THE WATER ECOLOGY

Monitoring water as a measure of well-being

Water is the magic that maintains our global ecosystems. But in a world out of balance, the salient question is: *Can water still do its magic? Can it support the complex ecosystems that filter air, synthesize energy, and maintain rather precise levels of chemical elements in the biosphere, while at the same time supporting the daily lives of the growing billions of people living in wildly divergent conditions around the world?*

The answer is (no surprise) complex. The water ecology is remarkably resilient, and it's difficult to calculate its limits the way we can calculate the limits of deposits of ore. Water re-circulates and recharges itself in a way other extractive resources simply don't. Therefore, in order to understand its limits, we need to look for signs of distress in the multitude of systems it supports, and when we do, we find plenty of reason for worry. We also find a multitude of levers for repair. And perhaps most important among these will be a rethinking of water itself: a shift from seeing it as a resource to seeing it as a very sensitive feedback system that directs the way we organize everything from our food systems to our communities.

WATER STRESS: SIGNALS OF A WORLD OUT OF BALANCE

The signs of water stress—which will certainly grow in the coming years—are signals of a world out of balance. We'll see this stress most clearly in the nearly 3 billion people who, by 2025, will be living with less than 1700 cubic meters of water per person per year (compared to a global average of 9000 cubic meters today and 5200 in 2025). This human water stress is driven by overall population growth, the great urban migrations taking place around the world, and even the growth-sustaining industry and consumption in emerging and advanced economies alike. Perhaps equally important, it is driven by poverty.

Over the next decade, we'll also see the signs of water stress in the impacts of climate change, from extreme droughts to extraordinary storms that disrupt streambeds and increase the flows of sediment, carrying disease pathogens, chemicals, and nutrients downstream. The stress will be visible in over-fished waters, collapsing ocean ecologies, and the loss of habitat that helps manage water naturally. We'll see it in the growing tensions over cross-boundary rivers and in the seemingly heroic efforts to move huge volumes of water from water-rich regions to those that are water poor. The tradeoffs between water-intensive alternative energy solutions and more water-efficient carbon fuels will also signal stress in our water ecology.

WATER RESOURCES: NOT EXACTLY "THE NEW OIL"

While water stress will loom large in the coming decades, thinking of it as "the new oil" is perhaps a misdirection. The absolute limits of petroleum deposits allow us to calculate peak oil and its effects, but the ecological resilience of water makes it harder to calculate peak water. In fact, we have to understand the limits of water in the context of the entire ecology. And that is, in fact, what the Pacific Institute has done: Meena Palaniappan and Peter Gleick have developed a framework for defining "peak ecological water" as the point where the value of ecological services provided by water intersects the value of human services provided by water. Peak ecological water will arrive at different times in different locations.

This framework assumes, of course, that we will eventually be able to measure the value of both the ecological and human services provided by water in fine detail. The last decade has seen advances in both arenas. The Gund Institute for Ecological Economics, for example, has pioneered the science linking ecological services to economic value. The Water Footprint Network has likewise advanced our ability to measure the virtual water we consume—that is, the water consumed as part of the products we buy and use. Over the next decade, these metrics will become much more refined.

WATER SOLUTIONS: TRACKING WATER FLOWS AS A DASHBOARD

As different water metrics improve, we'll get a high-resolution view of the value of water services—and the disruption of those services by our human activities. What we'll likely see is that the water stress we experience—the problems of human access to water and sanitation, of agriculture, and even of energy production—are not grounded so much in water as a limited resource but in the financial, industrial, and urban infrastructures that organize our daily lives.

In fact, water could become our dashboard. Just as we currently use measures of global monetary trade to estimate the well-being of our nations, we may begin to find that measures of water footprints and water trade—of the supporting and regulating services of water in the natural landscape—give us an even more sensitive measure of the overall health of our ecological and economic systems. By managing our human systems to maximize the benefits of water to both humans and ecosystems, we may find that we can avoid a post-peak water situation altogether.

SUPERSTRUCTING THE WATER ECOLOGY:
How will you live this forecast?

The **Superstruct Strategies** emerged from IFTF's 2008 massively multiplayer forecasting game, Superstruct. They suggest innovative ways to respond to this forecast.

EVOLVABLITY:
Nurture genomic diversity and generational differences

EXTREME SCALE:
Layer micro and massive scales for rapid adaptation

AMBIENT COLLABORATION:
Leverage stigmergy with environmental feedback

REVERSE SCARCITY:
Use renewable and diverse resources as rewards

AMPLIFIED OPTIMISM:
Link amplified individuals at massive scales

ADAPTIVE EMOTIONS:
Confer evolutionary advantage with awe, appreciation, and wonder

PLAYTESTS:
Challenge everything and everyone in fun, fierce bursts

EVOLVABILITY + EXTREME SCALE + REVERSE SCARCITY

Leverage efficiencies of coordination and scope rather than efficiencies of scale to develop a portfolio approach to meeting water needs. In analyzing the stability of ecosystem services, ecologists sometimes point to the "portfolio effect"—where diversification minimizes volatility and risk. In natural systems, a diversity of responses by a "suite" of species creates a stabilizing effect. In the human-water interface, a similar diversity of responses to the challenges of providing water could create reverse scarcity. Unbundling water needs and developing new networks of supplier-users for different needs could provide the equivalent of a portfolio approach to water. The opportunity is to use emerging network tools to achieve coordination at scales that matter in water management, from local neighborhoods to entire river basins.

EXTREME SCALE + REVERSE SCARCITY + AMPLIFIED OPTIMISM

Turn water into a reward system. If we think of water less as a commodity or utility and more as measure of value in an ecosystem, are there ways to create rewards from that value? For example, could low household water use be rewarded with a property tax discount? Could stream purity in a community be rewarded with a local festival, or could overall stream health in a region be rewarded with a regional holiday? Could low water footprints be banked against future water use for aging populations—sort of like saving water for retirement? Could precision-watered crops earn an automatic dividend? The key to success of all of these rewards would, of course, be refined monitoring systems.

EXTREME SCALE + AMBIENT COLLABORATION + PLAYTESTS

Develop massively multiplayer games to test the idea of water as a global feedback system. The kinds of scorekeeping and incentives built into massively multiplayer games, as well as the ability to mobilize large networks of participants, make them a perfect testing ground for the concept of water dashboards. They might create immersive online worlds that use real-world measurements of water services—both human services and ecosystem services—in the gameplay. The value of the gaming approach is that games can rapidly prototype lots of different strategies and test them at scale, drawing on the imagination of thousands to conjure solutions that otherwise might never come to light.

