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Will Water Constrain Our Energy Future?

WATER PARTNERSHIP PROGRAM

ESMAP Energy Sector Management Assistance Program

Korea Green Growth Partnership

WORLD BANK GROUP

Water – Energy Interdependence

energy needs water

Energy production processes require water

- hydropower
- thermoelectric cooling
- power plant operations
- fuel extraction and refining
- fuel production

water needs energy

Water production, processing, distribution, and end-use require energy

- extraction
- treatment
- transportation

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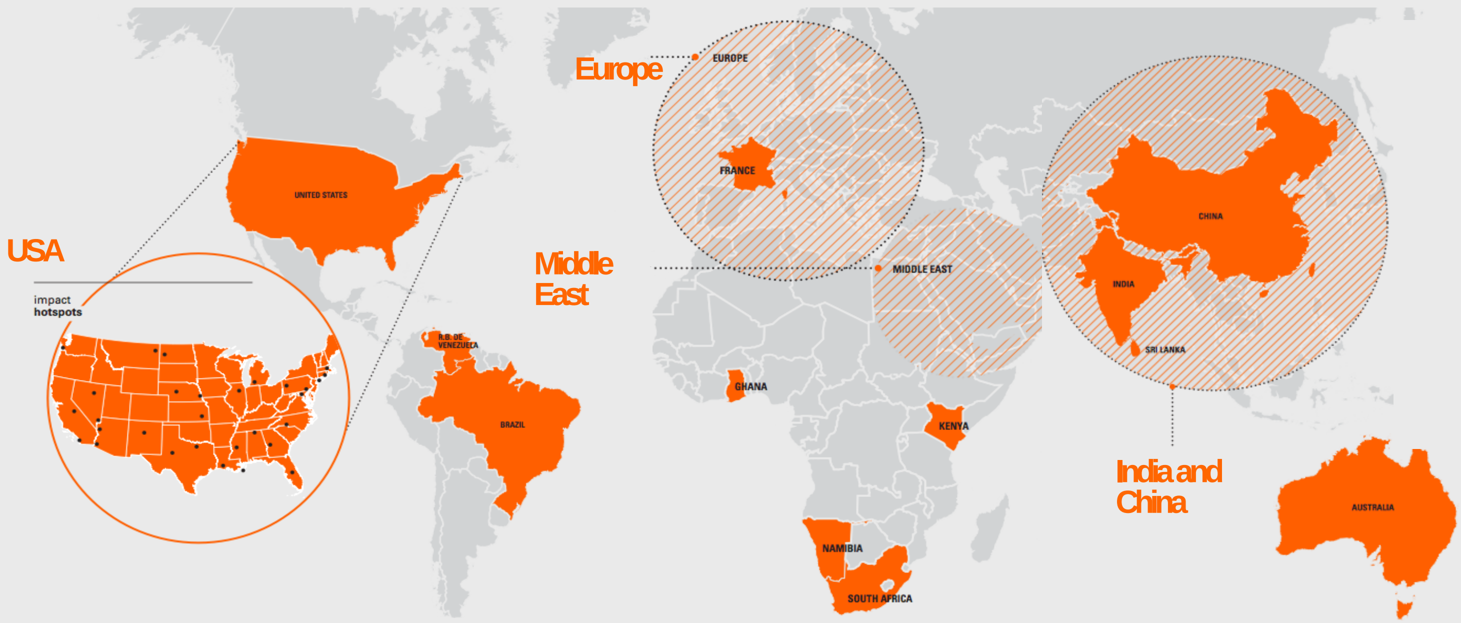
Water constraints are presently **impacting the energy sector**



- In the **U.S.,** several power plants have had to shut down or reduce power generation due to low water flows or high water temperatures.
- **In India**, a thermal power plant recently had to shut down due to a severe water shortage.
- **France** has been forced to reduce or halt energy production in nuclear power plants due to high water temperatures threatening cooling processes during heat-waves.
- Recurring and prolonged droughts are threatening hydropower capacity in many countries, such as Sri Lanka, China and Brazil.

Energy sector needs water and is **vulnerable to water issues**

water risks for **energy sector**

Increased water temperatures can prevent power plants from cooling properly

Decreased water availability can affect thermal power plants, hydropower, and fuel extraction processes due to their large water requirements

Regulatory uncertainty

Sea level rise could impact coastal energy infrastructure

Water quality can impact energy operations if it is not regulated and managed adequately

Power plants shut down or decreased power generation

Hydropower capacity reduced

Permits to locate power plants or extraction facilities denied

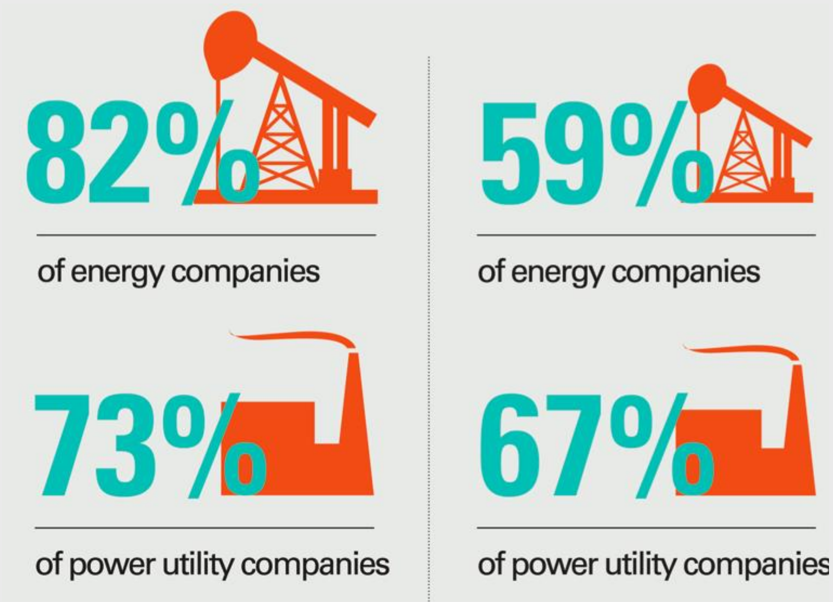
Financial losses CAPEX and operational costs increase

Social and political instability

the energy sector recognizes the magnitude of the issue

Impact on the world's top **energy and power** companies

Source: CDP Global Water Report, 2013



Indicate that **water is a substantive risk** to business operations

Have experienced **water-related business impacts** in the past 5 years

However, the majority of companies surveyed do not appear to be planning corollary increases in the breadth and scale of their water risk management practices

We need to understand better this interdependency and the sector differences

Need more data

- on the water use (withdrawal, consumption, discharge) and water pollution by the energy sector
- on the water needs of the water sector

Temporal and regional differences

- Unlike the GHGs, which are a global problem, water issues are a regional/local problem. For example, at a national level, the percentage of water used for gas extraction might look very small, but in the extraction areas, that percentage might be very critical, potentially impacting the water resources at the local level.
- Temporal changes in water availability (through the year and in the future, with climate uncertainty) make it challenging to understand potential impacts on the energy sector (dry seasons and unforeseen droughts can make a power plant shut down, incurring high financial losses)

Need to contextualize solutions

- The water and energy nexus is thus, a very regional/local problem
- We need specific solutions for each region/area

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We also need to understand **and quantify tradeoffs**

Dry cooling vs cost of electricity

Dry cooling systems require no water for their operation, but decrease efficiency of the plant:

- increasing capital and operational costs

- increasing GHG emissions per kwh

Water for energy vs. water for agriculture

The value of water for energy might be higher regarding economic outputs, but agriculture is often required for

- national security reasons (food)

- social reasons (people employed in the agricultural sector)

Water – GHG tradeoff

Some policies to reduce GHG emissions can increase water requirements by the energy sector if not designed properly

- biofuels, carbon capture…

Understand Environmental impacts and trade-offs

Hydropower

Assessing tradeoffs, environmental and social impacts and exploring the use of multipurpose dams is necessary for sustainable development

