2000	477.0	1 600	13	46	41	298
Mexico	2000	78.22	731	17	5	77	107
World	2000	5 000	769				6.5b

For comparison, the next table includes demographic projections to 2050 based on the world population extrapolations made by various expert groups (Photius) and the present relationship between water withdrawn per country and total energy consumption (in millions of tonne equivalents of oil). The last column is the result of dividing the per capita water withdrawal in each country by the per capita final energy consumption (*TPOE*) in tonnes of oil equivalent:

Country	Pop x 1 000 2010	Energy 2008	Per capita toe	water/energy 2008
Canada	34 419	270	7.85	176.6
USA	321 225	2340	7.28	219.8
Mexico	119 175	170	1.43	511.2
World	7 207 361	8 500	1.18	651.7

A quick conclusion to be drawn is that there seems to be a very marked water use diminishment as a country makes progress in developing its resources and industry, and thus increasing its per capita income, and a per capita marked improvement of both water and energy on a GDP per capita basis. It seems only logical that a country will use more efficiently its energy and reuse water more efficiently as it progresses, since progress always remains a threat to the environment that is confronted early in the development process: it seems that the more developed countries in Europe reached that turning point where energy is used with an ever increasing efficiency, and water is reused and recycled more intensively, shortly after World War II. It is apparent that the more developed regions of North America followed shortly thereafter; a technology trend is thus set that might be applicable to the rest of the world.

With these trends in mind, it is possible that the developed areas of North America will exhibit a constant (non-increasing) relationship between energy consumption on a per capita basis and also a constant (and possibly decreasing) relationship between energy and water requirements. Notice that new technology associated with renewable and energy efficiency also results in water savings, and the history of water in agriculture is very definite in terms of water savings with development. If these expectations are reasonable, the next table can be drawn. In the table, a per capita reduction of 30% in energy demand is assumed for the developed nations in NA, and of 10% for the rest of the region and the world:

Country	Pop x 1 000 2050	Energy consumption million tonnes equiv	Energy reduction 2050/2010 %
Canada	40 407	220	19
USA	397 063	2 023	14
Mexico	146 651	156	9
World	9 322 251	9 900	-16

Hence, it is possible to figure an approximate result to what the energy demand would be in the region in 2050, based on simple extrapolations of technology trends. The energy efficiency will come sooner to the most developed regions in the world, where water is more valuable and subject to market pressure. As found elsewhere, water is bound to be scarcer and more expensive in the least developed regions on earth, and energy demands to supply water of better quality will grow more markedly as development takes hold.

This study does not include a forecast or provision of what water requirements will be needed to supply in the future, as there are many water studies in this respect and their results vary considerably, depending on the scenarios and assumptions adopted. However, for the North American region, a particular scenario can be put forward based on the specific development trends of the three countries:

- Water withdrawal will increase as a proportion of population but at a pace reduced with improvements in technology

- Technology reduction of water needs for energy are taken with the same factor as for energy efficiency, stated above (30% developed regions and 10% in developing parts, on a per capita basis)

- First years in the second decade of the century will see non-increasing rates of water use per energy unit, and further in the future these rates (water per unit of energy delivered) will diminish until they represent the overall savings of 30% in developed regions and 10% in developing countries and the rest of the world.

Country	***Water withdrawal m^3/person year***	***Water withdrawal km^3/year (2050)***	***Savings, % 2050/2010***
Canada	1 386	39.2	13
USA	1 600	444.8	7
Mexico	731	96.5	-23
World	769	6 500	-29

The overall water withdrawal of the region might drop with respect to calculated values for 2010, if projected to 2050 with respect to the expected technology improvements in the energy sector and the reasonable coupling of its requirements to produce adequate water of the appropriate quality. The overall regional drop might reach about 3% with respect to present values, which might reduce water stress. However, the developing regions in the world will require more water in real terms, which means that investment in water recycling and reusing processes will have to increase dramatically.

3. WATER USE IN THE USA

Between 1950 and 1980 there was a steady increase in water use in the United States. During this time, the expectation was that as population increased, so would water use. Contrary to expectation, reported water withdrawals declined in 1985 and have remained relatively stable since then in spite of a steady increase in United States population. Changes in technology, in State and Federal laws, and in economic factors, along with increased awareness of the need for water conservation, have resulted in more efficient use of the water from the Nation's rivers, lakes, reservoirs, and aquifers.

Estimates of water use for 2000 indicate that about 408 billion gallons per day (abbreviated Bgal/d) were withdrawn for all uses during the year. This total has varied less than 3 percent since 1985 as withdrawals have stabilized for the two largest uses—thermoelectric power and irrigation. Freshwater withdrawals were about 80 percent of the total, and the remaining 20 percent was saline water. Saline water is defined as water with 1000 mg/L or more of dissolved solids; it is usually undesirable for drinking and for many industrial uses.

Thermoelectric power accounts for about half of total water withdrawals. Most of the water is derived from surface water and used for once-through cooling at power plants. About 52 percent of fresh surface-water withdrawals and about 96 percent of saline-water withdrawals are for thermoelectric-power use.

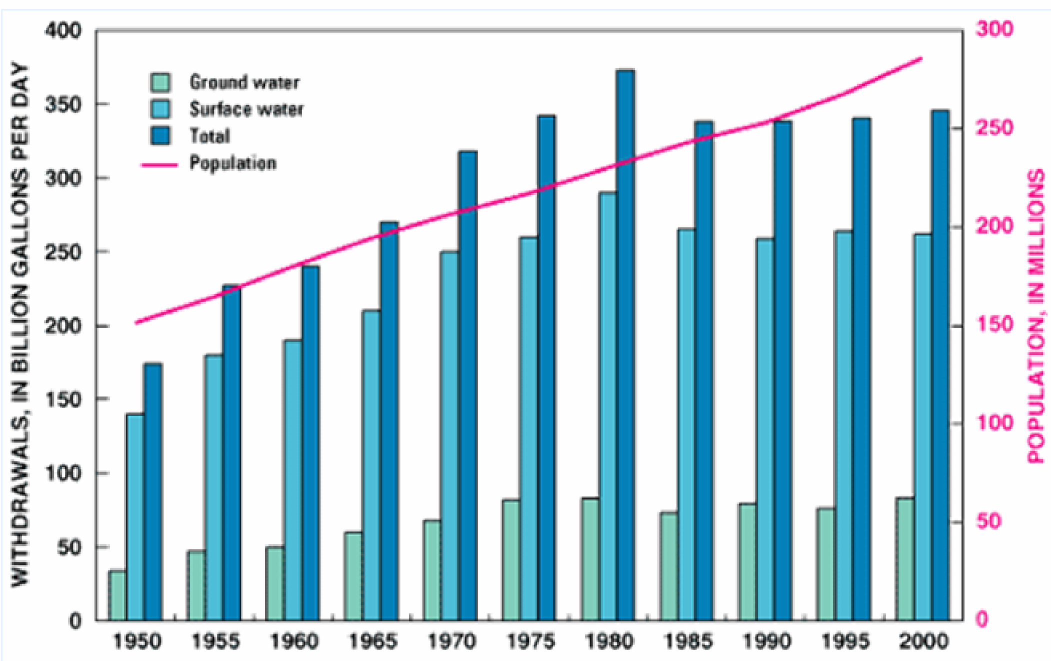
Irrigation accounts for about a third of water use and is currently the largest use of fresh water in the United States. Irrigation water use includes water used for growing crops, frost protection, chemical applications, weed control, and other agricultural purposes, as well as water used to maintain areas such as parks and golf courses. Historically, more surface water than ground water has been used for irrigation. However, the percentage of total irrigation withdrawals from ground water has continued to increase, from 23 percent in 1950 to 42 percent in 2000. Irrigated acreage more than doubled between 1950 and 1980, then remained constant before increasing nearly 7 percent between 1995 and 2000. The number of acres irrigated with sprinkler and microirrigation systems has continued to increase and now comprises more than one-half the total irrigated acreage.

