



REPORT

ZA

2014

FUNDED BY



British
High Commission
Pretoria

Understanding the Food Energy Water Nexus

Through the energy and water lens

AUTHOR

Manisha Gulati

ABOUT THIS STUDY

Food, water and energy security form the basis of a self-sufficient economy, but as a water-scarce country with little arable land and a dependence on oil imports, South Africa's economy is testing the limits of its resource constraints. WWF believes that a possible crisis in any of the three systems will directly affect the other two and that such a crisis may be imminent as the era of inexpensive food draws to a close.

WWF received funding from the British High Commission to establish a research programme exploring the complex relationship between food, water and energy systems from the perspective of a sustainable and secure future for the country. This paper is one of three summary papers based on nine reports in the Food Energy Water Nexus Study. The three summary papers are:

1. *Understanding the Food Energy Water Nexus: Through the food and energy lens*: Manisha Gulati
2. *Understanding the Food Energy Water Nexus: Through the energy and water lens*: Manisha Gulati
3. *Understanding the Food Energy Water Nexus: Through the water and food lens*: Tatjana von Bormann

PAPERS IN THIS STUDY

1. *Climate change, the Food Energy Water Nexus and food security in South Africa*: Suzanne Carter and Manisha Gulati.
2. *Developing an understanding of the energy implications of wasted food and waste disposal*: Philippa Notten, Tjasa Bole-Rentel and Natasha Rambaran.
3. *Energy as an input in the food value chain*: Kyle Mason-Jones, Philippa Notten and Natasha Rambaran
4. *Food inflation and financial flows*: David Hampton and Kate Weinberg
5. *The importance of water quality to the food industry in South Africa*: Paul Oberholster and Anna-Maria Botha
6. *The agricultural sector as a biofuels producer in South Africa*: Alan Brent
7. *Virtual water*: James Dabrowski
8. *Water as an input into the food value chain*: Hannah Baleta and Guy Pegram
9. *Water, energy and food: A review of integrated planning in South Africa*: Sumayya Goga and Guy Pegram

ABOUT WWF

The World Wide Fund for Nature is one of the world's largest and most respected independent conservation organisations, with almost five million supporters and a global network active in over 100 countries. WWF's mission is to stop the degradation of the Earth's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

DISCLAIMER

The views expressed in this paper do not necessarily reflect those of WWF. You are welcome to quote the information in this paper provided that you acknowledge WWF, the authors and the source. If you would like to share copies of this paper, please do so in this printed or PDF format.

In conducting the analysis in this paper, the authors have endeavoured to use the best information available at the time of publication. The authors accept no responsibility for any loss occasioned by any person acting or refraining from acting as a result of reliance on this paper.

CITATION

Should you wish to reference this paper, please do so as follows:

Gulati, M. 2014. *Understanding the Food Energy Water Nexus: Through the energy and water lens*. WWF-SA, South Africa.

For further information please contact: Tatjana von Bormann at tvbormann@wwf.org.za or Manisha Gulati at mgulati@wwf.org.za

CONTENTS

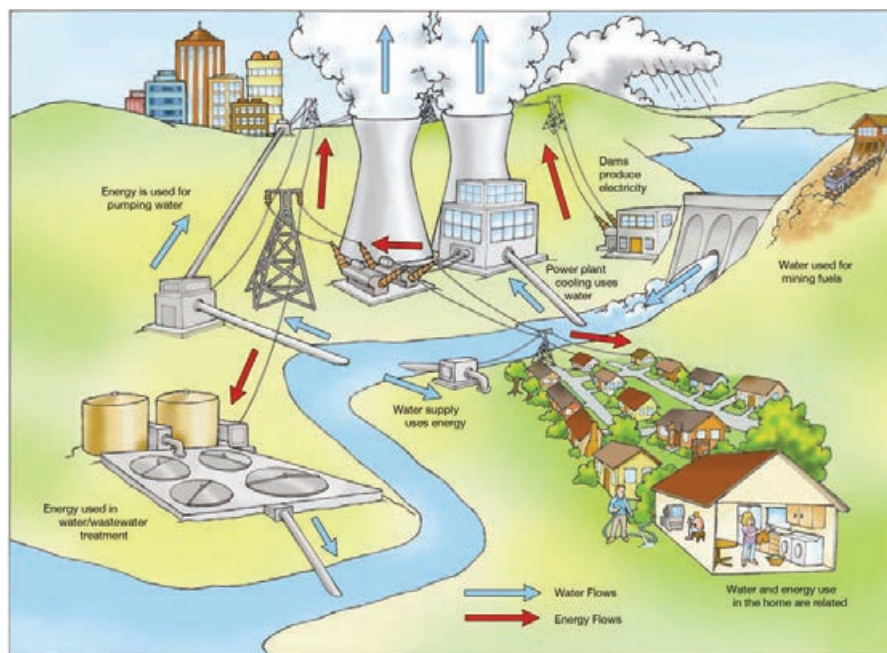
1.	Introduction	4
2.	Objective of this paper	5
3.	Water for energy	5
3.1	Importance of water for energy generation	7
3.2	Water requirements for energy technologies	7
3.3	Energy production and water quality	13
4.	Energy for water	16
4.1	Importance of energy for the water value chain	16
4.2	Energy intensity of the water value chain	17
5.	Policy and planning perspectives	20
6.	The way forward	24
6.1	Areas for further research	25
6.2	Recommendations	26
	REFERENCES	27

1. INTRODUCTION

Energy and water are connected in many ways (see Figure 1). The relationship can be compartmentalised into three segments:

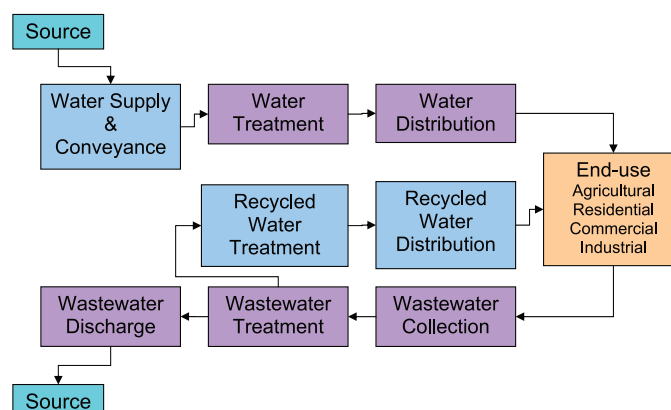
- **Direct relationship:** The production cycle for transportation fuels and energy generation requires water at various stages: fuel extraction (mining and refining, oil, gas, uranium and coal processing, and coal and gas liquefaction and gasification) and generation (US DoE 2006). Energy extraction 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 and to deal with the resulting waste.
- **Indirect relationship:** Energy is consumed by households and industry at the end-user level for heating and cooling water, and purifying and softening water for household use. Energy is also key to accessing water resources in agriculture, especially groundwater through pumping.
- **Embedded relationship:** Energy is required to manufacture chemicals used in the treatment of water and waste water. Water is used to manufacture chemicals used for energy extraction.

Figure 1: The energy-water nexus



Source: US DoE (2006)

Figure 2: Water-use cycle



Source: California Energy Commission (2005)

Clearly, energy is a water issue and water is an energy issue. As demand for the one increases, so will demand for the other. More importantly, shortages of the one can limit the availability of the other. The relationship between energy and water is therefore critical from a business, economic welfare, social development and environmental perspective. From a planning and management perspective, both water and energy are issues of national security and welfare. So, the interdependencies between energy and water coupled with increasing demands for energy and the diminishing availability of freshwater supplies pose significant challenges to ensuring the sustainability of these two critical resources.

It is possible that policies or regulations developed to support or enhance the one 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 freshwater or water quality, unless these policies are closely evaluated for both energy and water impacts. Thus, policy integration and public dialogue will be critical to address the intersecting challenges of energy security and water scarcity.

2. OBJECTIVE OF THIS PAPER

It may be argued that in aggregate terms, i.e. in terms of share of energy consumption, the water sector is not a significant energy user globally or in South Africa. However, for a water-scarce country such as South Africa that is also taking critical decisions about its future energy capacity and sources, a better understanding of how these resources interact at different levels and scales is essential to ensure that both water and energy supplies remain reliable for the immediate and distant future. It is in this context that this paper seeks to enhance the understanding of the energy and water relationship, also known as the energy-water nexus, and to provide the context to evaluate the key trade-offs associated with the interdependence of these resources.

In doing so, the paper deals with the direct relationship between energy and water. Specifically, it addresses the following:

- water requirements of energy technologies
- the impact of energy extraction and production on water quality
- the energy required to deliver water to end users and to remove contaminants from water and waste water.

Where possible, it raises concerns about the indirect relationship between these two resources. But it does not deal with the issue of embedded energy or embedded water in the energy-water nexus.

3. WATER FOR ENERGY

The direct water requirement for energy is 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). In other words, water consumption refers to water that is withdrawn from the source but not returned to the source. Because of declining water tables, many consider consumption to be the most important near-term dimension of the energy-water nexus (Glassman et al. 2011). Water withdrawal is an equally important issue because the quality of the water returned to the source may or may not be the same as it was prior to removal. Energy production also has an impact on water quality. Table 1 provides an overview of the impact of the energy sector on water availability and quality.

