Chapter 3

A Call to Cities: Run Out of Water or Create Resilience and Abundance?

Will Sarni and Josh Sperling

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.82853

Abstract

New management choices, with new approaches to urbanization and integrated water-energy-food management, are emerging as critical to combat water stress. Urban strategies and tactics are explored in this chapter with a focus on scaling effective solutions and approaches. This includes a focus on small, modular, and integrated water-energy-food hubs; off-grid and localized "circular economy" services that are affordable, accessible, and reliable; blended finance for new technologies, infrastructure and business models, strategic plans, and policies; and urban, behavioral, and decision sciences-informed decisions and new public-private-research-driven partnerships and processes. There are two key messages: first, business as usual could lead to "running out" of water where it's needed most—in cities and for agricultural and industrial production. Second, "innovators" and "early adopters" of market-based and data-driven efforts can help scale solutions led by people and communities investing in new ways to integrate urban water, energy, and food systems. The chapter concludes with discussion on a new, proactive "maturity" model, enabling integrated urban infrastructure systems, governance, and cross-sector innovation. This includes market-based and data-driven responses that first focus on improving quality of life, sustainability, and resilience of communities, bringing valued services via water-energy-food nexus decisions.

Keywords: water, energy, infrastructure, market solutions, nexus governance, cities

1. Introduction

For the first time in decades, water, energy, food, and other systems are experiencing significant innovations. These innovations—with breakthroughs in distributed, modular, and digitally connected technology and governance strategies for "energy and water as a service" options—are all recognized as having potential to transform dynamics that may lead toward dramatically different futures. One future is more water and energy use, aging infrastructure with deferred maintenance, and unhealthy communities. The other future is significant public and private benefits of more water choices, greater affordability and accessibility, and healthier, more livable communities, with less energy use and fewer costs. A new ethic around water is needed to achieve the latter. As this resource becomes "precious," new levels of maturity for co-designing urban nexus experimentation for resilience and abundance may emerge. Furthermore, market-based approaches and structural shifts in governance using emerging data, by bringing new transparency, will inform new ethical behaviors and moral decisions for crises and upscaling of innovations. Cities, utilities, and service providers will all be on frontlines of integrated solutions for the complex water dilemmas ahead. However, predicting and paying attention to the "late adopters and laggards" may be equally key.

Business as usual has not led to sustainable, healthy, nor resilient future pathways for urban and rural communities. However, necessity has been noted as a unique catalyst for innovation and may prove a key motivator for new approaches. In particular, cities are rapidly growing demand centers for maturity in sustainable and integrated resource management. Unique pressures and risks to economic growth [1], development, and social and ecosystem well-being are motivating many global cities currently struggling to supply equitable access to services to invest more readily in safe, secure, and affordable water systems. Lessons across urban systems, including those with reliable, affordable, secure water and energy, offer a key opportunity to improve management of impacts from pollution and extreme weather events.

Today, when supply exceeds demand, the absence of public policy or poorly conceived strategies for water can often go unnoticed with few, if any, consequences. This is no longer an option in a world where increased demand is creating scarcity and difficult allocation choices. In many parts of the world, demand currently exceeds supply due to rapid increases in population and associated needs for energy, food, and products. As a result, a key need is to accelerate urban water-energy nexus technology, partnerships, financing, business models, and public policies to ensure adequate water and energy infrastructure systems and governance approaches to upgrade urban services enabling economic development, thriving environments, and social well-being.

Data

- How can research-practitioner communities advance data-driven decisions—what strategies can best generate enhanced data and models of increasing equity to resilience?
- What nexus strategies will encourage innovation and reinventing of global urban water systems across emerging/converging energy-water-food systems/services environments?
- What will be the future of revenue and infrastructure (re)development, and in what direction do we need to move for harnessing technology and new services for positive economic/business model outcomes while reducing financial or environmental risks?

Assessment methods

- What are key priorities, modernization definitions, and related nexus metrics for reporting (e.g., water productivity for energy and agriculture systems or energy productivity for water and wastewater treatment to food storage and distribution)?

- What input data, models, and information resources can be drawn upon?
- How best to integrate resilient infrastructure investments and decision support system tools that are cross-sector, multilevel, and enabling of cost-effective/sustainable PPPs that offer market-based and data-driven strategies?

Box 1. Key questions on long-term impacts and urban nexus transformations.

While water-related crises are unfolding in cities all over the world, with less than adequate response strategies [2, 3], many will agree that cities will likely not "run out" of water; instead, these crises will lead to difficult and painful choices on allocation. In the long-term, what water may be left could primarily go to the privileged. This is why the questions noted in **Box 1** may become increasingly critical.

Cape Town offers one illustrative example: "About a quarter of Cape Town's population lives in the informal settlements, where they get water from communal taps instead of individual taps at home…." "One reality is that those 1 million people out of a population of 4 (million) only use 4.5 per cent of the water."—http://www.cbc.ca/news/world/cape-town-water-day-zero-1.4518226.