Public-supply water is water withdrawn by public and private water suppliers, in contrast to self-supplied water, which is water withdrawn by a user. Public-supply water may be used for domestic, commercial, industrial, thermoelectric power, or public-use purposes. In 1950, only 62 percent of the United States population obtained drinking water from public suppliers, but by 2000 about 85 percent did. Public-supply water use has increased steadily since 1950 and accounted for about 11 percent of water use in 2000.

In 2000, self-supplied **industrial** water withdrawals accounted for about 5 percent of water use. Industrial water use includes water used for fabrication, processing, washing, and cooling, and also includes water used by smelting facilities, petroleum refineries, and industries producing chemical products, food, and paper products. Industrial water use has declined 24 percent since 1985 and in 2000 was at the lowest level since reporting began in 1950.

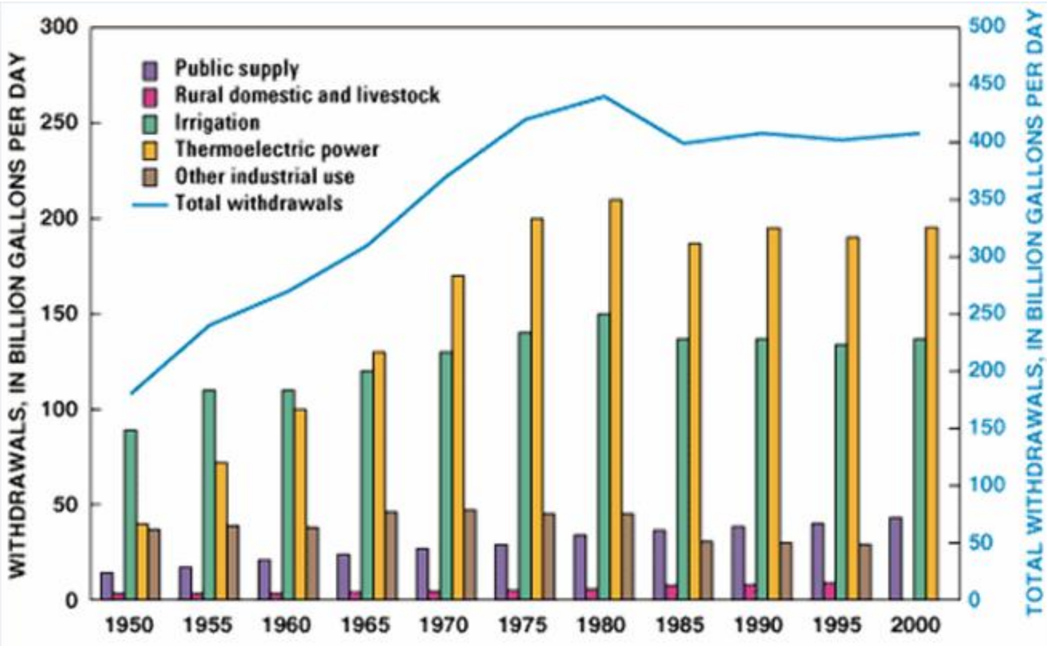
Other water uses. Combined withdrawals for self-supplied domestic, livestock, aquaculture, and mining activities represented about 3 percent of total water withdrawals for 2000. Self-supplied domestic withdrawals include water used for household purposes which is not obtained from public supply. About 43 million people in the United States self-supply their domestic water needs, usually from wells. Livestock water use includes watering, feedlots, and other on-farm needs for animals such as cattle, sheep, pigs, horses, and poultry. Aquaculture use is water used for fish hatcheries, fish farms, and shellfish farms. Mining water use encompasses water used for the extraction of minerals, including solids such as coal and ores, liquids such as crude petroleum, and gases such as natural gas. Also included is water used for processes done as part of the mining activity. Nearly all of saline ground-water withdrawals in 2000 were for mining.

Trends in water use



Trends in population and freshwater withdrawals by source, 1950-2000.

Estimates of water use show total withdrawals increased steadily from 1950 to 1980, declined more than 9 percent from 1980 to 1985, and have varied less than 3 percent since 1985. Total withdrawals peaked during 1980, although total U.S. population has increased steadily since 1950. Estimates of water use peaked during 1980 because of large industrial, irrigation, and thermoelectric-power withdrawals. Total withdrawals for 2000 were similar to the 1990 total withdrawals, although the U.S. population had increased 13 percent since 1990.



Trends in total water withdrawals by water-use category, 1950-2000. (Total withdrawals for rural domestic and livestock and for "other industrial use" are not available for 2000.)
Source: U.S. Geological Survey

Total withdrawals have remained about 80 percent surface water and 20 percent ground water since 1950. The portion of surface-water withdrawals that was saline increased from 7 percent for 1950 to 20 percent for 1975 and has remained about 20 percent since. The percentage of ground water that was saline never exceeded about 2 percent. The percentage of total withdrawals that was saline water increased from a minor amount in 1950 to as much as 17 percent during 1975 and 1990.

Energy and water interdependencies

Water is an integral element of energy resource development and utilization. It is used in energy-resource extraction, refining and processing, and transportation. Water is also an integral part of electric-power generation. It is used directly in hydroelectric generation and is also used extensively for cooling and emissions scrubbing in thermoelectric generation. For example, in calendar year 2000, thermoelectric power generation accounted for 39 percent of all freshwater withdrawals in the U.S., roughly equivalent to water withdrawals for irrigated agriculture (withdrawals are water diverted or withdrawn from a surface-water or groundwater source).

Water withdrawal statistics for thermoelectric power are dominated by power plants that return virtually all the withdrawn water to the source. While this water is returned at a higher temperature and with other changes in quality, it becomes available for further use. Many power plants, including most of those built since 1980, withdraw much less water but consume most of what they withdraw by evaporative cooling. In 1995, agriculture accounted for 84 percent of total freshwater consumption. Thermoelectric power accounted for 3.3 percent of total freshwater consumption (3.3 billion gallons per day) and represented over 20 percent of non-agricultural water consumption.

The Energy Information Administration (EIA) projects, assuming the latest Census Bureau projections in its reference case, the U.S. population to grow by about 70 million in the next 25 years and electricity demand to grow by approximately 50 percent. The EIA reference case is a projection which assumes that current laws, regulations, policies, technological progress and consumer preferences continue through the projection period as they have in the past. The EIA reference case provides a useful baseline against which possible changes to these assumptions can be evaluated.

Much of this growth is expected to occur in the Southeast, Southwest, and Far West, where water is already in limited supply. In a business-as-usual scenario, consumption of water in the electric sector could grow substantially, though increased demand for water would provide an incentive for technologies that reduce water use, thus dampening the increase in water use. Technologies are available that can reduce water use in the electric sector, including alternative cooling for thermoelectric power plants, wind power, and solar photovoltaics, but cost and economics, among other factors, have limited deployment of these technologies. In contrast, water use in the extraction and processing of transportation fuels is relatively small. However, as the U.S. seeks to replace imported petroleum and natural gas with fuels from domestic sources, such as biofuels, synfuel from coal, hydrogen, and possibly oil shale, the demand for water to produce energy fuels could grow significantly. Growth in energy demand occurs when freshwater resources and overall freshwater availability become strained from limitations on supply and increasing domestic, agricultural, and environmental demands.

