CHAPTER 7

The Energy and Water Nexus: The Case for an Integrated Approach for the Green Economy in South Africa

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INTRODUCTION

The fundamental requirement of any economy is that it delivers food, water and energy security for all. In a green economy this will be provided by renewable energy; green buildings, including green retrofits for energy and water efficiency; clean transportation utilising alternative fuels, hybrid and electric vehicles (see Mytelka's Chapter 5); water management, including water demand management and conservation, water reclamation, purification and recycling such as industrial and domestic effluent; waste management (see Pilusa and Mazenda's Chapter 8), brownfield remediation and sustainable packaging; and land management, including organic agriculture, habitat conservation and restoration, urban forestry and parks, reforestation and afforestation, and soil stabilisation (PwC, 2011). From the foregoing, it is clear that water and energy are key components of the green economy.

At a simplistic level, the relationship between water and energy pertains to energy intensity in the water sector or the amount of energy needed for extracting, treating, transporting and distributing water, disposing of waste water, and water intensity in the energy sector or the amount of water needed for harnessing, extracting, producing and transmitting energy. Decisions about one can exacerbate scarcity or enable better management of the other from the perspective of conservation, consumption efficiency, and reuse and recycling (of water). The energy-water relationship, therefore, goes beyond simple footprint calculations and involves an understanding of the interdependencies and complications of water and energy.

This relationship or nexus of water and energy is one of the key entry points into the green economy debate and solutions. The philosophy of the green economy requires increased resource use efficiency, improving energy and water security, securing sustainable access to water and energy, and maximising the social amenity of energy and water. A nexus approach will support the transition to a green economy by creating opportunities for addressing synergies and trade-offs across these two sectors and enhancing policy coherence. Appreciation of this nexus will also highlight the set of green investment opportunities that are starting to emerge.

The objective of this chapter is therefore to highlight how an integrated approach to water and energy is one of the critical ways to achieving the green economy in South Africa. In doing so, it will specifically focus, firstly, on the gaps in policy and planning from a nexus perspective and, secondly, on how addressing these gaps could be pivotal to achieving a green economy.

The chapter is organised as follows: the first section explores the relevance of the energy and water nexus (EWN) to a green economy. It looks at the various elements and concepts of the green economy to explore the importance and role of the EWN in delivering this economy. Addressing any debates over the concept or application of the green economy approach or debating the merits and demerits of this concept is beyond the scope of this chapter. The second section provides an in-depth understanding of the interdependencies between energy and water. The third section looks at the energy and water-related challenges in the context of South Africa. The final section provides recommendations on how integrated energy and water planning could help address these challenges, thereby helping achieve the green economy objectives.

ENERGY AND WATER NEXUS AND THE LINK TO A GREEN ECONOMY

The Concept of the Green Economy

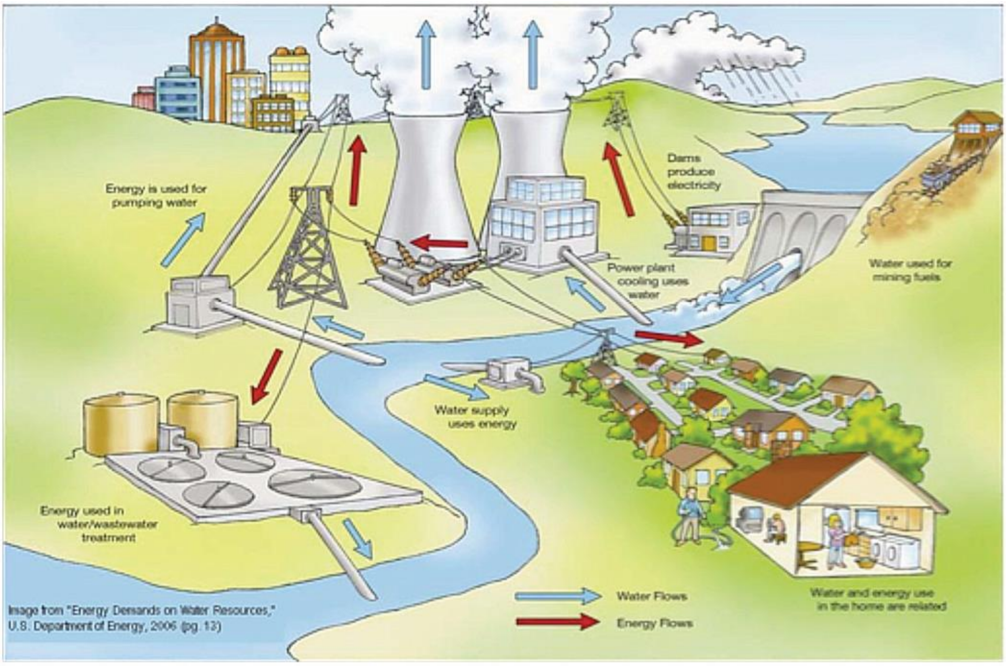
A green economy basically refers to a low-carbon economy with an efficient use of natural resources as well as traditional inputs such as labour and capital to produce well-being for the population. The philosophy underpinning the concept involves:

1. investing in, protecting and building the natural resource management and ecological restoration, particularly in the natural systems on which poor and indigenous communities depend for their livelihoods;
2. allocating environmental benefits and costs fairly for the achievement of a just and equitable society;
3. green economic services and industries incorporating efficiency gains in the quantity and quality of production that provides decent work, new employment prospects and affordable sustainable consumption alternatives; and
4. resource-efficient and low carbon economic development (Gulati, 2014b).