2. Data and insights informing a city maturity framework

How did Cape Town get to the point where it had to plan for "Day Zero," when extreme restrictions on access to water will be enforced? Some might ask, are there not ample technological solutions to address the shortages? How does a metropolitan area of nearly 4 million people manage to become "the first major city in the modern era to face the threat of running out of drinking water"? What we do know is that Cape Town is not alone, and the challenges extend beyond technology to multiple institutional challenges and the way water is valued today. With a recent report exposing 11 other cities at risk, many anticipate significant underestimates as to the number of cities in peril (https://www.greenbiz.com/article/avoiding-next-cape-town-water-strategy-shared-responsibility).

First, let us explore the narratives for Cape Town. What went wrong? Where should blame be placed, and which institutions and new policies led to a city more equipped for creating innovative responses? In addition, how are such problems prevented from arising again as access to fresh water becomes one of dominant public policy issues of the twenty-first century? Barriers identified to date have included:

- Lack of awareness
- Lack of sustainable business models
- Lack of dynamic and relevant pricing policies
- Lack of clear legal frameworks
- An abundance of conservativeness and reactive approaches

While additional, local, context-specific factors could continue to drive future water crises in Cape Town and other cities, these non-technological issues offer a much broader set of risks faced across many cities. Whereas drought and water supply shortage help to demonstrate the central role water plays in our lives, this role seems to remain underappreciated and, as a result, undervalued.

On the surface, the underlying story is about a failure in how the public sector manages water. All too often, public water policy is based upon poor data and information, inadequate public engagement, and a belief that the past is a good guide to the future. In other words, water is too often treated as a taken-for-granted asset rather than a strategic resource for economic development, social well-being, ecosystem health, and competitive advantage. Where water is viewed strategically, e.g., Israel and Singapore, water scarcity and stress do not limit economic development and business growth yet enhance it as these countries often turn their water technology innovation investments into an export initiative (e.g., WATEC, Singapore World Water Week).

In response, revolutions and leapfrogs in approaches may be needed to ensure both bottom-up to top-down approaches are accelerated to hold cities, states, utilities, businesses, communities, and national leaders accountable for this shared resource, both to each other and to future generations counting on getting this right for coupled human-environmental-economic security and regional stability [4]. Additional illustration of city examples representing inaction, reaction, and painful choices will be needed so we can learn from past failures and enable new advances and water culture shifts. Likewise, cities moving to resilience and abundance, through a new set of values, ethics, and norms—coupling technology-planning-governance-behavior-finance systems need to be further explored. This is elaborated on in the following sections.

3. Integrated approaches in moving to resilience and abundance

While there is considerable discussion of the energy-water-food nexus and associated impacts, there is less of a focus on innovative solutions. Resource stress and scarcity foster innovation in technologies, financing, business models, and partnerships. We are also seeing innovation in public policy to address nexus stress and scarcity. Public policy innovation is catching up to advances in technology, financing/funding, business models, and partnerships. Collectively, innovation will move the world from scarcity to abundance if managed effectively by the public sector, companies, nongovernmental organizations, and civil society. This section of the chapter explores initial innovative approaches to addressing water security within a context of energy, water, food, land, climate, and other systems and services that help reframe decisions as integrated solutions to *create abundance.* (https://www.routledge.com/Water-Stewardship-and-Business-Value-Creating-Abundance-from-Scarcity/Sarni-Grant-Orr/p/book/9781138642553 and https://www.routledge.com/Creating-21st-Century-Abundance-through-Public-Policy-Innovation-Moving/Sarni-Koch/p/book/9781783537518).

Also, invaluable experience was gained in working with XPRIZE (www.xprize.org), Imagine H2O (www.imagineh20.org), and 101,010 (www.101010.net) along with multinationals and nongovernmental organizations (NGOs) on water risks to food and energy production.

The bridging between engineering, entrepreneurship, data science, and public policy, among other fields, has the potential to help chart a better path forward. In this chapter, we refer to a new field of urban nexus science and innovation, one that helps move toward recognizing that 9 billion people deserve access to energy, food, safe water, sanitation and hygiene as part of a fundamental quality life, with a critical focus toward helping inform the integrated design and scaling of innovative solutions, while not just continuing to rely upon current 'siloed' approaches, which have yielded incremental progress.

3.1. An urban nexus response maturity model: from incremental transitions to breakthrough (or leapfrog) transformations enabled by market insights

Below offers a framework toward nexus-based solutions that enable increased abundance. Markets setting ambitious goals and using new performance metrics for risk mitigation are enabling new city competitiveness opportunities. Market-based approaches and structural shifts in governance using nexus data are also informing behaviors and decisions that may offer opportunities to upscale strategic innovations.

Cities, utilities, and service providers are increasingly faced with complex and challenging water-related dilemmas. **Figure 1** offers examples of how different types of urban water actors and institutions could begin to respond in the context of their own water systems and services, to think about linkages and opportunities by also tackling related food and energy systems and services.