Few new reservoirs have been built since 1980, and fresh surface-water withdrawals have levelled off at about 260 billion gallons per day. Many regions depend on groundwater to meet increasing water demands, but declining groundwater tables could severely limit future water availability. Some regions have seen groundwater levels drop as much as 300 to 900 feet over the past 50 years because of the pumping of water from aquifers faster than the natural rate of recharge. A 2003 General Accounting Office study showed that most state water managers expect either local or regional water shortages within the next 10 years under average climate conditions. Under drought conditions, even more severe water shortages are expected.

Depending on the water quality needs for particular applications, freshwater supplies can be augmented with degraded or brackish water. Water quantities available for use are dependent on the water qualities needed for each use. Increased use of brackish or degraded water may be required in some areas if water users can accept the quality limitations or can afford the cost of energy and infrastructure for water treatment.

Energy demands on water resources

These trends in energy use, water availability, and water demand suggest that the U.S. will continue to face issues related to the development, utilization, and management of the critical resources of water and energy. Increasing population will increase demand for water for direct use as well as for energy and agriculture. Historically, water withdrawals for domestic supplies have grown at about the same rate as the population, though recent trends show that rate growing about half the rate of population growth because of the implementation of water conservation measures in many regions. If new power plants continue to be built with evaporative cooling, consumption of water for electrical energy production could more than double by 2030 from 3.3 billion gallons per day in 1995 to 7.3 billion gallons per day.

Consumption by the electric sector alone could equal the entire country's 1995 domestic water consumption. Consumption of water for extraction and production of transportation fuels from domestic sources also has the potential to grow substantially. Meanwhile, climate concerns and declines in groundwater levels suggest that less freshwater, not more may be available in the future. Therefore, the U.S. should carefully consider energy and water development and management so that each resource is used according to its full value. Since new technologies can reduce water use, there will be a great incentive for their development by the public and private sectors. Given current constraints, many areas of the country will have to meet their energy and water needs by properly valuing each resource, rather than following the current U.S. path of largely managing water and energy separately while making small improvements in freshwater supply and small changes in energy and water-use efficiency.

Climate change and energy in the USA

An expert report concludes that, based on what we know now, there are reasons to pay close attention to possible climate change impacts on energy production and use and to consider ways to adapt to possible adverse impacts and take advantage of possible positive impacts. Although the report includes considerably more detail, here are the three main questions along with a brief summary of the answers:

- How might climate change affect energy consumption in the United States? The research evidence is relatively clear that climate warming will mean reductions in total U.S. heating requirements and increases in total cooling requirements for buildings. These changes will vary by region and by season, but they will affect household and business energy costs and their demands on energy supply institutions. In general, the changes imply increased demands for electricity, which supplies virtually all cooling energy services but only some heating services. Geographic distribution of expected climate changes is available. Other effects on energy consumption are less clear.

- How might climate change affect energy production and supply in the United States? The research evidence about effects is not as strong as for energy consumption, but climate change could affect energy production and supply

(a) if extreme weather events become more intense,
(b) where regions dependent on water supplies for hydropower and/or thermal power plant cooling face reductions in water supplies,
(c) where temperature increases decrease overall thermoelectric power generation efficiencies, and
(d) where changed conditions affect facility siting decisions.

Most effects are likely to be modest except for possible regional effects of extreme weather events and water shortages.

- How might climate change have other effects that indirectly shape energy production and consumption in the United States? The research evidence about indirect effects ranges from abundant information about possible effects of climate change policies on energy technology choices to extremely limited information about such issues as effects on energy security. Based on this mixed evidence, it appears that climate change is likely to affect risk management in the investment behaviour of some energy institutions, and it is very likely to have some effects on energy technology R&D investments and energy resource and technology choices. In addition, climate change can be expected to affect other countries in ways that in turn affect U.S. energy conditions through their participation in global and hemispheric energy markets, and climate change concerns could interact with some driving forces behind policies focused on U.S. energy security.

Because of the lack of research to date, prospects for adaptation to climate change effects by energy providers, energy users, and society at large are speculative, although the potentials are considerable. It is possible that the greatest challenges would be in connection with possible increases in the intensity of extreme weather events and possible significant changes in regional water supply regimes. But adaptation prospects depend considerably on the availability of information about possible climate change effects to inform decisions about adaptive management, along with technological change in the longer term.

Given that the current knowledge base is so limited, this suggests that expanding the knowledge base is important to energy users and providers in the United States. Examples of research priorities – which call for contributions by a wide range of partners in federal and state governments, industry, nongovernmental institutions, and academia – are identified in the expert report.

Sector	National Effects	Regional Effects	Other Effects	Comments
Residential and Commercial Buildings Annual Energy Use	Slight decrease or increase in net annual delivered energy; likely net increase in primary energy	Space heating savings dominate in North; space cooling increases dominate in South	Overall increase in carbon emissions	Studies agree on the direction of regional effects; national direction varies with the study
Peak Electricity Consumption	Probable increase	Increase in summer peaking regions; probable decline in winter peaking regions	Increase in carbon emissions	Most regions are summer-peaking due to air conditioning
Market Penetration of Energy-Using Equipment	Increase in market penetration of air conditioning	Air conditioning market share increases primarily in North	—	Very few studies. Strength of the effect is not clear.

Table 2.2. Summary of Qualitative Effects of Global Warming on Energy Consumption in the United States

Freshwater Needs of Electricity Generation in North America[17]

17 Estimating Freshwater Needs to Meet 2025 Electricity. Generating Capacity Forecasts, by Jeffrey Hoffmann, Sarah Forbes, and Thomas Feeley. U.S. Department of Energy/National Energy Technology Laboratory, June 2004

This important study analyses several scenarios that can yield specific forecasts of water requirements in this special energy sector. It is included in the present report to further support the need for better overall understanding of the nexus between water and energy in the more complex environmental context and in the increased value of water as results of an increased market demand.

The first table illustrates the simple change in water demand that results from the chosen cooling process. Once-through cooling systems require some 400 more water withdrawal than recirculation systems, but result in a consumption of only about one tenth to one fifteenth.

Table 1 – Cooling System Water Needs[8]

Fuel Source	Technology	Withdrawal (gal/kWh)	Consumption[9] (gal/kWh)
Fossil	Once-Through	37.7	0.1
	Recirc (Wet Tower)	1.2	1.1
Nuclear	Once-Through	46.2	0.1
	Recirc (Wet Tower)	1.5	1.5

In the following table the total projected changes in generating capacity are shown, to year 2025. Figures from 1995 are retained to illustrate the overall change in electric power capacity, which have resulted in an increase of about 15%.