There are many solutions, we need to start somewhere

solutions

integrate energy-water **planning**

- explore the use of multipurpose hydropower dams
- integrate energy-water infrastructure
- incorporate water constraints into energy planning
- strengthen joint energy-water governance and encourage political reform

reduce water **dependency**

- use alternative cooling systems in thermal power plants
- recycle and reuse water from operations
- conserve water and energy
- implement renewable energy technologies
- explore brackish and saline water options
- increase the economic value of water

enhance **efficiency**

- replace old, inefficient power plants
- improve power plant efficiency
- improve biofuels production efficiency

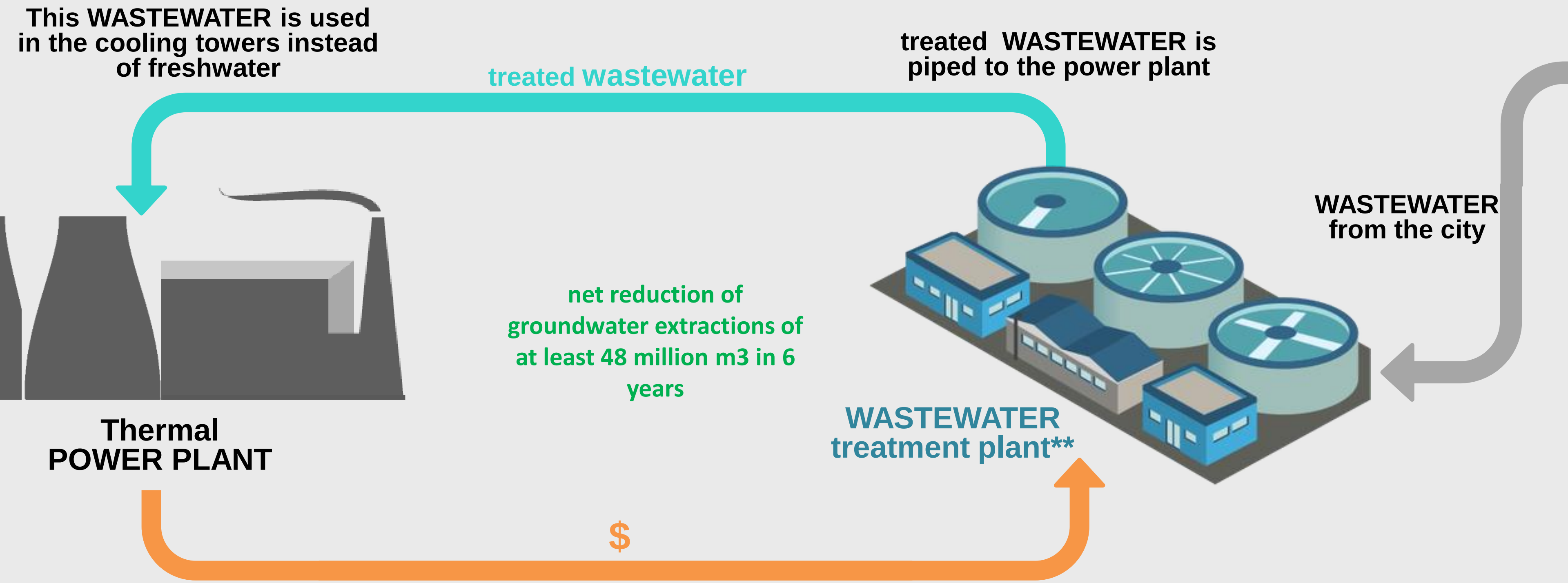
WASTEWATER REUSE FOR COOLING

TENORIO PROJECT* MEXICO

BENEFITS FOR THE POWER PLANT

The wastewater used by the power plant is 33% cheaper and more sustainable than the previously used groundwater

The plant has saved $18M in 6 years



BENEFITS FOR THE WASTEWATER TREATMENT PLANT

This extra revenue covers almost all operation and maintenance costs

* For more information on the project: http://www.reclaimedwater.net/data/files/240.pdf

**Wastewater treatment plant picture is by Tracey Saxby, Integration and Application Network, University of Maryland Center for Environmental Science

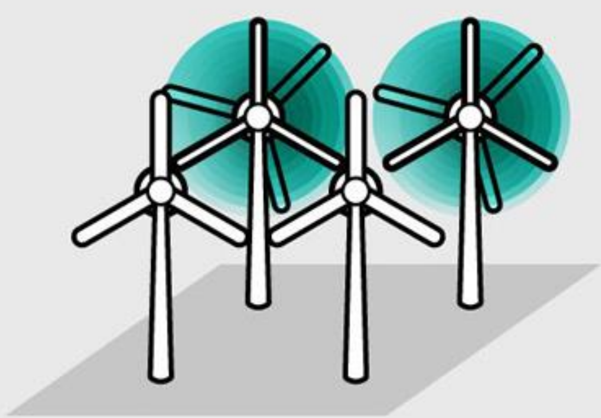
Investing in renewable energy that requires no water

solar
photovoltaics (PV)

Requires small amounts of water to wash the panels and increase efficiency, but is intermittent (only generates electricity when the sun is shining).

wind
energy

Requires no water to generate electricity, but is intermittent (only generates electricity when the wind is blowing).

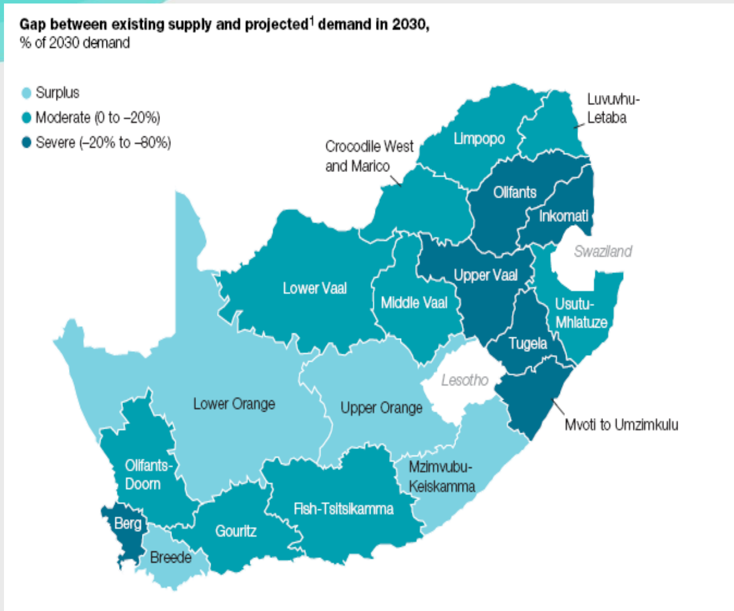


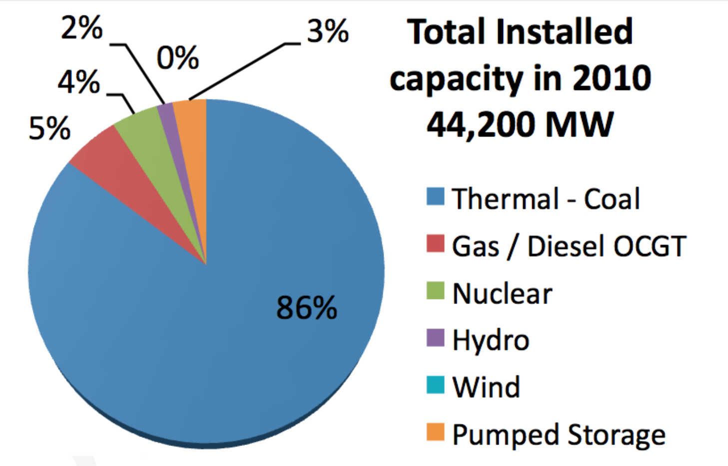
Thirsty Energy initiative

GOAL: to contribute to a **sustainable management and development** of the water and energy sectors by **increasing awareness and capacity** on *integrated planning* of energy and water investments **identifying and evaluating trade-offs and synergies** between water and energy planning.