This system integration framework and future mapping of related data can offer key inputs for water security to cross-sector impacts, helping address questions such as:

- What's the role of integrated or "nexus" solutions that include revolutionary data integration and transparency?
- How will responses to different hazards—e.g., extreme heat, drought—enable new resilient infrastructures and institutions that bridge public-private-entrepreneurial innovation?
- What if tomorrow's systems and services had "urban nexus solutions" (e.g., integrated resource efficiency, circular economy, renewable energy desalination, water reuse for food and energy production, integrated infrastructure and institutional (re)development, and modernization to address aging, centralized, legacy systems that are functioning poorly)?
- What are the best urban water, energy, and food pathways that efficiently advance water security, with radical transparency, offering "leapfrog" improvements to quality of life for all, complemented by decoupling of economic prosperity from environmental impacts?

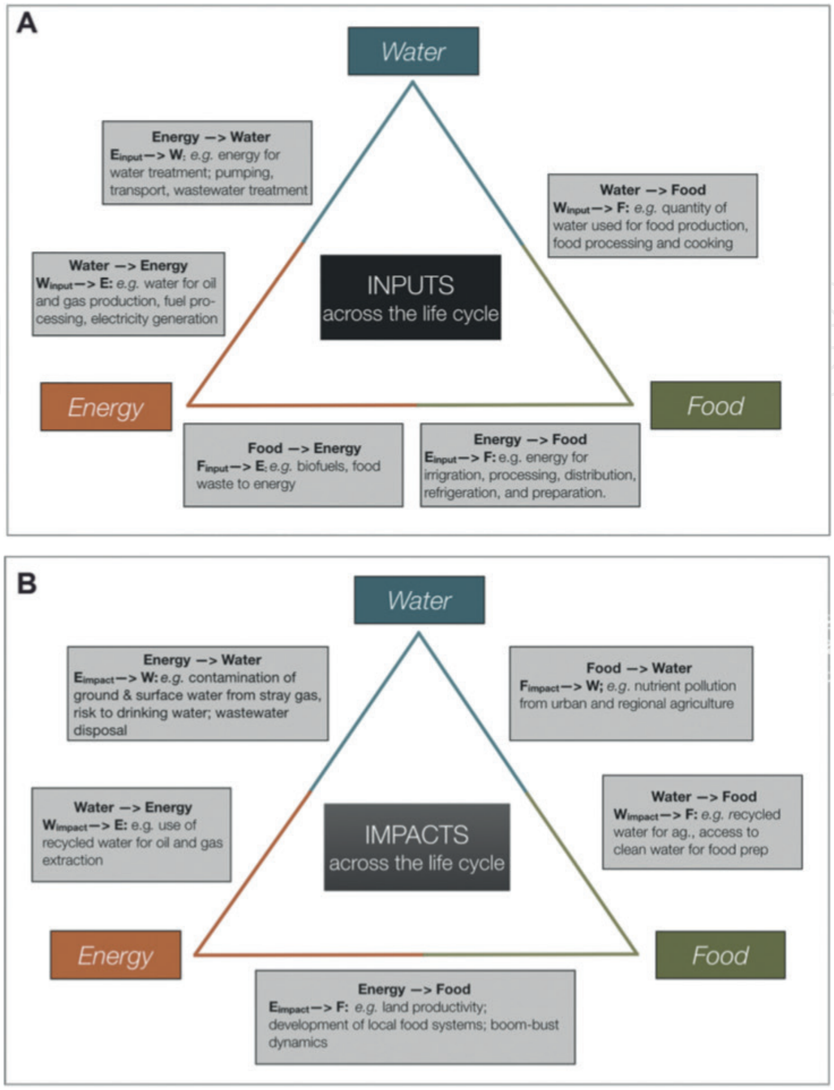

Figure 1. Illustration of initial pairwise relations in the FEW nexus framework for a proposed extension of an urban nexus maturity model, to inform and help develop nexus indicators at the urban-regional scale, considering (a) inputs to food, energy, and water systems as well as (b) impacts on each of these systems from the other two. Source: Ahamed et al. [5].

4. New urban nexus concepts for resilience and abundance

Water and energy are national and global priorities for security, economic prosperity, and human well-being. The term "coupling" has been applied to communities and nations that have effectively enabled new synergies between water and energy industries, technologies, infrastructure, or policy trajectories that maximize economic prosperity (or productivity) while enhancing resource or service sustainability (or resilience), respectively. Similarly, "decoupling" often refers to the positive outcome of increasing economic prosperity while reducing environmental impacts and unsustainable resource use. The term "leapfrogging" has also been applied to communities and nations that have adopted new forms of advanced infrastructure, technology, and cooperation, so as to reduce risk among competing uses through new insights. By bypassing traditional progressions, e.g., from no phones to cell phones—bypassing landlines altogether - the overallocation of resources or increasing competition for scarce freshwater sources could be bypassed through integrated approaches to water, energy, and agricultural productivity. For the first time in history, transitions and transformations (perhaps even "leapfrogging" opportunities) exist for energy-efficient water services and water and energy-efficient agricultural productivity across rural, suburban, and urban environments of the USA. Such innovation can be further catalyzed within a context of prizes and critical water issues for global geographies, with a focus on market-based solutions that enable national competition through improved energy and water services for smart, healthy, and resilient communities.

