Water-Energy Nexus; a Thematic Approach for Sustainable Future

Sunil[1]*, Arabinda Sharma[2],
[1]Department of Mechanical Engineering,
[2]Department of Civil Engineering
BRCM College of Engineering & Technology,
Bahal, Bhiwani, Haryana (127028)

Thakur Sanjay Kumar[3]
[3]Mechnanical Engineering Department
Darbhanga Engineering College
Darbhanga- 846005
Bihar

***Abstract*- Energy and water are inextricably connected. All sources of energy (including electricity) require water in their production processes: the extraction of raw materials, cooling in thermal processes, in cleaning processes, cultivation of crops for biofuels, and powering turbines. Energy is itself required to make water resources available for human use and consumption (including irrigation) through pumping, transportation, treatment, and desalination. Water is essential for the production, distribution and use of energy. Energy is crucial for the extraction and delivery of safe drinking water - and for the very safety of water itself. People everywhere - but especially the most vulnerable and marginalized - face great risks when access to either is limited or compromised.**

The energy and water nexus was coined as a focused area of study under the entire nexus to develop an understanding of the interdependencies and complications of water and energy alone. The water for energy and energy for water dependencies revolve around many elemental issues ranging from water management systems and water infrastructure to sustainable energy and efficient systems. This paper presents a thematic focus on water-energy nexus and sustainable approach to the management of both freshwater and energy resources.

Keywords: Water, Energy, Nexus, Sustainability, Policy Integration

I. INTRODUCTION

Water and energy, both central to the basic needs of people, and the well-being of our planet, are lifelines to sustainable economic and social prosperity. Water and energy have always been closely associated, and in many ways, have been the defining element in industrial and economic development. The notion of a "Nexus" of these sectors - that is a focal point at which the management, planning, and resource allocation intersect - is not new either. A number of conferences and meetings in the last decade have expounded on the notion of this decade, and with some variance have included a number of other elements also, including food, urbanization, health, etc. [1-3]. The idea that the Nexus approach can help bring down vertical silos separating historically distinct sectors, and thus achieving greater efficiency, is a major consideration in the ongoing dialogue on this topic. The idea, however, is not without its detractors who claim that such mergers across sectors and governmental bureaucracies are not feasible, and given some major disparities amongst the respective sectors, may even prove to be counter-productive. Energy generation, regardless of the technology or resource used, requires some form of water - either to move turbines in hydropower generation configurations, to cool energy generation thermal and nuclear plants, to irrigate bio fuel crops, or to serve as a drilling/pumping fluid in hydraulic fracturing systems [4]. Some forms of energy utilize water in a consumptive pattern, making it unavailable for subsequent use because of quality degradation or evaporation. Other forms, like hydropower are non-consumptive and may be further linked to water management and irrigation schemes. Conversely, water pumping, treatment, desalination, delivery, and wastewater management all require significant amounts of energy. Globally, it is estimated that about 8% of all energy generated is consumed for water management, making it a sizable energy consumer [5]. There is yet another societal nexus in which the lack of water and energy becomes a significant detriment to human, social, and economic development. The poorest of the poor - the so-called bottom billion - are people in developing countries who are without access to water, modern forms of energy, or adequate sanitation [6, 4]. The consequences are devastating in terms of a circular cycle of poverty, illness and deprivation. The author has publicly argued that addressing the global social development crisis requires a consolidated approach, in which combined solutions for water, energy and sanitation are provided to the bottom billion people on a priority basis [7].

As the United Nations collectively declared the World Water Day for 2014 to focus on the Water-Energy Nexus, a number of dialogues focused on the essentials, opportunities, and challenges of the Nexus. In order to better understand the nature of the "Water-Energy Nexus", a more fundamental analysis of the disparities, knowledge gaps, and policy roadblocks is needed. This paper aims to explore these underlying challenges, which may hinder the adoption of the Nexus approach, and offers some recommendations about ways to overcome them.