1. Rapid assessments in priority basins/countries
2. Implementation of case studies using existing tools when possible
3. Knowledge dissemination, advocacy and capacity building

South Africa:
the case of A Water Scarce Country





Sources: ESKOM and Department of Energy of South Africa

- Water scarce country with very stressed basins in terms of water allocation. Existing water supply systems at or approaching capacity: 97% of existing supply allocated.
- Coal Thermal Power plants account for almost 90% of the power capacity installed
- Competition for water across sectors will increase – Power plants have priority, which could negatively affect other sectors such as agriculture
- Fracking for Shale Gas is being explored, which will put additional pressure on water resources

From ESKOM

- Despite Eskom being classified as a **Strategic Water User** (2% of available water resources) with **high assurance of water supply**, the ability to meet this assurance is at risk due to:
  - **Water usage trends increasing beyond available catchment yields and current capacity limits of the water infrastructure and potential climate change impacts;** and
  - **Practices which reduces the available resource and supply** such as illegal abstraction and use, unaccounted for water losses, dilution of pollution, inefficient water management practices and inadequate infrastructure maintenance.
- Eskom's **license to operate is under pressure** due to:
  - Non-compliance to some water use license conditions;
  - **Increasingly stringent legal requirements imposed by the Regulator on Eskom's operations to prevent pollution and protect water resources**
- **Eskom continues to influence energy policies with other key sustainable development issues, most notably water, agriculture/food, and climate change**

Thirsty Energy Case Study in South Africa

- The World Bank has partnered with the Energy Research Center (ERC) of the University of Cape Town to incorporate water constraints in their energy planning tools.
- The ERC has developed and maintained now for many years an energy optimization model for South Africa (TIMES/MARKAL - SATIM).
- At the start, this model did not contain water as a constraining factor, nor did it include any water-related costs.
- The World Bank's Thirty Energy initiative in South Africa has completed the coupling of the energy and watering planning models and conducted a preliminary energy-water nexus analysis.

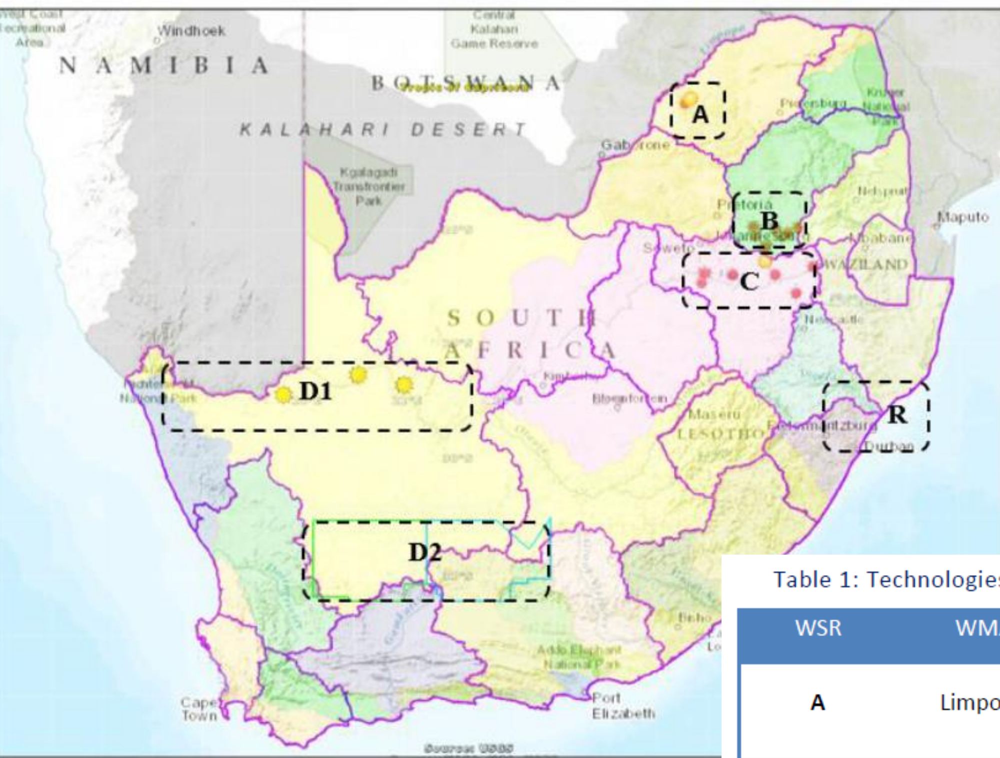
Water already represented in the model but…

SATIM PARAMETERISATION OF POWER PLANT TECHNOLOGIES

PARAMETERS	ADDITIONAL PARAMETERS FOR CHP PLANTS	ADDITIONAL PARAMETERS FOR NEW PLANT TECHNOLOGIES
Energy input commodity or fuel	Industrial process heat	Limits on capacity
Water consumption[1]	Operation in back pressure	Investment cost
Efficiency	Additional input fuel	Technology life
Output commodity		…hnology lead-time
Energy availability		…er bound on new capacity
Capacity availability		…er bound on capacity factor
Capacity credit		…nds on wind classes
Fixed operating and maintenance cost		… intermittency
Variable operating and maintenance cost		Capacity credit of wind
Refurbishment/retirement profile		Diurnal production of solar with and without storage by timeslice
"Season" & "Daynite" operating categories		

…but as of now there is no constraint on it, the model assumes that it is an infinite resource and with no price or regional constraint

SOURCE: ERC - UCT



Developing the SATIM-Water Model:

1. Matching energy producing regions with water resource areas (WMAs) in South Africa

Table 1: Technologies represented in SATIM-W for Phase 1 implementation by water supply system.

WSR	WMA	Region	Activity
A	Limpopo	Lephalale	• Open-cast coal mining • Coal thermal power plants with FGD option • Coal-to-Liquids refineries
B	Olifants	Mpumalanga, Witbank	• Open-cast & underground coal mining • Coal thermal power plants with FGD option. • Coal-to-Liquids refineries
C	Upper Vaal	Mpumalanga, Secunda	• Open-cast & underground coal mining • Coal thermal power plants with FDG option • Inland gas thermal power plants • Inland Gas-to-Liquids refineries
D1	Lower Orange	Northern Cape, Upington	• Concentrated Solar Thermal Power Plants (CSP)
D2	Lower/Upper Orange	Northern Cape, Karoo	• Shale gas mining • Gas thermal power plants • Inland gas-to-liquids refineries
R	n/a	Richards Bay Coal Export Terminal	• Coastal open-cycle coal power plants with seawater cooling and seawater FGD option

In SATIM-W the cooling systems for thermal power plants may be either closed-cycle wet-cooled or direct dry-cooled. The model is free to choose the cooling type, except for open-cycle wet-cooled plants which are restricted to the coastal region, as part of determining the least-cost energy-water integrated system.

Need to "geo-reference" somehow the power plants and energy facilities in order to regionally constraint the amount of water available :

by assigning the different power plants and energy extraction locations to their basin

Developing the SATIM-Water Model:
2. Including water costs into the energy model

Marginal Cost Curves for Water Supply were calculated for each area (A, B, C, D) except for R (coastal area where power plants use seawater for cooling). Those cost components (and the corresponding water yields) were added to the model to represent the cost of supplying water to the energy facilities.