While aging and deficient infrastructure systems for water, wastewater, transportation, and energy have become the norm in the developed economies, humanity is experiencing new frontiers in digital technologies, globalization, and water-energy connectivity. The trends of urbanization [6], in particular, have many countries and their communities in emerging markets asking how and why water technology and infrastructure modernization could help to increase competitiveness in attracting talent and businesses, enabling new "leapfrogs," and decoupling economic prosperity from environmental damage. Setting triple bottom-line goals—social, economic, and environmental—while harnessing new technologies, training-entrepreneurship-innovation roadmaps, and multi-sector approaches that meet rising demands for services and while not being hampered by legacy, aging, or deficient systems—may offer cities and nations a competitive advantage within a global economy.

To keep pace with growth, it is estimated that by 2030—just 12 years from now—the world may have to produce 40% more clean water, 35% more food, and 50% more energy (UN, World Water Development Report, 2014). Moreover, these basic resources are mutually interdependent—to produce more of any one of the resources requires more of either one or both of the other resources. Increasingly, these resources will have to be made more accessible to locations where the majority of populations will reside in years ahead or to areas increasingly exposed to risk and vulnerability.

A fundamental step to address these challenges is to improve the efficiency of water and energy use. Intrinsically linked, wasteful operating practices in both energy and water systems increase the scarcity and cost of these resources. Both energy and water systems require focused efforts to optimize resource use. The cost and energy savings associated with improving water/wastewater system efficiency through variable frequency drives, fixing pipeline leaks and breaks, and tightening building envelopes to reduce energy loss are well understood. The key challenge to the adoption of these efficiency measures is funding. Funding gaps by power and water/wastewater utilities create significant obstacles to realizing these simple system improvements.

The following sections offer new city-related concepts and exhibits into the people and communities investing in transformations in urban systems related to water, energy, food-related infrastructure, governance, and new behaviors. These exhibits also help respond to the identified 20 top challenges facing the urban water sector (as identified in an AWWA report: top 20 challenges facing water sector (2018 survey results) in https://www.awwa.org/Portals/0/files/resources/water%20utility%20management/sotwi/2018_SOTWI_Report_Final_v3.pdf.

4.1. Exhibit A. Designing integrated water-energy-food technology hubs

Digital solutions. John Deere is now using sensors in several of its products to increase farm productivity (http://www.bigdata-startups.com/BigData-startup/john-deere-revolutionizing-farming-big-data/). John Deere uses sensors added to its latest equipment lines to help farmers manage their fleets and to decrease tractor downtime while also saving on fuel. Sensor information is combined with historical and real-time data on weather prediction, soil conditions, crop features, and many other data sets. These tools aim to increase the productivity and efficiency of crops, resulting in higher production and revenue.

RENEWW Zones. By 2030, impoverished peri-urban areas are expected to double in size to almost two billion people. Rapid growth in resource demands due to population growth is already outpacing many governments' ability to extend basic services to slums and informal settlements, while centralized legacy water and sewer infrastructure systems are breaking down. How will communities that cannot meet their populations' needs for sustainable water, food, and energy now be able to meet them in future?

In response to this challenge, the USA is catalyzing a Renewable Energy, Nutrition, Environment, and Water and Waste resource recovery initiative (RENEWW). Innovation zones co-design partnerships between civil society, businesses, academia, and grassroots organizations to build capacity and harness innovations at the nexus of food, energy, water, and other systems that support and foster inclusive, smart, sustainable, healthy, and resilient communities that leverage the best of US innovation. To stimulate the development of game-changing solutions, RENEWW is launching a highly leveraged, incentivized community prosperity prize competition that pushes the limits of what's possible, captures the world's imagination, spurs new thinking, and accelerates change through the creation of RENEWW Zones.

RENEWW Zones are decentralized, closed-loop models of spatial planning and peri-urban service provision that replace fossil energy with renewables; derive new water, biogas, and fertilizer from wastewater; and produce food and biofuel with the recycled inputs, all cogenerated at near net-zero waste. Each RENEWW Zone would offer a green space for community recreation, recycling and sanitation services, as well as a place to purchase fresh food, recycled goods, biofuels, and safe drinking water, all within walking or cycling distance. Ideally, well-planned RENEWW Zones placed at the outer edge of existing informal settlements would provide a basis for adjacent planned urban extensions. RENEWW Zone business models would create local employment, reinvest profits to support operational costs, and engender new public and private financing. Profitable Zones would scale through replication as local private investors realize the potential profit in serving society's bottom billion.

4.2. Exhibit B. Off-grid "circular economy" services—affordable, accessible, and reliable

Zero Mass Water (https://www.linkedin.com/company/zero-mass-water) has built a residential solar air moisture capture system that can provide safe drinking water for a family of four. The system has been deployed in Ecuador, Jordan, Mexico, and the USA. Essentially, off-grid, safe drinking water is powered by solar energy.