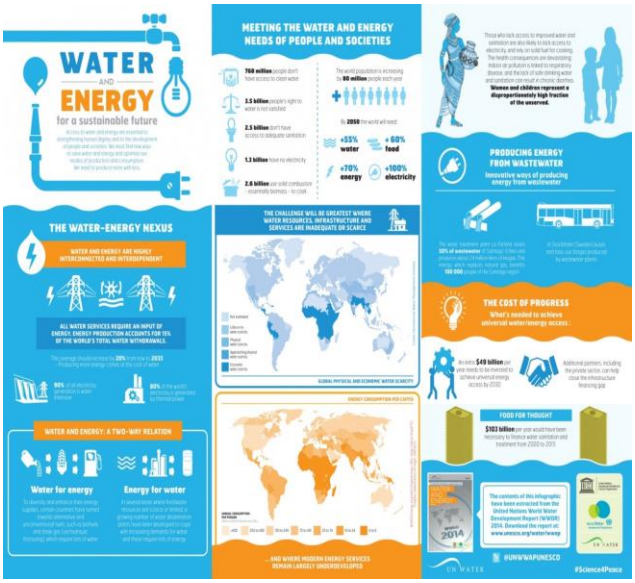

Fig. 1. Handout "Governing the water-energy nexus", World Water Week 2015

Ensuring that energy and water demands are met has profound implications on the other respective resource, as water is needed to generate energy (hydropower, thermoelectric cooling, fuel extraction and refining, irrigation for bio fuels) and energy is needed to extract, treat and distribute water and to clean the used and polluted water. No matter what the source, energy and water are inextricably linked, and must be addressed.

II. KNOWLEDGE CHALLENGES FOR THE WATER-ENERGY NEXUS

A. *Identifying and Quantifying Tradeoffs*

The competition for capital and financial resources for water and energy sectors is significant and often not neutral [8]. In other words, policy formulation at national level must account for some tradeoffs. Many national development processes are oblivious of these tradeoffs or do not possess the tools to adequately quantify these tradeoffs for rational policymaking [1]. For example, switching to aircooled or water-efficient thermal power plants requires a higher capital investment up front but could lead to long-term cost savings, particularly in terms of the water delivery costs [3]. Such higher initial capital investments can be more readily justified in situations where water scarcity or water pricing have resulted in water becoming a major cost component in energy generation. Similarly, many developing countries have shied away from investment in large-scale dams; the common arguments offered in opposition are societal impacts through displaced population, environment and ecosystem impacts of reservoirs, perturbation of water sharing amongst riparians, etc. However, these dialogues often become politicized and polarized; it is rare to have an unbiased discourse that would also account for savings in energy costs, creating of economic opportunities, increase in food security, and flood protection [9]. A major hurdle is that the full range of benefits associated with these elements cannot be easily monetized. The asymmetries between the water and energy sectors also feed into the difficulty of rational quantification of tradeoffs. Globally, energy sector is estimated at about US$ 6 trillion, whereas the water sector is estimated to be less than a tenth of that [4]. In many countries, the energy sector is greater in its financial mobilization by one or two orders of magnitude when compared to the water sector. That also implies that the respective interest lobbies are also disproportionate in size and wield asymmetric influence in policy formulation processes.

B. *Leveraging Benefit and their Sharing*

As noted earlier, it is often difficult to conduct quantitative tradeoffs between the water and energy sectors, but it is even more challenging to quantify knock-on benefits. For example, more efficient energy generation could have beneficial impacts on human and ecosystem health, but they might accrue in the medium - to long-term; direct attribution and accounting of ecosystem benefits poses a major scientific challenge. Similarly, better provisioning of water and energy at the household level could drive the public health costs associated with acute and chronic health problems. Accurately projecting these indirect benefits, such as reduced health care costs, is often beyond the financial planning capacity available in developing countries. This situation becomes progressively more challenging when water and energy are shared across jurisdictions and/or boundaries. Mechanisms for transboundary sharing are typically aligned to work on either energy or water, and very rarely both. From a rational standpoint, one might argue that mutually sharing conjoined water and energy-related benefits would create more options and opportunities for reaching compromises. The geopolitical realities and historical resource conflicts often intercede and interrupt the likelihood of mutually agreeable benefit sharing formulas.