THE POVERTY FACTOR

The connection between poverty and access to both drinking water and safe sanitation is apparent at the individual household level as well as the level of regional ecosystems. Most of the financial burden for building and maintaining access to safe drinking water and adequate waste disposal systems falls on households. Thus, it's not surprising to find that almost two-thirds of all people who lack access to safe drinking water survive on less than $1 per day (extreme poverty). Nearly a billion without adequate sanitation live on less than $2 per day (official poverty level).

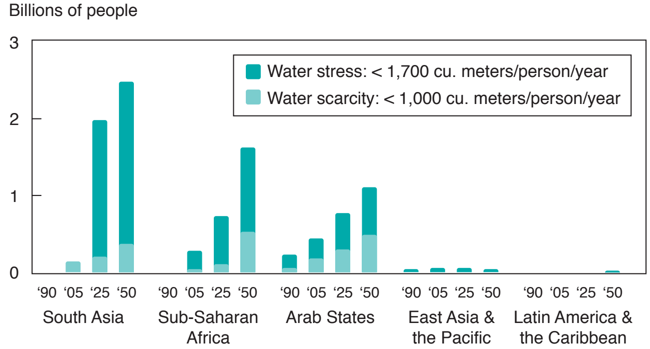
Taking a regional ecosystem view, we can see that the largest populations living in a state of water stress or water scarcity are also projected to be those that live in the poorest regions: South Asia, Sub-Saharan Africa, and the Arab states. As a result of population growth, urbanization, and climate change, those living in a state of water stress or water scarcity worldwide are expected to grow to two-thirds of the world population by 2025 (Figure 1).

CLIMATE CHANGE

Ecologically speaking, 1.4 billion people already live in river basins where water use exceeds sustainable levels. In the next couple of decades, climate change is expected to increase the total global freshwater supplies, but the increases will be unevenly distributed and, in some cases, inopportune. For example, many areas will experience atypical periods of extreme drought and/or extreme flooding, both disrupting reliable planting and harvesting patterns as well as creating regional crises in water access.

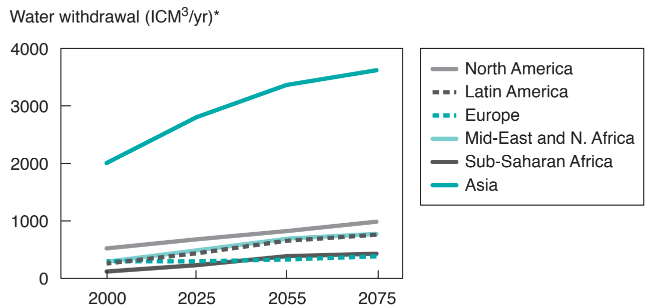
At the same time, different responses to climate change are likely to produce different levels of water demand. The Intergovernmental Panel on Climate Change has produced four alternate scenarios for global CO^2 emissions, based on socio-economic assumptions, known as the SRES scenarios. Figures 2 and 3 compare future water withdrawals (the removal of water from a source, such as a watershed, for use by humans) under two of these scenarios. Figures 2 and 3 reveal a dilemma for both climate mitigation and adaptation strategies. In the short term, through 2025, continued economic growth and global development produce lower water withdrawals than strategies aimed at conservation and dematerialization of the economy. But in the longer term, through 2075, the dematerialization scenario produces significantly lower water demands. In both scenarios, Asia will have the largest water demand by far.

FIGURE 1 Some of the poorest regions in the world have the largest populations living with water stress or scarcity.



Source: David Michel et al, *Troubled Waters: Climate Change, Hydropolitics, and Transboundary Resources*, 2009.

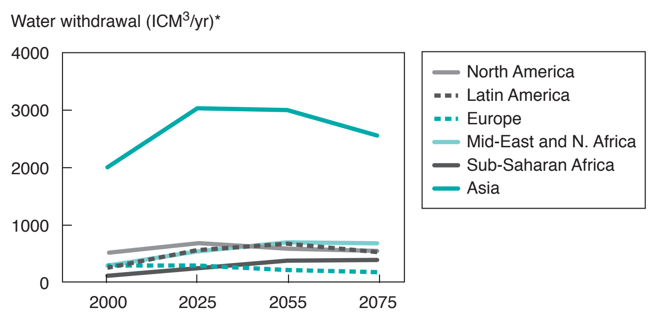
FIGURE 2 With continued globalization and reliance on fossil fuels, water use continues to rise through 2075.



*Under SRES scenario A1, which assumes continued globalization and primary reliance on fossil fuels, compared with other SRES scenarios.

Source: IFTF from data in Yanjun Shen, et al., "Projection of future world water resources under SRES Scenarios: Water Withdrawal", *Hydrological Sciences*, 2008.

FIGURE 3 With coordinated sustainability and improved equity, water demands rise in the coming decades but drop significantly by 2075.



*Under SRES scenario B1, which assumes a global convergence around a strategy that focuses on environmental sustainability and improved equity.

Source: IFTF from data in Yanjun Shen, et al., "Projection of future world water resources under SRES Scenarios: Water Withdrawal", *Hydrological Sciences*, 2008.

WATER FOOTPRINTS

Another way to understand the present and future demand for water is to calculate our water footprints—the amount of water we consume as individuals, as companies, and as nations. A.Y. Hoekstra and his colleagues at the Water Footprint Network have done extensive modeling to compute the water footprint of nations based, not just on water consumption within a single country, but also on the water represented by the products that the country imports—so-called *virtual water* (Figure 4).

GDP AND VIRTUAL WATER TRADE

We can take these analyses a step further to forecast the future growth of the global water footprint. In regression analysis comparing global virtual water trade with global GDP, IFTF found a significant correlation (R-square = .719, significant at 0.44). We can thus use projections of future GDP to forecast future growth of virtual water trade. For this analysis, we used forecasts of GDP growth under four alternate scenarios from the Economist Intelligence Unit (Figure 5).