Relevance of Energy and Water Nexus to Green Economy

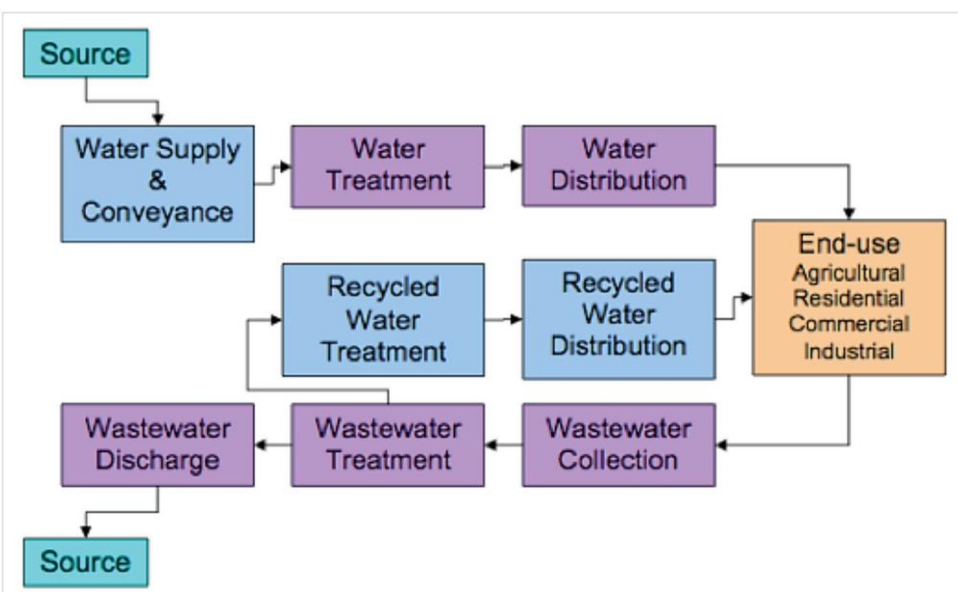
The term EWN is used to describe the interdependent, synergistic and mutually reinforcing relationship of energy and water. The production cycle for fuels and energy requires water at various stages: fuel extraction (mining and refining; oil, gas, uranium and coal processing; and coal and gas liquefaction and gasification), and cultivation of crops for energy production and generation (see Figure 1). Energy extraction and production also have an impact on water availability and quality. Similarly, energy is required at all stages of the water-use cycle (see Figure 2). Large amounts of energy are required to pump, treat and distribute water for urban, industrial, and agricultural use, human use, and to deal with the resulting waste. In fact, relative to its value, water is heavy, and, in energy terms, it is expensive to pump water over long distances as well as to lift it (UNEP, 2011). Energy is used by agriculture for accessing water resources, especially groundwater through pumping, and by households and industry for heating and cooling water (Gulati, 2014a). It is also used to purify and soften water for household use (Gulati, 2014a).

Figure 1: Water-use cycle



Source: US Department of Energy (DoE), 2006

Figure 2: Water-use cycle



Source: California Energy Commission (2005)

Table 1: Role of water and energy in poverty alleviation and human development as represented through the Millennium Development Goals

MDG Goal	Direct contribution of energy for achieving the MDG	Direct contribution of water for achieving the MDG
MDG 1: Eradicating extreme poverty and hunger	• Increased production, business development and income saving	• Factor of production in economic activity • Direct input into irrigation for grain production, for rearing livestock, tree crops, and subsistence agriculture
MDG 2: Universal primary education	• Improved educational environment through water, sanitation, lighting and commuting to school	• Improved school attendance rates on account of access and provision of safe, secure and clean water services
MDG 3: Promoting gender equality and empowering women	• Less time spent by women in collecting firewood and performing manual farm labour	• Opportunities for productive activities for women and girls and improved social and economic capital for women in terms of leadership, earnings and networking opportunities with improved water services • Lower risk of sexual assault of women and girls when gathering water and searching for privacy with location of water and sanitation facilities closer to homes
MDG 4 and 5: Reducing child mortality and improving maternal health	• Support access to health services, improving clean water availability and reducing water-borne diseases	• Lower maternal mortality risks due to improved health and reduced labour burdens from water portage and lower morbidity and mortality factor for children due to improved quantities and quality of domestic water and sanitation

MDG Goal	Direct contribution of energy for achieving the MDG	Direct contribution of water for achieving the MDG
MDG 6: Combating HIV and AIDS, malaria and other diseases	• Enable refrigeration of medicines, a distribution system for medicines, and access to health education through ICT	• Better water management for reduced mosquito habitats and malaria incidence as well as incidence of a range of diseases caused by poor water management
MDG 7: Ensuring environmental sustainability	• Enable mechanical power in agriculture to reduce demand for land expansion; reduce dependence on biomass; reduce environmental impact of energy sector	• Improved water management, including pollution control and sustainable levels of abstraction helping maintain ecosystems integrity

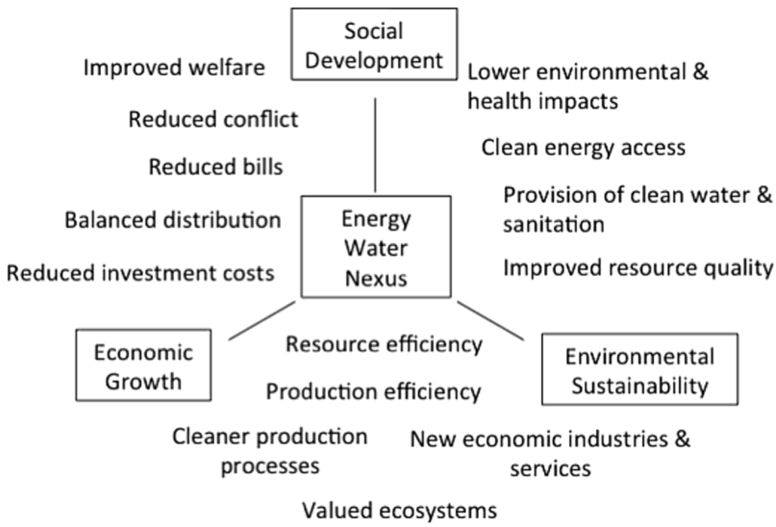
Source: UNECA, 2013; Paul, 2003; and Human Development Report, 2006

Clearly, energy is a water issue and water is an energy issue. Increase in demand for one will increase the demand for the other while shortage of the one can constrain the availability of the other. This is problematic given that both water and energy are crucial for human development, poverty alleviation and economic development (see Table 1).