Table 2 -- Projected Changes in Power Generating Capacity, GW[11]

	1995	2001	2002	2010	2015	2020	2025
U.S. Electric Power Generating Capacity							
Net Generating Capacity							
Coal Steam	304.9	310.7	310.9	310.2	321.5	353.5	412.3
Other Fossil Steam[12]	139.6	134.9	133.6	106.1	102.7	101.1	96.5
Combined Cycle	14.7	65.5	110.4	160	191.7	217.3	235.2
Nuclear Power	99.2	98.2	98.7	100.6	102.1	102.6	102.6
Total	558.4	609.3	653.6	676.9	718	774.5	846.6
Cumulative Power Capacity Additions (Planned and Unplanned) - 1995 Baseline							
Coal Steam	0.0	5.8	6.0	12.8	24.6	57.8	117.7
Other Fossil Steam	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combined Cycle	0.0	50.8	95.7	145.3	177.0	202.7	220.6
Nuclear Power	0.0	0.0	0.5	2.4	3.9	4.4	4.4
Total	0.0	56.6	102.2	160.5	205.5	264.9	342.7
Cumulative Power Retirements - 1995 Baseline							
Coal Steam	0.0	0.0	0.0	7.5	8.0	9.2	10.3
Other Fossil Steam	0.0	4.7	6.0	33.5	36.9	38.5	43.1
Combined Cycle	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Nuclear Power	0.0	1.0	1.0	1.0	1.0	1.0	1.0
Total	0.0	5.7	7.0	42.0	45.9	48.8	54.5

The calculation of water required in the future can be done under 6 general scenarios, or cases, as stated below. Probably the most realistic will eventually prove to be Case 6.

• Case 1 - All additions and retirements occur at facilities using freshwater.
• Case 2 - Additions and retirements are proportional to current source withdrawals
(70% freshwater/30% saline).
• Case 3 - All additions and retirements occur at facilities using saline water.
• Case 4 - Additions occur at freshwater facilities, while retirements occur at saline
facilities.
• Case 5 - Additions occur at saline facilities, while retirements occur at freshwater
facilities.
• Case 6 – All retired coal units in Table 2 are assumed to be once-through cooling.
These units are repowered rather than retired but the existing once-through cooling
system continues to be used. New capacity additions in Table 2 are reduced by the
repowered units.

The analysis projects that by 2025 daily freshwater withdrawals required to meet the needs of U.S. thermoelectric power generation may decrease to 113 billion gpd or increase to 138 billion gpd depending upon the assumptions made about source of cooling water and type of cooling technology employed for new and retired capacity.

This compares with USGS estimates that thermoelectric power plants withdrew approximately 132 billion gallons per day (gpd) of freshwater in 1995 and approximately 136 billion gpd of freshwater in 2000 -- an approximate 3% increase from their 1995 estimate.

Table 3 presents the range of potential daily freshwater withdrawal based on the cases described above.

Table 3 – Projected Power Sector Freshwater Withdrawals

Freshwater Withdrawals - Billion gallons/day	1995	2001	2002	2010	2015	2020	2025
Case 1	132.1	131.0	131.1	120.0	119.8	119.6	119.2
Case 2	132.1	131.3	131.4	123.6	123.5	123.3	123.1
Case 3	132.1	132.1	132.1	132.1	132.1	132.1	132.1
Case 4	132.1	132.5	133.0	134.2	135.2	136.4	137.9
Case 5	132.1	130.6	130.2	117.9	116.6	115.3	113.4
Case 6	132.1	132.4	132.7	133.3	134.6	135.6	136.8
Maximum	132.1	132.5	133.0	134.2	135.2	136.4	137.9
Minimum	132.1	130.6	130.2	117.9	116.6	115.3	113.4

Because a significant fraction of water withdrawn for use in an evaporative cooling tower is lost through evaporative consumption (see Table 1) projected change in consumptive use was also estimated. The USGS estimates that in 1995, freshwater consumption by U.S. thermoelectric power plants was approximately 2.5% of withdrawals, or 3.3 billion gpd.

This study projects that by 2025, 3.3 to 8.7 billion gpd may be consumed. Table 4 presents the range of potential daily freshwater consumption based on the cases described above.

Table 4 -- Projected Power Sector Freshwater Consumption

Freshwater Consumption - Billion gallons/day	1995	2001	2002	2010	2015	2020	2025
Case 1	3.3	3.7	4.1	5.2	6.2	7.3	8.7
Case 2	3.3	3.6	3.9	4.7	5.4	6.1	7.1
Case 3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Case 4	3.3	3.7	4.1	5.3	6.3	7.4	8.8
Case 5	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Case 6	3.3	3.6	3.9	4.5	5.8	6.7	7.8
Maximum	3.3	3.7	4.1	5.3	6.3	7.4	8.8
Minimum	3.3	3.3	3.3	3.3	3.3	3.3	3.3

It appears that the water consumed in energy processes in North America will not increase very much on an overall continental basis, and will very likely still be a small fraction of water demanded if compared with irrigation and agriculture. The EIA projects about a 52% increase in generating capacity by 2025 compared to 1995, much of it happening after 2005. Nearly 196 GW of the more than 342 GW of new capacity will be thermoelectric generation. This analysis indicates that the withdrawal of freshwater to operate the 196 GW of new thermoelectric generating capacity in 2025 will range from a 14% decrease to a 4% increase compared to freshwater withdrawals in 1995. Changes in freshwater consumption in 2025 will range from a 2% decrease to as much as a 165% increase compared to 1995.

Similar trends in freshwater withdrawal and consumption are projected for the additional coal-based generating capacity that will come on line by 2025.

Overall freshwater demand reduction

According to a U.S. Geological Survey report[18], the U S is using less water now than during the peak years of 1975 and 1980, despite a 30 percent population increase during the same time period. The report shows that in 2005 Americans used 410 billion gallons per day, slightly less than in 2000. The declines are attributed to the increased use of more efficient irrigation systems and alternative technologies at power plants. Water withdrawals for public supply have increased steadily since 1950–when USGS began the series of five-year trend reports–along with the population that depends on these supplies.

Nearly half (49 percent) of the 410 billion gallons per day used by Americans was for producing electricity at thermoelectric power plants. Irrigation accounted for 31 percent and public supply 11 percent of the total. The remaining 9 percent of the water was for self-supplied industrial, livestock, aquaculture, mining and rural domestic uses.

"Because electricity generation and irrigation together accounted for a massive 80 percent of our water use in 2005, the improvements in efficiency and technology give us hope for the future," Castle said. The report also underscores the importance of recognizing the limits of the drinking water supplies on which the growing population depends. While public-supply withdrawals have continued to increase overall, per capita use has decreased in many states during recent decades.

The largest uses of fresh surface water were for power generation and irrigation, and the states with the largest fresh surface-water uses were California, Texas, Idaho and Illinois. The largest use of fresh groundwater was irrigation, and the states with the largest fresh groundwater uses were California, Texas, Nebraska and Arkansas.

The average amount of water withdrawn to produce a kilowatt-hour of electricity in the United States has decreased steadily from 1950 to 2005. This change is attributable to an increase in the number of power plants that use alternatives to once-through cooling, as underlined in the previous chapter of the present study.

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18 Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009. Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.

4. WATER AND ENERGY IN CANADA

The richest water country on earth

As stated before, Canada has the highest availability of water on earth, if measured by almost any standard, including the international water assessment practices. On a per capita basis, Canada enjoys a comfortable water margin, both on a world level and at NA level. As seen on page 17, the amount of water employed for each energy unit is about 80% of what is used in USA and less than 35% in Mexico, which reveals that Canada is also very efficient in employing water for energy. The coupling of proper energy production practices with a cold weather results in little water consumed by the energy sector[19].

On a world basis, with 7% of the earth's land surface, Canada possesses about 7% of the world's renewable freshwater. The nation's modest population in relation to its immense land area and correspondingly large water resource has much to do with the local perception of unlimited freshwater availability. Canadians use more than double the average European freshwater per capita. However, the very richness of the country, in this and other respects, has been examined as a possible cause of concern as it is variedly considered a subject of international trade and a growing worry due to climate change[20]. In the present study, only a brief mention is made of possible international concerns of the national growing debate around the subject of water for energy, as the available data suggests that Canada might be the last country on earth to suffer from stress in this respect.