C. *Undertaking Meaningful Risk Analyses*

From first principles, it stands to reason that ineffective management of water and energy resources exposes societies to a range of risks [10-11]. These include impacts of extreme events like floods and droughts, social unrest caused by energy and water shortages, economic destabilization by disruption in flow of critical resources for industrial and agricultural activity, reduced agricultural production and impacts on food security, and increased costs in public health. Some researchers are claiming, for example [12] in the case of the ongoing Syrian civil war, that a combined realization of these risks can cause major societal disruptions. Even when adverse impacts can be quantified, the results of such meaningful risk analyses are often trumped by short-termed political expediencies. While governments are hampered by political exigencies, the private sector has recently stepped up and taken on the task of quantifying risk based on scientific evidence. Foremost amongst these is the reinsurance industry, which has invested considerable resources in understanding and quantifying risks, and exploring risk mitigation approaches [13]. More generally the World Business Council on Sustainable Development has also taken on a more forward-looking stance towards understanding and addressing these risks [14-15].

D. *Assessing Resource-Efficient Technologies*

It remains a challenge to assess the efficiency of existing and new technologies in terms of water consumption, and somewhat less so for assessing energy generation and transmission efficiency. In most developed and developing countries, the notion of energy efficiency is relatively well established and does not require expenditure of political capital to demonstrate success. Water efficiency, however, becomes a factor only in extreme water scarcity situations, but is otherwise ignored. A key reason for this is the inadequacy of water pricing, allowing excessive water consumption with little financial consequence. At the same time, pricing of water services and supply remains a politically and emotionally charged issue - most politicians tend to shy away from that topic, as a consequence.

III. CREATING PARTNERSHIPS FOR POLICY INTEGRATION

In order to overcome some of the challenges identified in the previous section, out-of-the-box and innovative thinking is required. One might argue that policy integration around the Water-Energy Nexus can break down knowledge barriers and create enabling environment for demonstrating achievement of higher benefits. Such opportunities are often accompanied by risks, both of which are discussed in this section.

A. *Opportunity – Driving Development Agenda*

The Water-Energy Nexus offers a fresh policy perspective in which emerging notions like the green economy and triple bottom lines can be easily incorporated [7]. The "novelty" of the concept, on its own, can create space for policy dialogue, and the ability to define the nexus in specific national contexts. As the international community gears up to define the Post-2015 development agenda in terms of Sustainable Development Goals (SDGs), this agenda needs to be further translated in national terms, identifying approaches for implementation and resource allocation. Recent reports have argued that the Water-Energy Nexus offers a stable platform for this development agenda formulation [16].

B. *Opportunity – Promoting Sustainable Consumption Patterns*

Many researchers in the recent years have explored the notion of planetary boundaries and whether our current consumption patterns are crossing irreversible thresholds [17]. Whether one agrees fully with these global expert assessments or not, it is apparent that consumption patterns and consumer behaviours need a major re-think to achieve sustainable economic and industrial development. A dialogue around the Water-Energy Nexus offers a new opportunity to engage the general public and elicit its interest into a forward-looking dialogue. Many of the benefits achieved from improved water-energy security accrue in the short-term, making the notion tangible and digestible to the general public. The same argument could also apply to consumptive sectors of the economy, most notably manufacturing and agriculture. Creating a space for policy dialogue offers the opportunity for these sectors to look outside the 'box' and determine how increased water-energy efficiency can drive towards improved bottom lines.