The concept of "circular abundance" has been introduced recently for brainstorming new water and energy-related challenges and prize competitions, and the concept focuses on capitalizing on the innovative integration of energy- and water-efficient businesses, technologies, or other resources that flow from one to another in a synergistic, sustainable manner. It envisions a closed-loop model of responsible conservation and economic development that replaces fossil fuels with renewable sources; derives new water from wastewater, rain, and agricultural water; and produces food with recycled energy and water while creating near net-zero waste.

This nexus model aggregates and co-locates solutions—such as vertical farming; blue, green, and solar roofs; and waste-to-energy technologies—so as to allow the movement and utilization of resources easily from one production facility to the next. For example, using waste from a fish farm and converting it to energy to run the facility and then incorporating other technologies like efficient water filtration, water reuse, LED grow lights in vertical green houses, and solar panels can make the location ecologically and financially self-sustaining. Sewage water can be transformed into drinking water, electricity, biogas, and ash. And polluted water can be processed to extract fertilizer, industrial chemicals, and metals for reuse/resale. And by co-locating these production processes, we will maximize the efficiency of each individual process, minimize the amount of raw resource inputs (such as fuel, water, and land) required, and eliminate waste. Creating a system of "circular abundance" requires holistic water-food-energy planning—but in large-scale disconnected systems, the technical and social complexity of the challenge generally overwhelms even the most qualified urban sustainability planners.

4.3. Exhibit C. Conservation synergy and blended finance

Conservation synergy and blended finance. In 2008, the investor-owned, California-based utility PG&E, along with several water agencies in California, offered a rebate program for high-efficiency clothes washers. The rebate in 2013 ranged from \$100 to \$125—this includes a \$50 rebate from PG&E and a variable rebate from \$50 to \$75 from the water utility. PG&E has seen a 63 percent increase in customer participation since the water utilities joined the program and the water utilities have seen a 30 percent increase in their customer participation. The program has since expanded to 41 municipal, regional, and private water utilities.

We are also seeing a movement toward "blended finance" which, as the name implies, brings together diverse sources of capital to fund much needed investment in infrastructure. Two of the key actors in this movement is OECD and University of Oxford (OECD, 2017. Blended finance: mobilizing resources for sustainable development and climate action in developing countries and OECD-WWC-Netherlands Roundtable on Financing Water Second meeting 13 September 2017, Tel Aviv Session 4. Background paper The potential for public, purposed, development and hybrid finance to bridge the water infrastructure gap Alex Money, University of Oxford).

There is also great opportunity for the private sector to drive competition and innovation to help water and wastewater utilities adopt efficiency measures. Energy savings performance contracts are established mechanisms used in a variety of sectors to implement building energy improvements; however, these mechanisms are scarcely used in the water/wastewater arena. A challenge specifically focused on fostering private investment in the water/wastewater sector would reduce both energy use and costs. Through innovative finance models, the private sector would foster a measurable and significant impact on energy use in the water/wastewater sector while also providing capital to help these utilities with the investments needed to address the growing challenge of aging infrastructure. This effort would help to build capacity within the water/wastewater sector on energy use and conservation opportunities while overcoming the perceived obstacles of private sector investment in their systems. It would further incentivize private sector investors to evaluate the business propositions of water/wastewater utilities, identifying new opportunities for US business growth. The energy conservation measures addressed through this financing would be measurable in both cost and energy savings. The end result would be robust water/wastewater utilities that have optimized system performance to conserve energy and cost, freeing up operating budgets to invest in infrastructure repair and replacement programs.

4.4. Exhibit D. Urban, behavioral, and decision science on public-private partnerships

While humans historically planned for choices related to one-way flows of energy, water, and information (e.g., from a TV/radio, water/wastewater treatment and power plants), new energy and water technologies and their integrated services affording two-way and multi-directional information, energy, and water flows (and feedback for increased efficiency and economic opportunity) have the potential to become essentially ubiquitous in the decades to come. However, the opportunities to provide targeted services that optimize human prosperity, energy, and water benefits remain vastly underutilized and under-imagined.

Moreover, many institutions still appear slow to recognize and respond to the fact that water and energy systems can now behave more nimbly and adapt in real time as a result of recent disruptive changes in technologies and services. A prize is needed to address growing service and industry demands (e.g., for water management in hydraulic fracturing, (waste)water reuse, water for energy/agriculture, asset management, energy in water, and wastewater systems).

By creating a “race” to address the rapid pace of techno-economic change, increased connectivity, and transition opportunities toward improved services, prizes can improve the cost efficiency of water and energy services, and communities could continue to move toward circular economies with resource-efficient systems (including considerations that bring together energy, water, agricultural productivity, land, materials, waste, etc.). These technology and infrastructure service disruptions, if guided by prize challenges that enable higher public benefit, can provide for rapid expansion in choices, new finance revenues, and potential “leapfrogs” in enabling new businesses and industries that improve resident and business siting for co-locating near better services (faster, cheaper, safer, more reliable, cleaner, higher quality). Hybrid decentralized-centralized systems are increasingly viewed as key, and new data and analyses that evaluate the “decoupling,” “leapfrogging,” and “competitiveness” potential of new, integrated, market-based approaches will be needed.