From a planning and management perspective, the interdependencies between energy and water, coupled with increasing demands for energy, the need to lower carbon emissions, and the reduced availability of fresh water supplies pose considerable challenges to ensuring the sustainability of both resources. For example, policies to reduce carbon emissions such as carbon capture and sequestration could increase water use and policies for promotion of biofuels for transportation could increase competition for water resources. Irrigated first-generation soy- and corn-based biofuels can consume thousands of times more water than traditional oil drilling (Glassman, *et al.* 2011). The supposed low water intensity of second- and third-generation biofuels is yet to be proven. Similarly, harnessing new, distant or poor-quality water supplies and stringent standards for water and wastewater treatment could increase energy requirements.

At the same time, measures to support or enhance the conservation, consumption efficiency, and reuse and recycling of water or another resource could have unintended consequences for the other. For example, increasing energy supplies through certain types of incentives, or the lack thereof, or subsidising energy supplies could have unintended negative impacts on the national or regional availability of fresh water or water quality unless these policies are closely evaluated for both energy and water impacts. Similarly, efficient energy production facilities lead to more energy produced per unit of water used.

Figure 3: Relevance of the Energy and Water Nexus to the Green Economy



Source: Author

The EWN is therefore an important entry point into the green economy debate. The framework in Figure 4 conceptualises the importance of the EWN from the perspective of the green economy. The EWN will provide a systems perspective that is key to supporting the transition to a green economy through a better understanding of natural resource requirements for water supply and energy production; increasing social justice; decreasing poverty; increasing efficiency in the use of these resources; identifying synergies and addressing trade-offs across these two sectors; optimal allocation of these resources between sectors, geographical areas and population groups; enhancing policy coherence; optimising investments; and delivering high-quality energy and water-related services with less use of resources to support social and economic development in an eco-efficient and inclusive manner.

In doing so, the EWN will improve energy and water security; secure sustainable provision of water and energy; link growth, equity, poverty and sustainability; ensure that future resource needs will be met; improve economic efficiency across multiple sectors that use these resources; and help build resilience. Appreciation of this nexus will also highlight the set of green investment opportunities that are starting to emerge. Some such opportunities could be low water footprint energy technologies and low energy footprint water technologies.

UNDERSTANDING THE ENERGY AND WATER NEXUS

The Nexus From an Energy Perspective

From an energy perspective, the link between energy and water refers to the water requirements of energy technologies as well as the impact of energy extraction and production on water quality. Energy production requires water at the stages of fuel extraction, transportation, processing and refining, as well as at the energy-generation facility level. This water requirement is typically defined by way of water withdrawal and water consumption. Water withdrawal refers to the amount of water that is removed from the ground or diverted from a water source for use but does not indicate the amount that is returned to the source after use. Water consumption refers to the amount of water that evaporates, transpires, is incorporated into products or crops, or is otherwise removed from the immediate water environment (Macknick, *et al.* 2011) but not returned to the source.

Water requirements for fuel extraction, transportation, processing and refining, and the water-use implications associated with the land required for infrastructure construction for energy generation (Pegasys, 2011) (Table 2) suggest that upstream activities related to coal require the maximum amount of water. Coal mining requires significant amounts of water for beneficiation (coal washing), equipment cooling and lubrication, dust suppression, site operations (potable water) and post-mining replanting of vegetation (Eskom, 2011 and US DoE, 2006). In practice, this water consumption is included under the industrial or mining sector and is not reflected under the water intensity of the electricity-production technology.

Withdrawals for fuel refining and transport are relatively small compared to those for thermoelectric cooling, but are still significant (American Geophysical Union, 2012). Oil refineries consume about 880 MGD (million

Table 2: Water requirements for upstream activities related to coal-, gas- and nuclear-based electricity production

Lifecycle stage	Withdrawal (gal*/MWh)	Consumption (gal*/MWh)
Coal		
Mining/processing	58	16
Transport (slurry pipeline)	473	170
Plant construction	7	N/A
Total	538	186
Gas		
Extraction/purification	44	15
Transportation/storage	14	8
Environmental control	235	N/A
Total	323	23
Nuclear		
Mining/processing	66	19
Plant construction	8	3
Spent-fuel disposal	5	N/A
Total	79	40

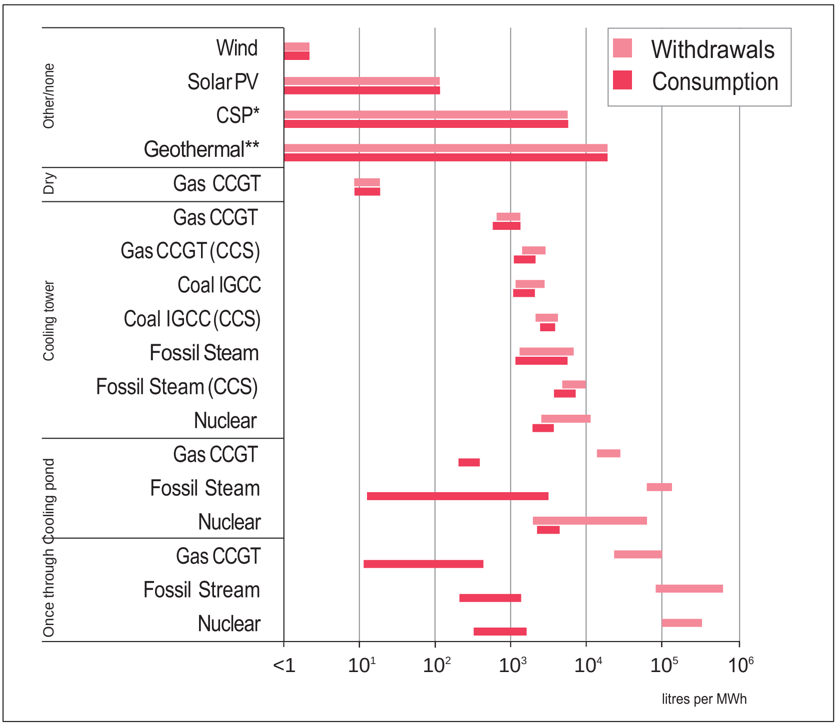
*One gallon = 3.78 litres

Source: Wilson, *et al.* (2012)

gallons per day) of water (about 1 gallon of water for each gallon of oil refined), and natural gas refining and pipeline transport consume about 400 MGD (American Geophysical Union, 2012).