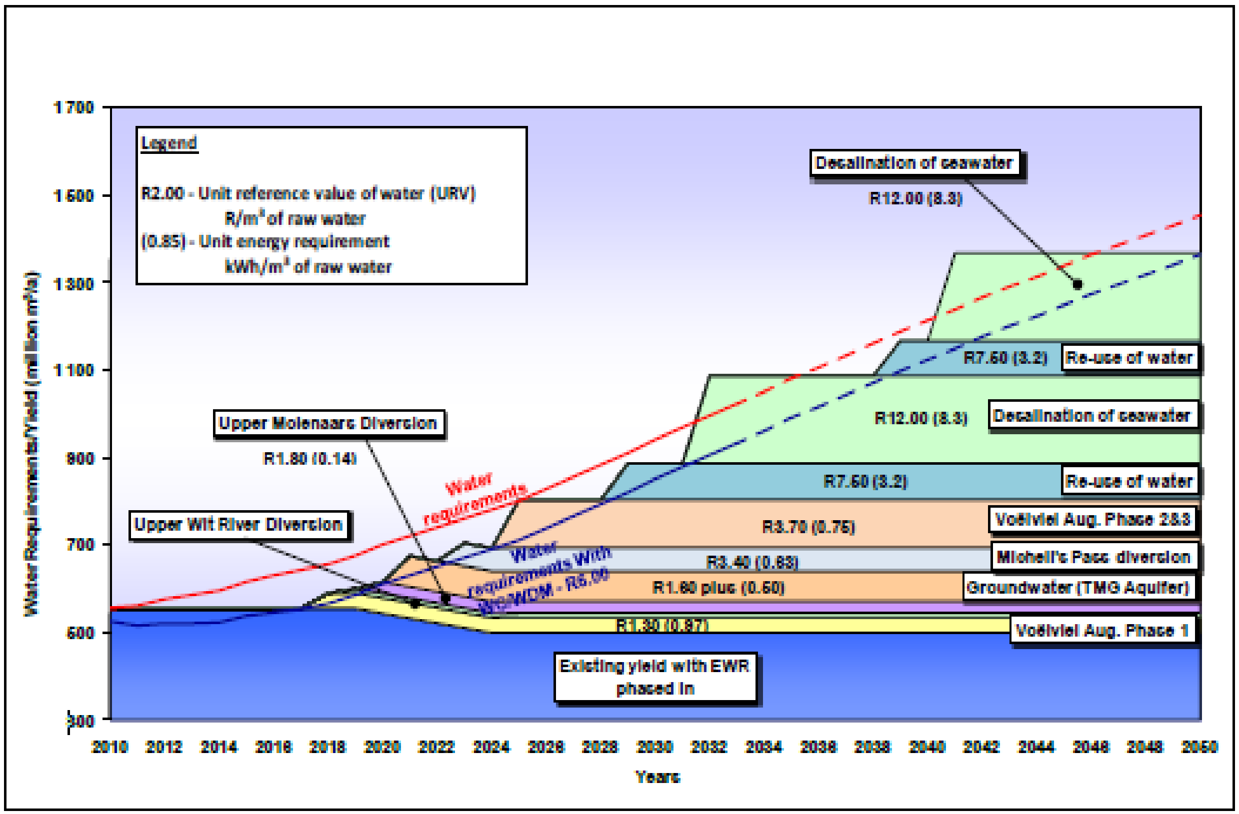
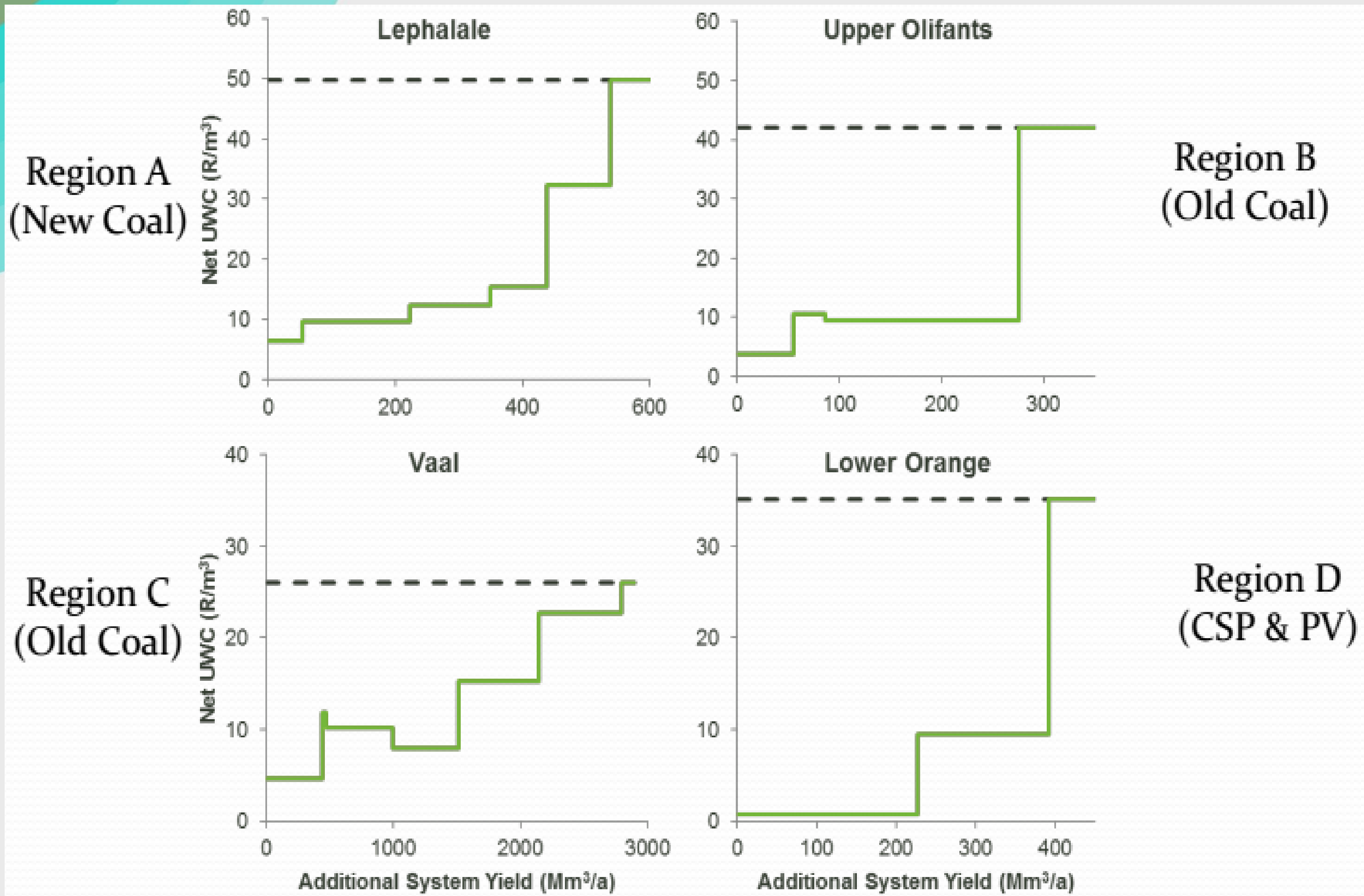


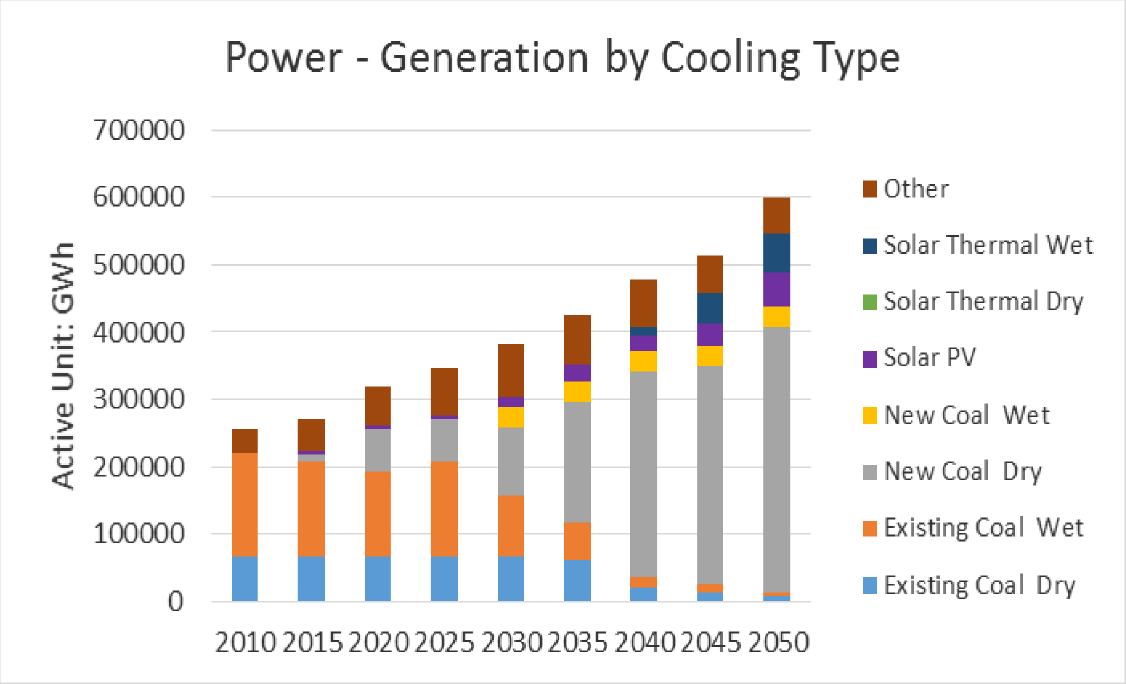
Figure 4.10 (a) Western Cape Augmentation Options (without climate change)