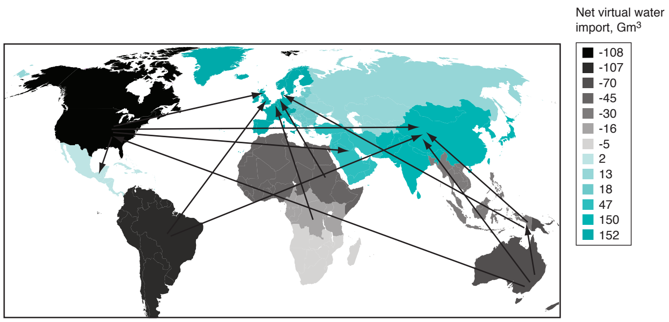
These virtual flows, in turn, provide insights about the present and future dynamics of the global water economy (Figure 6). They also reflect the US leadership position in world trade. In a very real sense, US water resources and US trade advantages go hand in hand. Future water shortages, especially in places like California, with its rich agricultural industry, thus have a direct impact on future US trade position overall.

The map of virtual flows tells a different story about the future water challenge for China, with its growing population. As a net importer of water, China will most likely not be able to climb out of its "water debt" in this century. If water becomes an increasingly expensive commodity, China's overall balance of trade will likely suffer.

WATER AS A LUXURY PRODUCT

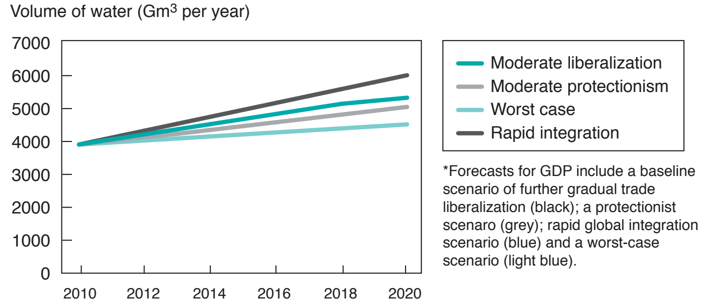
As the global water footprint increases—and quality sources of available water become less reliable—water prices will almost certainly rise over the next decade. This increase will likely exceed overall inflation. It may also flip the categories of basic and luxury goods. Many of the commodities we consider basic today have a much higher water footprint than products that are generally deemed discretionary (Figure 7). By 2020, a hamburger may be a luxury item, while a memory-foam mattress could be cheaper than a set of sheets.

FIGURE 6 Water balance of trade by region (1995–1999) shows regions that are net exporters (in black) supporting regions that are net importers (in green).



Source: The Water Footprint Network, http://www.waterfootprint.org/?page=files/VirtualWaterFlows

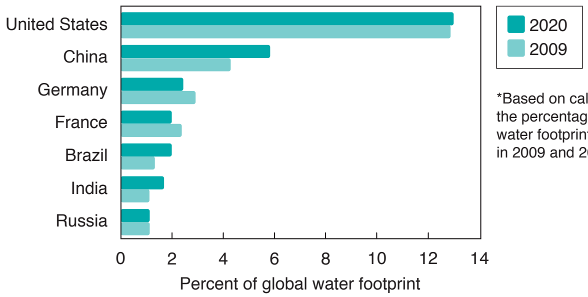
FIGURE 4 Future global water footprint will continue to grow with GDP under all four alternative GDP scenarios.*



*Forecasts for GDP include a baseline scenario of further gradual trade liberalization (black); a protectionist scenaro (grey); rapid global integration scenario (blue) and a worst-case scenario (light blue).

Source: IFTF, using data from The Water Footprint Network; CIA World Factbook; International Macroeconomic Dataset of the US Department of Agriculture.

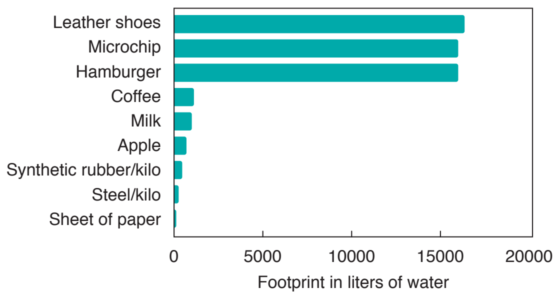
FIGURE 5 The US will continue to dominate the world water footprint but China will grow the most by 2020.*



*Based on calculations of the percentage of the global water footprint for countries in 2009 and 2020.

Source: IFTF, using data from the World Footprint Network and the Economist Intelligence Unit; http://graphics.eiu.com/files/ad_pdfs/eiuForesight2020_WP.pdf

FIGURE 7 Water shortages could redefine daily basics as luxuries.



Source: Peter Gleick, "Water Content of Things," Pacific Institute, with data drawn, in part, from waterfootprint.org.

HARD PATH VS. SOFT PATH STRATEGIES

Building on Amory Lovins's concept of a soft energy development path based on conservation and efficiency, Peter Gleick and the Pacific Institute have, for the last several years, been advocating a corresponding "soft path" for water development. Recognizing the high environmental and economic costs of the traditional "hard path"—large-scale wastewater treatment plants, aqueducts, reservoirs, and long-distance transport of bulk water—soft path development seeks to alleviate water scarcity and water stress by re-thinking human water needs and ensuring water for ecological needs.

For example, instead of targeting a basic allotment of water per person, a soft path approach would look for ways to reduce water requirements across a host of human activities, products, and services. Focusing on the ultimate need (for example, providing protein) shifts innovation from water development per se to alternative water-light ways to meet that objective (Figure 8).

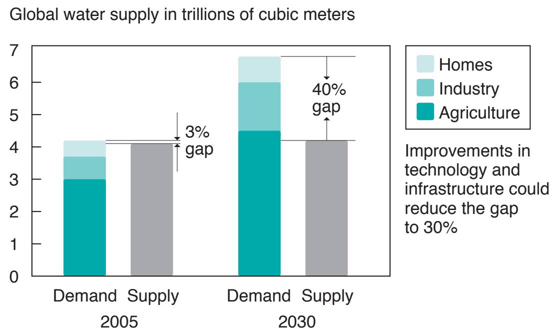
DESALINATION

With the demand for water growing worldwide—and especially in drought-prone regions—many governments are looking to desalination as one of the most obvious ways to increase usable water supplies even as water withdrawals from river basins and underground aquifers approach their limits. Desalination actually refers to a wide range of processes for purifying water, many of which have been in use for years. But investments in large-scale seawater desalination solutions have grown in recent years and will likely continue to grow in the next decade. (Figure 9.)