A growing area of interest is at the intersection of water and energy system operations. These systems are often disconnected and operated independently. However, when considered in tandem, system integration may enable new opportunities to revolutionize the current paradigm of thinking. Energy use in the water/wastewater sector is poised to grow in order to meet the demands of population growth, deteriorating water quality, and increasingly stringent water regulations. Widespread deployment of variable electricity generation (e.g., wind and solar) is also placing a premium on power system flexibility. The extent to which drinking water and wastewater systems are powered by electricity and can be operated flexibly due to their inherent storage capacity and deferrable loads highlights the growing importance of the relationship between these two critical infrastructure systems and the need for integrated, resilient energy and water systems that perform reliably under normal conditions and are prepared for and can recover from disruptive events.

The power grid is continuously balancing supply, demand, and power quality requirements. Ancillary services are services provided to the grid that help match supply to demand and maintain power quality. Controlling or changing loads to support the grid or “demand response” is a strategy used by power system operators to balance supply and demand. Water/wastewater systems are beginning to explore participation in demand response programs, but they are still not widely adopted.

Multinationals and nongovernmental organizations (*NGOs*). The 2030 Water Resources Group (http://www.2030wrg.org/) released an online database of case studies to address water scarcity risks. It is designed to facilitate adoption of leading practices to cover a wide range of common scarcity challenges as well as proven solutions. The group offers for free download the full catalog of in-depth solutions (http://www.waterscarcitysolutions.org/).

These interdisciplinary and integrated responses have breakthrough and “leapfrog” potential for improving quality of life and the sustainability and resilience of communities in the context of water.

4.5. Bridging the rural-urban divide: harnessing emerging technologies and services, strategic planning, policy, behavior change, and finance

Today, characterization of the critical urban-to-rural water-energy-food sustainability considerations is often lacking, despite increased realization that the drivers of urbanization and city demands also have critical rural impacts—especially under quickly changing economic/environmental dynamics.

Going forward, can we predict—using data and multiple metrics—where and when rural and urban environments will see vulnerable communities become hotspots of vulnerability and/or seedbeds of innovation? For example, this could include demand/supply/ecological quantity/quality—and identifying where gaps are growing and where climate may add risk—and potentially bring new ethical dilemmas and painful choices. By first taking a look at some key consequences from already unfolding urban water crises, it may be possible to unpack several key messages/hypotheses for further rapid experimentation and evaluation of effectiveness.

This can include city strategies and objective assessments that include the ability to:

- Define and measure innovation, reinvention, and maturity of responses.
- Identify sweet spots of service users, designers/operators, and cross-scale policy actors (including public, civil society, business/firms) and their roles in rural to urban settings.
- Proactively move responses at the speed of need by creating continuous dialog and exchange, communities of practice, and feedback loops.
- Predict, mitigate, and finance immediate responses to long-term strategy (with evaluation of past failures, ethical dilemmas, and policy processes) for enabling secure and resilient cities.
- Expose future interurban risk/vulnerability hotspots and resilience strategies (as maps).

5. A path forward: urban maturity framework

How do we move past business as usual, and what is the road map or response framework for cities? Can cities and nations achieve competitive advantage through integrated sustainability and resilience strategies for transformation toward secure, affordable, reliable water systems and services? Themes emerging in this chapter and across the water industry pointing to new, integrated opportunities increasingly include:

- Personalized and valued services
- Shared/circular economy/closed-loop services
- Data/transparency for agile development
- Multidisciplinary approaches to breaking down boundaries and enabling new finance
- Diversification and decentralization with limited hierarchy enabling new accessibility
- Advocating and measuring for "excellence" using creative, entrepreneurial approaches

While there are several answers to move cities to a thriving, resilient state with equitable access to safe drinking water, there is no silver bullet. Clear examples exist on two sides of the same coin (as to human behavior/decisions): 'necessity as the mother of innovation' and 'if it ain't broke, do not fix it, both of which are business as usual responses. In essence, how do we avoid business as usual failures in Cape Town, South Africa, that have occurred also across the many other cities?

Certainly, what is needed are better data and actionable information. However, we also need a process to use actionable information to inform public policy innovation to accelerate scaling of innovative technologies, funding and financing strategies, and partnerships and business models. To a significant extent, we need to mobilize all stakeholders, including but not limited to the public sector, to ensure water to drive economic vitality (Averting the Next Cape Town).

"Ultimately, water scarcity is a challenge for society as a whole, which needs to gather the will to develop a strategic water plan to avert the otherwise inevitable 'Day Zeroes' to come."