Table 1: Connections between the energy sector and water availability and quality

Energy element	Connection to water quantity	Connection to water quality
Energy extraction and production		
Oil and gas exploration	Water for drilling, completion, and fracturing	Negative impact on shallow groundwater quality
Oil and gas production	Large volume of produced, impaired water	Produced water can negatively affect surface and groundwater
Coal and uranium mining	Mining operations can consume large quantities of freshwater and generate large quantities of waste water	Tailings and drainage can negatively affect surface water and groundwater
Electric power generation		
Thermo-electric (fossil, biomass, nuclear)	Surface water and groundwater for cooling* and scrubbing	Thermal and air emissions negatively affect surface water and ecology
Hydro-electric	Reservoirs lose large quantities to evaporation	Can negatively affect water temperatures, quality and ecology
Solar photovoltaic (PV) and wind	None during operation; minimal water use for panel and blade washing	
Refining and processing		
Traditional oil and gas refining	Water needed to refine oil and gas	End use can negatively affect water quality
Biofuels and ethanol	Water for growing and refining	Refinery waste-water treatment
Synfuels and hydrogen	Water for synthesis or steam reforming	Waste-water treatment
Energy transportation and storage		
Energy pipelines	Water for hydrostatic testing	Waste water requires treatment
Coal slurry pipelines	Water for slurry transport; water not returned	Final water is of poor quality; requires treatment
Barge transport of energy	River flows and stages impact fuel delivery	Spills or accidents can negatively affect water quality

* Includes solar and geothermal steam-electric plants

Source: US DoE (2006)

3.1 IMPORTANCE OF WATER FOR ENERGY GENERATION

Energy-production facilities are often critically dependent on water. Thermal power-generation facilities could be at risk from decreasing water availability and increasing ambient water temperatures, which would reduce the efficiency of cooling, increase the likelihood of exceeding water thermal intake or effluent limits that protect local ecology, and increase the risk of partial or full shutdowns of generation facilities. Similarly, oil and gas production, including unconventional oil and gas production (which constitutes an expanding share of the nation's energy supply) is vulnerable to decreasing water availability given the volumes of water required for enhanced oil recovery, refining and hydraulic fracturing.

Much evidence has emerged in recent years of how the shortage of water can affect energy production. In February 2013, a 1 130 MW thermal power plant in India¹ was shut down because of a severe water shortage in the region where it is sited.² Another thermal power plant with an installed capacity of 1 720 MW was generating suboptimally at 840 MW per day due to water scarcity.³ The heat waves of 2003 and 2006 led to a shutdown of conventional and nuclear power plants in Europe because of reduced river flows and the rise in river temperatures and consequently the reduced cooling efficiency of thermal power plants. Power plants in the Susquehanna River Basin in the USA had difficulty securing adequate water for power generation during the 1994 drought, and Washington State in the USA spent \$1 million in 2001 to offset the loss of revenue to the Bonneville Power Administration due to water shortage (GAO 2003). Changes in rainfall patterns and droughts have also led to a decline in hydropower generation.

3.2 WATER REQUIREMENTS FOR ENERGY TECHNOLOGIES

Different energy technologies have different water withdrawal and water consumption requirements. These requirements are governed by a number of factors such as fuel type, quality of raw water, quality of fuel and processing needs (American Geophysical Union 2012). Therefore, a single-figure water requirement value cannot be denoted, even within technology categories. A range is more appropriate.

In the case of electricity-generation technologies, the water consumption factors for both conventional and non-conventional electricity-generating technologies vary substantially within and across technology categories (Table 2). The difference in water withdrawal and water consumption for the different technologies makes it difficult to compare technologies. But the water requirements can be put into some perspective by comparing the water requirements for

¹ Parli thermal power plant in Maharashtra.

² The plant used to receive water from the Khadka Dam, but the supply was stopped as the water in the dam had almost dried up.

³ There was a drastic decrease in the water level of the River Krishna, which supplies water for the power plant.

Table 2: Water requirements for energy technologies (gal[#]/MWh)

Fuel type	Cooling	Technology	Water consumption	Water withdrawal
Nuclear	Tower	Generic	581–845	800–2 600
	Once-through	Generic	100–400	25 000–60 000
	Pond	Generic	560–720	500–13 000
Natural Gas	Tower	Combined cycle	130–300	150–283
		Steam	662–1 170	950–1 460
		Combined cycle with CCS [#]	378	487–506
	Once-through	Combined cycle	20–100	7500–20 000
		Steam	95–291	10 000–60 000
	Pond	Combined cycle	240	5 950
	Dry	Combined cycle	0–4	0–4
	Inlet	Steam	80–600	100–750
Coal	Tower	Generic	480–1 100	500–1 200
		Subcritical	394–664	463–678
		Supercritical	458–594	582–669
		IGCC*	318–439	358–605
		Subcritical with CCS	942	1 224–1 329
		Supercritical with CCS	846	1 098–1 148
		IGCC with CCS	522–558	479–678
	Once-through	Generic	100–317	20 000–50 000
		Subcritical	71–138	27 046 –27 113
		Supercritical	64–124	22 551–22 611
	Pond	Generic	300–700	300–24 000
		Subcritical	737–804	17 859 –17 927
		Supercritical	4–64	14 996 –15 057
PV	N/A	Utility-scale PV	0–33	
Wind	N/A	Wind turbine	0–1	
CSP ^e	Tower	Trough	725–1 057	
		Power tower	740–860	
		Fresnel	1 000	
	Dry	Trough	43–79	
		Power tower	26	
	Hybrid	Trough	105–345	
		Power tower	90–250	
	N/A	Stirling	4–6	
Geothermal	Tower	Dry steam	1 796	
		Flash (freshwater)	5–19	
		Flash (geothermal fluid)	2 067–3 100	
		Binary	1 700–3 963	

Table 2 (continued)

Fuel type	Cooling	Technology	Water consumption	Water withdrawal
		EGS ^f	2 885–5 147	
	Dry	Flash	0	
		Binary	0–270	
		EGS	300–1 778	
	Hybrid	Binary	74–368	
		EGS	813–1 999	
Hydropower	N/A	Aggregated in-stream and reservoir	1 425–18 000	

^aOne gallon = 3.78 litres

^cCCS – carbon capture and storage

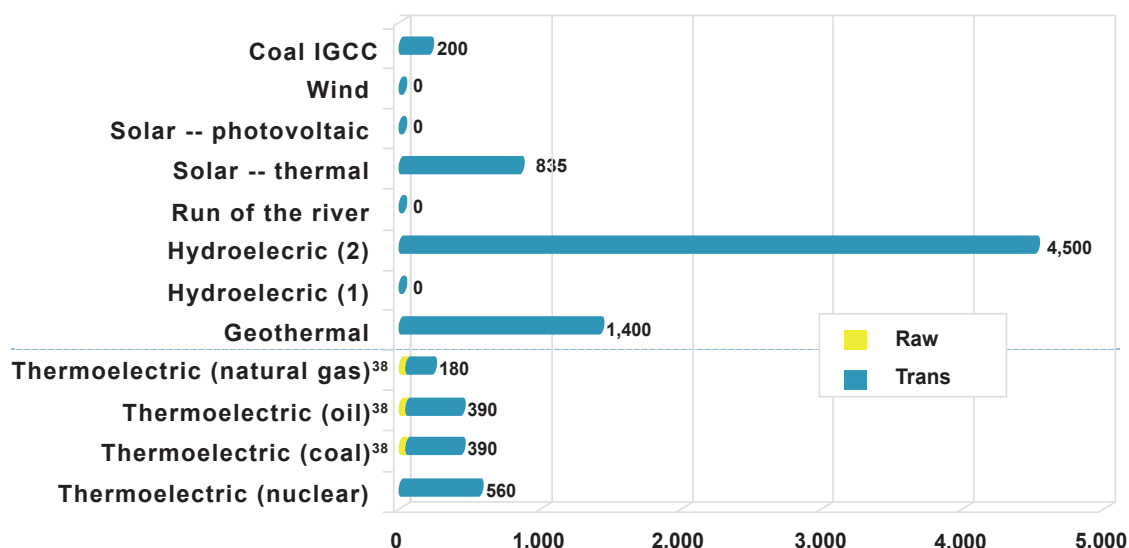
^eIGCC – integrated gasification combined cycle

Source: Macknick et al. (2011)

^cCSP – concentrated solar power

^fEGS – enhanced geothermal system

Figure 3: Average number of gallons* of water consumed to produce 1 MWh of electricity



*One gallon = 3.78 litres

Source: World Policy Institute – EBG Capital in Glassman et al. (2011)

It can be seen that technologies that deploy evaporative cooling towers have the highest water consumption. This is because most of the water consumed by power plants is used for cooling. In general, thermal power plants have a higher water requirement because water is required for the cooling process, flue gas desulphurisation (FGD), (the reduction of sulphur emissions in the case of coal plants), boiler make-up water (to make up for water lost in the steam cycle), the disposal of ash in the case of coal plants and dust suppression in dumping ash, the removal of heat generated in plant auxiliaries, and various other plant consumptive uses.