Nevertheless, large-scale desalination isn't necessarily the answer to the world's water problems. First, desalination has as yet-unmitigated environmental costs, including the destruction of ocean life near plant sites. These projects are also more expensive than many of the recycling and reuse strategies that have not yet been fully exploited in managing local and regional water supplies. And even if it were possible to realize substantial decreases in the energy costs of desalination, overall increases in the cost of energy would likely wipe out some of the savings.

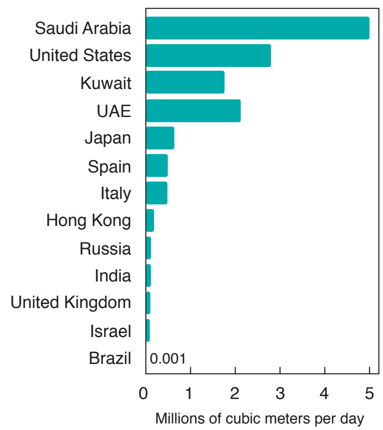
Finally, the problem of safe water and sanitation is often more a problem of financing than of technology, and over the next decade, experiments in microfinancing could combine with small-scale purification technology to build resilient local solutions for water needs leverage the soft path and avoid the costs—environmental and financial—of large-scale desalination (Figure 10).

FIGURE 8 Technology and infrastructure investments will likely reduce the gap between demand and supply by only 10%.



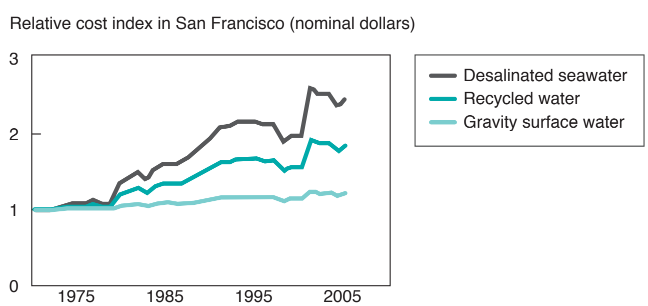
Source: The Daily Stat, Harvard Business Review, from "The Business Opportunity in Water Conservation," in McKinsey Quarterly, 2010. http://web.hbr.org/email/archive/dailystat.php?date=020810

FIGURE 9 The Middle Eastern countries are leading desalination capacity with heavy petroleum-based energy investments.



Source: Pacific Institute, 1996; http://www.worldwater.org/data19981999/table16.html

FIGURE 10 A comparison study of costs of desalination vs. recycling shows that the actual costs of desalinating seawater outstripped the cost of recycling water in San Francisco from 1980 to 2005.



Source: Heather Cooley, et al., "Desalination, with a Grain of Salt," The Pacific Institute, 2006.

MAKING THE CONNECTIONS

In a complex world, forecasts intersect. These are key intersections between The Water Ecology and other 2010 forecasts.

WATER + CARBON + POWER

Climate change will entangle the worlds of water and energy policy. Carbon emissions are the global driver in local water problems, creating a classic social dilemma of misaligned interests. We can expect this dilemma to increase global tensions over the next decade. Yet there are policies that can leave everyone better off in the long term. A global scenario where society moves toward a service and information economy leads to lower water withdrawals—and less disparity across regions (Figure 11).

Concerns about future water supplies are already creating cross-border tensions in Asia and North America. The Chinese government is undertaking a major project to divert water from the Yangzte River to the Yellow and Hai Rivers, bringing trillions of gallons to support the growing megalopolis surrounding Beijing. A controversial piece of this plan is to divert water from the Brahmaputra River that arises in Tibet and exits the Himalayas into India to flow into the Ganges, which is experiencing stresses of its own. India has other cross-boundary water problems with Pakistan, due to both countries building dams on the Indus River, purportedly in violation of the terms of a 1960 treaty between the two countries.

In North America, a decade-long struggle between the United States and Canada over the shipment of bulk water from the water-rich north to the parched areas of the American Southwest has yet to be resolved. At issue is whether the water is subject to the terms of the NAFTA agreement called the Security and Prosperity Partnership. Even within the United States, conflict between the Great Lakes Region and drier areas of the south has been magnified by recent droughts in the southeast.

In Africa, which stands to see the most extreme increases in water insecurity, tensions are rising along the Nile. Ten countries have a stake in the river, and current tensions arise from concerns that both agricultural diversion of water and hydroelectric dams will reduce downstream flows, especially in Egypt. Pollution of the Nile is also a concern.

While many have argued that shared waterways have led to geopolitical cooperation more often than to conflict, small-scale conflicts over waterways dot the history of territorial conflicts (Figures 12 and 13). In an era of super-empowered individuals and open-source strategies, such conflicts could quickly scale to impact thousands and even millions of lives.

FURTHER READING

Heather Cooley, et al., *Desalination, with a Grain of Salt*, The Pacific Institute, 2006.

A.Y. Hoekstra, editor, *Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade,* IHE Delft, 2003.

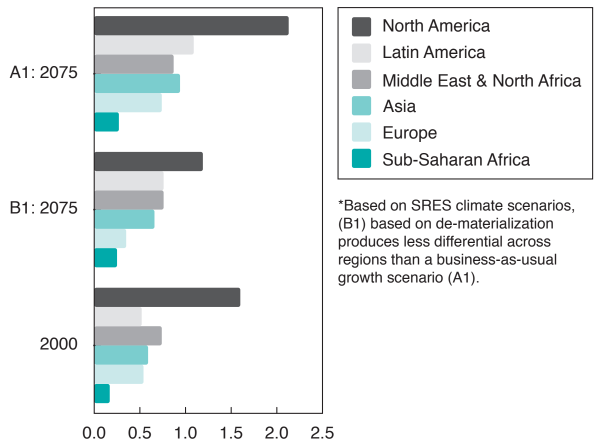
David Michel et al, *Troubled Waters: Climate Change, Hydropolitics, and Transboundary Resources,* Henry L. Stimson Center, 2009.

Meena Paaniappan and Peter H. Gleick, "Peak Water," in *The World's Water*, 2008-2009, The Pacific Institute, 2009.

Yanjun Shen, et al., "Projection of future world water resources under SRES Scenarios: Water Withdrawal," *Hydrological Sciences,* 2008.