Regional Marginal Cost Curves for Water Supply



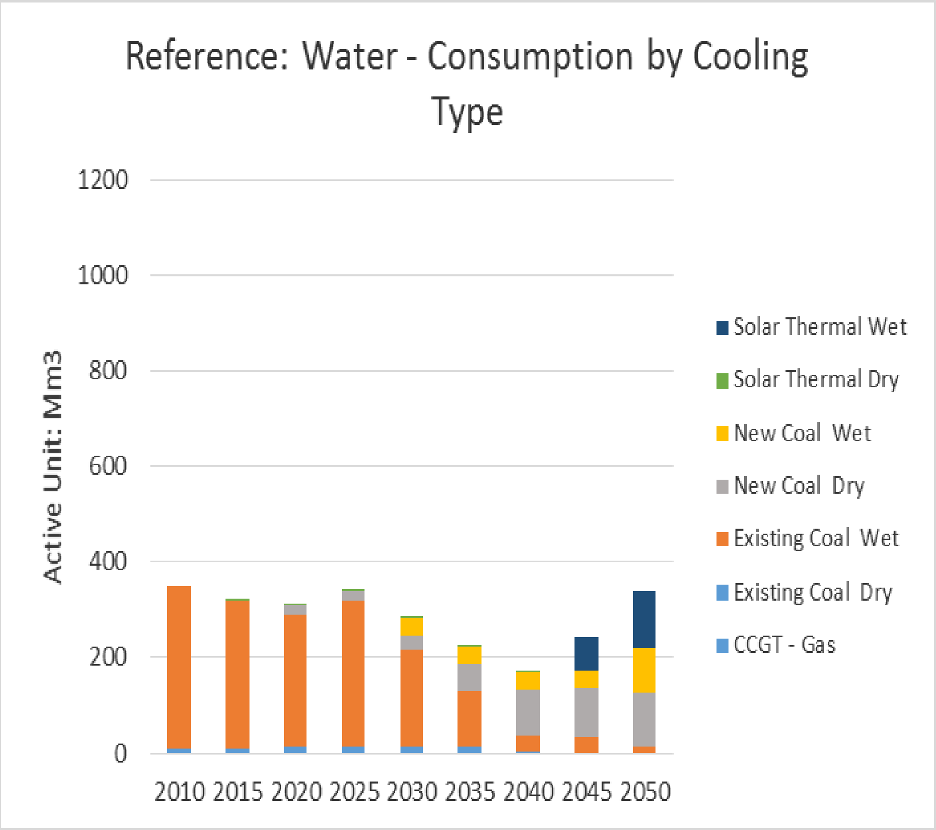
Main preliminary findings

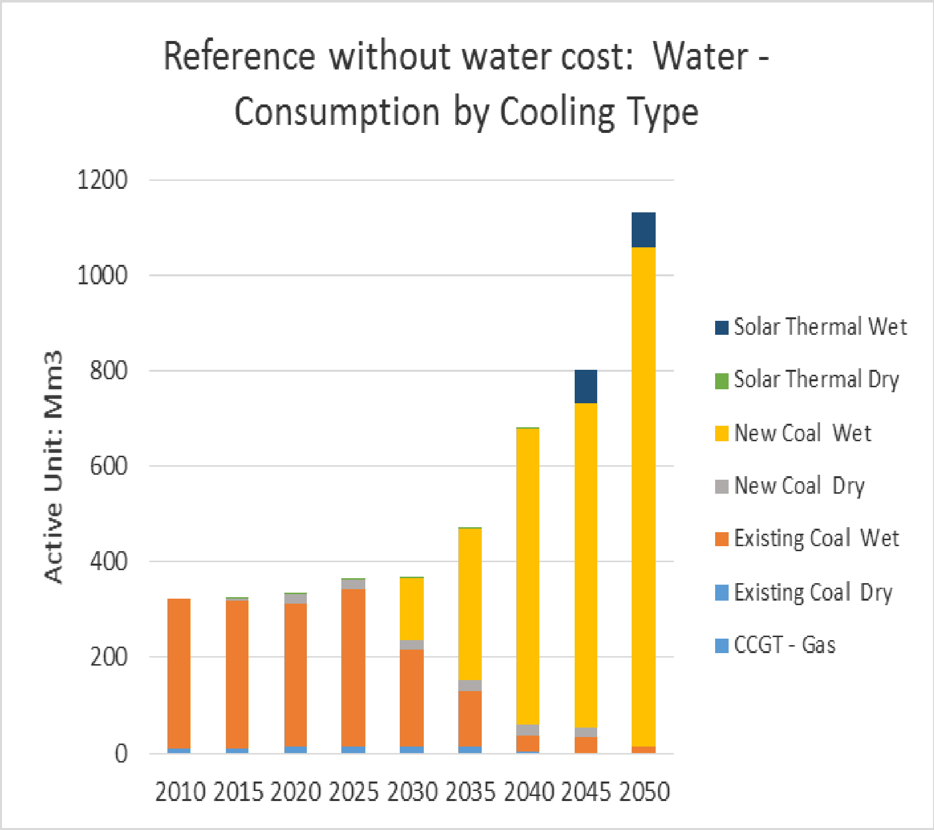
- **Water for power in South Africa is supported by major inter-basin transfers**. Even if the amount of water consumed by the energy sector is a small percentage, it has already changed the water picture in South Africa.
- **Once the true costs of water supply are incorporated into the energy model, the model chooses dry cooling for most coal power plants**. This means that dry cooling makes economic sense in South Africa even if dry cooling decreases the efficiency of the power plant.



Power Generation. Reference Scenario (with water costs)

Main preliminary findings





Water consumption in the reference scenario (left) and reference scenario without water costs (right)

