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Global Agenda Council on Energy Security

The Water-Energy Nexus: Strategic Considerations for Energy Policy-Makers

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> **The interconnection of water and energy will increasingly affect policy issues in the 21st century.**

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This paper explores the interconnection between water and energy production and presents energy policy-makers with factors to take into consideration for both the present and the future.

Historically, the overlap of energy and water issues received little attention. Potable water became increasingly available with the use of energy to dig wells and to construct piping systems. Meanwhile, energy sources – from wood to workhorses, mined fossil fuels to steam generation – were extracted, processed and produced with water. Long overlooked, more people are becoming familiar with this water-energy nexus as demand for electricity grows and water supplies dwindle in certain regions across the world.

In recent years, competition and disputes over resources have increased the volume of scientific documentation on the water-energy linkages. The Global Agenda Council on Energy Security has prepared this paper to raise awareness about the water-energy nexus and to find ways to work with other Global Agenda Councils to further progress.

This paper offers an outlook to world energy policy-makers as they consider how best to plan energy and water infrastructures for the future.

Smart energy policy must take into account the realities of the water industry and the world's need for affordable, clean and abundant energy, as well as the shared responsibilities and opportunities influencing these two resources.

Water: a unique natural resource

Although the earth has 35 million cubic kilometres of freshwater, it is unevenly distributed across the planet or is located in areas that are expensive to tap or access: 70% is trapped in the form of ice or snow, or deep underground.[1] The remaining 11 million cubic kilometres of readily available freshwater reserves are under increasing stress – human freshwater usage has tripled in the past 50 years alone.[2] Today, there are roughly 700 million people across 43 countries living in regions with severe water scarcity.

Water is a unique natural resource with the capacity to become renewable: water that has been "consumed" is not lost to the hydrologic cycle or to its future use – it is simply recycled by natural systems. Therefore consumptive uses of water only refer to uses of water that make water unavailable for immediate or short-term reuse (evaporated, transpired, incorporated to crops or consumed).

While water can eventually be recovered for future use and even desalinated, population growth, urbanization and modernization demand that policy-makers be prepared to respond to inextricably linked and time-sensitive water and energy security concerns.

As a result, industry leaders from energy-intensive fields will increasingly find themselves accountable for smart water use.

[1] "Statistics: Graphs & Maps," UN Water. http://www.unwater.org/statistics_res.html "Water consumption – sources and methods," Worldometers. http://www.worldometers.info/water/

[2] "International Energy Outlook 2013" electricity webpage, US Energy Information Administration. http://www.eia.gov/forecasts/ieo/electricity.cfm

Growing energy production

The US Energy Information Administration (EIA) estimates that global energy production will increase by around 49% from 2007 to 2035. Non-OECD countries will represent 84% of this additional consumption.

At the same time, energy demand is on the rise; the EIA's *International Energy Outlook 2013* predicts 2.2% annual growth in electricity delivered to end-users through 2040.[3] With this staggering growth projection, the ability to produce affordable, sustainable energy becomes more essential than ever to secure economic stability and growth. And since most major sources of energy require large amounts of water, this means that existing water sources will be put under even more strain beyond the effects of increasing population and growing agricultural demands.

Reports indicate that an estimated 78% to 90% of power plants across the world[4] heat water into steam to turn large turbines attached to a generator. Additionally, water serves as the primary coolant in power generating stations, maintaining appropriate temperatures for everything from coal boilers to nuclear reactors.

As water is a complex issue, this paper focuses on key strategic considerations that affect water quantity and electricity production rather than the effect water quality has on electricity production.