Gary Wolff and Eric Hallstein, Beyond Privatization: Restructuring Water Systems to Improve Performance, Pacific Institute, 2005.

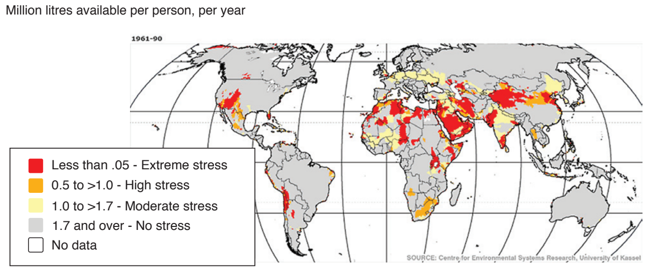
FIGURE 11 In all climate scenarios, water withdrawal per capita remains highest in North America, but dematerialization reduces the differential.*



*Based on SRES climate scenarios, (B1) based on de-materialization produces less differential across regions than a business-as-usual growth scenario (A1).

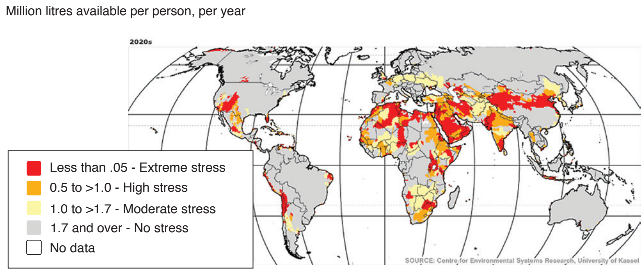
Source: IFTF from data in Yanjun Shen, et al., "Projection of future world water resources under SRES Scenarios: Water Withdrawal," Hydrological Sciences, 2008.

FIGURE 12 Areas of water stress and water scarcity are already visible today.



Source: BBC News; http://news.bbc.co.uk/2/hi/7821082.stm

FIGURE 13 Over the next decade, water stress is likely to intensify and spread to new areas, triggering global conflict—or more optimistically—global cooperation over water.



Source: BBC News; http://news.bbc.co.uk/2/hi/7821082.stm

GROWTH

The Desalination Economy

In an economy where technology continues to drive growth, water replaces oil as the critical resource, and heroic efforts at desalination become a symbol of high-tech approaches to solving all kinds of resource problems. Water also replaces oil as the measure of wealth. Making water fungible (even if it's not quite) means that we start to see economic development in terms of water trade, and Gross Water Production (GWP) becomes a key indicator of national wealth. At the same time, water independence emerges as an issue of local, regional, and national security: long-standing water agreements are reconsidered, and water bargaining becomes a rider in all kinds of cross-border trade accords. However, even small-scale desalination solutions do little to meet the needs of those who are perennially without access, and water prices rise in exponential curves that exaggerate the gap between rich and poor for all kinds of goods.

- As desalination technologies become a matter of national security, even nations with abundant water supplies are compelled to enter the desalination race. China and the United States steal the lead in technology innovation from Israel.

- Nations pursue divergent strategies and scales of desalination, using unique formulas to balance energy costs and water prices that meet their resource and market profiles. Middle Eastern countries can afford to overspend on energy in the short term, while the water bargain for other nations is more difficult to strike.

- Recognizing that water stocks have been recession-tolerant in the first decade of the century, traders invest heavily—and sometimes riskily—in water, driving a boom in water markets of all kinds, not just water technologies.

- Large water infrastructure projects go hand-in-hand with investments in desalination plants, and the traditional global leaders in power infrastructures look for future growth in water development.

- The volatility of water resources—exacerbated by more extreme cycles of flood and drought—leads to price spikes that disrupt consumer markets across the board, and threaten food security in particular.

- The growing scarcity of water in some areas and the growing costs in others give conservationists the platform they need for extending the concept of carbon credit trading to water. Here, however, the frameworks are more complex: the value of water is measured in diverse eco-system services, and the costs of those services are difficult to assess. As a result, the most successful trading markets tend to be linked to specific watersheds, shaping local business cultures more than global practices.

- In poorer developing regions, village-scale desalination solutions meet with mixed results; as in the past, local resources to maintain the technologies are lacking, and many installations fall into disuse and disrepair once the initial grants have expired.

- For consumers, the steadily increasing price of water leads to demand for many new kinds of water-saving appliances and devices—driving new markets for innovators in these offerings.

- A hierarchy of water products emerges, as consumers attempt to evaluate the safety and health impacts of various kinds of "processed water," from tap water to bottled water. A movement emerges for food and drug companies to disclose the source of the water they use.

- Large-scale desalination plants become the focus of environmental activism, as they threaten the viability of a wide range of aquatic life, both in the input stream and as a result of waste stream

SIGNALS OF GROWTH
IN THE WATER ECOLOGY

LARGE-SCALE DESALINATION, LARGE PRICE TAG

While desalination technology has been around for a long time and is routinely used in purifying water from many sources, the buzz is around seawater desalination on a large scale to boost levels of available freshwater as droughts deplete rivers and human enterprise depletes groundwater. The cost of desalination is high: $1–2 for a cubic meter, compared to 10–20 cents for water from rivers or aquifers. It also has a high energy pricetag. Nevertheless, countries with severe water shortages are already building huge desalination plants.

The world's largest desalination plant is the Jebel Ali desalination plant in the United Arab Emirates. It has the capacity of producing 300 million cubic meters of water per year.

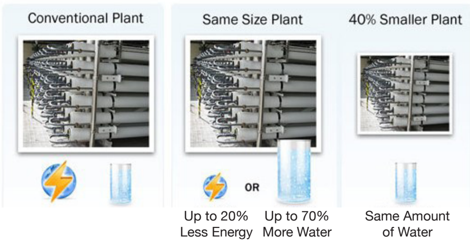
Source: http://www.dewa.gov.ae/arabic/aboutus/electstats2006.aspx

Australia, which has suffered severe drought for the past several years, has built a new desalination plant in Sydney that is designed to meet 15% of the city's water needs.

Source: http://news.bbc.co.uk/2/hi/asia-pacific/8483009.stm

VERY SMALL-SCALE FILTERS, SOMEWHAT SMALLER PRICE TAG

Nanotube technology is one of the innovations that promises to bring down the energy cost of desalination. Desalination systems use an osmosis membrane to purify the water, and membranes that leverage nanotube technology have been shown to improve performance by increasing the flow of water through the filters, giving desalination plants the option of increasing output or reducing energy costs—or even building smaller plants.