What has to change? Here are six steps viewed as essential yet only a beginning:

1. *Engagement*: If the public is unaware and/or does not care, we are destined to see more Cape Towns. It is the responsibility of the public sector to provide access to safe drinking water (SDG 6) but also the responsibility of the public to support such efforts.
2. *Innovation*: We need a broader view of innovation beyond technology to include business models, financing/funding, public policy, and partnerships.
3. *Scale*: Innovative solutions need to be scaled which requires adequate and sustained funding from consumers, government, and the private sector.
4. *Pricing*: Access to water is not free; it is now a costly necessity. We need to treat it as such by recognizing that access to water requires investment to protect and provision equitably.
5. *Urgency*: Voluntary approaches will not address the water crisis. We need regulatory action that fosters innovation and enforces conservation and does it quickly.
6. *Honesty and transparency*: The public sector must acknowledge a new normal, and investments are required to ensure access to water. We no longer can blame the weather. As long as we continue to refer to Cape Town as a natural (rather than man-made) disaster, hope will be the best water strategy we can muster.

Given a shared responsibility to manage our scarce fresh water supplies, self-interest demands action. All individuals are ultimately accountable for this shared resource, both to each other and to future generations counting on our decisions to get this right.

What is the road map for cities? An urban water strategy maturity model is a useful framework to guide cities in developing an actionable strategy to avoid a "Day Zero." Below offers a timeline observing the evolving decision systems that are moving from reactive emergency/crisis response modes, voluntary programs, and inadequate data systems to proactively accepting responsibility for informed responses to increasing frequency and intensity of extremes (**Figure 2**).

In this maturity model, a road map can move cities from either no strategy or a severely outdated strategy to one where abundance with regard to water is created. Abundance is feasible but only if we acknowledge our current reality and leverage all stakeholders to apply the appropriate technologies and strategies available in the twenty-first century.

A critical aspect of moving along the maturity model is ensuring access to granular data and actionable information. For example, values for water/wastewater sector energy use are either high-level estimates (e.g., US water pumping, treatment, and distribution in 2015 required 34.65 billion kWh) or the energy use of specific processes (e.g., ultraviolet disinfection requires 255.5 kWh/million gallons treated). These data are insufficient for researching energy-water utility interactions on a city or national scale as energy use is a function of local water quality, regulations, technologies used, populations served, and geographical layout of systems.

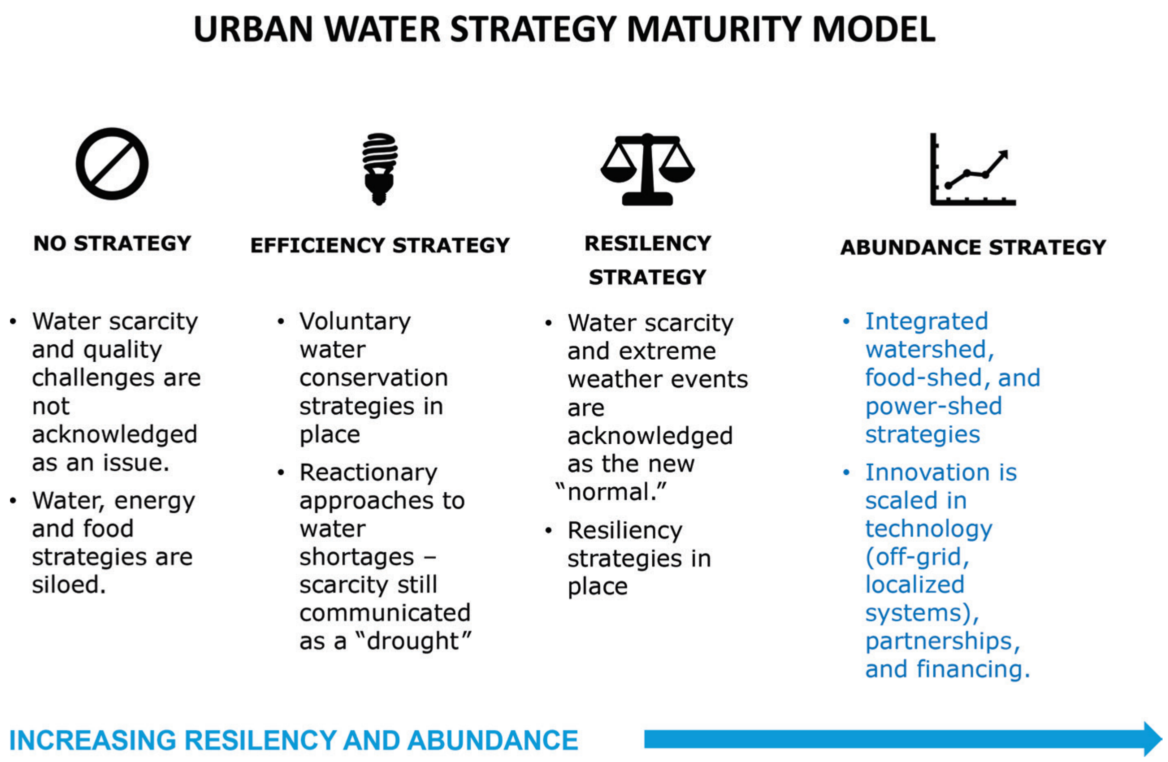

Figure 2. Urban response maturity model.