[3] "Energy resources: occurrence, production, conversion, use," Wiser, Wendell H. and US Energy Information Administration

[4] "Solar Cell Makers, Consider Another (Potentially) Renewable Resource: Water," 17 June 2011. Renewable Energy World. http://www.renewableenergyworld.com/rea/news/article/2011/06/solar-cell-makers-consider-another-potentially-renewable-resource-water

Outlook for water scarcity and the implications for energy generation

Water scarcity has direct implications for energy security. The potential for economic development and stability enabled by a reliable, stable and sustainable supply of energy at affordable prices is limited in a growing number of areas by a lack of access to water. To date, energy and water infrastructure and policy decisions have been made independently of one another, often with outdated assumptions regarding rising demand and resource scarcity.

Water stress and water scarcity will become more common in the next few decades. Water stress occurs when water supplies drop below 1,700 cubic metres per person, per year. Water scarcity is defined as less than 1,000 cubic metres per person, per year and absolute scarcity is defined as less than 500 cubic metres.[5]

According to Population Action International, and based on the UN projections of global population, more than 2.8 billion people in 48 countries will face water scarcity conditions by 2025.[6] Out of these countries, 40 are located in West Asia, North Africa or sub-Saharan Africa. By 2050, the number of countries that will face water scarcity scenarios will grow to 54 and 40% of the projected global population will be affected.

The implications for the energy sector are significant. Any energy policy being drafted in these regions will have to consider that power plants across these areas will face some form of water scarcity. The life cycle of power plants is estimated at on average 20-40 years, so any electric generation facility being planned or under construction in these regions will have to factor water scarcity into the equation.

[5] "Water Scarcity," UN. http://www.un.org/waterforlifedecade/scarcity.shtml

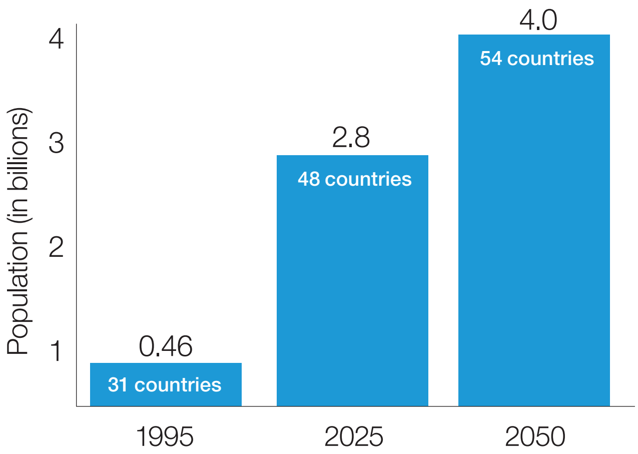
[6] "Vital Water Graphics," UNEP. http://www.unep.org/dewa/vitalwater/article141.html

All forms of energy require water at some stage of their life cycle: from production to distribution and use. In particular, water is a major component in thermoelectric and hydropower generation today.