Some renewable energy technologies such as concentrated solar power (CSP) trough and CSP Fresnel technologies are also water intensive, even though their water requirements are lower than coal-based electricity-generation technologies. Wind and solar photovoltaic (PV) generation require minimal amounts of water and are the most water-efficient forms of electricity production. CSP Stirling solar technologies and natural gas combined-cycle facilities that employ dry-cooling technologies also have low operational water consumption factors.

Water withdrawal factors for electricity-generating technologies show a similar variability within and across technology categories. The highest water withdrawal values result from nuclear technologies, which require more water than coal plants of the same capacity because of the need for cooling since these plants operate at reduced steam conditions. The smallest withdrawal values are for non-thermal renewable technologies.

It is interesting to note that the picture is mixed in the case of clean coal technologies. The integrated gasification combined-cycle process reduces a coal plant's water consumption by half. However, carbon capture and storage (CCS) technologies could increase water volumes by between 46 and 90%, depending on the technology of the power plant (Eskom 2011). This is because flue gases in such technologies are required to be scrubbed to a higher purity and power station efficiency is reduced (Eskom 2011). Specifically, combined cooling and power technologies could increase water consumption by an estimated 90% for a subcritical pulverised coal plant, 87% for a supercritical pulverised coal plant, 76% for a natural gas combined-cycle plant, and 46% for an integrated gasification combined-cycle plant, depending on whether the gasifier is dry- or slurry-fed (Gerdes & Nichols 2009).

However, the above discussion only focuses on water withdrawal and water consumption at the electricity-generation facility level. The actual water intensity of electricity-generation technologies would be higher depending on the water requirements for fuel extraction, transportation, processing and refining (American Geophysical Union 2012) and the water-use implications associated with the land necessary for infrastructure construction for energy generation (Pegran et al. 2011) (Table 3). 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). Typically, this water consumption is included under the industrial or mining sector and is therefore not reflected under the water intensity of the electricity-production technology.

Table 3: 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)

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 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).

In the case of transportation fuels, conventional oil and gas consume the least water per unit of energy produced (Table 4). Natural gas is the least water intensive, consuming approximately two gallons per million British thermal units (BTUs)⁴ of energy content (Glassman et al. 2011). Both emerging petroleum and alternative transportation fuels could consume more water than conventional fuels (Glassman et al. 2011). The main biofuel feedstocks require relatively plentiful water at commercial yield levels (Figure 4). Irrigated first-generation soy- and corn-based biofuels can consume thousands of times more water than traditional oil drilling, primarily through irrigation (Glassman et al. 2011). While it is commonly believed that second- and third-generation biofuels are less water intensive, this has not been proven. In the case of fracking, current data indicates that natural gas produced by hydraulic fracturing consumes seven times more water than conventional gas extraction, but roughly the same amount of water as conventional oil drilling (Glassman et al. 2011).

Table 4: Average water consumption by transportation fuel (gal*/million BTUs)

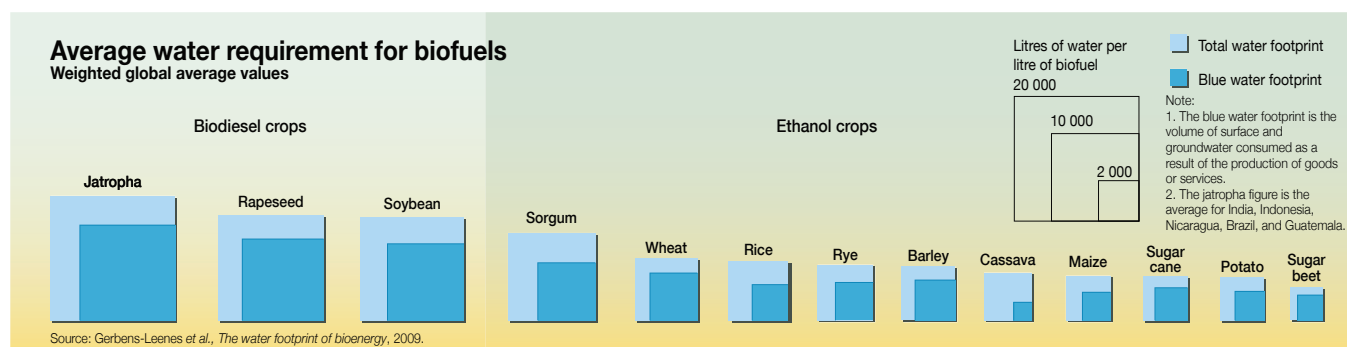
	Raw materials	Transformation
Oil (traditional)	1.4	12.5
Natural gas (as on land)	0	2
Unconventional natural gas (shale)	12.5	2
Oil sands	260	12.5
Enhanced oil recovery	1 257	172
Biofuels (irrigated corn)	15 750	9
Biofuels (irrigated soy)	44 500	9

*One gallon = 3.78 litres

Source: Glassman et al. 2011

⁴ One BTU is the quantity of heat needed to raise one pound of water by one degree Fahrenheit.

Figure 4: Average water requirements for first-generation biofuels



Source: UNEP (2011)

While the above discussion provides an insight into the water requirements of different technologies on a broader level, it is crucial to understand the water requirement of these technologies in the context of South Africa. In general, the country's energy sector is highly reliant on water because of the reliance on coal-based energy. Coal is the most abundant source of energy in the country and, because it is of low quality with a low heat value and high ash content, it is suitable for cheap power generation.

Currently, South Africa produces nearly 86% of its electricity through coal-fired power stations, with a heavy reliance on relatively water-intensive, wet-cooled coal power stations. In 2010, wet-cooled coal power stations represented approximately 78% of the country's power generation, while consuming 98% of the water requirements of the power-generation utility, viz. Eskom (Eskom 2011). Moreover, although the majority of existing power stations have been built in water catchment areas, certain areas are water scarce and therefore necessitate the need for interbasin water transfers. This requires the use of water pipelines, pumping stations and various other components – all of which in turn require energy to operate.

Discussions with stakeholders on the water usage of different electricity-generation technologies within the country indicate a poor availability of information on this subject in the public domain. This could be attributed to the electricity-generation capacity of the country, which has historically been dominated by a coal-based supply. It is expected that with diverse renewable energy technology-based power plants being set up in the country, better information on the water requirements of these plants under domestic conditions would emerge. Table 5 provides the best available overview.

Table 5: 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)

It can be seen that coal-fired plants with wet-cooling technologies have the highest water usage, while wind and solar PV are most efficient from a water perspective. Some estimates put the water use of coal power plants at much higher levels. According to one study (Wassung 2010), the water use in the average coal power plant in the country can be estimated to be in the region of 3.086 l/kWh. This study also estimates that the fresh-water use by coal power plants is above 1.34 l/kWh but below 3.086 l/kWh.⁵

Several factors contribute to higher-than-necessary water usage at coal-fired power plants in the country. These include the age and thermal efficiency of existing plants; declining coal quality, which requires burning more coal to produce the same amount of electricity; and declining raw water quality supplied to plants, which means that more clean water is needed to dilute the extra salt (Wassung 2010).

While South Africa and Eskom are transitioning to dry-cooled coal-burning power stations (which require 5–10% of the water relative to wet-cooled stations), these power stations are still 100% dependent on water. However, the above estimates of fresh-water use associated with coal-based electricity-generation technologies do not reflect the water use associated with coal extraction and cleaning. The volume of freshwater used to mine and clean⁶ a tonne of coal for electricity-generation purposes is estimated at between 347 and 430 l/tonne (Wassung 2010). Given that 0.56 kg of coal is required to produce 1 kWh of electricity, between 0.194 and 0.240 l of fresh water is required during the mining and coal-cleaning stages to produce 1 kWh of electricity (Wassung 2010). Therefore, the total amount of fresh water required over the lifecycle of coal-based electricity generation can be estimated at between 1.534 l/kWh and 3.326 l/kWh (Wassung 2010). In terms of total water usage, it is estimated that if the available freshwater yield in the country is pegged at about 13 227 000 Ml per annum (DWA 2004), the full coal-burning power-generation process actually requires about 4.84% of the national water supply.

Discussions with stakeholders indicate that although the water usage associated with coal mining is high, a number of coal mines treat and reuse polluted mine water at the mine's complex to provide the purified water needed for operations and in turn prevent discharge to the environment. Although the current practices at the mines are inconsistent and site specific – depending primarily on the depth of mining, water resource availability and the sensitivity of the receiving water environment – discussions with stakeholders indicate that the large coal-mining companies are treating and reusing water. Consequently, water use at the coal-mining stage does not appear to be a problem.

3.3 ENERGY PRODUCTION AND WATER QUALITY

Many elements associated with energy development have the potential to negatively impact on water quality. Energy resource mining and processing, such as coal and uranium mining and shale oil and gas development, can contaminate surface and groundwater. Run-off from both main mine operations and tailings piles can significantly reduce pH levels and increase heavy-metal concentrations in mine drainage water (US DoE 2006). In addition, run-off from oil shale residue can wash into surface waters, and by-products from in situ retort methods could negatively affect groundwater quality (US DoE 2006).