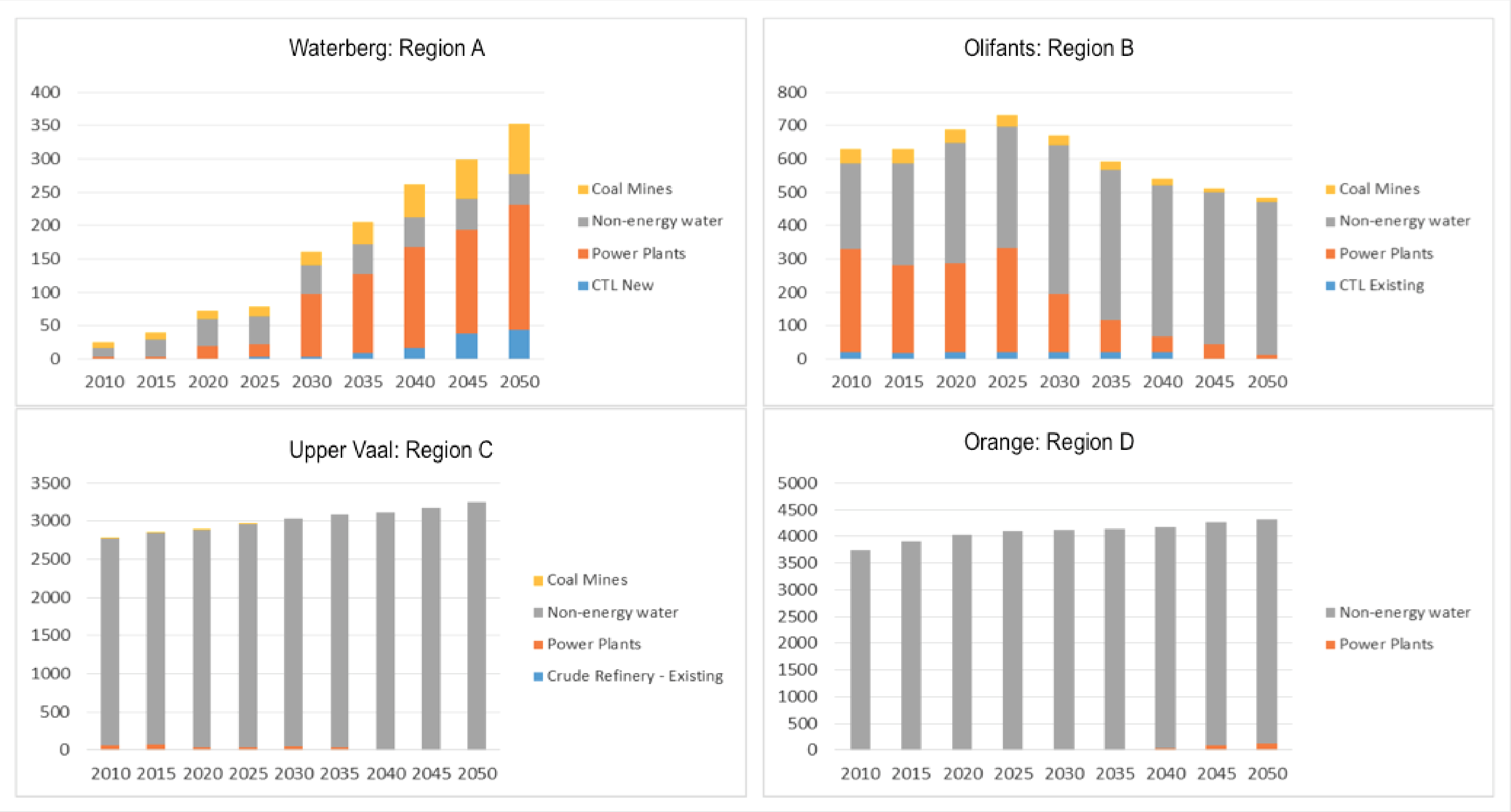
Main preliminary findings

- Once the true costs of water are incorporated, there is a shift to dry cooling and solar, which decreases substantially water consumption but also decreases CO_2 emissions for the overall system with an associated modest increase in total system cost.
- On the other hand, not including the costs for water results in building more wet cooled coal-fired power plants with an associated 80% increase in water consumption for power generation and increases CO_2 emissions about 2%.

Scenario	System Cost		Water to Power		Power Plant Builds		CO2 Emissions	
	2010MZAR	%	Mm3	%	GW	%	kT	%
Reference (BAU)	6,855,224		14,000		117.06		17,449,206	
Reference (BAU) no cost water	-76,099	-1.11%	11,054	78.96%	-7.89	-6.74%	350,419	2.01%

Main preliminary findings

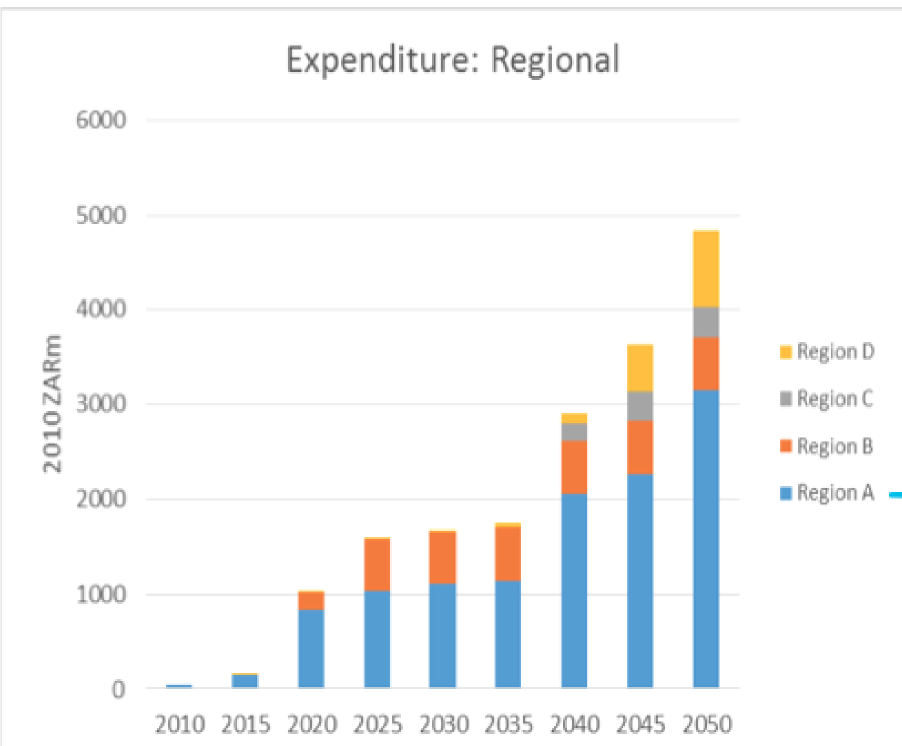
- **The Waterberg (Region A) is the region more exposed to the water-energy nexus.** Non-energy water demands dominate the other regions. In the Olifants region, water needs for the energy sector shrink substantially as existing power plants retire.