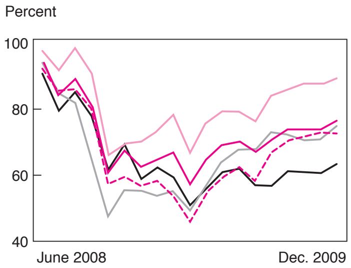
Source: http://www.nanoh2o.com/Technology.php5?category=Economics

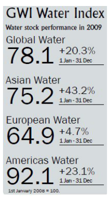
NanoH20 is a company that is commercializing thin film nanocomposite membranes for desalination that were originally developed at UCLA.

WATER INVESTMENT, ECOSYSTEM SERVICES

In a world where water becomes the "new oil," it's not surprising to find that water infrastructure, water technology, and water trade remain attractive investment opportunities. Harvard Business Review estimates that there will be a 40% gap between supply and demand by 2030, requiring either massive new infrastructure or water conservation or both (for example, about $1 billion in investment for water piping in the United States alone). At the same time, watersheds are taking a broader look at the ecosystem services that water provides and developing frameworks for investing in those services.

Water stocks did better than most during the downturn of 2008–2009.





Source: http://www.globalwaterintel.com/archive/11/1/general/water-stocks-didnt-bounce-in-2009.html

The Willamette Partnership is an example of a regional ecosystem services market. Under a grant from the EPA, the group is working to develop the technical and legal framework to facilitate exchanges of ecosystem service credits in the Willamette Basin of Oregon.

Source: http://willamettepartnership.org/

CONSTRAINT

Water Footprinting

As human impacts—from climate change to rapid urbanization—threaten the availability of water resources worldwide, water follows the path of carbon. National, local, and individual water targets and quotas drive conservation, and advanced water monitoring tools and practices support a robust science of water footprinting. In the spirit of conservation, technology focuses on water reclamation, while agriculture is reinvented as a low-water industry. A soft-path philosophy of re-thinking human water needs and ensuring water for ecological needs leads to a diversity of locally appropriate solutions, but historical degradation of the water ecology leaves it less than resilient.

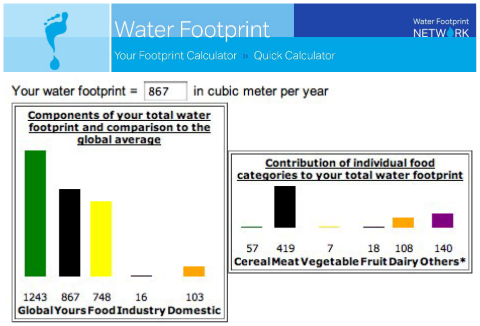
- Water conservation targets, water quotas, and personal water footprint monitoring become part of daily life. Watersheds develop "threat level" codes to guide water usage, not unlike the color codes for national security or fire danger codes.
- Public scoreboards in communities display threat levels as well as daily water quality, water use, and conservation goals. Violations of water use regulations carry stiff fines, and pervasive monitoring equipment helps both citizens and civil servants evaluate their "water citizenship."
- Water monitoring is incorporated into education and entertainment. Urban children measure water quality in tap water, local streams, and rain capture basins for urban agriculture, participating in global online games to win points for their communities.
- A wide range of products carry water footprint labeling, identifying the virtual water content of the product. For some products, the labels also indicate the water/energy balance, as decreasing one often increases the other.
- Economic incentives, including tax rebates, encourage installation of zero-waste systems that create multiple streams of water for multiple purposes, allowing businesses and households to reuse and recycle water more effectively. In less developed areas, a similar support of multi-purpose water streams allows the very poor to use their household water solutions for small livestock and domestic manufacturing operations—supporting their economic lives.
- At the level of ecologies, the science of water gets a big boost from collaborative international water monitoring projects in which sensors play a key role. Stepped-up monitoring regimens produce rich data sets that can be used to model future water services for lakes and rivers.
- The links between local urban water quality and health become more obvious as more people monitor more chemicals in the water system. The Quantified Self movement leverages information about the water system to uncover new links between specific local water issues and local or even personal health statistics.
- Cross-boundary water agreements rely on modeling of future water services, not only to set the terms but also to evaluate claims of future impacts of current violations. In short, these models tend to dispel fears, reduce conflicts, and encourage cooperative solutions to complex needs.
- Alternatives to large-scale irrigation of crops fall into two camps. On one hand, high-tech precision agriculture uses sensors and robotics to precisely monitor and drip-water crops according to actual minimal needs. On the other, low-tech solutions make use of simple drip irrigation kits, no-till agriculture with mixed crop planting (permaculture), and even water-efficient hydroponic methods. Plant breeders work to produce both patent-protected and open-source drought-tolerant plants.
- Urban farms are integrated into sustainability plans for cities and regions, emphasizing the relative water efficiency of urban mixed-crop farming vs. large-scale monocropping. Local food movements evolve to include campaigns to "keep water local."
- In Australia, the European Union, and parts of North America, the evolving science of ecosystem services allows communities to set economic incentives that encourage whole-ecology approaches to water solutions: communities that invest in their local watershed protection get discounts on water for household and business use.

SIGNALS OF CONSTRAINT
IN THE WATER ECOLOGY

PERSONAL WATER FOOTPRINTS

Just as people are beginning to calculate their carbon footprints and use those metrics to guide their consumption and lifestyle choices, they now have some preliminary frameworks for establishing their water footprints. Waterfootprint.org has an online calculator that can make rough estimates of water footprints based on country, income, gender, and overall diet, or more detailed estimates based on specifics of diet, domestic indoor and outdoor water use, and industrial goods consumption.

Even a middle-income vegetarian living in the US has twice the water footprint of the global norm.



Source: http://www.waterfootprint.org/index.php?page=cal/waterfootprintcalculator_indv

The US Environmental Protection Agency has introduced a rating system for water-efficiency of products comparable to the Energy Star systems.

WaterSense Meets EPA Criteria

Source: http://www.epa.gov/watersense/

GLOBAL COLLABORATIVE WATER MONITORING

Understanding of the water ecology is getting a big boost from sensor technology and global collaborative networks. For example the Global Lake Ecological Observatory Network (GLEON) is a grassroots network of limnologists, ecologists, information technology experts, and engineers who have a common goal of building a scalable, persistent network of lake ecology observatories.