At the energy production stage, energy technologies differ on water withdrawal and water consumption requirements. These requirements depend on factors such as fuel type, quality of raw water, quality of fuel and processing needs (American Geophysical Union 2012) and vary substantially even within technology categories. Therefore, these requirements are represented through a range rather than a specific single number. This also makes the comparison of technologies difficult. Therefore, electricity-generation technologies are often compared on the basis of water requirements for each unit of electricity generated (Figure 4), while transportation fuels are compared by water usage per unit of energy produced (Table 3).

Figure 4: Water use for electricity generation by cooling technology



Source: Hoffman, A., Olsson, G., Lindstrom, A. 2014

Table 3: Average water consumption by transportation fuel (gal*/million BTUs)

	Raw materials	Transformation
Oil (traditional)	1.4	12.5
Natural gas (as on land)	0	2
Unconventional natural gas (shale)	12.5	2
Oil sands	260	12.5
Enhanced oil recovery	1,257	172
Biofuels (irrigated corn)	15,750	9
Biofuels (irrigated soy)	44,500	9

*One gallon = 3.78 litres

Source: Glassman, *et al*. 2011

The Nexus From a Water Perspective

From a water perspective, energy consumption and loss of energy through the water value chain and the impact of energy outages, specifically electricity, on the water supply chain, are key (Table 4). Water weighs 8.35 pounds per gallon and therefore requires a significant amount of energy to lift (Water in the West, Undated). The energy intensity of each stage of the water-use cycle can vary significantly (Table 5) depending on the source of the water, topography between the source and places of use, stage of the water supply chain, technology deployed, condition of infrastructure, and the quality of the water being treated.

Table 4: Power outage impacts on the water supply chain

Stage of water supply	Impacts
Abstraction	• Adverse impact on pumps, equipment and telemetry devices • Problem in extracting water • Adverse impact on users of small-scale abstraction schemes such as boreholes
Water treatment	• Adverse impact on equipment, pumps, telemetry devices and dosing apparatus • Difficulty in transporting water • Negative impact on water quality due to non-functional water treatment processes • Negative impact on water treatment facility by way of revenue loss, reduced operational capacity, increased labour costs, water wastage, increased pump start-up costs and possible back-up generator costs
Water distribution/reticulation	• Non-operating pumps and telemetry equipment • Adverse impact on water distributed • Higher costs on account of back-up generators, portable water storage tanks for local communities, portable sewage spill bins and sewage spill clean-up costs
Wastewater treatment	• Non-operating pumps and telemetry devices • Limited control of treatment stops and sewage flows • Higher costs on account of equipment damage, possible back-up generator costs, portable sewage spill bin costs, increased labour costs and increased pump start-up costs

Source: Winter 2011

Table 5: Range of energy intensities for water-use cycle segments

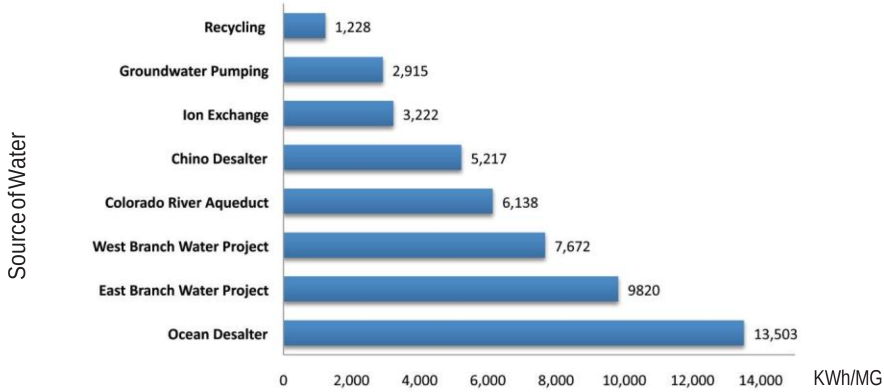
	Range of energy intensity (kWh/MG*)	
Water-use cycle segments	Low	High
Water-supply and conveyance	0	14,000
Water treatment	100	16,000
Water distribution	700	1,200
Waste-water collection and treatment	1,100	4,600
Waste-water discharge	0	400
Recycled water treatment and distribution	400	1,200

*MG – million gallons

Source: California Energy Commission (2005)

A comparison of water source options available to water utilities suggests that, with energy intensity ranging from 1,000 kWh/MG to 500,000 kWh/MG, desalination is often the most energy-intensive water option and water recycling is often the least energy-intensive option for utilities (Figure 5). Some estimates suggest that desalination could be 10 times more energy intensive than accessing local water resources (Hoff, 2011). Energy is also the largest single variable cost for a desalination plant. It is estimated that energy cost varies from one-third to more than one-half the total cost of desalinised water (Chaudhry, 2003 in Water in the West, 2013). Further, a 25 per cent increase in energy cost could potentially raise the cost of produced water by 11 per cent and 15 per cent for reverse osmosis and thermal plants, respectively (Cooley, *et al.* 2006 in Water in the West, 2013).

Figure 5: Energy Intensity of Water Supply Options for Inland Empire Utility Agency, US



Source: Water in the West, 2013

The energy intensity of a desalination plant depends on the quality (i.e., saltiness) and volume of water being desalted, and the technology deployed. Similarly, the energy intensity of recycled water depends on the quality of wastewater being recycled and on the end use of this water. The latter determines the standards to which water must be treated and, therefore, the process and technology to be deployed for collecting, treating, and disposing wastewater. Recycled water intended to be potable needs to be treated to high-quality standards, necessitating advanced treatment technologies that often have higher energy requirements (Gulati, 2014a). The distribution of recycled water often has a higher energy cost than the distribution of potable water, since wastewater facilities are typically sited at lower elevations to take advantage of gravity (Water in the West, 2013).