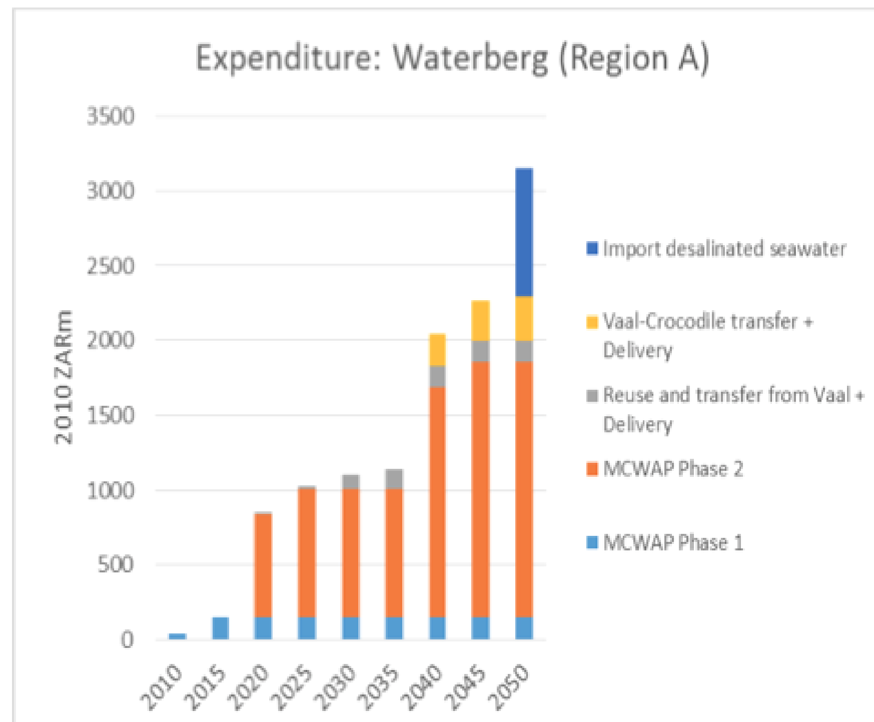


Water consumption (Mm3) by region

Main preliminary findings

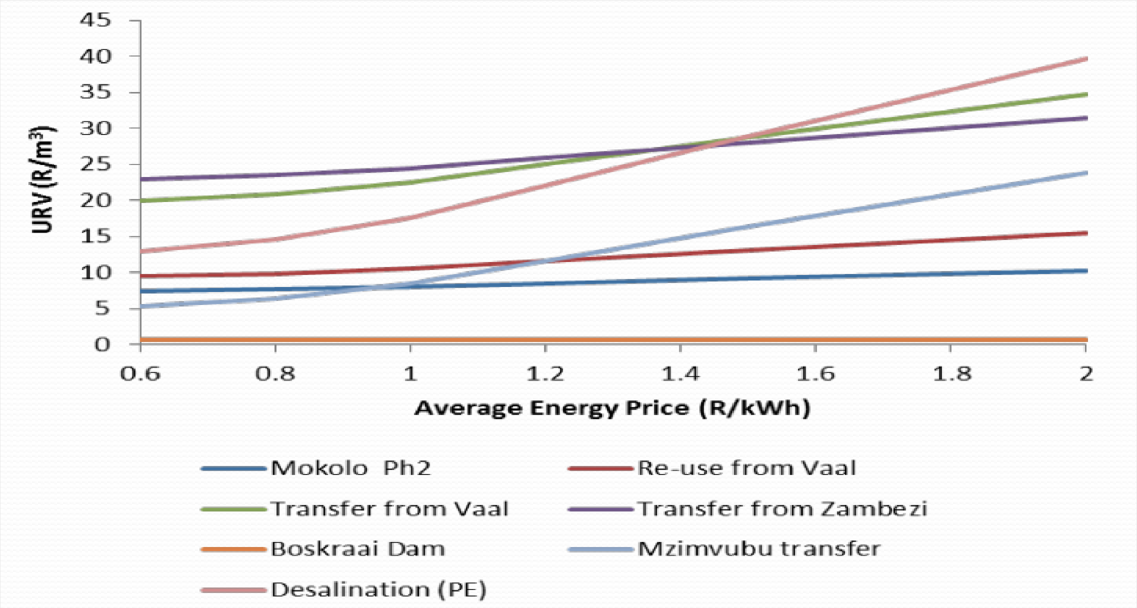
- **The bulk of water for energy expenditure therefore, also occurs in Waterberg, where a potential water shortage can be experienced by 2050.** By then, and according to preliminary estimates, the only option on the supply side will be to use seawater desalination. A deep dive in this particular region may be justified





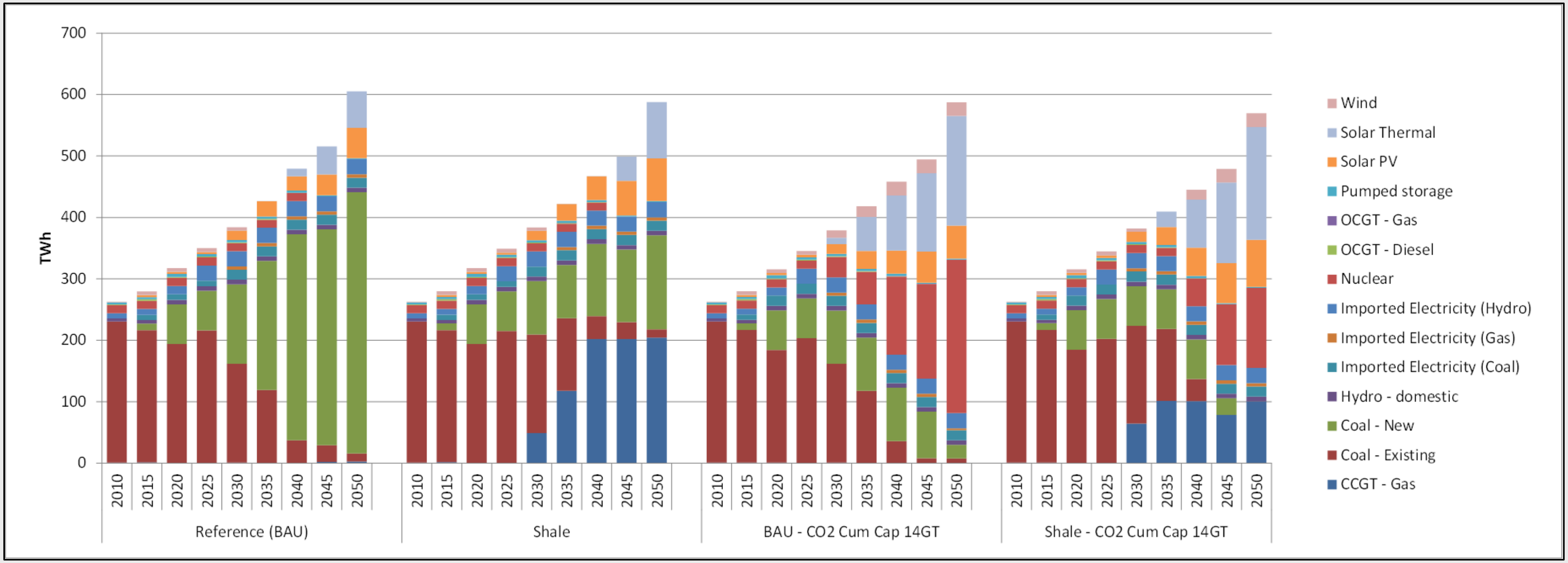
Main preliminary findings

- The transfer and treatment of water is very sensitive to energy costs



- Poor water quality is one of the main water-risks for the energy sector. Poor water quality impacts power stations by increasing cost due to the need of extra water purification technologies on site.
- Climate Change: The complex and intricate water resources management systems seems to be resilient to future impacts from climate change

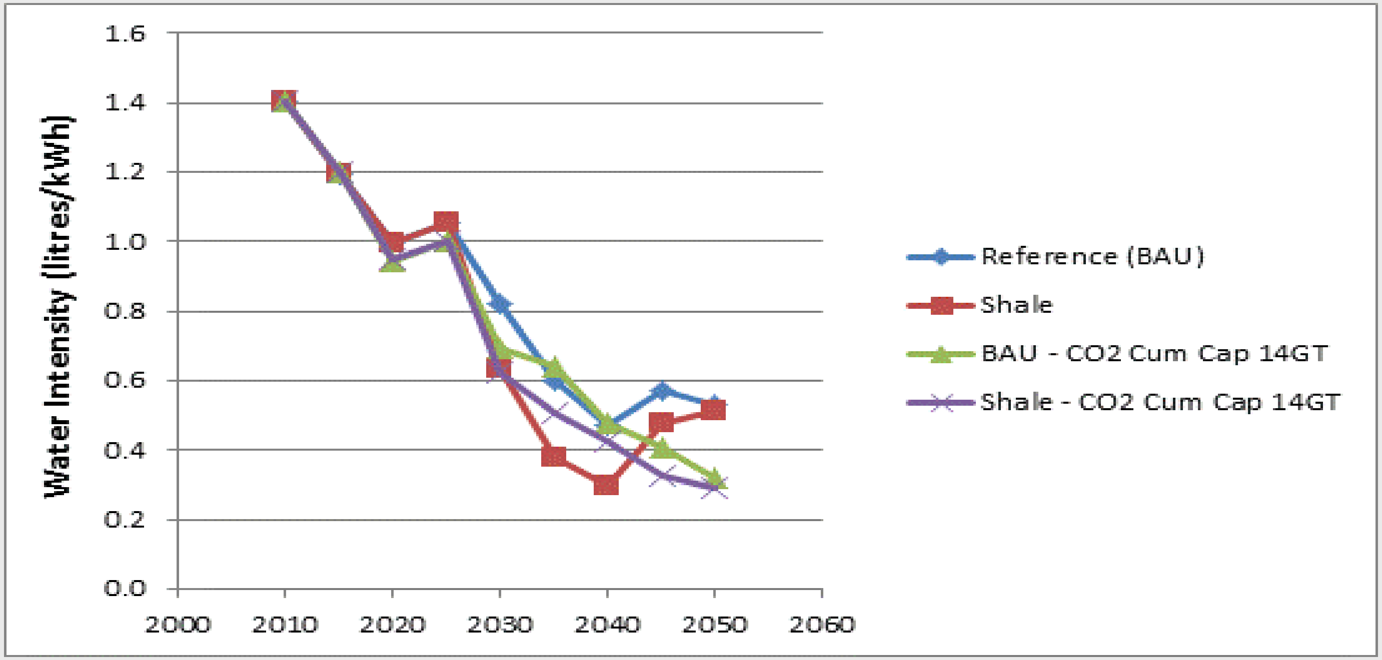
Preliminary results of the different Scenarios
(only power sector)