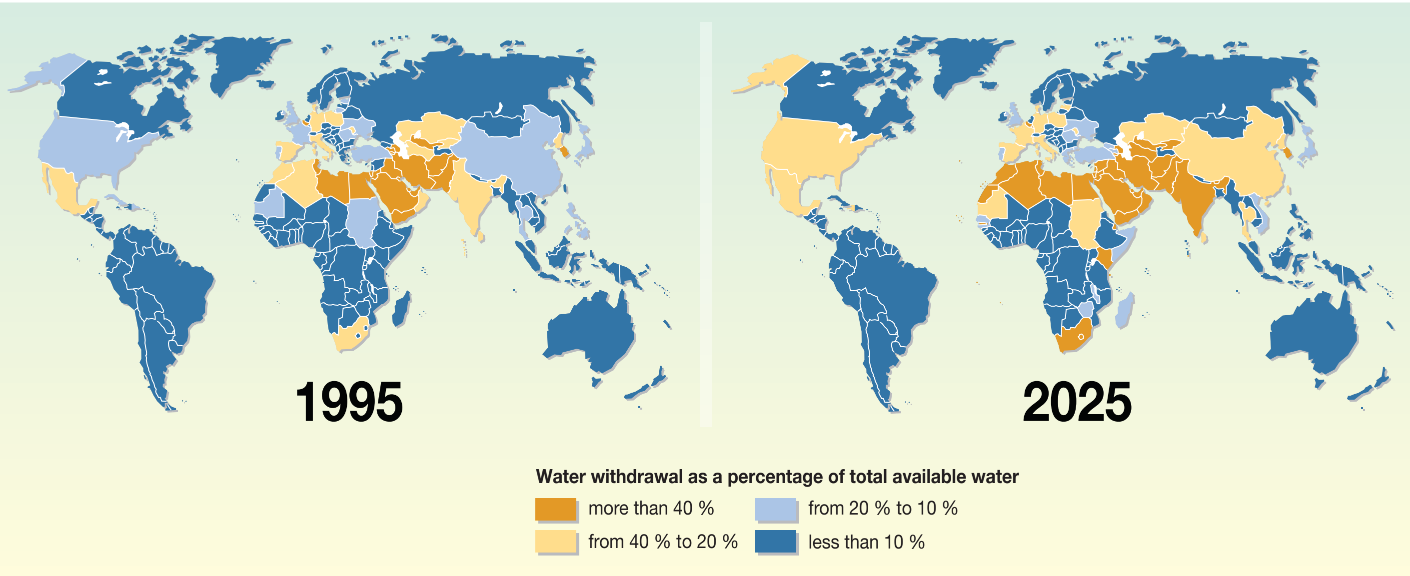
It is not only on-site electricity generation that relies on water; drilling, extraction and processing of fuels also require significant amounts of water. Methods such as mining or hydraulic fracturing, which releases trapped oil and natural gas deep underground, are water-intensive practices, accounting for the use of billions of gallons of water worldwide every year. Even producing photovoltaic solar panels consumes significant amounts of water: the average solar panel manufacturing facility uses more than 1,000 cubic metres of water a day.[7]

[7] Solar Cell Makers, Consider Another (Potentially) Renewable Resource: Water," 17 June 2011. Renewable Energy World. http://www.renewableenergyworld.com/rea/news/article/2011/06/solar-cell-makers-consider-another-potentially-renewable-resource-water

Figure 5: Water Scarcity and Stress
Population in water-scarce and water-stress countries, 1995-2050



United Nations Environment Programme – Global water withdrawal projections



Lack of planning

Issues related to water demand cannot be addressed without taking into account one of the largest users of this limited resource – energy producers.

In the past, the fundamental problem was due to poor planning: a lack of smart policies and foresight prevented the sustainable administration of water. Shortages occur when water is withdrawn on a timescale that is not commensurate with the natural replenishing process.

Some functions can only be performed by water, such as sustaining organisms and nourishing plant life, some of which can be used for food. However, water is also used for functions where it is simply the most convenient option. There is an important opportunity for policy-makers to protect water's essential functions, even if it comes at the expense of its non-essential uses.

Today, the use of additional energy extracts more water and speeds the depletion rate of groundwater and rivers. The hydrological systems of local ecosystems struggle to compensate and adapt. Aquifer replenishment can take hundreds or even thousands of years, so once the extraction of water in aquifers outpaces the rate of infiltration, water scarcity exerts pressure on the operations of end users.

This is an urgent issue. According to some estimates, humans already appropriate almost 50% of all renewable and accessible freshwater flows.[8] Also, since 1900, half of the world's wetlands have disappeared.[9]

In regions affected by water scarcity, electricity generation competes for water against other uses, like drinking water and agricultural irrigation. When this occurs, case studies show that water use for human consumption and agriculture is given priority over energy generation. This means that, in some extreme cases, power plants have to lower their output and incur high financial losses.