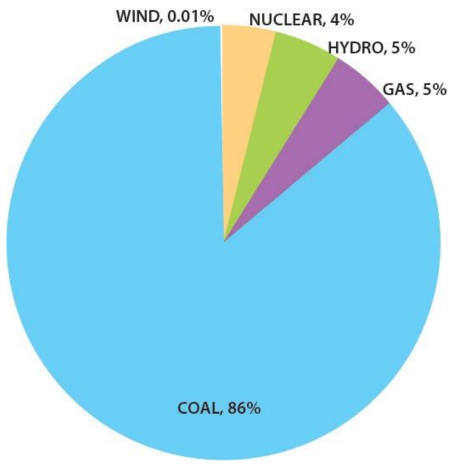
The next important aspect is the loss of energy in the water cycle and its impact on the cost of water supply and services. Energy is lost in the water cycle for reasons such as leaks in water conveyance systems or inefficient use of water; inefficient pump stations due to poor design; old pipes with high head loss; and bottlenecks in the supply network (Feldman, 2009). Leaking water distribution systems and lost water mean that utilities must produce a greater volume of treated water, implying increased energy consumption for abstraction, treatment, and distribution (Gulati, 2014a). It is estimated that, when global water-loss average is approximated at 30 per cent, the same quantum of energy is lost (Feldman, 2009). This in turn suggests that the potential for energy savings in the water cycle can be as high as 20 to 30 per cent of current consumption (Gulati, 2014a).

In case of energy outages, the impact on the water supply chain depends on plant characteristics and availability of back-up power (Winter 2011). Pumping is most vulnerable to electricity outages in the water supply chain. Energy outages also affect water security for end users due to the adverse impacts on abstraction, distribution, or water treatment points in the supply chain (Winter 2011).

THE NEXUS PERSPECTIVE OF ENERGY AND WATER RELATED CHALLENGES IN SOUTH AFRICA

The energy sector in South Africa is highly reliant on coal. Nearly 86 per cent of the electricity in the country is produced from coal (Figure 6) on the back of relatively water-intensive, wet-cooled coal power stations. Not surprisingly, there is codependence on electricity production and water use (Figure 7) and a shortage of water can affect electricity availability. The water requirement of electricity generation technologies in the context of South Africa is provided in Table 6. In 2010, wet-cooled coal power stations represented approximately 78 per cent of the country's power generation, while consuming 98 per cent of the water requirements of Eskom (Eskom, 2011).

Figure 6: South Africa's electricity generation capacity (2011)



Source: Eskom

Table 6: Water use by electricity-generation technology type for South Africa

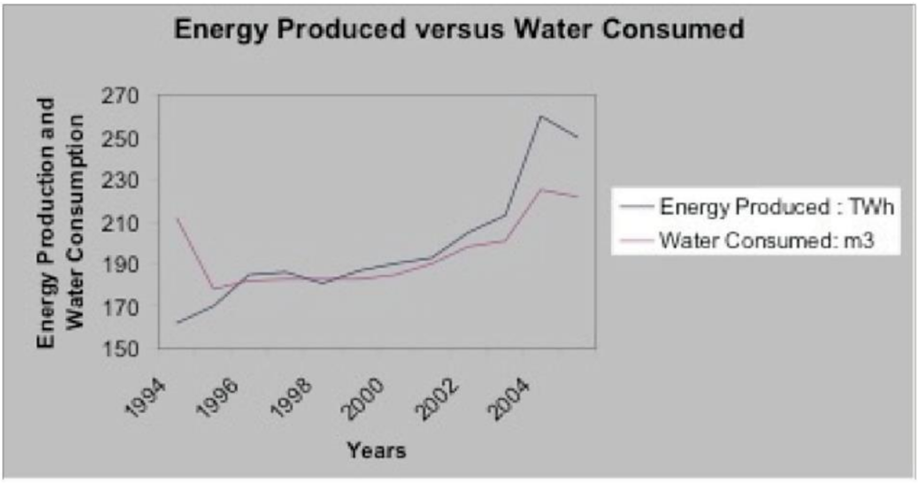
Technology type	Water Use (ℓ/kWh)
Wet-cooled coal (existing)	1.15–2.30
Wet-cooled coal (future)#	2.12–2.80
Dry-cooled coal (existing)	0.11
Dry-cooled coal (future)*	0.36
Nuclear	0.055
Open cycle gas turbine	0.01
Combined cycle gas turbine	0.25
Solar photovoltaic (PV)	0.01
Concentrated solar power (dry-cooled)	0.34
Wind	0

Refers to committed and uncommitted future capacity

* Includes flue-gas desulphurisation (FGD) technology

Source: Eskom, 2011

Figure 7: Relationship between water consumption and energy production by Eskom from 1994 to 2005



Source: Eskom, 2008 in Winter (2011)

This high dependency of the country's energy sector on water is of paramount concern given the grim situation of water resources. Out of the 19 water management areas (WMAs), five were already experiencing water shortages by 2000, 10 areas broke even and only four enjoyed a surplus of water. It is estimated that by 2025 South Africa's water shortfall would be 1.7 per cent based on current water usage. Shortage of water could therefore affect electricity generation.

The problem can be put in perspective when combined with the fact that most of the country's coal-based power plants are within regions partially or severely constrained in terms of water (Pouris and Thopil, 2015). Existing plants such as Camden, Komati and Grootvlei are located in the Olifants and Inkomati WMAs that are severely constrained while new coal-fired power plants, Medupi and Kusile, are located in the moderately constrained WMA of Limpopo and the severely constrained Olifants WMA, respectively (ibid.).

Various measures have been implemented in the country to conserve water at power stations. This includes a shift to dry-cooling technology for coal-fired power stations, which have 5 to 10 per cent of the water requirements of wet-cooled stations (Eskom, 2011). Nevertheless, these power stations are still 100 per cent dependent on water (Eskom 2011) and a rising demand for energy in the future has the potential to significantly increase water consumption.