A first clarification

In Canada, policy research and the science-policy interface occur inside government, at universities, or to a lesser extent, in think-tanks and lobby groups. In the US, think-tanks play a much larger role in both research and influencing the public policy agenda, although government and universities are also important contributors. While linkages already exist between Canadian and US governments, Canadian and US academics, and Canadian and US think-tanks,

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19 Environment Canada. www.ec.gc.ca

20 Ibid, Key Water S&T Reports, www.ec.gc.ca/INRE-NWRI/default.asp

the links between Canadian universities and US think-tanks are – at best – weak. Thus, there is potential gain to be had in improving those links. For example, links could be fostered between individual researchers, between institutions, or along topical lines. Among these possibilities, a topical approach to strengthening these ties is likely to be the most useful for developing strong, long-lasting linkages.

Several themes have been suggested for piloting an initiative to strengthen such links. One such theme is fresh water. Several aspects of fresh water give rise to policy issues, many of which are common to both Canada and the US. On June 15, 2007, the Government of Canada's Policy Research Initiative (PRI) organized a planning meeting to identify freshwater topics that could be pursued. The participants decided to examine areas of collaboration on "Water and Climate Change" and "The Energy-Water Nexus," and how different systems of governance, different needs, and different political drivers have influenced current science and policies in Canada and the US. The bulk of these findings are retained in the present report since they represent a very accurate state of the present situation and perspectives in Canada as regards to the present issue.

On October 2, 2007, the Woodrow Wilson International Center for Scholars hosted a meeting in Washington, D.C., to explore possible areas and means of improving Canada-US policy research links in fresh water policy in the context of "Water and Climate Change" and the "Energy-Water Nexus".

The roundtable meeting was organized by the PRI and chaired by Dr. Howard Alper and Dr. Heather Munroe-Blum. An equal number of Canadian and American experts in fresh water science and policy participated, observed by senior Government of Canada officials from Environment Canada, Natural Resources Canada and Foreign Affairs and International Trade Canada.

The content of this section reflects the presentations and discussions that occurred on October 2, beginning with a review of "Water and Climate Change," followed by "The Energy-Water Nexus." The section also includes a synthesis of the policy "pushes" and science "needs" identified by the participants, and closes with a short discussion of conclusions and next steps. A link to background materials is provided at the end of the text. This material, which was prepared by participants, will provide additional information on many of the subjects discussed in the document.

Water use in the energy sector

The energy sector is an intense user and consumer of water. For example, thermal power generation is the largest user of water in Canada and one of the two largest in the United States. Beyond the generation of electricity, large amounts of water are needed for hydro power; oil and gas extraction and production; refining and processing various energy sources; and transportation. This heavy use of water could affect both water quantity and quality, especially in areas of intensive use.

Water efficiency has improved in the energy sector by more than 66 percent over the past 50 years, but with energy use increasing seven-fold over this period, water use in the sector is increasing. Furthermore, the areas of highest growth and highest energy demands often have the least amount of water, and as water shortages increase, supply issues will become critical. In the US, 36 states are predicting water shortages in the next decade, suggesting that solutions need to be found now.

Water-efficient technology and innovation will continue to be essential in the energy sector. Many opportunities for improvements with technology and alternative water sources are being explored. For example, air cooling can be used as an alternative to water cooling in thermal power generation, although its benefits are limited to cooler climates – this method is not efficient in warmer climates, where water shortages are most severe. Investing in technology will not only benefit the environment, but the bottom line – which is an important driver for industry. In some cases, a relatively small investment in existing technologies could lead to considerable savings.

One industry that is in urgent need of innovation is the oil sands. In Canada, water use discussions in the energy sector are largely focused on oil production in Alberta, which is second only to Saudi Arabia in oil reserves. Oil-sand production reached one million barrels a day in 2005, and is expected to double by 2015.

Extracting bitumen from the oil sands is very water-intensive. On average, 2 to 2.5 barrels of water are needed to produce 1 barrel of oil, and most of the water that is withdrawn to extract the oil is too toxic to be returned. Only 10 percent of the water that is removed from the Athabasca River is returned. Such large withdrawals are decreasing the flow of the Athabasca River and many of the tributaries that feed the Mackenzie River. The changing climate is also contributing to decreasing these rivers' flow. This reduced flow is particularly problematic in winter, when there is not enough water available for oil production if the province's in-stream flow guidelines are to be met. Water will be the limiting factor for this industry unless more efficiency is found and implemented. This will be a huge innovation challenge and opportunity for Canada.

Another rapidly growing energy sector that is gaining a lot of attention is biofuels. The use of ethanol is gaining political favour because it is perceived to be an environmentally friendly alternative to fossil fuels. However, there are still a number of environmental concerns associated with this industry, including the negative impacts it will have on aquatic ecosystems. For example, the majority of corn production in the US occurs in existing agricultural areas that have some of the highest nutrient and pesticide levels in the country. As corn production increases, water quality problems will only worsen, both locally and downstream. Furthermore, marginal agricultural land may be brought into production to accommodate the growing demand for corn. To achieve adequate yields from these areas, above average amounts of water, fertilizer and pesticides may be required, thereby putting additional stress on ecosystems.

In addition, new ethanol plants are proposed in areas that have declining aquifers, thus causing additional strain in water-stressed environments. With corn production expected to grow to 93 million acres in the next few years, there is a potential for serious water quality impacts and water shortages. The gains that are linked with biofuel renewable technologies may not be enough in terms of minimizing the environmental effects associated with our energy use. In the short to medium term, it may be more beneficial to invest in reducing the impacts of non-renewable energy supplies, rather than rushing into renewable technologies for which the true environmental gains and costs are not completely recognized.

Another area of research that is relevant to the energy-water nexus is the impact of carbon reduction strategies on water. Because of the strong interdependence of water and energy resources, it is thought that carbon reduction strategies, such as a cap and trade system, may lead to more efficient water use. Carbon sequestration, whereby carbon dioxide is pumped into deep aquifers, has unknown implications for water. If this practice is to increase, we must determine the potential impacts for drinking water and groundwater dynamics in general.

General discussion

Following the organized discussions on water and climate change and the energy-water nexus, the participants were asked to identify the policy and science needs that they felt to be the most pressing. From this query, there was significant convergence on the following themes:

- Data and Modelling
- Water-Related Research for the Energy Sector
- Watershed Management
- Policy and Programs to Increase Water Efficiency, and
- In-stream Flow Requirements and Ecosystem Needs.

The following sections discuss the identified needs surrounding these topics separately, although it should be noted that there are several science and policy links between them.

Data and modelling. There appear to be several needs with respect to data. First, there is a consensus that existing measurement and monitoring programs are insufficient. More capacity is needed to collect data that will improve our understanding of hydrologic systems and how our water resources are being used. However, although more data and trend assessments will help to inform better management decisions, we will need to resolve issues that arise from inconsistencies. In many cases, data from shared watersheds do not match up at political borders, making it difficult to understand what is going on. Neighbouring jurisdictions will need to work together to ensure that their respective measurement programs are complementary.