In 2011, Texas experienced the worst single-year drought in its history. The drought ruined cotton crops and forced ranchers to sell cattle that would have otherwise died. This drought also affected regional energy sources, raising concern among grid operators. It became apparent that there would not be enough water for all the usual demands.[10]

India is another prime example of the trade-offs that come with water scarcity. Farmers have desperately attempted to draw crops from the land despite a lack of water, often using enormous amounts of energy to pump water from deep underground. Some estimates suggest that energy usage in certain drought-stricken areas has increased by 25%. This energy used to collect water comes from electricity generating stations that must use even more water to satisfy the larger energy demands.[11]

[8] "Human Appropriation of Renewable Fresh Water," 9 February 1996. Postel et al. Science.

[9] "Great Swamp – A Threatened Freshwater Wetland," 1984. Katz Annals of the New York Academy of Sciences.

[10] "How Energy Drains Water Supplies," 18 September, 2011. New York Times. http://www.nytimes.com/2011/09/19/business/global/19iht-green19.html?_r=0

[11] "India's drought punishes farmers, highlights challenges to climate change adaptation," 3 August 2012. E&E Publisching, LLC. http://www.eenews.net/stories/1059968355

The fundamental role of energy policy-makers

The Global Agenda Council of Energy Security believes that energy and water policy-makers can play a critical role in composing smart policies to address the challenges that lie ahead for both water and energy.

Planning contributes to responsible management. The energy sector must begin to plan for more volatile availability of cheap, abundant water, just as the water industry can no longer take low-cost electricity for granted. With rising demand for both resources, policy-makers, the energy industry and the water sector must take action now to avoid conflict in the future.

As managers of existing energy and water infrastructure, and planners of sustainable and reliable infrastructure, energy and water policy-makers must assess how water scarcity will affect their infrastructure and implement changes to ensure the reliability of the system.

The challenge, particularly in water-stressed parts of the world, is to enhance energy security through infrastructure development choices that eliminate or reduce stress on water supplies, or substitute water altogether for some functions.

The key recommendations of the Global Agenda Council of Energy Security are:

Emphasize the economic value of water

One of the principles that came from the 1992 International Conference on Water and Environment was that water has an economic value.[12] This means that even if, all things equal, one energy source is cheaper than another, the relative prices could shift dramatically depending on competition for water. As the world moves closer to enumerating water's true value, long-term energy planning and policy will need to take water costs into greater consideration when performing cost/benefit analyses for new energy projects.

Revise current water and energy policies and infrastructure

Effectively managing the use of water in power production is key to meeting the world's electricity needs.

Many regions across the world are now suffering the consequences of poor energy policy-making, as power plants are beginning to be affected by water-related issues.

For example, a drought in 2006 caused several European utilities to shut down or scale back electricity production at some nuclear energy plants due to diminishing water supplies.[13] Extreme drought has also reduced the capacity of Brazil's hydropower industry, causing dramatic price increases.[14]

These cases reflect how important it is for energy policy-makers to introduce a greater level of flexibility in regulation to adapt to the changing reality of water scarcity and climate change while respecting environmental requirements.

Thoroughly plan new infrastructure, with careful consideration to siting of power plants and scenario planning for water-related influence on power plants

Long-term energy policy and planning must take into account issues like droughts, increasing water temperatures and rising seas.
Energy producers and policy-makers must also be wary of some indirect effects of water shortage on energy generation. As the world's water supply becomes increasingly contaminated, energy stations may no longer be able to operate with the water available.

Droughts can also affect fuel delivery. For instance, low water levels on parts of the Mississippi stalled coal barges heading for power plants, forcing the US army corps of engineers to dredge channels to maintain commercial barge traffic.[15]

Countries that are rapidly expanding their energy supplies are also facing water issues. As reported in *The Guardian*, "China wants to significantly increase its coal electricity generating capacity in order to expand its economy. But this introduces a critical resource concern: more than half of the proposed plants will depend on water resources that are under high or extremely high stress."[16]

Many nations are reflecting life-cycle costs in their energy planning decisions. Still more are considering carbon emissions and the costs of climate change. Water consumption and the associated costs must also be considered in effective energy planning if we are to avoid unintended consequences and costs brought on by water stress, water scarcity and energy-water conflicts resulting in disruptions that diminish energy security.