The dependence on coal also raises concerns in terms of the impact of its extraction on water quality. Acid mine drainage (AMD) from coal-mining areas has led to acidification of rivers and streams and elevated metal levels (WWF-SA, 2011). This is problematic given that the quality of freshwater resources in the country has been declining and 40 per cent of freshwater systems are now in a critical condition while 80 per cent are threatened.

In some cases, coal mining has impacted catchment water quality to the extent that the catchments have been rendered unsuitable for the use of the very coal-fired power plants these mines supply. One such example is the Olifants River catchment where coal mining has contaminated rivers and streams to the extent that the water cannot be used in the coal-fired power stations there (WWF-SA, 2011). Water from this catchment needs to be treated before being used in coal-fired power plants, incurring additional costs and consuming additional energy, or it must be supplied from an alternative cleaner river system (WWF-SA, 011). Similarly, the Camden power station in Mpumalanga is reliant on inter-basin transfers from the unimpacted Usutu River system originating in eNkangala for water that is fit to use in the power station (WWF-SA, 2011).

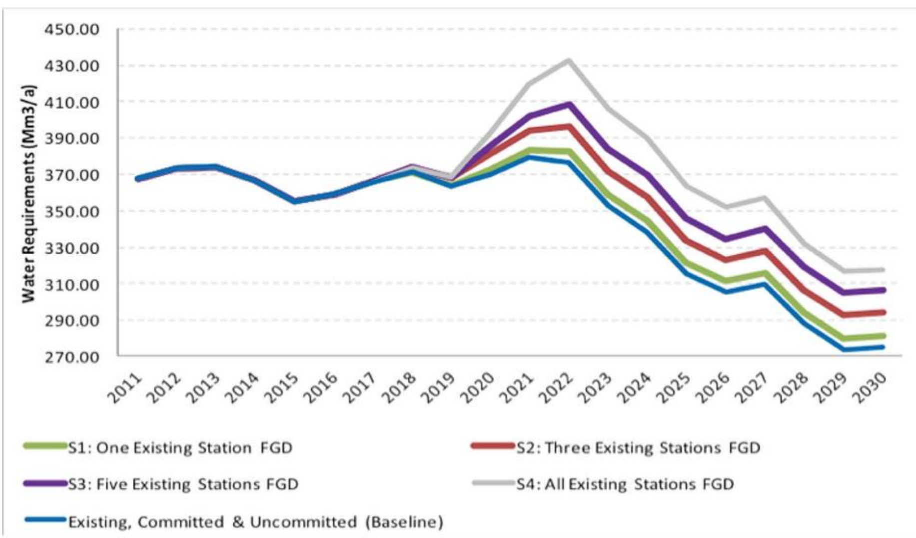
Although legislative changes have ensured that mine water is integrally considered in the mining process and have led to good practices such as the eMalahleni water purification plant situated in the Witbank coalfields of the Mpumalanga province, turning mine effluent into a usable resource (WWF-SA, 2011) across the industry requires significant technical and financial resources that are often beyond the reach of smaller mining companies.

Heavy reliance on coal also makes the electricity sector account for half the country's greenhouse gas emissions. The electricity system is thus a key point of intervention from the environmental perspective. Measures to this end include an increasing share of renewable energy (RE) in the electricity generation capacity, and the development of carbon capture and storage (CCS) technology that has the potential to achieve emission reductions of between 80 and 85 per cent (Eskom, 2011), and installation of flue-gas desulfurisation (FGD) technology at coal-fired power stations for meeting local air-quality standards. These measures could have a significant bearing on the energy sector's water requirements.

Some RE technologies, such as concentrated solar power (CSP), are water-intensive technologies, even though they place a lower demand on water resources compared to coal-fired power generation. As with coal power plants, CSP plants are also located, or are proposed to be located, in areas facing water stress. This means that local water availability for these plants could potentially be a problem (Gulati, 2014a). This water requirement can be mitigated through the same dry-cooling technology as coal-fired plants (Gulati, 2014a). The bidding process deployed to select the CSP projects to be developed in the country does not provide for a preferential payment to CSP with dry cooling. Since the cost of implementing this technology is about five times greater than the regular wet-cooling technology (Gulati, 2014a), it is important that CSP with dry cooling be incentivised in the process.

Carbon capture and storage (CCS) technology could also increase the water consumption of power plants between 46 and 90 per cent depending on the technology deployed (Eskom, 2011). Similarly, retrofitting existing coal-fired power stations with FGD and installing FGD at all new coal-fired power stations could dramatically increase water requirements for the electricity sector (Figure 8), although the water requirements in 2030 are expected to be lower than 2011 requirements (Eskom, 2011).

Figure 8: Water requirement implications of FGD retrofitting and installations



Source: Eskom (2011)

Eskom's modelling of future water requirements for the most likely power-generation scenarios in the country show that 1) water requirements in 2030 would increase by 23 Mm^3/annum with coal replacing the planned nuclear capacity and FGD being installed on only new coal capacity; 2) 42.5 Mm^3/annum with existing plants being decommissioned as planned and FGD being installed at all existing, committed and uncommitted power stations; and 3) 173.7 Mm^3/annum with a generation-capacity gap, no existing plants being decommissioned and FGD being installed at all existing and future power stations. The third scenario has the biggest potential impact on water requirements in the future and could therefore pose serious trade-offs for water allocation to agriculture if it materialises (Gulati, 2014a).

The issue of nuclear is of significance here. The Integrated Resource Plan (IRP) 2030 plans for the procurement of 9.6 gigawatts (GW) of nuclear power. On the water-use side, nuclear power plants use large quantities of water for steam production and for cooling. Some nuclear power plants remove large quantities of water from a lake or river. On the water-quality side, the build-up of heavy metals and salts in the water used, as well as the higher temperature of the water discharged from nuclear power plants, can negatively affect water quality. Waste generated from uranium mining operations can contaminate groundwater and surface water resources with heavy metals and even traces of radioactive uranium.

Two other lower carbon technologies also merit discussion: gas-to-liquids (GTL) and hydraulic fracturing for shale gas. GTL is the conversion of natural gas into petrol distillates such as transportation fuel or other chemicals. Once again, a wide range of values for consumptive water use can be associated with this technology. The water-intensity average of GTL is 42 gallons per MMBTU and ranges from 19 to 86 gal/MMBTU.