Source: http://gleon.org/DB_Lists/gleon_map.php

The GLEON network has individual and institutional members from countries around the world, including such diverse nations as Pakistan, China, Taiwan, Brazil, Israel, Turkey, Estonia, and Finland, as well as the United States and several European Union nations.

LOCALLY APPROPRIATE TECHNOLOGY

Throughout the Global South, communities are increasingly focusing on locally appropriate solutions to water stress—recognizing that technologies and practices imported from the North are often abandoned shortly after they are introduced due to a mismatch with local culture and circumstances. For example, in India, where agriculture accounts for 80–85% of water use and the country is already suffering from water stress, the Indian NGO IDEI has created a simple drip irrigation kit that costs only $4.

MUSgroup

Source: http://www.musgroup.net/page/620

The Multiple Use Group is an international organization that is implementing alternative domestic water solutions. The group recognizes that domestic water is often used to support a variety of needs, such as securing water for livestock, as in this household in Bolivia.

COLLAPSE

Troubled River Basins

Failing to mobilize citizens, businesses, and governments around the looming water crisis, the world is repeatedly taken by surprise as floods and droughts disrupt entire river basins. Some dry up altogether in a startlingly short time span, forcing inhabitants to seek lives elsewhere. Others are subject to cycles of drought and flooding that destabilize local communities and economies. Meanwhile subtle and not-so-subtle climate changes begin to drive major crop migrations, undermining long-standing regional advantages in trade. Without large-scale efforts to create resilient water ecologies, all these disruptions prompt surges of human migration, many to cities where water is already often in short supply. Water conflict grows at all scales, as people and nations jockey to meet their water needs with patchwork solutions that fail to recognize the complex interconnections that could make them more resilient.

- In addition to a rapidly growing water-poor segment of the population (reaching about one-twelfth of humanity by 2020), episodic water crises become more frequent and widespread. These crises span all the continents, but their effects are more devastating in poorer regions where there is less capacity to absorb migrants and provide alternative shelter and food.

- The economic toll of water disasters is significant, with local economies experiencing what many recognize as 10-, 25-, or even 50-year setbacks in their economies. New Orleans provides a case study in the difficulty of economic restoration in the aftermath of water disasters.

- Tensions over water increase to the point of conflict with increasing frequency. Long-standing cross-border river treaties are violated, and local factions take up arms to protect their interests.

- The foreign land acquisitions of nations seeking to secure their future food security (especially in Africa and the Middle East) set the stage for water struggles between the indigenous farmers and the new land-owners.

- Water piracy becomes a focus of local, regional, and national security. It takes two forms: illegal drawing of water (often from groundwater supplies) and indirect water-related piracy, as water-displaced persons seek illicit means of support (sometimes through high-seas piracy, as in Somalia).

- Water-borne disease spreads, as flooding is frequently followed by epidemics.

- Recurring famines spread malnutrition worldwide, and even in wealthier nations, a growing proportion of the population is hungry day-to-day.

- Hydroelectric plants find that their capacity to generate electrical power is threatened by falling water levels in reservoirs.

- While tri-sector cooperation grows to meet these needs, the debt burden across the global economy makes it hard for any sector or nation to respond consistently to the level of need.

- Innovative solutions aimed at addressing the bottom of the pyramid begin to gain some foothold: with growing recognition that the most pressing issue is not water supply, but rather water access, these innovations focus on financial and behavioral innovations.

- Declining wildlife disrupts the ecological balance in watersheds, reinforcing cycles of drought and/or flooding. Faced with disaster, people often engage in ecologically unsound practices, further reinforcing the cycle of disaster.

- Water security becomes a military priority, and water management agencies become increasingly militarized.

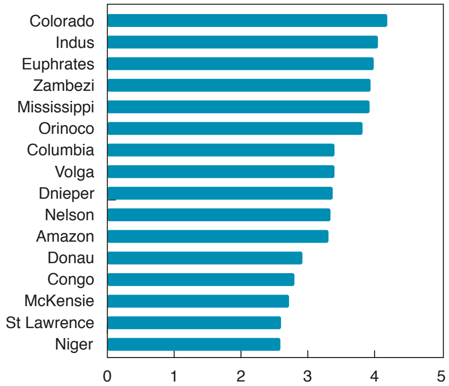
- Water bills of rights proliferate, often with a focus on local water rights. However, they all contain a general message of water as a human rights issue.

SIGNALS OF COLLAPSE
IN THE WATER ECOLOGY

FLOODING AND DROUGHT IN THE RIVER BASINS

Atypical weather patterns as a result of climate change are already visible today. Scientists measure these divergences in terms of 100-year norms. For example, a so-called 100-year storm is a measure of the most extreme flooding in a century. Scientists in Japan have estimated that in this century, we will see such storms returning at a rate of less than 10 years for five rivers (including the Columbia, the Yellow River, and the Brahmaputra) while many others will see return rates in 20-, 30-, 40-, or 50-year cycles. Meanwhile drought can be measured in the increase in "drought days" in a year. Nearly 20 major river basins can expect to see their drought days increase by a ratio of 2 to 4—that is doubling or quadrupling—during this century.

These rivers are likely to see at least twice as many drought days as in the last century.



Source: IFTF from data in Yukiko Hirabayashi, et al., "Global projections of changing risks of floods and droughts in a changing climate," *Hydrological Sciences*, August 2008.

The Colorado River system is expected to experience a 10–30% decline in runoff over the next 30 years, with a 50% chance that, by 2017, reservoir levels in Lake Mead will drop too low to allow hydroelectric power generation.

Source: http://ucsdnews.ucsd.edu/newsrel/science/02-08Lake-Mead.asp

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SAME WATER, NEW FINANCIAL MODELS

Many water activists are quick to point out that the problem of access to water for the world's poor is not so much an issue of water availability as it is the financial structures that underpin our water and sanitation infrastructure. The burden of cost for connecting to the infrastructure generally rests with the household, and in many parts of the world, that cost is too high. Organizations like Water.org are working with new micro-finance models to allow more households to gain sustainable access to water. Over the next decade, expect to see more pro-poor financial innovations focused on providing basic water and sanitation.