Focusing on innovation

To begin to decouple the growth of energy demand from water demand, decision-makers and researchers must find ways to increase water efficiency in energy production, increase energy efficiency in water production, promote water-conscious energy infrastructure development and encourage best practices in water-smart energy development.

[12] "The New Economy of Water: The Risks and Benefits of Globalization and Privatization of Fresh Water," February 2002. Gleick et al. http://www.pacinst.org/reports/new_economy_of_water/

[13] "Drought could shut down nuclear power plants," 23 January 2008. NBC News. http://www.nbcnews.com/id/22804065/ns/weather/t/drought-could-shut-down-nuclear-power-plants/

[14] "Water Issues Challenge Power Generators," 1 July 2013. David Wagman, Power Magazine. http://www.powermag.com/water-issues-challenge-power-generators/?pagenum=1

[15] Ibid.

[16] "China must manage the conflict between coal and water," 9 September 2013. Tianyi Luo, Betsy Otto and Andrew Maddocks, The Guardian. http://www.theguardian.com/sustainable-business/china-conflict-coal-fired-plants-water

Energy policy should encourage innovation and water efficiency so that the sector better manages the water available to it. Reducing demand for water in the energy sector can help end power producers' dependence on this natural resource. Technological advances will play a role. For example, advanced supercritical coal-fired power plant in Australia uses innovating cooling technology (air cooling) and recycled wastewater to greatly reduce its water consumption. This power plant uses 90% less water than a traditional plant. Policies that encourage innovative changes in water-energy processes will spur greater efficiency.

Modern advances in technology have created a vast spectrum of available energy-producing methods, including solar, geothermal, hydroelectric, wind, nuclear, natural gas and coal. Policy-makers should encourage innovation to make every energy source more water efficient. In some instances that may involve better management of water. In other cases, it could be encouraging research and development breakthroughs. Scientists should be encouraged to more seriously pursue ways to increase the water efficiency of existing energy options and to find suitable alternatives for water in the generating process. Some nuclear reactors in Russia and China are being retrofitted to use liquid sodium as a coolant and heat transfer medium rather than water. This not only reduces water consumption, but has significant advantages over water in terms of efficiency and reliability.[18]