Hydraulic fracturing is a technology used to harness shale gas and involves pumping fluid composed of water, proppants, and chemicals into the ground at very high pressure. The pressurised water and chemicals create and enlarge cracks in the shale formation, increasing its permeability by 100- to 1,000-fold and allowing hydrocarbons to flow more easily to the wellbore (Reig, Luo and Proctor, 2014). Shale gas resources in the country are pegged at around 485 trillion cubic feet (Tcf), though the economically recoverable reserve is yet to be determined (Fakir, 2015). The volume of water required for hydraulic fracturing depends on the nature of the fractures that have to be performed. Based on experience in the United States, drilling a single well can require between 0.2 million and 2.5 million litres of water and hydraulic fracturing of a well can require between 7 million and 23 million litres of water, 25 per cent to 90 per cent of which might be consumptive use (Reig, Luo and Proctor, 2014). The water required by a single well can be roughly equal to the water consumed by New York City in seven minutes, or by a 1,000-megawatt coal-fired power plant in 12 hours (Reig, Luo and Proctor, 2014).

Limited experience with hydraulic fracturing and the wide range of values for consumptive water use associated with it indicate the high levels of uncertainty about its possible impacts on freshwater availability, although nationally the effects of water consumption for fracking may not be significant. That said, given that South Africa is a water-stressed country, the vast water quantities needed over the lifespan of a shale gas well, where water is used to fracture rock under high pressure, may pile further stress on local fresh water sources (SIWI, 2014).

The problem with the use of potable water is that a quantity of it is permanently lost and what is returned as flow-back and produced water (essentially wastewater from fracturing) is a mix of the originally pumped fresh water (which is now contaminated) and formation water (water rich in brine from the targeted shale gas-rich rock) (Fakir, 2015). Water that is not recycled or reused will incur an opportunity cost given the local water stress (Fakir, 2015). If properly treated, returned water can be reused in other fracking operations. But treatment methods for the returned water are often inadequate to achieve a potable water standard. If improved treatment procedures are developed, it will most likely be at considerable cost. Water quality is also under threat from fracking (SIWI, 2014). The risk of ground water contamination can be high if stringent standards are not adhered to for drilling of the borehole, installing the well casings and cementing them in place (Fakir, 2015).

The green economy demands not only a low-carbon economy but also allow water-use economy. Therefore, the low-carbon transition needs to be planned with due consideration to the implications for water requirements. Otherwise, the low-carbon economy could risk constraining the country's energy supply further and go against the tenets of the green economy.

The country is currently facing an electricity crisis. This crisis is expected to continue at least over the next two to three years. This is likely to aggravate the country's water crisis, which is already projected to be under stress with the growing population. There already exist examples of how the energy shortage in the country has led to plummeting reliability of water systems while threatening public health and safety. During the recurring rolling blackouts of 2007 and 2008, municipalities were unable to provide water and wastewater services. While Cederberg and the City of Cape Town experienced higher costs on account of damage to equipment and the cost of back-up services, Howick in KwaZulu-Natal and Zandvlei in the Western Cape experienced adverse health and environmental impacts, respectively (Winter, 2011).

Impending water scarcity and deteriorating water quality would speed up the exploration of new processes or technologies to access or treat existing water resources to make them usable. Desalination and wastewater treatment could be energy intensive (Table 7), and the shortage of energy or rising energy prices could either prohibit the feasibility of these options or involve trade-offs between water and energy security.

Table 7: Energy consumption range for the South African water supply chain (in kWh/M)

Process	Minimum	Maximum
Abstraction	0	100
Distribution	0	350
Water treatment	150	650
Reticulation	0	350
Waste water treatment	200	1,800

Source: Winter (2011)

In the past, the water sector, as has been the case with every sector in the country, has not given precedence to electricity efficiency measures due to historically low electricity tariffs. This situation started changing since 2008 on account of electricity shortages and rising electricity prices. Average electricity prices increased by 24 per cent per annum between 2008 and 2012. While further annual average increases of seven per cent were estimated until 2019, actual increases in many years have been well over seven per cent. For example, in 2015 average electricity prices rose by 12 per cent. There is no doubt that these price hikes are having a substantial effect on the actual cost of service of water utilities. Thus, there is a need to ensure that the selection of technology must consider electricity costs, and technologies should be as cost effective as possible and should pursue energy-efficiency optimisation in waterworks (Scheepers and Van der Merwe-Botha, 2013).

On the water and wastewater treatment side, the inability of existing water resources to dilute pollutants would necessitate that raw water will increasingly have to be treated, or standards for water treatment will have to be progressively increased (Gulati, 2014a). Wastewater management and treatment has, in fact, long been considered an important instrument for public health and the control of pathogens, and municipalities are consistently faced with stricter effluent discharge standards (Scheepers and Van der Merwe-Botha, 2013). Currently, only 76 per cent of Water Service Authorities (WSAs) treat the raw water supplied to end users and the level of treatment varies considerably amongst them (Winter, 2011). With all WSAs treating water to 100 per cent, energy consumption and related costs could increase substantially, necessitating higher municipal service charges.

This does not imply that there is no understanding of the link between energy and water amongst policymakers and planners (Gulati, 2014a). Water is recognised as a key constraint in the planning of future electricity generation capacity under IRP 2010–2030. The Biofuels Industrial Strategy, which provides the framework and incentives for the development of biofuels, initially proposed a five per cent penetration level of biofuels in the national liquid fuels pool. This was reduced to two per cent after the National Treasury expressed concerns over the water requirement implications of such a mandate.

However, policies have deficiencies. For example, IRP 2030 only considers water usage under the decision-making criteria. It does not consider either the risks of potential water scarcity for the planned generation capacity and electricity supply or the electricity sector's ability to provide reliable and sustainable energy supply in the event of water insecurity (Gulati, 2014a). Similarly, the mandate for all new coal power plants to utilise dry-cooling technology can be short-sighted if it omits an effective and long-term solution for a low-water-intensive electricity system (ibid.).