We also need to share data and information relating to water needs with municipalities and other local stakeholders, and effectively communicate to policy-makers. Furthermore, we need to link empirical data to forecasting models to compare model outputs with what is happening on the ground. Better data will inevitably help improve hydrologic models. However, other upgrades are needed. Linking hydrologic and climate models could be very beneficial and informative, specifically for predicting potential climate related impacts on water supply. Mainstreaming climate issues in general seems to be preferred from both a modelling and planning perspective. (It should be noted that there are other types of biofuels and sources of ethanol that are not discussed here, which will have varying environmental benefits, impacts, and concerns).

Water related research on the energy sector

There are two specific issues relating to water and energy that urgently need research:

- The impact of corn-based biofuels on water quality and supplies, and
- Water use in bitumen extraction.

First, given the rapid growth of the biofuel industry, it is essential that the full implications of increased corn production be understood in terms of the effects on water quality and aquatic ecosystems. Corn production is expected to expand rapidly, which would increase non-point-source pollution in areas that are already heavily contaminated with nutrients and pesticides. Additional concerns, which could be exacerbated in a changing climate, stem from the energy and water requirements of ethanol plants and their placement in locations that have depleting groundwater supplies. If biofuels are found to have an unacceptable impact on the environment, there is an opportunity to influence renewable energy policies before additional damage is done.

- Oil production in Alberta is thriving, but the rapid growth of the oil sands industry could be limited by water if innovative solutions are not found.

As discussed, bitumen extraction is water-intensive and the region is experiencing serious water availability concerns. There is a need for research and development in this area: efforts and resources should be focused on finding water efficient technologies and alternatives so that Canada can benefit sustainably from this valuable resource.

More generally, research is needed to find innovative technology throughout the energy sector; to improve our understanding of the links between energy consumption and water; and to determine how efficiencies applied to one resource can influence the other.

Conclusions and next steps

The exchange between the meeting's participants was rich and informative and the level of convergence on important issues was both telling and encouraging. In terms of next steps, it is felt that there is value-added in continuing bilateral discussions: several options for collaboration and advancement of key issues were discussed.

First, it will be important to engage stakeholders that were not present at the October meeting: specifically, industry representatives from the energy sector and American academia. With those key inclusions, both place-based and issue-based collaborations were proposed as next steps.

The participants suggested forming political and academic partnerships in important transboundary regions, such as the Great Lakes, to advance the research topics discussed. They also suggested comparing two jurisdictions with comparable geography on either side of the border (such as Saskatchewan and Kansas) to see how different institutions are addressing water and climate issues on a similar landscape. A comparison of legislative solutions and approaches at the national level may also prove to be a useful exercise.

There was consensus that much of the expertise to research the scientific needs resides in academia in both the US and Canada. As a next step, the participants suggested that a university consortia be established to address one or two of the themes that have emerged from the meeting's discussions, such as in-stream flow needs. The consortium could address specific questions and concerns and help to develop a common understanding of the topic despite differences in research methods. Regardless of the approach, any further collaborations and discussions should be multidisciplinary, with active participation from industry, government and relevant research institutes, and should focus on science policy integration.

In addition to discussing important topics related to water, a key purpose of the October meeting was to strengthen links between Canadian and US think-tanks and academics. Given the level of exchange between participants, it is believed that new connections have been formed. The strength of these connections will be demonstrated by continued and sustained interaction. The identification of key policy and science needs has created an opportunity to advance key issues that are important to both Canada and the US in a collaborative, multidisciplinary and productive manner, and to communicate the importance of water to those beyond the water community.

5. WATER AND ENERGY IN MEXICO

A general appraisal

Mexico, just like so many developing countries, face daunting water resources challenges as the needs for water supply, irrigation and hydroelectricity grow; as water becomes more scarce, quality declines and environmental and social concerns increase; and as the threats posed by floods and droughts are exacerbated by climate change. As a consequence, there is a high and increasing demand for World Bank engagement[21].

As is generally accepted, water resources management and development are central to sustainable growth and poverty reduction. Managing water resources involves a dialectic between integration and subsidy. Within the World Bank, business strategies for specific water-using sectors (such as water and sanitation, irrigation and drainage, and hydropower) are, in accordance with the subsidiarity principle, determined primarily as part of the strategies for these sectors. This strategy focuses on how to improve the development and management of water resources, while providing the principles that link resource management to the specific water-using sectors.

For these reasons, this approach imposes a criterion for Mexican water allocation, which is largely governed by political and social interests, regardless of any consideration for the real value of water. About 85% of all fresh water in Mexico is given to agricultural societies, and most of it is given free of charge. The situation is very far from being changed solely by market forces, by international loans or by national policy: water is largely a business controlled by agricultural politicians. Other water uses, remarkably that of cities and for human consumption, are usually left unattended. Water markets are developing with difficulty in an uncertain legal and regulatory framework, and most of the drinking water is sold bottled by private firms. Municipal water is rated, by law, at a transaction cost of about US $ 0.55 per cubic meter, which is very heavily subsidised.

Water quality and availability

Concern for water quality is as recent as 1989, when the federal government organisation, the National Water Commission (CONAGUA, for its Spanish initials)

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21 Water Resources Sector Strategy. Strategic Directions For World Bank Engagement, 2003 (88pp)

was created[22]. Water quality records are then not older than twenty years, and many academics doubt that the national capacity for keeping good records is any good for decision making. However, official records indicate that, during the last decade or so, the amount of water deemed of excellent quality has been reduced in about 32%, while the amount of water considered as polluted has increased by nearly the same amount. The fraction of the available water that is said to be heavily contaminated has been kept constant at 12% of the total.

Water use and rainfall

The largest fraction of agricultural land is still irrigated directly by rainfall, although a growing portion is located in hydraulic districts. The strong dependence of food production on rainfall is depicted in the following figures[7]. The largest demand for agriculture irrigation is centred in the northern regions of the country, where solar irradiance is highest but rainfall is lower. Rain exceeds one metre in the southern states of Guerrero, Oaxaca and Chiapas, where most of the Indigenous population concentrate, which retains very ancient agricultural practices which are generally considered very sustainable, although overpopulation is exceeding land capabilities in many regions. At the same time, the Gulf states of Tabasco and Campeche, as well as the southern portion of Veracruz and the north of Chiapas can have several metres of rain in an average year, creating lasting floods and the loss of life and property. The flat lands of this region have suffered from flooding during all of recorded history.