C. *Risk – Enhancing Skewed Public Perceptions*

In Considerable negative opinions and suspicions exist around the private domains of the water and energy sectors. Examples abound. The hydraulic fracturing energy sector is viewed as a major pollutant of aquifers and even causing minor local earthquakes. The hydropower sector is deemed to be a destroyer of aquatic and land-based ecosystems, and a disruptor of communities impacted by water reservoirs. Coal-based power generation is deemed to be a major contributor towards global climate change, a cause of negative impacts in local health and ecosystems. Nuclear energy sector, impacted by recent disasters in Japan, is viewed with great suspicion. The water sector does not fare much better in public perception. Many view engagement of the private sector as a recipe for unbridled exploitation and depletion of water resources. In the Canadian context, many are concerned about the potential transport of water resources by the shiploads by the private sector to other countries [18]. As a consequence of pre-existing and persistent notions of malfeasance on part of the private sector, there is a significant risk that the Water-Energy Nexus may be viewed as a further collusion to deprive the general public of its wellbeing. This notion is further exacerbated by the misconception that the United Nations General Assembly has now declared water as a human right, and hence, it should be available to everyone free of cost. Those aiming to support the Water-Energy Nexus in the public-opinion space thus face an uphill battle for gaining the trust and favour of a suspicious audience.

D. *Risk – Lobbies Over-riding Public Interests*

In most cases, the energy sector lobbies exert considerable influence over politicians and policymakers –being driven by large-scale elements of the national economies. The same is often not true of the water sector, which is in contrast hampered by over-legislation or regulations. Nonetheless, proponents of the Water-Energy Nexus have to pay considerable attention to how abusive lobbying may be prevented and its potential negative impacts minimized.

E. *Disparity in Energy-Water Data Availability and Access*

As the energy sector is commercialized to a much greater extent, streamlined within economic flows, and retains considerable private sector engagement and interest, pertinent data are readily available at sub national, national and international scales. In contrast, the availability of water data suffers from considerable gaps, particularly for larger units such as transboundary shared river basins or aquifers. Water and related data are often characterized as state secrets and guarded as such. This unavailability and limited access to data translates directly or indirectly into the challenges outlined in terms of knowledge gaps presented in earlier sections.

IV. PUTTING THE WATER-ENERGY NEXUS IN SUSTAINABLE DEVELOPMENT GOALS

A green economy necessitates a focus on people, profit, and planet (the so-called triple bottom line), an aspiration that requires greater efficiencies, and synergies around the water-energy nexus. Building on the outcomes of Rio+20 and the predication of the post-2015 agenda in part, on a green economy, and the importance of water and energy for not only economic growth but environmental stewardship and social development, integration of both sectors is crucial. Economic and financial models of integrated systems can demonstrate not only the fluxes and flows, but the benefits which accrue to the triple bottom line. Thus the concept of sustainability may provide a method for conflict resolution; rather than profit maximization, the most feasible sustainable solution will be the determining factor for implementation.

A dedicated water goal in the post-2015 development agenda, with key interlinked targets in the energy goal, is essential to achieving a sustainable future. These interlinked targets, developed as part of the Sustainable Development Goals, include energy efficiencies in water and wastewater processes as well as water efficiency in energy production. Other areas for cross consideration include effluent water quality standards and management of hydropower installations for multi-use water storage purposes and not simply energy (i.e. flood control and irrigation, particularly in drought conditions).

A. Inserting Water-Energy in the Post-2015 Development Agenda

The Sustainable Development Goals must include universal access to water and energy as endpoints. Universal access to Water, Sanitation and Hygiene (WaSH) will be far easier to achieve within the context of universal access to energy. Synergistically, improved health, wellbeing, and productivity as a result of universal WaSH will likely facilitate willingness and ability to pay for energy access. Where affordability is still a barrier, integrated solutions which use either human waste to generate energy, or low-cost renewable energy to provide WaSH services can be implemented.

Interlinked targets post-2015 should highlight the benefits leveraged by the water-energy nexus on poverty reduction, empowering girls and women and achieving gender equality, ensuring healthy lives, creating jobs, sustainable livelihoods, and equitable growth as well as managing natural resource assets sustainably. As indicated in the opening section, the water-energy nexus, and the goal of water and energy for all, are necessary conditions for achieving these other goals. While the extent of the nexus role may be greater or lesser depending on which goal discussed, its absence will result in insufficient conditions for success.