Installed Power Capacity under different scenarios

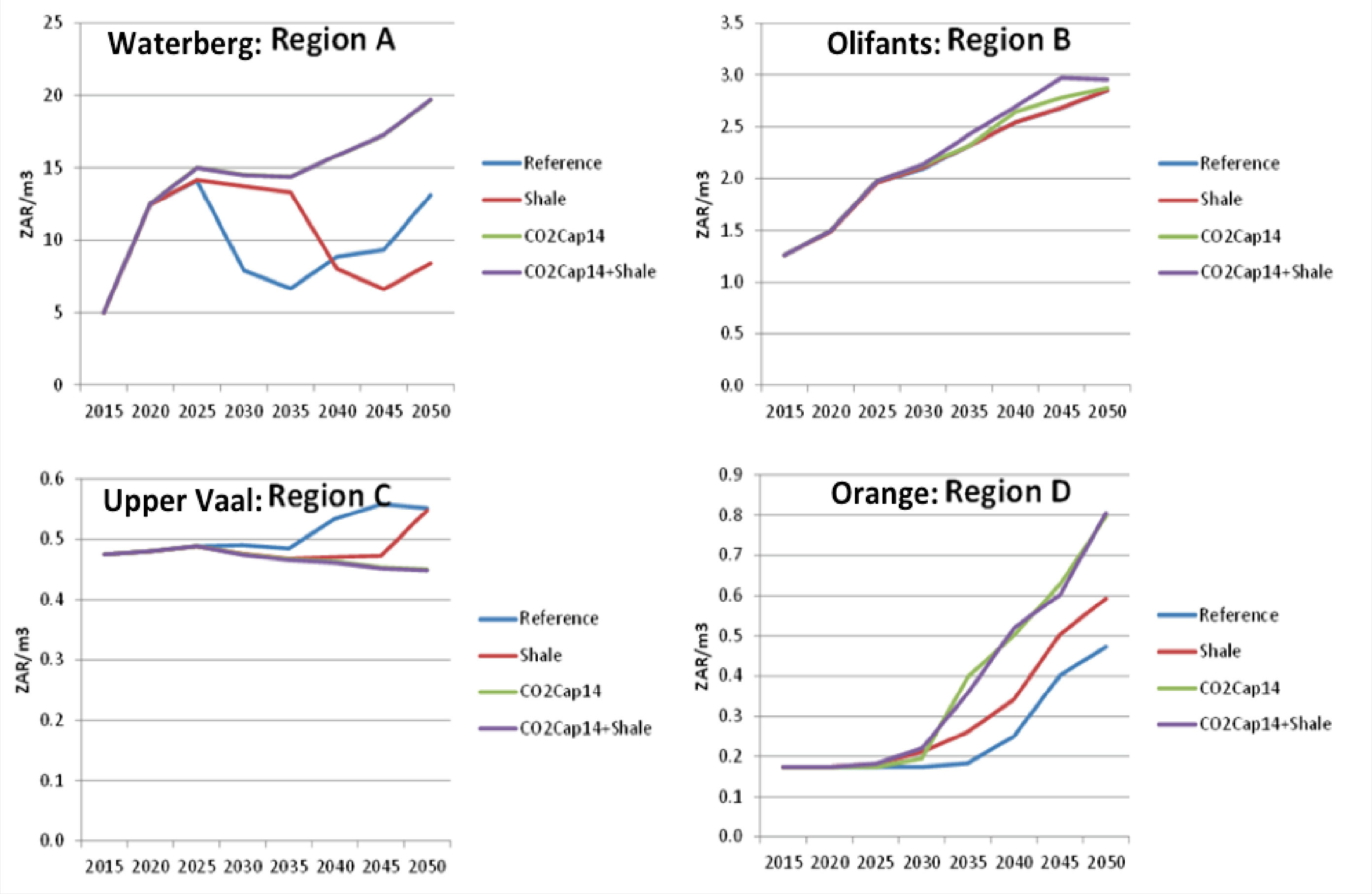
Preliminary Water Intensity of the Power Sector by Scenario

- In all scenarios, water intensity of electricity generation exhibits a decreasing trend (all scenarios have water costs included in the model, resulting in the deployment of mostly dry cooling systems when cooling is needed).
- Overcapacity from committed projects in the near term results in an increase in water intensity in the mid-term due to the increased utilization of older (less efficient) wet-cooled plants.
- A more stringent cumulative CO2 cap favors less water intensive technologies bringing down water intensity of generation earlier, steeper and deeper, leveling off at about 0.2 liters/kWh.



Preliminary Results

In the Waterberg, water supply costs drop in the Reference as more energy projects take up capacity of water infrastructure. The drop is delayed with Shale and doesn't happen with the CO2 cap.



Average cost of regional water supply by scenario

Feedback from stakeholders

- **One of the true added value of the model is being able to represent water needs of the energy sector by region,** and being able to understand which type of water infrastructure will be required to supply the energy sector, its location and timing. In South Africa, given that virtually all water is allocated, any future demand for water in the energy sector will require new water infrastructure. The planning, design, and construction of infrastructure requires long-term engagement. Hence, the results from this exercise can assist to ensure the timely planning of investments for the delivery and treatment of water for the energy sector
- **Poor water quality is one of the main water-risks for the energy sector.** Poor water quality impacts power stations by increasing cost due to the need of extra water purification technologies on site. For example, at the Duvha Power station a diversion pipeline was constructed to bypass the polluted areas of the Olifants river system; the cost of the infrastructure was R1.5 Bn. One recommendation of the group was to analyse the potential impact of poor water quality. This could be done through a sensitivity analysis, looking at increasing the costs of water treatment in regions where water quality is already of concern or where there is a high risk for water quality degradation.
- **Water consumption will increase as flue gases are required to be scrubbed to a higher purity and power station efficiency is reduced**. One scenario will look at the enforcement of FGD systems in all new power plants.
- **Suggestion for other potential scenarios.** For example, given the high value of water for power, would it be more economical to free water from agriculture for the power sector? Would water trading make sense before we incur large costs of desalination? Other scenarios suggested can be found here

Status

June 2013: First consultative meeting

During the meeting the team discussed extensively the most appropriate way to include water in the model, taking into account the regional and temporal differences between energy and water and including the price of water in the optimization.

January 2014: ERC presented a preliminary assessment at the 2014 UN-Water Annual International Conference

September 2014: the draft interim reports of Task 1 "*Develop marginal water supply cost schedules*" and Task 2 "*Task 2: Develop the "water smart" SATIM model*" were prepared.

May 2015: Mission to discuss preliminary results of Task 3: "*SATIM Energy-Water Nexus Model Simulations*" prior to the formulation of the final report

Next Steps:

December 2015: The final report (Task 4: *Report on Integrated Energy-Water Analysis in South Africa*) is expected to be finalized

A World Bank Initiative

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Thank You

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www.worldbank.org/thirstyenergy

WATER PARTNERSHIP PROGRAM
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Partners

Form stronger alliances. The challenge presented by the nexus is too large for any country, region, development finance institution or implementing agency to tackle alone

Funding Partners:

- Water Partnership Program (WPP)
- ESMAP
- Korea Trust Fund for Green Growth

Private Sector Reference Group

- Abengoa
- Électricité de France (EDF)
- Alstom
- Veolia

Other collaborating partners

- International Energy Agency (IEA)
- Stockholm International Water Institute
- World Resources Institute (WRI)
- UN Water / Sustainable Energy For All
- GIZ
- Others