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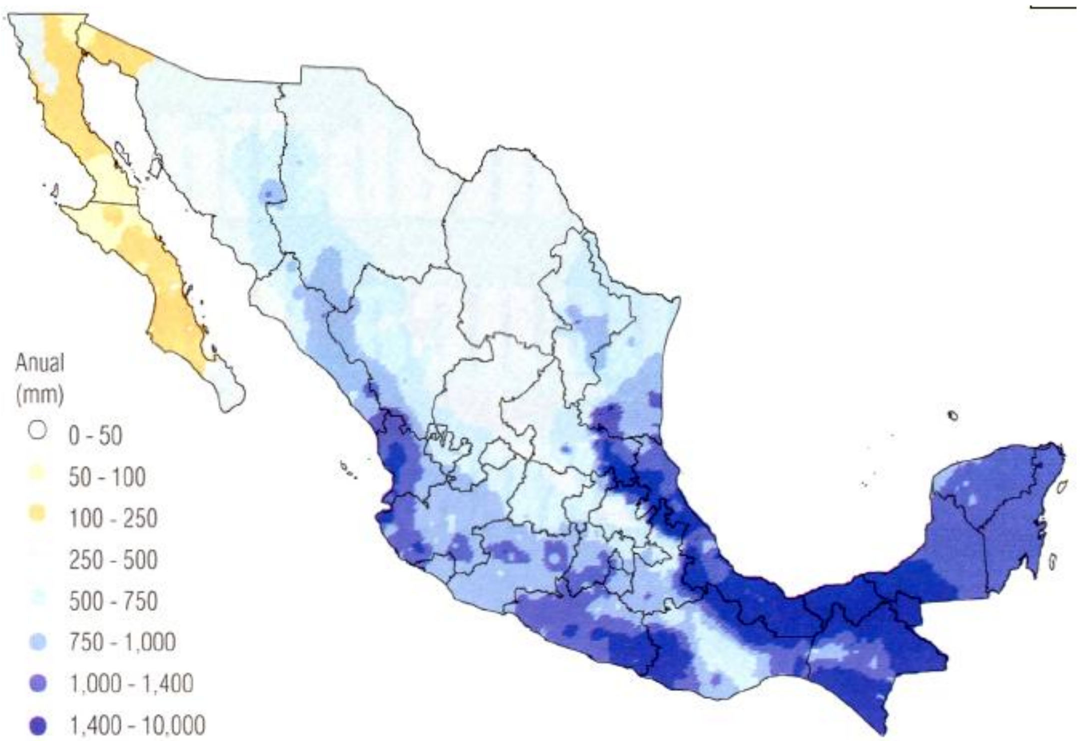
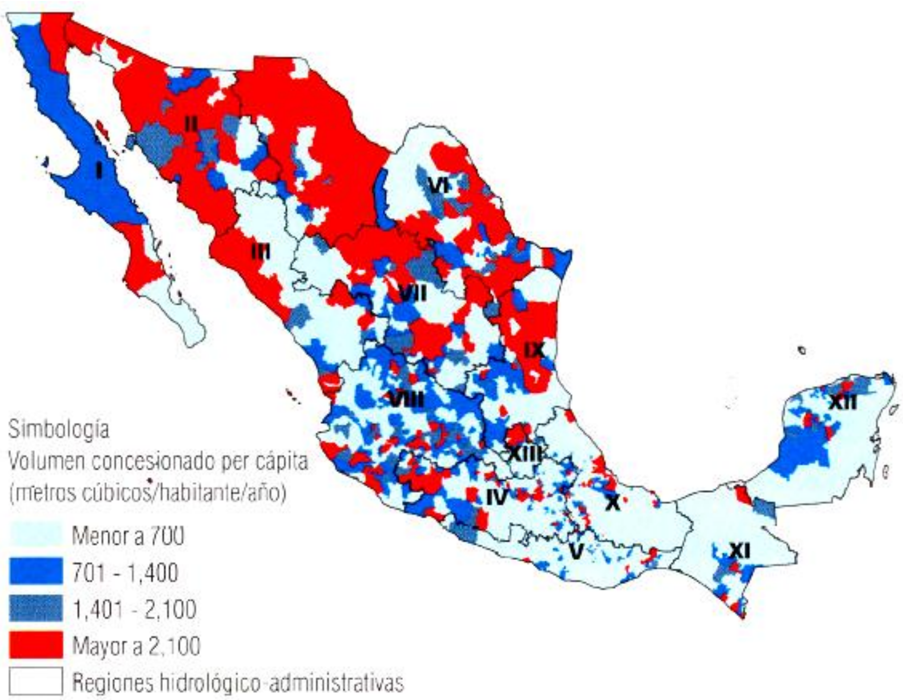
22 Mexican Academy of Sciences "The Water Agenda" (in Spanish). México, 2008 (60 pp).





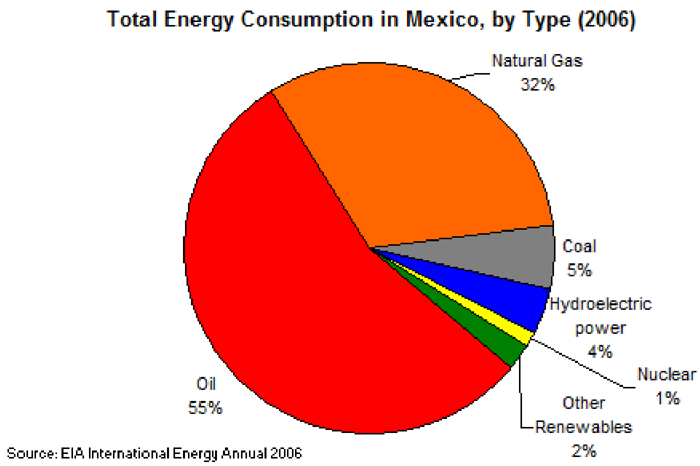
In the previous figure, the red areas, where more water is allocated on a per capita basis, coincide with those where rainfall is less. A potential conflict in the north is more likely, between water for energy and for other uses, given the fact that these regions are growing faster, mostly due to increasing economic development in terms of close neighbourhood with the United States, with which over 3 400 km of border is shared. This fact has promoted a very marked increase in electricity generation in the last decade, an energy that is both employed for improved economic development and exportation to the USA. Some Mexican firms have chosen to establish themselves in the northern industrious states (from Tamaulipas to Baja California) and also set up factories and workshops in American soil. This gives them advantage in terms of NAFTA.

Basic energy data[23]

In 2008, Mexico was the seventh-largest oil producer in the world, and the third-largest in the Western Hemisphere. State-owned Petroleos Mexicanos (Pemex) holds a monopoly on oil production in the country and is one of the largest oil companies in the world. However, oil production in the country has begun to decrease, as production at the giant Cantarell field declines. The oil sector is a crucial component of Mexico’s economy: while its relative importance to the general Mexican economy has declined, the oil sector still generates over 15 percent of the country’s export earnings. More importantly, the government relies upon earnings from the oil industry (including taxes and direct payments from Pemex) for about 40 percent of total government revenues. Therefore, any decline in production at Pemex has a direct effect upon the country’s overall fiscal balance.

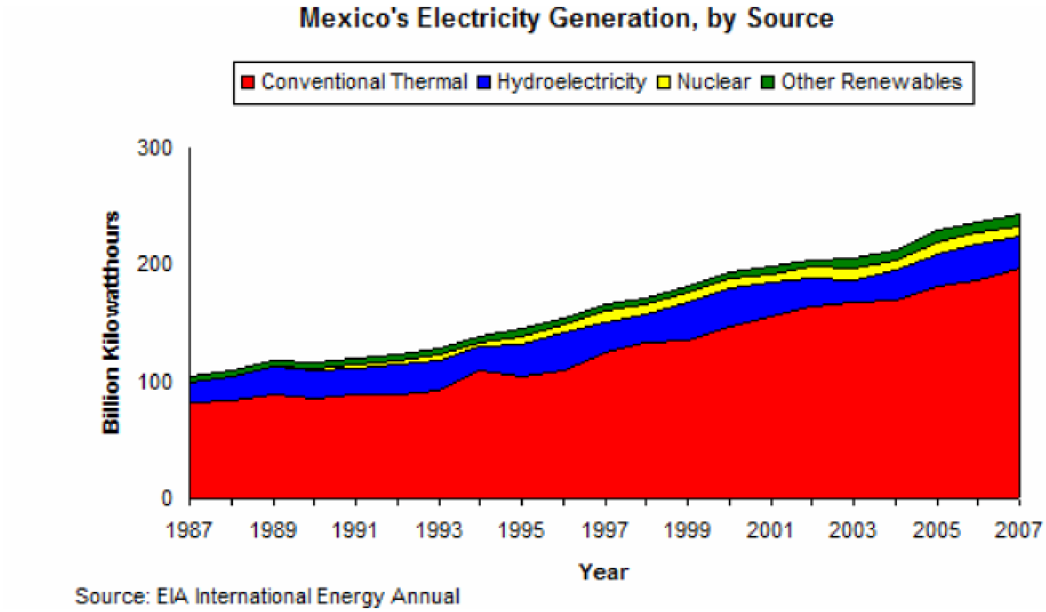
23 EIA Energy Information Agency, USA, http://www.eia.doe.gov/cabs/Mexico/Background.html

As can be seen in the previous map, where the names of places with thermal electric plants are located, a large portion is situated by the sea, to take advantage of the open loop cooling cycle. The plants posses a low thermodynamic efficiency and hence produce large amounts of GHG, but are preferred to other, newer plants, mostly designed to burn natural gas, since their marginal production cost is lower.