Reduced infiltration would mean that groundwater recharge is decreased. Groundwater recharge is a process in which surface water infiltrates the soil and replenishes water supplies underground. Where infiltration is reduced, groundwater replenishment (recharge) decreases. This results in reduced water availability. Salination of water sources can increase, which can render water unusable for drinking, irrigation or other activities. Acid mine drainage (AMD) can contaminate surface and groundwater, and can also occur in closed or abandoned mines (Miller 2005). AMD can be treated chemically or passively, but certain passive treatments such as aerobic wetlands require water.

⁵ The balance of water use can be attributed to rain water or reused water.

⁶ Water use for coal washing depends on the design of the plant and the number of washing stages.

At the energy-production level, both the construction and the operation of energy-production facilities affect water resources. For example, in the case of a power plant, the construction phase impacts water resources through the removal of vegetation to develop the sites. This can alter the flow of water, resulting in erosion and sediment carrying into downstream water bodies or, through redirecting water provision to the power station, corresponding coal mines and support communities, washing run-off pollutants from the construction sites into downstream water bodies.

In the production phase, power production produces large quantities of both solid and liquid waste that have the potential to pollute ground- and surface-water resources. Oil and gas production that is not adequately managed and monitored can contaminate surface water and shallow groundwater through drilling and production operations, or from spills of produced hydrocarbons or produced brackish water. There are numerous examples of how oil spills can and have polluted water resources, making them unusable. These include the oil accidents of Exxon Valdez in Alaska in 1979 and the Deepwater Horizon in the Mexican Gulf in 2010, and the annual oil spills in the Niger Delta (Olsson 2014). It is estimated that one drop of oil can make 25 litres of water unpotable (Olsson 2014). A leak from a gas plant into Parachute Creek in the USA, which feeds into the Colorado River, spilled over 65 000 gallons of oil and hydrocarbon material, resulting in benzene levels above safe drinking water standards (Food & Water Watch 2013).

Non-conventional oil and gas production through hydraulic fracturing, popularly known as fracking, has a big water impact. Fracking a single well requires millions of litres of water. Some estimates peg this at up to 8 000 m³ of water for the life of the well (Olsson 2014). Widespread fracking could thus compete with essential water needs in regions prone to water shortages. Drilling and fracking also pose long-term risks to underground water sources. Toxic fracking liquids are reported to have contaminated water wells in the US (Food & Water Watch 2012). In addition, there is the need to dispose of the waste water that flows to the surface after each well is fracked.

It is estimated that, depending on geology, between 25 and 75% of the millions of litres of fracking fluid used for each well returns to the surface as waste water (Olsson 2014). A large volume of salty water containing naturally occurring contaminants is also typically produced at each well as waste water (Olsson 2014). Combined, these waste waters contain the toxic chemicals added to fracking fluid, as well as any radioactive materials and other pollutants leached from deep underground (Olsson 2014).

Evidence suggests that nearly three-quarters of the more than 240 Pennsylvania and West Virginia gas wells studied in the USA produced waste water with high levels of radiation, including at least 116 wells with levels that were hundreds of times the US Environmental Protection Agency's (EPA) drinking-water standard, and at least 15 wells with levels thousands of times the standard (Olsson 2014). According to stakeholders coalbed methane is worse and has an even bigger footprint on water than fracking.

The refining and processing of oil and gas can generate by-products and waste-water streams that, if not handled appropriately, can cause water contamination. Fuel additives, such as methyl tertiary-butyl ether, that have been used to reduce air emissions have also emerged as potential groundwater contaminants.

Energy transportation and storage development can also negatively affect surface water and groundwater quality. Water used for pipeline testing, coal-slurry pipelines and solution mining for oil and gas storage caverns creates a range of contaminants that can contaminate freshwater or coastal water sources if not adequately managed and disposed of.

In South Africa, the biggest risks to water quality come from coal mining and proposed shale gas development. There are two common types of coal mining: surface mining and underground mining. Surface mining takes place where coal seams are relatively shallow and includes practices such as strip mining, mountaintop removal and open-pit mining. Underground mining is used to access deeper beds of coal by digging under sedimentary rock using practices such as long-wall and room-and-pillar mining. In South Africa, coal mining takes place both on the surface and underground.

Mining for coal, in particular surface mining, typically results in the alteration or outright destruction of large areas of land. These land-use changes can result in numerous negative consequences for nearby water bodies, including altered flow patterns and water pollution from heavy metals and minerals leaching into groundwater and surface supplies. In reality, the impact of coal mining is highly variable as a result of different levels of environmental management and governance. Although water discharged from mines during operations and following mine closure must meet the water-quality standards specified by the government, the weaknesses in governance and the legacy of abandoned mines mean that South Africans cannot rely on a minimum standard of impact, nor do polluters pay for the devastation they cause (WWF-SA 2011). Moreover, AMD from coal-mining areas has had devastating impacts on water resources, with acidification of rivers and streams, and elevated metal levels (WWF-SA 2011). These impacts are often insufficiently managed (WWF-SA 2011).

In some cases, water quality in catchments has been impacted to such an extent by coal mining that the water in these catchments is unsuitable for the use of the very coal-fired power plants these mines supply. For example, in the Olifants River catchment, 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). Eskom's water either needs to be treated – costing money and more energy – or it must be supplied from another river system that has not been polluted by mining (WWF-SA 2011). Similarly, the Camden power station in Mpumalanga requires interbasin transfers from the unimpacted Usutu River system (that originates in Enkangala) to provide water that is clean enough to use (WWF-SA 2011).

Nevertheless, good practices do abound and minimise the impact of coal mining on water resources. Legislative changes have also created a paradigm shift within the mining industry (WWF-SA 2011). As a result, mine water is now integrally considered in the mining process. This has culminated in good practice such as the eMalahleni water purification plant, situated in the Witbank coalfields of the Mpumalanga province, which turns mine effluent into a usable resource (WWF-SA 2011). These practices also help to ensure that any deterioration in water quality does not potentially affect the ability to mine coal. As indicated earlier, it is the power plants that would be affected by poor water quality, as these plants would need to demineralise the water, in so doing potentially incurring higher costs.

However, the technical and financial efforts that go into such examples are significant, and require a willingness among mining companies to prove good practice in the long term. Some smaller mining companies do not necessarily have the same long-term commitment to manage their environmental impacts, or the financial stability to ensure funding.

4. ENERGY FOR WATER

Water-supply systems consume energy at every stage of the water production and supply chain, through water abstraction, treatment, distribution to end users, waste-water reticulation and treatment. A large share of the energy consumed by the water supply chain pertains to electricity. However, natural gas and diesel could also be consumed in significant amounts. Electricity consumed by the water supply chain in California, USA, accounts for 19% of all electricity used in the state. Similarly, water-related natural gas consumption amounts to 30% of all natural gas consumed in that state. In addition, the water supply chain also consumes more than 80 million gallons of diesel fuel.

4.1 IMPORTANCE OF ENERGY FOR THE WATER VALUE CHAIN

The importance of energy for water supply and services can be gathered from the fact that energy costs alone can account for about 75% of the processing and distribution cost of municipal water (Pate et al. 2007). Moreover, in many cities, between 30 and 50% of the municipal energy budget is consumed by water-supply processes (Pate et al. 2007). This importance can be better illustrated through the impact of energy shortages, specifically electricity, on the water supply chain (Table 6).

Table 6: Power outage impacts on the water supply chain

Stage of water supply	Impacts
Abstraction	• Impacts on pumps, equipment and telemetry devices. • Water cannot be abstracted. • Users of small-scale abstraction schemes (boreholes) may be negatively impacted because of the need for alternative water sources.
Water treatment	• Impact on equipment, pumps, telemetry devices and dosing apparatus. • Water cannot be transported and treatment processes cease to function. • Water quality decreases. • The water treatment facility suffers revenue loss, reduced operational capacity, increased labour costs, water wastage and increased pump start-up costs. • Chemical dosing may have to be conducted manually as opposed to mechanically. • Possible back-up generator costs.
Water distribution/ reticulation	• Pumps and telemetry equipment cannot operate. • Water and waste water cannot be distributed. • Costs are incurred to purchase back-up generators and portable water-storage tanks for local communities. • Costs are incurred to purchase portable sewage spill bins and sewage spill clean-up costs.
Waste-water treatment	• Pumps and telemetry devices cannot operate. • Treatment stops and sewage flows cannot be controlled. • Equipment damage costs, possible back-up generator costs, portable sewage spill bin costs, increased labour costs and increased pump start-up costs are incurred.

Source: Winter (2011)

The extent of the impacts is dependent on the characteristics of the plant and the availability of back-up power (Winter 2011). Pumping is the activity that is most vulnerable to electricity outages in the water supply chain. However, water security for end users can also be affected by the impact of power outages, commonly known as power cuts or power failures, on abstraction, distribution or water treatment points in the supply chain (Winter 2011). Waste-water treatment is very energy intensive and is also vulnerable to electricity outages (Winter 2011).