POLICY RECOMMENDATIONS AND CONCLUSION

Understanding the EWN and managing energy and water resources in a comprehensive and systematic way is critically important to meeting the basic needs of these resources and achieving the green economy objectives. It provides the opportunity for integrated planning that is key to assessing pathways that are affordable in the short-term and sustainable for the long-term, thereby meeting the concept of the green economy. In fact, there are risks that energy and water policies developed in isolation to increase efficiency in one sector may not only be creating additional demand in the other sector but also creating risks pertaining to broader allied economic activity and lowering the resilience of relevant social systems. Below are some recommendations that would facilitate the cooperative and adaptive management of these vital resources and help to achieve the green economy goals for South Africa.

Addressing Data Gaps

There is a clear need to improve the quality of the data on energy-for-water and water-for-energy use. The real understanding of the energy-water nexus and its impact on green economy objectives, such as resource security and economic and social development, will be possible only with reliable, current and comprehensive national and local-level data. Improved availability and accuracy of data will facilitate informed decision-making; prioritise investments in both energy and water infrastructure; and lead to better water and energy use practices. Examples of data requirements include water usage for liquid fuel production; water usage for exploration of new energy sources; the impact of new energy sources on water quality; energy use by new water sources; water usage patterns for new coal technologies; mapping of water usage of coal power plants in relation to water inventories in water deficient WMAs; the impact of low-carbon technologies on water usage; and water usage patterns in renewable energy technologies (Pouris and Thopil, 2015 and Gulati, 2014a). Significant attention needs to be paid to improvements in industry reporting, data collection and the sharing of data.

Integrated Resource Planning and Management

The EWN needs to be better recognised in policies, planning and related regulations, and laws dealing with the management and development of water resources and energy systems. This will optimise potential benefits, provide the right business and investment environment, protect the environment, and further the basic philosophy of the green economy.

This process could start with a review of existing policies to identify disincentives or positive synergies to integrated planning and management and sustainable supply of the two resources. Sectoral policies and plans for both water and energy need to better account for the multiple interrelationships of the two resources, as well as the impact of these interrelationships on different sectors of the economy.

To begin with, water security needs to be central to the energy-planning debate. In the event of regional integration of energy supplies and possible regional hydropower procurement, the energy-water nexus could become an important debate. Then policies should support the upscaling of new energy-efficient water technologies and water-efficient energy technologies, even though these may be expensive and deter energy technologies that pose risks for water availability or quality. In the case of new and emerging technologies, these must not be allowed unless the true scale of water impacts can be estimated.

There will be practical difficulties in achieving such integrated planning as water-resource planning is carried out at the level of river basins and energy planning is done at a national level. Nonetheless, coordinated planning will help meet the objectives of the green economy.

Coordinated energy efficiency and water conservation programmes could help garner savings of both water and energy, and synergistic energy and water production could enhance both water and energy security. For example, power plants and desalination or water treatment facilities could be co-sited and power plants could provide electricity at a preferential rate to these water-related facilities.

For example, minimising water loss through an active leakage reduction programme will reduce the energy wastage embedded in the lost water. Waste heat from power plants can be used in some desalination cycles, and biogas from wastewater treatment plants can be used for combined heat and power production. This is a relatively untapped energy source in the country.

Efficiency Improvement

There is an urgent need to prioritise reduction in leakage and energy efficiency in the water sector. Measures that can be considered to this end include water pressure management (as water leakage is driven by water pressure), sludge management activities such as aeration efficiency improvement, varying operating conditions, using chemical pre-treatment (this could lead to a potential electricity saving of 250–280 MWh/year), and optimisation of the operation of the distribution system by pumping at off-peak periods while ensuring minimum emergency levels in all reservoirs (Swartz, van der Merwe-Botha and Freese, 2013). The latter will not only effect energy savings in terms of electrical energy used for pumping but may also delay upgrades to the water distribution system (ibid.). Energy audits form the key to the identification of energy savings and therefore need to be mandated for water and wastewater systems.

Appropriate Pricing of Water and Energy Resources

Appropriate resource pricing can play an important role in driving conservation and innovation in management and use of both resources. Underpricing of resources encourages wasteful consumption of resources and misses a valuable opportunity to secure resources for effective protection and management of water. Energy and water subsidies help drive the cycle of inefficient and energy-intensive water use by hiding the true resource costs (Wolff, *et al.* 2004 in Water in the West, 2013). Of course, principles of equity would need to be considered and applied when higher pricing of water and energy resources is implemented. There is also a need to offer better incentives or to reconsider subsidies to manage the risks posed by the one resource to the other. For example, CSP project developers need to be given incentives to deploy the water-saving, dry-cooling technology.

Increased Funding for Research and Development (R&D)

The EWN presents the opportunity to develop more efficient technologies, practice cost-effective approaches to using lower-quality, non-traditional sources of water to supplement or replace fresh water for cooling and other power plant needs. Future R&D should focus on the following areas:

- energy sources that can meet future water needs sustainably, specifically for the array of water-scarce areas in the country;
- technical solutions that successfully couple energy and water generation;
- reducing water use in thermal power generation through advanced cooling technologies, scrubbing, innovative source-water intake designs, use of non-traditional waters and increased power-plant efficiencies;
- treatment of returned water from fracking operations to enable its reuse;
- applications and treatment methods for non-traditional or lower quality water sources such as saline or brackish water specifically aimed at providing alternative or supplementary sources of water for energy generation and for uses that could supplement water resources in water-stressed areas; and
- determining the manner in which the state and the costs of the existing and future power supply affect the costs of water-related technologies and the capacity to deliver water services in the country.

Creating Consumer Awareness

While the electricity tariff hikes and rising oil prices in recent years have created an awareness of energy consumption amongst consumers, awareness remains rather low on the water-use front. Urgent steps need to be taken by the government, and the water companies need to take steps to increase consumer awareness of water use. Tools such as the certification and labelling of consumer products to reflect embedded water and energy use in their manufacture or usage need to be mandated.

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