B. Means for Achieving Water-Energy Sustainability

The nexus will only be realized through the mobilizing of capital for synergistic action. In turn, this will require that international finance corporations take the risk out of private sector investments. Perhaps the newly established financing mechanism by the BRICS countries can lead the way. Changes to the business model of energy companies can further decrease risks, as can using technology to balance risk portfolios (e.g. shale gas extraction not feasible in water stressed regions). Regulators can further include resilience expenses into tariffs, passing on the cost of some risk mitigation to customers, while ensuring pro-poor mechanisms are in place. Funding windows must be created to drive advances in different sectors. While this begins with the water and energy sectors, it must expand into other sectors dependent on these, such as transportation and agriculture.

V. RENEWABLE ENERGY SOLUTIONS IN THE WATER-ENERGY NEXUS

The energy sector relies heavily on water for energy extraction and production, accounting for 15% of water withdrawals globally and up to 50% in some countries. As energy demand grows, conflicts with other end-uses of water, such as agriculture, are intensifying and further compounded by climate change. It is, therefore, becoming necessary to decouple energy sector expansion from water use. Renewable energy technologies can facilitate that decoupling by enabling an accelerated, secure and environmentally-sustainable expansion of the energy sector, while reducing water use. Solar PV and wind, the most rapidly growing renewable energy technologies globally, consume up to 200 times less water than conventional power generation options including coal, natural gas and nuclear. Substantial water saving are already being realized in markets where these technologies have been deployed at scale. Indeed, the business case for renewable energy is further strengthened by the opportunities it offers for water conservation, an aspect closely analysed in IRENA's Renewable Energy in the Water, Energy and Food Nexus report. IRENA will present findings from the report highlighting renewable energy opportunities in the water-energy nexus as well as measures that could help realise these through integrated water-energy decision making.

A. Solutions for a sustainable future

A sustainable future is possible within the range of the existing resources. The inventory and the evaluation of best water and energy technologies available, show that there is room for improvement in human development. Many alternatives do exist that are compatible with growth and development and also make possible reversing natural degradation trends and the building up of a more adaptable and more resilient society. However, the relative optimism of this conclusion cannot shade the magnitude of the challenge of transforming the promise into a reality.

There is a vast literature presenting different solutions to the integrated investments of water and energy and as such there are many other opportunities for the joint development and management of water and energy infrastructure and technologies that maximize co-benefits and minimize negative trade-offs. Economic analysis can allow countries to decide if such models are viable in their context. Combined power and desalination plants, combined heat and power plants, using alternative water sources for thermal power plant cooling, and even energy recovery from sewage water are just a few other options that can provide income for one operation and make a waste a resource. It is even possible to

save energy and water more simply, through leakage reduction in the water sector, improving energy efficiency, or increase awareness of the issue to change the consumer behaviour and decrease energy and water waste. Besides the pursuit of new technical solutions, political frameworks need to be designed to promote cooperation and integrated planning among sectors as well. Integrated resource planning of the Energy-Water challenge emphasizes the importance of establishing a more open and participatory decision-making process and coordinating the many water institutions that govern water resources. Therefore, Energy-Water planning approaches should encourage the development of new institutional roles in addition to new analytical tools. It also promotes consensus building and alternative dispute resolution over conflict and litigation. Reforming existing management frameworks, from modelling, economics, and political, countries will be able to develop a more systematic approach to consider the complexities of water and energy issues, and the existing interactions and relationships between sectors. But this is easier said than done. Reforming political and institutional process is not an easy task. Transferring technologies either, as this process is highly correlated with existing capacities and regulatory and legal environments in the countries.

Furthermore, many of these technologies are quite costly and difficult to implement. Understanding the local contexts becomes essential if we are to ensure that many of the existing solutions can be fully implemented in the developing world. And quantification of potential tradeoffs and synergies is essential. Economic analysis can help capture tradeoffs in Energy-Water management decisions. Water and energy are crucial inputs into economic production. Tightening constraints may introduce the potential for reductions in economic activities. Actual outcomes will depend on the capacity of a community to adjust, rates of technological progress in development of water efficiency in energy and food production, rates of knowledge provision, institutional, governance, and planning arrangements to facilitate efficient investment and synergies in water and energy planning. One of the more difficult issues to manage is the fact that the economic value of water to the energy sector, at the margin, will generally be greater than its economic value to agriculture, while the implicit political power of the agricultural sector can sometimes be greater than that of the energy sector. This implies that the energy sector will generally be willing and able to pay more for water than competing agricultural uses - with the associated risk that some agricultural groups may seek to use their political power to redress this difference in economic power, such as by portraying the energy sector as damaging agricultural interests and threatening food security.