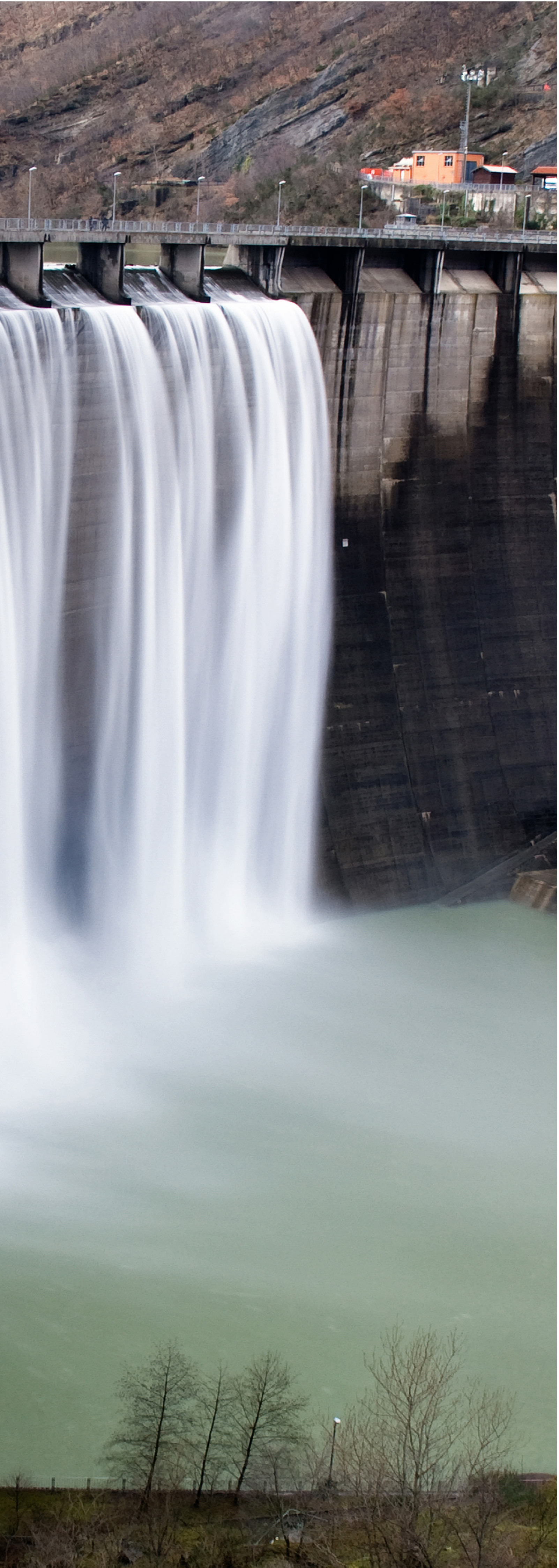
Photovoltaic solar and wind energy generation may offer alternatives, but their technology is not yet sufficiently advanced for them to serve as baseload power sources and the amount of water needed to manufacture the equipment for solar panels should be taken into account. This is another important area for continued research and development.

Similarly, innovation plays a key role in improving the fuel efficiency of desalination. The evolution of desalination plants from co-generation membrane-based filtration plants to stand-alone pressure-based efficient reverse osmosis (RO) has provided new solutions for commercially viable desalination. However, desalination is not a solution for regions deep in the interior of a continent or at high elevation, and some of the world's most water scarce areas are located in these inaccessible regions.

In line with the *Getting Serious about Innovation* report from the Global Agenda Council on Energy Security, there is a great opportunity for water scarce countries to collaborate in areas of common interest to make significant advancements in innovation.

[17] "Water Issues Challenge Power Generators," 1 July 2013. David Wagman, Power Magazine. http://www.powermag.com/water-issues-challenge-power-generators/?pagenum

[18] "Sodium coolant arrives at fast reactor," 24 January 2013. World Nuclear News. http://www.world-nuclear-news.org/nn_sodium_coolant_arrives_at_fast_reactor_2401131.html



Conclusion

As the world's population grows, demand grows with it, and no two demands are more pressing than those for fresh water and energy. If nothing changes, an increase in energy production will continue to involve an increase in water consumption, and an increase in water collection and distribution will involve an increase in energy use. But this is only if nothing changes, and it is not too late for the global community to come together and find a solution.

Long-term planning will encourage people to make decisions now to avoid negative impacts on future generations, and cooperation between policy-makers and technologists will help regulators enact realistic requirements and spur innovation as ever-more efficient energy options are sought with an eye towards water conservation.

Water must be seen as having its own economic value, and become a visible part of the equation to determine the most cost-effective energy options. No longer can power plants be evaluated just on fuel costs or capital costs. Smart planning must take into account a richer model that includes life-cycle costs such as fuel collection, refinement and distribution as well as carbon and water costs. For when the available supply of water is depleted, energy production becomes irrelevant.

For policy-makers, a proper understanding of scope will be essential for effective regulations to be established. Energy is a global issue since fuel and electricity are relatively easily imported and exported, even halfway around the world. Water, on the other hand, is not easily transported, and is therefore very much a local issue. Individual nations must make immediate and long-term decisions based on their own supplies of water to develop smart, sustainable energy policies.

When these issues are understood and planned for, particularly in regions where water stress and water scarcity are growing issues, industry leaders can begin to develop a vision for smart policy on technology and infrastructure.

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