A solution to this critical challenge is to create an industry-validated energy dataset for water and wastewater utilities, and a water dataset for municipal, energy, and agricultural production activities helping to inform and quantify demand response opportunities for water/wastewater utilities and cities and provide new insights into the complex flows between electricity, agriculture, and water/wastewater utilities in the USA. Through a competitive prize challenge, entities could submit innovative approaches to collect and maintain this data, make it publicly available, and apply it to quantify, at a national level, the opportunities that exist for water/wastewater utilities to provide grid services.

This type of concept could define and enrich the understanding of how energy is used in the water and wastewater sectors or vice versa, as well as the potential for utility services that these systems can provide, helping to bridge the knowledge gap between water and energy systems and advancing maturity in this area. Identifying potential energy-water value propositions to water/wastewater utilities and the electric utilities that serve them is key. Further, such work can foster future dialog, technology, and policy solutions to complex challenges of integrating water-energy-"X" systems.

6. Conclusions: partnerships to inform smart and resilient systems

Additional research and practitioner efforts are needed to develop a network and community of research and practice that brings together interdisciplinary innovations from universities and national labs to the private sector who will coordinate their work, with focus on assessment of and enabling decision-making. This can include foci of water yet also broader emerging technologies coupled with new insights into human behaviors and decision processes within contexts of urban crises. Urban dimensions of mitigating risks to and increasing productivity of water infrastructure services are now more critical than ever. Further, road maps could aim to explore how, why, and where connected, automated, decentralized, and 100% renewable energy-driven water treatment systems and the critical services they enable can help achieve smart, sustainable, healthy, and resilient cities.

Future research and analyses could focus on at least three urban sites moving from painful decisions to abundant choices and increased resilience that has returns on investment (e.g., from new revenues enabled via system integration). In-depth case studies over several years may also be needed in order to inform effectiveness of responses to acute challenges as well as the longer-term design, operation, and use of systems/services in urbanizing to aging/legacy infrastructure-dependent cities.

Existing and new data streams coupled with visualization tools as means to provide interdisciplinary teams with evidence for water security, water-efficient energy, and agricultural systems to energy-efficient water delivery systems and infrastructure could all prove valuable.

Maturity models and frameworks that operationalize the extent to which urban areas are harnessing emerging data technology-human behavior-decision processes that can help enable transformations is a key message of this chapter, building on the characterization of the extent to which current challenges exist, motivating conditions for (revolutionary and disruptive) change to future prospects of sustainable trajectories toward the security and resilience of people, infrastructures, and resources.

New integrated road maps have the potential to substantially increase water and energy productivity, affordability, and resilience of urban (and trans-boundary regional) infrastructure. These infrastructures not only refer to the maturity of the technological and built environments yet also the diverse engineered-natural-social-cyber systems that provide water, energy, goods, and information services to more than 50% of the population living in cities today.

With rapidly increasing populations, projected resource scarcities, and vulnerability to disasters, smart and resilient cities will require new, high-performing, cost-effective infrastructures for future water (and energy) systems. One overarching question to be addressed moving forward might be: 'What are the interconnections of sectors, disciplines, and decision-making domains that must be explored to design sustainable, smart, resilient, and modern urban water and infrastructure systems of the future?'

Author details

Will Sarni[1]* and Josh Sperling[2]

*Address all correspondence to: will@waterfoundry.com

1 Water Foundry, Denver, Colorado, United States

2 National Renewable Energy Lab, Denver, Colorado, United States

References

[1] Arup. The Future of Urban Water: Sao Paulo. 2016

[2] eNCA. Bangalore Faces Man-Made Water Crisis. 2018. https://www.enca.com/world/bangalore-faces-man-made-water-crisis [Accessed: July 2018]

[3] Rashad J. The world's longest river is in trouble. The Washington Post. 2018. https://www.washingtonpost.com/news/theworldpost/wp/2018/03/22/egypt/?utm_term=.826b245a97c9 [Accessed: July 2018]

[4] Tellman B, Bausch JC, Eakin H, Anderies JM, Mazari-Hiriart M, Manuel-Navarrete D, et al. Adaptive pathways and coupled infrastructure: Seven centuries of adaptation to water risk and the production of vulnerability in Mexico City. Ecology and Society. 2018;**23**(1):1. DOI: 10.5751/ES-09712-230101

[5] Ahamed S, Sperling J, Galford G, Stephens J, Arent D. The food-energy-water nexus, regional sustainability, and hydraulic fracturing: An integrated assessment of the Denver region. Case Studies in the Environment. 2019;**2019**:1-21. DOI: 10.1525/cse.2018.001735

[6] McDonald RI, Weber K, Padowski J, Flörke M, Schneider C, Green PA, et al. Water on an urban planet: Urbanization and the reach of urban water infrastructure. Global Environmental Change. 2014;**27**:96-105 https://www.sciencedirect.com/science/article/pii/S0959378014000880 [Accessed: July 2018]