Moving towards less water intensive energy sources and less energy intensive water sources, saving water and energy in any production and consumption process and reallocating water and energy to their more valuable uses are all alternatives that take advantage of these synergies in opening the option of producing more with less. Nexus solutions can and should be implemented by building partnerships to allow a joint action and support in the search and implementation of effective measures. Building partnerships consists of making agreements to reap the benefits of cooperation in the water and energy sector. Not only are the challenges involved in the Water and Energy Nexus beyond the scope of any individual public authority, business or stakeholder but actions can be coordinated in such a way that the whole is greater than the sum of its parts.

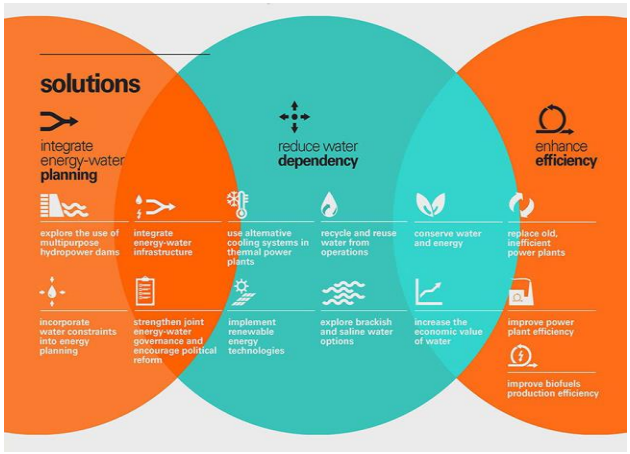

Fig. 2. Solutions to address the Water Energy Nexus (Source: http://www.worldbank.org/thirstyenergy)

VI. THE FUTURE OF WATER AND ENERGY

As the implications of water pricing illustrate, water is not a simple issue. Neither is energy. Water is largely seen as an essential right and a pre-requisite for human well-being. Energy, too, is tied in some way to everything that governments and businesses hold sacred: economic development, national security and environmental sustainability. If there is one lesson to be learned from the increasing demands on these resources, it is that neither energy nor water can be thought of in a silo. No longer can decisions about how to use or produce one quantity or the other be based solely on cost. Instead, impacts on all stakeholders within the watershed and on the electric grid-ranging from customers to supply chain partners, and communities to other businesses-should be considered. Moving ahead, this shift in mindset from competition to collaboration is anticipated to be essential to avoiding collisions and maintaining a free flow of opportunities at the intersection of water and energy.

Embracing new economic and business models means that meeting the needs of the water-energy nexus is not a zero sum game, but part of the new world of wins.

VII. CONCLUSION

Meeting future demands for water and energy resources requires innovative approaches that encourage cross-sectorial cooperation and improve analysis of water and energy tradeoffs at the national and regional levels. Furthermore, as organizations and experts go forward, creating Sustainable Development Goals and other targets, it is critical to cut across sectors in analysis because improvements for one goal may have negative impacts on another. Such as increasing the share of bio fuels in renewable energy generation may have a

greater impact on water resources than other renewables. Establishing emissions caps can promote the use of more water-intensive energy producing technologies with potential negative impacts on the sustainability of water resources and imposing negative environmental externalities. As governments and institutions globally consider goals of the future, best practices of today can be employed to enhance efficiency, resiliency, and integrated planning. These approaches will help governments and companies avoid financial losses in energy and power investments, infrastructure prone to risk in the wake of climate change, and unstable economies. The water-energy nexus require innovative and pragmatic solutions, application of the right technologies, and supportive economic enablers. These elements need to be integrated into national policies for more efficient and effective energy and water services.

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