There are several South African examples of how energy shortages can impact the water supply chain. In fact, the recurring rolling blackouts of 2007 and 2008 in South Africa brought the energy-water link to the fore in the country. Municipalities such as Cederberg were affected not only because they were unable to provide effective water and waste-water services but also financially, because of damage to equipment and the cost of back-up services (Winter 2011). The City of Cape Town also incurred financial costs on account of installing back-up power supplies (Winter 2011). Besides these impacts, adverse health and environmental impacts were observed in Howick in KwaZulu-Natal, and in Zandvlei in the Western Cape respectively (Winter 2011). A case in the Ugu district in KwaZulu-Natal revealed a direct impact on commercial business, which resulted in a loss of revenue and salaries for casual labour (Winter 2011).

4.2 ENERGY INTENSITY OF WATER VALUE CHAIN

Numerous factors influence the amount of energy consumed in the water supply chain, including the stage of the water supply chain, the technology deployed, the condition of assets and the quality of the water being treated (Winter 2011). Ageing infrastructure, both at treatment facilities and within collection and distribution systems, outdated treatment processes and obsolete controls can result in higher-than-necessary energy use within the water and waste-water sectors. Inflow, infiltration and combined sewers result in greater pumping requirements within the collection system and the waste-water treatment works, leading to higher energy consumption. Leaking distribution systems and lost water force utilities to produce a greater volume of treated water, once again affecting energy consumption for abstraction, treatment and distribution.

The energy intensity of each stage of the water-use cycle can exhibit considerable variability (Table 7). These intensities can vary within regions, depending on factors such as the source of the water, distance and elevation differences between the source and places of use, and the local topography. Where water is moved over long distances by pumping, transportation alone can be the most energy-intensive process in the water-use cycle. In some areas, heating water for domestic use can use more energy than supply and treatment.

Table 7: Range of energy intensities for water-use cycle segments

Water-use cycle segments	Range of energy intensity (kWh/MG*)	
	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

* MG – million gallons

Source: California Energy Commission (2005)

The loss of energy plays a crucial role in the water cycle because it affects the cost of water supply and services. Moreover, activities such as water treatment and desalination could be energy intensive, and the shortage or costs of energy could undermine such activities. Energy is lost in the water cycle for various reasons (Feldman 2009), such as:

- inefficient pump stations due to poor design
- installation or maintenance work
- old pipes with high head loss
- bottlenecks in the supply network
- excessive supply pressure
- inefficient operational strategies of the various supply facilities.

Energy can also be wasted due to water leaks or the inefficient use of water. When the worldwide water-loss average is estimated to be 30%, it means that the very same portion of energy is lost (Feldman 2009). This also means that energy consumption savings in the water cycle can be pegged at as much as 20 to 30% of current consumption.

In terms of water treatment, as treatment requirements become more stringent, energy consumption will increase for both purification and waste-water treatment. Certain treatment technologies consume more energy than others. For example, reverse osmosis membranes use significantly more energy than other filtration techniques. Energy requirements are also high for the desalination process, which is an option for areas near the sea and in regions with saline groundwater. Thus, this technology would be viable only if water is very scarce and desalination becomes an economic option.

Once again, having understood the importance of energy for the water supply chain, it is also important to understand the energy intensity of the water supply chain in the country and the energy requirements of different water-related technologies in the local context. Discussions with stakeholders indicate a limited availability of information on the energy intensity of the water supply chain. The reasons cited are many. Water and waste-water managers typically do not track energy utilisation in their facilities. This can be attributed primarily to the historically low electricity tariffs and the abundance of energy supply – in the past energy costs were typically not a concern for water managers. The variable nature of energy consumption levels across the supply chain makes it difficult to model energy utilisation and power outage impacts at local or regional levels (Winter 2011). Table 8 provides an illustrative energy consumption range for each water supply chain stage in the country.

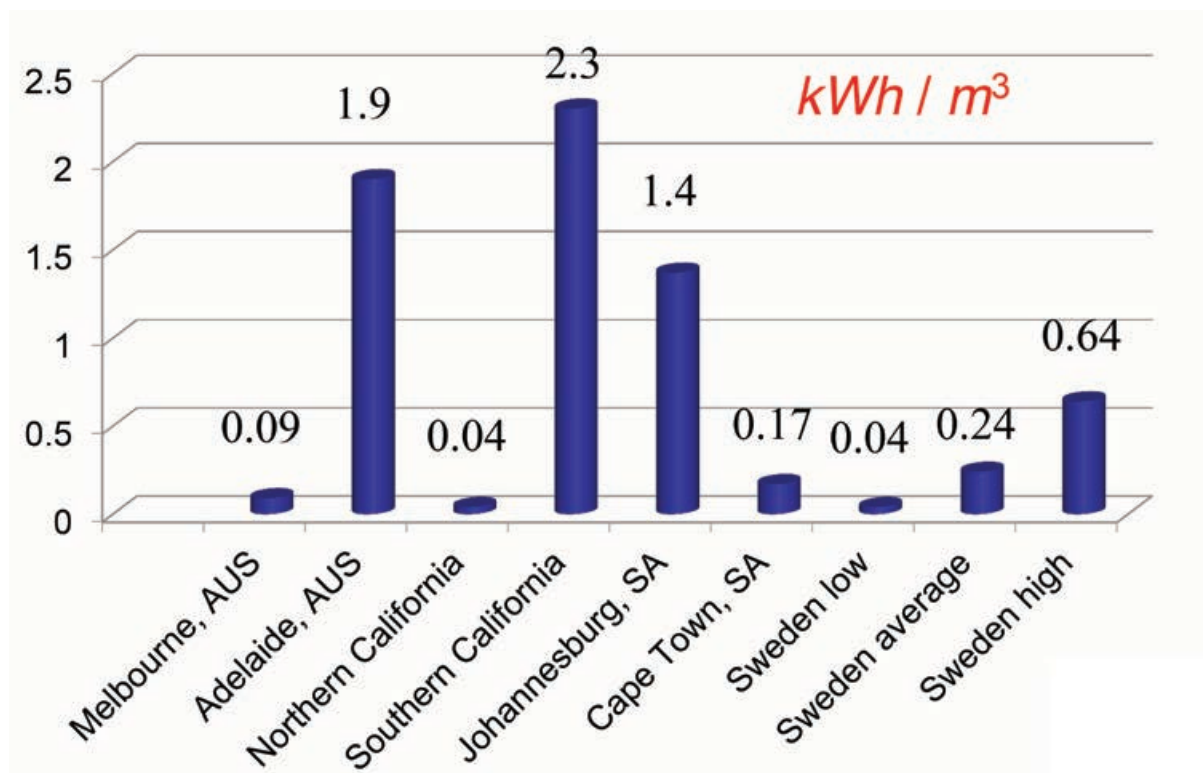
Moreover, energy consumption for different water-related activities could exhibit significant differences across cities (Figure 5). Information available on the energy consumption for water-related services in Johannesburg and Cape Town indicates that not only does this consumption vary radically, but the two cities also fare very differently in terms of benchmarking at international level.

Table 8: Energy consumption range for the South African water supply chain (in kWh/Mℓ)

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)

Figure 5: Energy consumption for pumping water from source to waterworks



Source: Olsson (2014)

Information is also not available for the energy requirements of water-related technologies, but a sense of the energy requirements of different plants can be gauged from the energy consumption of water as well as waste-water treatments plants (Tables 9 and 10). It can be seen that the energy consumption for water treatment and waste-water treatment plants varies significantly. The reasons lie in a number of factors, of which plant attributes are the most important. Another factor that influences energy consumption is the location of the plant. In the case of water-treatment plants, it can be seen that a plant such as Rand Water, which uses gravitational feeds, has a lower energy consumption per megalitre (Mℓ) of water treated (Winter 2011). The Wiggins water treatment plant in KwaZulu-Natal is another example where low electricity consumption is recorded due to the high utilisation of gravity-fed water (Winter 2011). On the other hand, in the case of Sedibeng Water (which serves parts of the Northern Cape, North West Province and the Free State), which exhibits the highest energy consumption, the majority of water treated is pumped. In the case of waste-water treatment, larger plants are typically more efficient. But once again, a plant such as the Athlone Waste-water Treatment Works (WWTW) in Cape Town, which utilises gravitational feeds, consumes less energy per megalitre of water treated than Wildevölvlei WWTW on the Cape Peninsula, which relies on pumping.