Mexico's total energy consumption in 2006 consisted mostly of oil (55 percent), followed by natural gas (32 percent). All other fuel types contribute smaller amounts to Mexico's overall energy mix. Natural gas is increasingly replacing oil as a feedstock in power generation. However, Mexico is a net importer of natural gas, so higher levels of natural gas consumption will likely depend upon higher imports from either the United States or via liquefied natural gas (LNG).

Finally, the next graph depicts the evolution of electric generation as dependent on technology for conversion. Notice that the fraction of thermal (combustion) conversion over the years has increased steadily, as well as other renewables (mostly geothermal and wind), although these still represent a small portion of the total, about 2%.



Near future challenges

The general supply of electricity and water to new housing projects is very poor, since the general infrastructure is in bad conditions and energy and water are themselves in short supply. Water is very seldom treated for re-use; hence very important amounts of energy are demanded in water pumping through long distances. These facts, coupled with an ancient deficit of urban housing, have given rise to a project known as “sustainable integral urban development”, or DUIS for its Spanish initials, which aims at reducing the combined demand of water and electricity with modern eco-friendly technology. This includes water recycling, rain water capture and storage, eco architecture to reduce heating and air conditioning loads, advanced illumination and intensive use of photovoltaic and wind energy small systems. In one recent demonstration[24], electricity demand was reduced up to more than 95% by using recent technology to replace old fluorescent tubes.

This experience and others are planned to face the challenge of one million new houses within three years, which are expected to produce the same level of comfort as current, energy and water intensive houses. Similar experiments have revealed that water requirements in agriculture can be reduced very markedly without hampering with the social and economic aspects of agricultural production, and at the same time, adding value to that activity by increasing

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Pilot project on efficient lighting at the National Autonomous University of Mexico (UNAM). UNEP/Wuppertal Institute collaborating Centre on Sustainable Consumption and Production, Sept 2009.

investment in equipment and automation, through a very notable reduction in electricity bills. In general, it can be said that a number of projects under way offer the perspective of added value and increased levels of comfort and health, while saving important amounts of water and energy.

Regulatory framework

The history of Mexico, that would help explaining many of its characteristic legal framework and "uses and costumes", has evolved a set of laws that gives the Federal Government near absolute control of natural resources and, as a more recent extension, of energy production, transmission and distribution. Different governments have experienced various processes that allow for private and social participation in decision making and resources management, but in the end the final decision rests on the official appointed for the relevant state function. Even further than the legal framework stipulates, the practice of exercising official power results in the rise of power groups that effectively control the resources allocation (water, oil, gas) with very little, or none at all, outside supervision. This situation is changing with the arrival of modern communications technology and a stronger social desire for "transparency" and participation, but it will take a considerable time for the Mexican decision making process to be compatible with decision practice in the northerner North American partners.

The governments of Canada, Mexico, and the United States have demonstrated their support for a strengthening of North America's energy markets through the creation of the Security and Prosperity Partnership (SPP) and its North American Energy Working Group (NAEWG), within which they agree to work together according to each country's respective legal framework[25].

However, in the 15 years of application of NAFTA, it has been clear that the peculiar regulatory framework of Mexico makes it very difficult to effectively merge energy and water policies with the rest of North America. Political groups oppose what they call "privatisation", which in practice means that the influence groups do not stand to gain from a better or more efficient use of resources; hence the association with their North American counterparts is not desirable. International agreements will not be possible until the gap in interests is overcome. Again, this situation is arriving, although slowly. The growing electricity generation in the northern states of Mexico, based on renewable energy sources and geared toward exportation to the USA, is a clear indication that energy practice is changing for the better. However, it will take a while before the whole country comes along. The process is worth observing, since it will provide a clue

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25 WEC North American Regional Report. Executive Summary. 126 pp. 11 Sep 2007

as to how to deal with the rest of Latin America in the process of integrating the American economic block.

6. FUTURE CHALLENGES AND OPPORTUNITIES

North America is an energy community, fortunate to be endowed with a rich and varied resource base. It consumes about a third of the world's energy and produces about one quarter of world energy supply.

North America depends on a mix of complementary energy sources that should remain competitive but not in conflict. The current supply mix varies between Canada, the United States and Mexico, but fossil fuels are dominant across the region, leaving the three member countries vulnerable to a myriad of risks associated with traditional supply sources. Energy trade between all three countries is also a major contributor to the region's economy. Thus, the impetus for collaboration across the region has grown out of the common goals of energy security and economic prosperity[9]. In the view of growing international concern with the environment, WEC North America faces the extraordinary challenge of capitalising its varied and rich natural resources and cultural diversity, to develop original and lasting processes for reducing ecological impacts and maturing an exportable model for economic and wealth development with reduced ecological impact. Surely, the Latin American portion of the regional alliance will be expected to produce important suggestions for the eventual integration of the whole continent.

Among the riches in the region, it can be highlighted the prevalence of several locations where hydroelectricity is still the main driver of energy development. These parts share many of the experiences and energy distribution characteristics that prevail in many other regions in the world, such as South America and Africa, and offer valuable opportunities for technology development (in classical and mini hydro) to improve energy generation while reducing carbon footprint. The region shares a growing concern with its dependence on fossil fuels, but is rich in alternative primary energy sources and is clearly contributing in an important fashion to the development of renewables. The growing expectation of technological change must be exploited for the region to gain competitiveness in the future of energy production and consumption, in order to satisfy the high energy demands of North America, but also to develop a world wide applicable model that satisfies developed nations, providing the expected degree of comfort attained in recent years, with reduced primary energy requirements. The development of this challenging energy technology is actually the only choice for accommodating an extra three billion people on earth within the next few decades and satisfying their legitimate demands for food and water, while reducing carbon emissions at the same time.

In general, the energy issue in North America poses very challenging opportunities for improvement of comfort and productivity while reducing the input of fossil primary sources. The opportunities are further enriched by the obvious need to reduce water consumption, not only in the energy sector, where the USA and Canada are already making very noticeable improvement, but also in other water intensive tasks such as urban requirements and agriculture, where energy consumption is rising in the less-developed areas of the region. The development of improved technology to face these tasks without sacrificing comfort and security is a welcome extra. All information available reveals that economic pressures on water prices will drive energy improvement and further business opportunities. It is clear that the water energy nexus is providing and will increasingly provide more of these business opportunities in the coming future. Only a region where energy wealth, technological skills and social proactive environment policies combine in a balanced matter, will successfully translate these challenges into international economic progress avoiding undue social unrest and ecological harm.

ANNEX

Actualised Enerdata set (samples)
WEC consulted documents
Specific country documents (water and energy)
Reading list (all titles and urls)