Source: http://water.org/

Water.org channels charitable giving into micro-lending programs that help poor households connect to the water infrastructure.

CROP MIGRATION

Throughout history, crop migration has been as significant a driver of human migration as war or colonialism. Already we're starting to see climate-sensitive crops shifting. For example, rising temperatures are driving vineyards to cooler, higher climates. The combination of water and temperature changes will likely drive more agricultural migration over the next decade, and these shifts will, in turn, shift populations, jobs, wealth, and environmental risk.

Source: http://www.mnn.com/food/wine/stories/some-vineyards-suffer-while-others-thrive

The Spanish winemaker Torres has moved its coastal vineyards in Chile and California into more mountainous areas.

TRANSFORMATION

Oceans of Invention

Water has always been an invitation to human exploration, from our early seafaring forebears to adventurers who used the world's waterways to penetrate new frontiers and establish new civilizations. In a world of gradually shifting paradigms, water again begins to take on this quality of territory. It becomes not just a resource but also a frontier for remaking our human civilization. And while this new territorial view—a distinctly ecological view—touches water in all its many geographies, it is most obvious in the shifting human relationship with the oceans. Although oceans are seen as resources to be exploited, perhaps more important is the abundant information they begin to provide about who we are biologically and ecologically. Belonging to no single nation, the oceans are the substrate for global cooperation. They are the canvas for invention and expression of future visions. In a quirky twist of evolution, we find ourselves contemplating a return to underwater life.

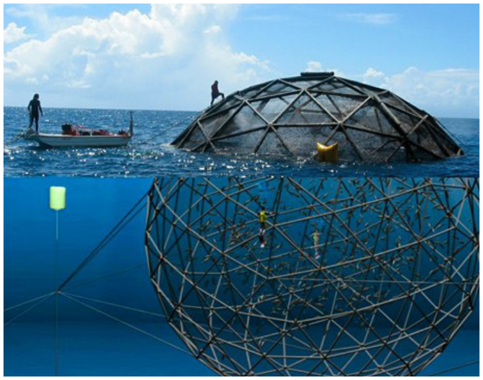
- In a rush to save the world's fisheries—sometimes using robotics—we amass extreme volumes of data about the ocean ecology that help us become better farmers of the ocean than we are of the land.
- Like early explorers who rigorously catalogued all the plant and animal life they encountered along their routes, humans embark on an effort to catalog the plant and animal life underwater, often using remote sensing and monitoring and enlisting citizen scientists.
- Large-scale collaborations leverage social technologies as well as cyber-infrastructures to map, model, and generally build human intelligence about the oceans—and more generally about the global ecology.
- The very small-scale world within the vastness of the ocean becomes the basis for high-resolution views of biological processes, creating the underpinnings for an increasingly sophisticated bioengineering paradigm.
- The world increasingly looks to the oceans to provide its basic food stocks, not only restoring fisheries but seeking novel uses of sea vegetables and algae.
- Unable to claim ocean territories, countries and companies lay claim to new intellectual property (IP) from ocean-based innovations. However, the coordinated efforts and scale required tend to favor an open-IP approach to ocean research, which is reinforced by a sense of urgency about fine-tuning the ocean environments to mitigate climate change.
- Nevertheless there is a bounty of new IP for everything from medicine to materials, food, and energy. Conflicts over ocean IP grow.
- Robots become our partners in a wide array of ocean enterprises, from monitoring and cleanup of the ocean to fish farming to repair and restoration of the coral reefs.
- Like explorers and colonizers before them, those who would settle the ocean territories with new tools and cultures often disturb existing cultures—human and otherwise—leading to increasing conflicts at sea.
- The dream of living in the ocean becomes a global meme, and several groups attempt to establish ocean colonies, exploring alternative models of how to live on and in the water. The most popular future vocations for youth growing up are oceanography and ocean architecture

SIGNALS OF TRANSFORMATION
IN THE WATER ECOLOGY

ROBOTS IN THE REALM OF FISH

Robots are increasingly deployed to do our bidding underwater—and especially in big ocean projects. MIT scientists are experimenting with super-sized fish-farm cages that can be controlled with remote-control propeller systems, anticipating a future of artificially intelligent cages that seek out good fishing waters on their own. Meanwhile, a UK project is releasing schools of robotic fish off the shores of Spain with the mission of detecting chemical leaks from ships.

In a 21st century vision of aquaculture, the Aquapod fish-farming cage, which can be as large as 92 feet in diameter, is being outfitted with remote-control propeller systems and might eventually move independently.



Source: http://news.nationalgeographic.com/news/2009/08/photogalleries/future-fish-farms-pictures/photo2.html

Schools of pollution-fighting robotic fish were created by the BMT Group in UK. Each "fish" is approximately 6 feet long.

Source: http://www.bmt.org/News/?/3/0/510

UNDERSEA MAPPING

An indicator of the interest in the "new territory" of oceans is the extent of mapping, cataloguing, and monitoring of undersea life. The first ten-year *Census of Marine Life* will be released this year, drawing on a global effort of collaborating scientists. These efforts scan lifeforms at every scale, from microbe to mammal. A variety of platforms for this work are being constructed from the cyber-infrastructure for studying marine microbial metagenomics at Calit2 in San Diego to Facebook-based efforts by earthdive.com to engage amateur divers worldwide in posting observations of marine life.

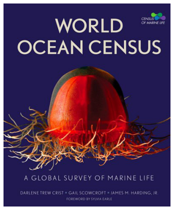
CAMERA, or Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis, is developing the framework and platform to support the data tools and resources to use the growing body of metagenomic information—that is, information about genetic samples collected from the natural environment.

camera
Marine Microbial Ecology

Source: http://camera.calit2.net/

The Census of Marine Life is releasing its first *World Ocean Census* this year. The project taps marine scientists from around the world.

CENSUS OF MARINE LIFE



Source: http://www.coml.org/results-publications/worldoceancensus

OCEAN AS HUMAN FRONTIER

Among the visionary projects that look to the ocean as the next human frontier is Open Sailing, which hopes to inspire the building of an International Ocean Station, taking inspiration from the International Space Station. The project includes subprojects involving oceanographers, maritime engineers, biotechnologists, farmers, physicians, and designers

Source: https://sites.google.com/a/opensailing.net/www/

The Open Sailing project is a collection of ocean labs and a think tank focused on defining a new oceanic urban structure.