Table 9: Energy consumption of water treatment facilities in South Africa

Water board/treatment works	Average energy consumption (kWh/Mℓ)
Rand Water (Gauteng, Mpumalanga, Free State and North West)	662
Bloem Water (Free State)	562
Amatola Water (Eastern Cape)	824
Sedibeng Water (Free State and North West)	1 154
Wiggins Water Treatment Works (KwaZulu-Natal)	57

Source: Winter (2011)

Table 10: Examples of energy consumption at waste-water treatment works in South Africa

Water board/treatment works	Average energy consumption (kWh/Mℓ)
Athlone WWTW (Cape Town)	220–630
Wildevölvlei WWTW (Cape Town)	450–1 450
Wiggins WWTW (KwaZulu-Natal)	706
Howick WWTW (KwaZulu-Natal)	950
Darvill WWTW (KwaZulu-Natal)	400

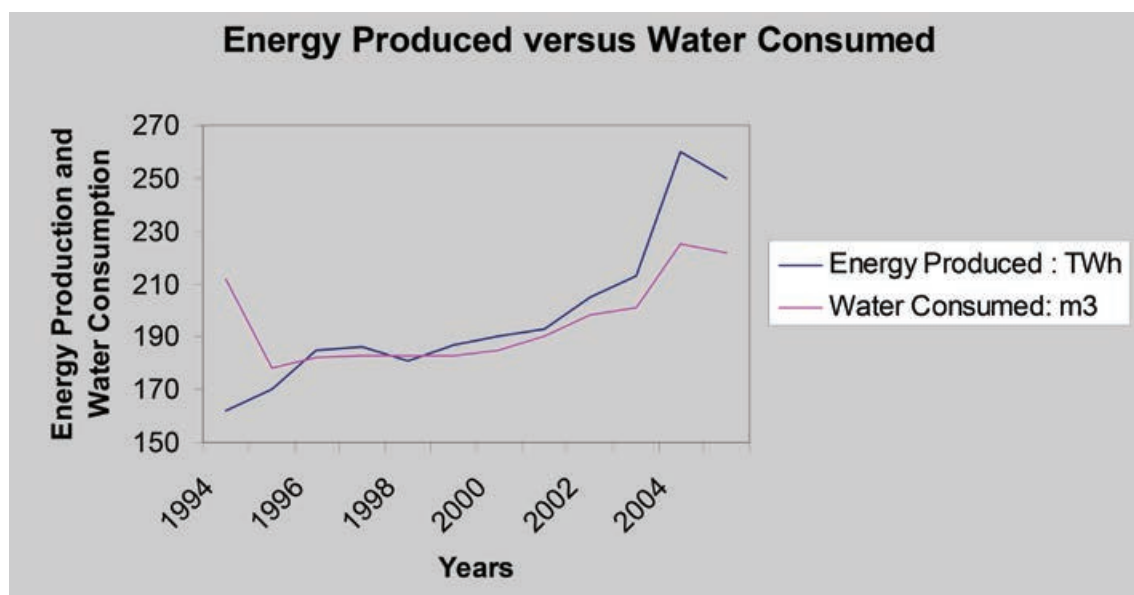
Source: Winter (2011)

5. POLICY AND PLANNING PERSPECTIVES

The energy-water nexus is quite clear: energy cannot be created without water, and water or waste water cannot be treated, distributed or supplied to end users without energy. In the case of South Africa, water is of strategic importance to power generation because the technologies used in power generation use water as an essential input resource (Eskom 2011). Similarly, the water sector is heavily reliant on a consistent supply of energy. The impending worsening of the country's water scarcity in the years to come poses a challenge for future power-generation plans and electricity supply. The links between energy and water mean the undersupply or unreliability of energy supply would affect the water sector, and vice versa.

On the energy side, various measures have been implemented by Eskom to conserve water at power stations. Eskom is also pursuing a transition to dry-cooled coal-fired power stations, which have 5 to 10% of the water requirements of wet-cooled stations (Eskom 2011). Nevertheless, these power stations are still 100% dependent on water (Eskom 2011) and there is a high co-dependency between water use and electricity production (Figure 6) (Eskom 2008 in Winter 2011). A rising demand for energy in the future therefore has the potential to significantly increase water consumption.

Figure 6: Relationship between water consumption and energy production by Eskom from 1994 to 2005



Source: Eskom 2008 in Winter (2011)

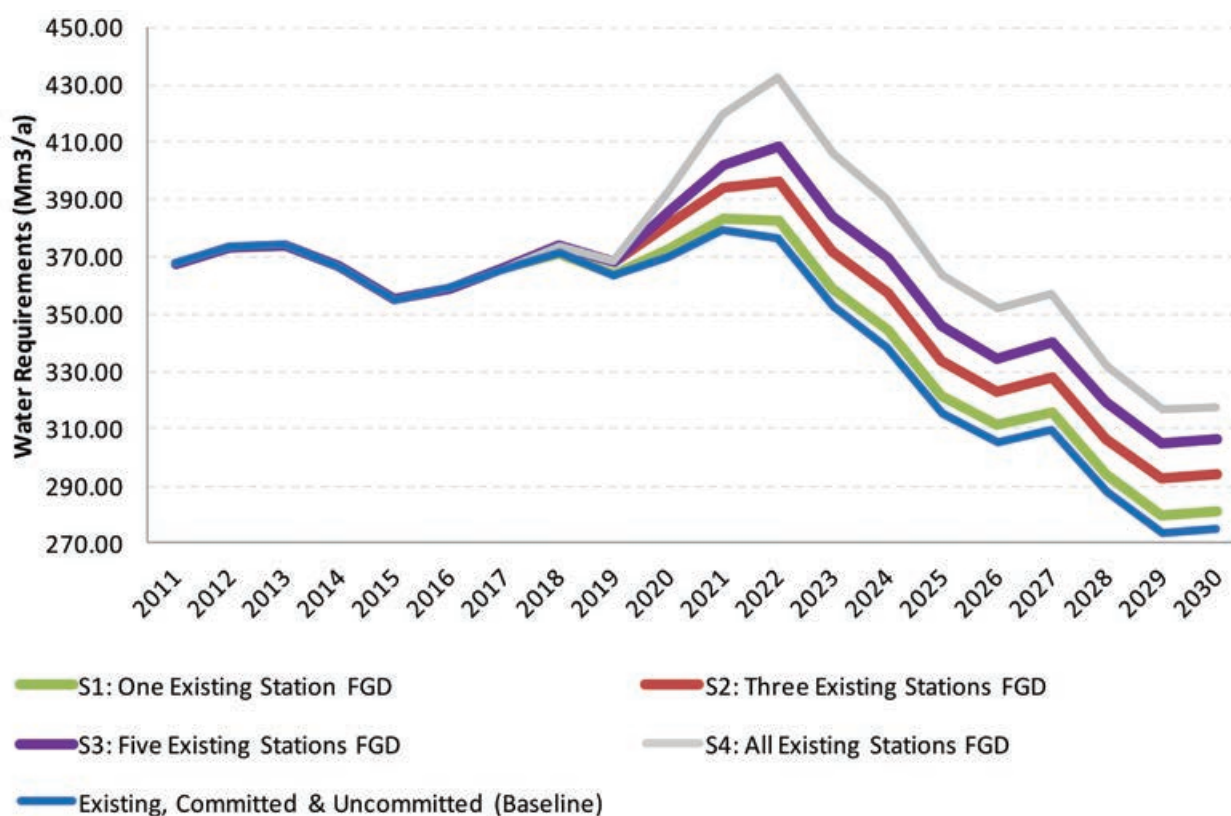
The electricity sector is also under pressure to reduce its greenhouse gas (GHG) emissions, requiring the country to transition to a less carbon-intensive economy and to reduce air pollution from power plants (and thereby improve local air quality). This has necessitated various policy actions:

- The future capacity-building plans for electricity propose a larger share of renewable energy than is currently the case. However, coal would continue to account for over 60% of the generation capacity in 2030.
- There is a significant focus on the development of carbon capture and storage (CCS) technology. CCS technology has the potential to achieve CO₂ emission reductions of between 80 and 85% (Eskom 2011).
- Meeting local air-quality standards has necessitated the installation of flue-gas desulphurisation (FGD) technology for the existing fleet of coal-fired power stations. However, these policy actions could have a significant bearing on the energy sector's water requirements.

Some forms of renewable energy proposed in future capacity-building plans, and those so far implemented, are more water-intensive technologies – even though they place a lower demand on water resources compared to coal-fired power generation. What is important to note is that the water requirements of water-intensive renewable technologies such as concentrated solar power (CSP) can be mitigated by implementing the same dry-cooling technology as coal-fired plants. But, according to stakeholders, the cost of implementing this technology is about five times greater than the regular wet-cooling technology. 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. The benchmark tariffs used for bidding for and the selection of CSP projects are the same for CSP with both dry cooling and wet cooling. Therefore, CSP project developers have no incentives to deploy the water-saving dry-cooling technology. Furthermore, the areas in which these CSP plants are located face water stress. This means that local water availability for these plants could potentially be a problem.

In the case of CCS, it can be seen that water consumption could increase by between 46 and 90% depending on the technology of the power plant. In the case of FGD, power stations that require this technology also require limestone to act as a sorbent in the process of SO₂ collection/removal. The provision of this sorbent to new power stations will more than likely significantly impact the required production levels, and therefore increase the amount of water required for those plants (Eskom 2011). Moreover, 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 7), although the water requirements in 2030 are expected to be lower than 2011 requirements (Eskom 2011).

Figure 7: Water requirement implications of FGD retrofitting and installations



Source: Eskom (2011)

Additionally, Eskom's modelling of future water requirements for the most likely power-generation scenarios in the country show that water requirements in 2030 would increase by 23 Mm³/annum, if coal replaces the new nuclear capacity and FGD is installed on only the new coal capacity (assuming a 90% load factor); 42.5 Mm³/annum if existing plants are decommissioned as planned and FGD is installed at all existing, committed and uncommitted power stations; and 173.7 Mm³/annum if the country faces a generation-capacity gap and consequently no existing plants are decommissioned and FGD is installed at all existing, committed and also uncommitted 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.

Clearly, the mere plan to transition to a less carbon-intensive electricity sector is not adequate. This transition needs to be planned while keeping in mind the implications for water requirements. Otherwise, the transition could risk adding to demands on water resources.

This is not to say that there is no understanding of the link between energy and water in policy making. The Biofuels Industrial Strategy, which outlines the government's approach to policy, regulations and incentives for biofuels, mandates the achievement of a 2% penetration level of biofuels in the national liquid fuels pool. The penetration level of biofuels was initially proposed at 5%. But with the National Treasury expressing concerns about the water requirement implications of such a mandate, the level was reduced to 2%. Similarly, water is recognised in the Integrated Resource Plan 2010–2030 (IRP) as a key constraint and risk for the electricity sector. Water usage is included as one of the criteria in all the scenarios. The Department of Water Affairs (DWA) has recommended dry-cooling technology at new power plants "where feasible" (Greenpeace Africa 2012).

However, policies have shortcomings. The IRP takes only water usage into account. It does not model the risks of potential water scarcity for the planned generation capacity and resulting electricity supply in the country. It also does not look at the electricity sector's ability to provide a reliable, affordable and sustainable energy supply in the event that the quality, quantity and accessibility of water resources decline. Similarly, the DWA's recommendation for dry-cooling technology is an efficiency solution, but is short-sighted and ineffective. The DWA has not demanded a transition to relatively "water-free" energy technologies, a more effective and long-term solution, which would have a greater impact on alleviating water scarcity in the country (Greenpeace Africa 2012).

At a stage when the country is in the process of evaluating future energy options, water security needs to be an integral part of the energy-planning debate. Currently, options such as hydropower do not figure on the country's energy agenda. But with increased regional integration of energy supplies in the future of hydropower procurement from river basins outside the geographic borders of the country, the energy-water nexus could become an important debate. It is therefore important to incorporate this nexus in the planning process.

On the water sector side, it is evident that a failure of energy infrastructure would mean that the reliability of water systems would plummet and threaten public health and safety. Municipalities may need to cover additional costs, and recover them through higher charges for consumers. The extent of the impact is dependent on the characteristics of the plant in question and the availability of back-up power. Waste-water treatment is very energy intensive, hence it is vulnerable to power outages. There could be indirect impacts such as the loss of revenue to local businesses, which may force the closure of certain businesses and have an adverse effect on livelihoods – particularly for casual labour.

Besides a shortage of energy, the cost of energy could also pose risks to the water sector. Electricity tariffs have increased by 25% per annum over the three-year period up to 2012, followed by further annual increases estimated at 7% over a seven-year period (Scheepers & Van der Merwe-Botha 2013). These tariff hikes are likely to have a substantial effect on the actual cost of the service (Scheepers & Van der Merwe-Botha 2013). From a policy and planning perspective, this has two implications:

- There is a need to ensure that the selection of technology takes electricity costs into account, and technologies should be as cost effective as possible (Scheepers & Van der Merwe-Botha 2013).
- Operations at the works must be effective, optimised and maintained to prevent works becoming unsustainable. This would include dedicated energy-efficiency optimisation (Scheepers & Van der Merwe-Botha 2013).

There are other policy challenges as well:

- The country's water scarcity and a deepening of the water crisis in certain areas may mean the need to pump deeper and longer for groundwater. This will mean increased energy for pumping, which in turn will place further demands on water resources.
- A shortage of water coupled with deteriorating water quality could necessitate new processes or technologies to access or treat existing water resources to make them usable. The quality of freshwater resources has been in a steady decline owing to increased pollution where 40% of freshwater systems are now in a critical condition and 80% are threatened. This means that the existing water resources would lose the capacity to dilute pollutants. As a result, raw water will increasingly have to be treated, or standards for water treatment will have to be increased. Recycling waste water, desalination, interbasin water transfers (i.e. taking water from areas of surplus to areas where water is in critically short supply), treatment of brackish water, and decentralised water-supply solutions such as rainwater tanks may therefore become the norm to contribute to the available water supply. The DWA is already increasing regulatory pressure on municipalities to comply with stricter effluent discharge standards (Scheepers & Van der Merwe-Botha 2013).

These processes or technologies could be energy intensive. For example, some estimates suggest that desalination could be 10 times more energy intensive than accessing local water resources (Hoff 2011). The achievement of higher and more exacting effluent treatment quality requirements often requires advanced treatment technologies that are also associated with higher energy requirements. Rising electricity costs could either prohibit the feasibility of these options, or involve serious trade-offs between water and energy security because meeting increased energy demands placed by these options would require more water. It is also important to note that the times when the highest energy-intensity water-supply options will be most needed are most likely to occur during multi-year drought periods when surface water supplies are low and groundwater levels drop, requiring even more energy for pumping each gallon of water (California Energy Commission 2005).

- There is currently a significant variation in the levels of treatment of raw water between Water Service Authorities (WSAs). Only 76% of WSAs treat all the raw water they supply to end users (Winter 2011). The country's raw water resources are typically of a high quality and do not require extensive treatment. However, this is changing due to the declining quality of water in the country. If all WSAs treat water to 100% in the event of the scarcity of freshwater in SA, the energy consumption and related costs for raw water treatment could significantly increase, necessitating higher municipal service charges.

Clearly, the challenges of water security and energy security cannot be dealt with in isolation. In fact, there are risks that policies (whether they be education campaigns, economic subsidies, stringent regulation or new infrastructure) developed in isolation to increase efficiency in one sector may be creating additional demand in the other sector. The energy-water nexus needs to be better recognised in policies, planning and related regulations and laws in the country. Integrated water and integrated energy plans have been prepared and these plans are updated from time to time. But they do not really take into account the multiple interrelationships of water and energy. There is also a need to offer better incentives to manage the risks posed by the one resource to the other.

There are practical difficulties in achieving this. Water-resource planning is often carried out at the regional level of river basins, while energy planning is undertaken at a national level. Coordinated planning offers benefits and will enable the country to capitalise on the opportunities presented by the nexus. For example, minimising water loss through an active leakage reduction programme will reduce the energy wastage embedded in the lost water. Similarly, coordinated energy efficiency and water conservation programmes could help save both water and energy. Reducing water consumption can save energy for water supply and treatment, as well as energy for heating water, thereby reducing the water requirements of the energy sector. Synergistic energy and water production could enhance both water and energy security. Throughout the energy sector, there are opportunities to co-produce energy and water. Locating power plants adjacent to water treatment facilities or more brackish water resources could at least partially displace fresh-water needs. In addition, waste heat from power plants can be used in some desalination cycles, and biogas from waste-water treatment plants can be used to generate power.

The energy-water nexus also presents the opportunity to develop cost-effective approaches to using lower-quality, non-traditional sources of water to supplement or replace freshwater for cooling and other power plant needs. Water-quality requirements for cooling systems can be less stringent than many other applications such as drinking-water supplies or agricultural applications, so opportunities exist for the utilisation of lower-quality, impaired water sources. Similarly, the country could identify and invest in technologies that maximise water efficiency and minimise carbon dioxide emissions.

6. THE WAY FORWARD

Meeting future energy needs depends on water availability, and meeting water needs depends on wise energy policy decisions. Some energy-production modes pose a threat to water quality – the treatment of which may become increasingly necessary in order to meet the water demands of the country. Such treatment would need energy. The importance of both sectors to the economy – and in particular of freshwater resources for ecosystem services and the clear vulnerability that exists when the links between them are not taken into account or are mismanaged, suggest that the energy-water nexus represents environmental, business and security risks for the country. The nexus deserves more attention than is currently the case.

6.1 AREAS FOR FURTHER RESEARCH

First and foremost, there is a need to raise the energy-water nexus to a higher degree on the policy agenda in the country. This requires greater awareness at multiple levels: policy makers, utilities and consumers. It also requires further research. Information about energy usage in the water cycle is fragmented, weak and incomplete. Greater emphasis is required on the energy implications for the water cycle and related technologies. Literature or discussions, where they exist, focus on the water requirements in electricity generation and do not provide insights into energy requirements for delivering water.

Then there is an urgent need to improve the quality of the data on water consumption in energy production, and energy consumption in the water cycle. International data provides a sense of the magnitude of the problem. But the real understanding of the energy-water nexus and its impact on future resource security and economic and social development will be possible only with national and specifically local-level data. This is because the data specific to the location, climatic conditions and characteristics of the concerned facilities can affect energy or water use and, as the case may be, overall efficiency, costs and the trade-offs involved. For example, in the USA, plants burning fossil fuels and using cooling towers may have water consumption and withdrawal factors that differ by more than 16%, depending on their location (Macknick et al. 2011). Similarly, water consumption factors of concentrated solar power (CSP) plants utilising cooling towers may differ by as much as 20% (Macknick et al. 2011).

Research and Development (R&D) is needed to address other crucial aspects. In light of the discussions in this paper and the discussions with stakeholders, it is suggested that future R&D should focus on:

- improving information collection, data management and decision support tools to help integrate energy and water databases and to provide tools for managers in the energy, water and other sectors to improve energy and water management for multiple uses and needs (Ho et al. 2006)
- identifying possible portfolios of energy sources that can meet future water needs sustainably, specifically for the array of water-scarce areas in the country
- identifying existing and possible technical solutions that successfully couple energy and water generation
- focusing on water withdrawal and water quality by energy type, including breakdowns by technology and proposed locations of energy-generation facilities
- 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 (Ho et al. 2006)
- identifying applications and treatment methods for non-traditional water sources such as saline or brackish water; particularly with the objective of providing an alternative or supplementary source of water for power generation and for uses that could supplement water resources in water-stressed areas (Ho et al. 2006)
- determining the manner in which the state and the costs of the existing and future power supply affects the costs of water-related technologies and the capacity to deliver water services in the country
- understanding energy and water use, and managing demand through an assessment of “easy wins” and “no regrets” policies in energy and water demand
- analysing how the country uses energy and water, and assessing where policy making can target the best savings
- using the regulatory framework to minimise the negative trade-offs and maximise the synergies in the energy-water nexus.
- managing the water requirements of second- and third-generation biofuels, and water impacts due to increasing bioenergy production; reducing fresh-water use in biofuels processing, and fresh-water demand in bioenergy production (Ho et al. 2006).

Additionally, the energy-water nexus needs to be explored in the context of climate change and at all levels. In this regard, there is also a need to evaluate how policies aimed at climate mitigation and adaptation affect policies developed in the energy and water sectors, thereby aggravating or benefiting the energy-water nexus.

6.2 RECOMMENDATIONS

- **Integrated approach:** An integrated approach to policy, planning, management and development of water resources and energy systems is imperative to optimise potential benefits, provide the right business and investment environment, protect the environment, and enable truly sustainable development. The challenge of energy and water security coupled with environmental harm will continue to loom large unless this step is taken.
- **Review existing policies:** Existing policies should be reviewed to identify disincentives to change or positive synergies that may exist. The policy formulation process must include system-level evaluations and a technical understanding of how emerging energy and water policies, regulations, standards or economic incentives can impact on regional energy and water reliability and sustainability, as well as the different sectors of the economy. Mechanisms will also be needed to ensure that there is an ongoing process of review to identify problems and adapt to changing conditions. Policies should support the up-scaling of new energy-efficient water technologies and water-efficient energy technologies, even though these may be expensive.
- **Stringent evaluation of water impacts:** Policies must deter energy technologies that pose risks for water availability or quality. In the case of new and emerging technologies, technologies must not be allowed unless the true scale of water impacts can be estimated. A start needs to be made by way of improvements in industry reporting, data collection and sharing, and regulatory enforcement. Meeting electricity-generation demand with technologies that require less water would also preserve water supplies and provide a more reliable power system during droughts.
- **Plan water transport:** On the water side, there is a critical need for better planning to transport water from where it is available to where it is needed. This will help minimise the implications of energy availability and the costs for water services.
- **Regional and local level:** Policy making needs to go a step further and identify the dynamics of the energy-water nexus at regional and even local level to ascertain the risks and vulnerabilities from the nexus for the resilience of relevant social systems. There is a need to acknowledge that the risks may go beyond the energy or water-related facility or technology in question, and may pertain to broader allied economic activity. For example, a new energy facility may appear water friendly because of its reliance on sea water for cooling, but it may spur on construction and economic activities in the area that could create significant recurring water demands.
- **Reflect water and energy content on products:** Options such as the certification and labelling of all products to reflect embedded water and energy use in their manufacture or usage could go a long way in promoting the sustainable use of energy and water.
- **Educate consumers:** Given the close relationship between water and energy demands, there is an urgent need to educate consumers and influence behaviour. The electricity tariff hikes in recent years and rising oil prices have brought about a higher awareness of energy consumption among consumers, but awareness remains rather low on the water-use front. Both the government and the water companies need to take steps to increase consumer awareness of water use.

REFERENCES

- AGU. 2012. *Water-Energy Nexus: Solutions to Meet a Growing Demand*. American Geophysical Union (AGU), Washington, DC. [Online] Available at: http://sciencepolicy.agu.org/files/2013/07/6Sept2012_WENAGU_fullreport.pdf.
- CEC. November 2005. *California's Water – Energy Relationship*. Final Staff Report. Prepared in Support of the 2005 Integrated Energy Policy Report Proceeding (04-IEPR-01E). California Energy Commission (CEC), California.
- DWAF. 2004. *National Water Resource Strategy: Our blue print for survival*. (1 ed) Department of Water Affairs and Forestry (DWAF), Pretoria.
- Eskom. 2011. *Eskom's Submission to the DWA for the National Water Resources Strategy Review*. Eskom, Johannesburg.
- Feldman, M. 2009. *Aspects of Energy Efficiency in Water Supply Systems*. Miya Water, Tel Aviv. [Online] Available at: http://www.miyawater.com/user_files/Data_and_Research/miyas_experts_articles/o8_Other%20aspects%20of%20NRW/o1_Aspects%20of%20Energy%20Efficiency%20In%20Water%20Supply%20Systems.pdf.
- Food & Water Watch. 2012. *Fracking: The New Global Water Crisis*. Food & Water Watch, Washington, DC.
- Food & Water Watch. 2013. *Fracking Colorado: Illusory Benefits, Hidden Costs*. Food & Water Watch, Denver.
- GAO. 2003. *Freshwater Supply: States' Views of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages*. Report to Congressional Requestors GAO-03-514. Governmental Accounting Office (GAO), USA.
- Gerdes, K. and Nichols, C. 2009. Water Requirements for Existing and Emerging Thermoelectric Plant Technologies. *National Energy Technology Laboratory Report 402/080108*. US Department of Energy, Morgantown, West Virginia.
- Glassman, D., Wucker, M., Isaacman, T and C. Champilou. 2011. The Water-Energy Nexus: Adding Water to the Energy Agenda. *A World Policy Paper*. World Policy Institute, New York and EBG Capital, Zurich.
- Greenpeace Africa. 2012. *Water Hungry Coal. Burning South Africa's Water to Produce Electricity*. Greenpeace Africa, Johannesburg.
- Ho, C.K., Hightower, M.M., Pate, R.C., Einfeld, W., Cameron, C.P., Hernandez J., O'Leary, M.C., McMahon J.E. and C. Mulligan. 2006. Development of a Technology Roadmap for the Energy and Water Nexus. Presented at the ASME 1st Water Quality, Drought, Human Health & Engineering Conference, October 18-20, Las Vegas, Nevada.
- Hoff, H. 2011. *Understanding the Nexus*. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm.
- Macknick, J., Newmark, R., Heath, G. and K.C. Hallett. 2011. *A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies*. National Renewable Energy Laboratory, Colorado.
- Olsson, G. 2014. *Water and Energy Linkages*. Public Lecture, January 24, 2014. Department of Science and Technology (DST), Pretoria.
- Pate, R.C., Hightower, M.M., Cameron, C.P. and W. Einfeld. 2007. *Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources*. Sandia National Laboratories, Albuquerque, New Mexico.
- Pegram, G., Eaglin, F. and K. Laing. 2011. *Conceptual Framework for Assessing Water Use in Energy Generation, with a Focus on Hydropower*. Final Draft. Pegasys, Cape Town.
- Scheepers, R and Van der Merwe-Botha, M. February 2013. Waste Water Treatment Plants in South Africa: A Realistic Perspective of Energy Optimisation Considerations. *ReSource*: pp 56-58.
- UNEP. 2011. *Biofuels Vital Graphics: Powering a Green Economy*. United Nations Environment Programme (UNEP), Paris.
- US DoE. 2006. *Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy & Water*. US Department of Energy (US DoE), Washington D.C. [Online] Available at: <http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf>.
- Wassung N. 2010. *Water Scarcity and Electricity Generation in South Africa. Part 1: Water Use in the Coal-to-Electricity Process*. Master of Philosophy Thesis, School of Public Management and Planning, Stellenbosch University. [Online] Available at: <http://scholar.sun.ac.za/bitstream/handle/.../wassung%20thesis%202010.pdf>.
- Wilson, W., Leipzig, T. and B. Griffiths-Sattenspiel. 2012. *Burning Our Rivers: The Water Footprint of Electricity*. River Network, Portland, Oregon.
- Winter D. 2011. Power Outages and their Impact on South Africa's Water and Wastewater Sectors. *WRC Report No. KV 267/11* ISBN 978-1-4312-0101-3. Water Research Commission (WRC), Pretoria.
- WWF-SA. 2011. *Coal and Water Futures in South Africa: The Case for Protecting Headwaters in the Enkangala Grasslands*. World Wide Fund for Nature (WWF-SA), Cape Town.

100%
RECYCLED



Why we are here

To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

panda.org.za