“Water-smart” TIMES modeling in South Africa and China

ETSAP Water-Energy Nexus Workshop

Zürich, Switzerland
December 13, 2017
Why is the water-energy issue important?

Of the 7 Billion people on Earth today,

- **2.5 Billion** have unreliable or no access to electricity (Source: EIA, 2012)
- **2.8 Billion** live in areas of high water stress (Source: WRI, 2012)

By 2035, energy consumption will increase by **35%**

which will increase energy water consumption by **85%**

Increasing pressure on **finite water resources**

→ **Water scarcity is increasing** as demand for water intensifies with population and economic growth

→ **Climate change is exacerbating** water and energy challenges
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.
The challenge: how do we plan & design our investments in a sustainable way?

Political-level challenges impede effective planning:

- The two sectors have been regulated separately
- Current energy planning is often made without considering changes in water availability and quality, competing uses or the impacts of climate change

Challenges in securing enough water for energy and energy for water will increase with population, economic growth and climate change

Stronger integrated planning will be necessary to evaluate tradeoffs, find synergies, and ensure sustainable development
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

Water scarce country with very stressed basins in terms of water allocation, though with sophisticated inter-basin transfer provisions.

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.

Need for Water and Energy Integrated planning to achieve a sustainable future and avoid water scarcity problems in the next years.
China’s “Big Five” Power Utilities are all highly exposed to water disruption

Most energy reserves and power plants are located in water scarce areas (northern Energy Bases)

Pollution problems are severe and water resources degraded

Expansion plans for coal power plants in China might not be feasible due to water scarcity issues (Bloomberg, 2013)

- Policy landscape is changing with dry-cooling now required for all future coal power plants in the northern energy bases
Water “Smart” Model South Africa: water supply, infrastructure & treatment investment decisions within the energy system

https://openknowledge.worldbank.org/handle/10986/26255
Water “Smart” Model China: incorporates cost & limit of delivered water in the energy system

Water supply / cost curves for energy only

<table>
<thead>
<tr>
<th>No.</th>
<th>Source</th>
<th>Start Year</th>
<th>Volume (billion m³)</th>
<th>Price (RMB/ m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Existing reservoirs</td>
<td>2010</td>
<td>0.90</td>
<td>2.5</td>
</tr>
<tr>
<td>2</td>
<td>Recycled water (industry/urban)</td>
<td>2010</td>
<td>0.10</td>
<td>2.9</td>
</tr>
<tr>
<td>3</td>
<td>New reservoirs</td>
<td>2010</td>
<td>3.86</td>
<td>3.3</td>
</tr>
<tr>
<td>4</td>
<td>Recent reservoir construction project</td>
<td>2010</td>
<td>0.15</td>
<td>3.66</td>
</tr>
<tr>
<td>5</td>
<td>Water diversion project</td>
<td>2015</td>
<td>0.07</td>
<td>3.7</td>
</tr>
<tr>
<td>6</td>
<td>Mid-term water diversion project</td>
<td>2020</td>
<td>0.56</td>
<td>3.8</td>
</tr>
<tr>
<td>7</td>
<td>Mid-term recycled water</td>
<td>2025</td>
<td>0.32</td>
<td>4.0</td>
</tr>
<tr>
<td>8</td>
<td>Long-term recycled water</td>
<td>2030</td>
<td>0.72</td>
<td>4.8</td>
</tr>
<tr>
<td>9</td>
<td>Long-term water diversion project</td>
<td>2030</td>
<td>4.88</td>
<td>5.0</td>
</tr>
</tbody>
</table>

“Water-smart” TIMES Modelling in South Africa and China
Impact on Water of Pricing and Policies in South Africa

- Once the true costs of water supply are incorporated into the energy model, dry cooling replaces wet cooling for coal power. This means that dry cooling makes economic sense in South Africa even if it decreases the efficiency of the power plant (supporting Eskom’s current policy).
- Water intensity of the power sector drops to a quarter of the ‘no water cost’ 2050 level.

Water use levels increase under CO₂ caps scenarios as CSP using wet cooling is deployed, though when a Drier Climate is factored in the CSP switches to dry cooling.
The decision by the government to require dry-cooling for any future coal-fired power plants built in the north is economically (and socially) justified when the cost of water is factored in.
Regionalizing the water picture: Supply & use vary greatly by region

South Africa (Reference)

China (2014)

EIM
- Agriculture water, 72.72%
- Industrial water, 14.17%
- Energy sector, 10.25%

Ordos
- Agriculture water, 76.06%
- Domestic water, 13.11%
- Energy sector, 80.95%

Shanxi
- Agriculture water, 54.42%
- Industrial water, 21.11%
- Energy sector, 90.95%

Xinjiang
- Agriculture water, 90.95%
- Ecological water, 4.95%
- Energy sector, 24.08%

Note: CTL = coal to liquids; Mm³ = millions of cubic meters.

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## Policies examined with the Water-Smart TIMES models

### South Africa Study

<table>
<thead>
<tr>
<th>Policy Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base (No Water Cost)</td>
<td>Status quo planning continues without consideration of water.</td>
</tr>
<tr>
<td>Reference (Water Cost)</td>
<td>Status quo planning continues with proper consideration of water.</td>
</tr>
<tr>
<td>Shale Gas</td>
<td>Shale-gas extraction occurs in the Orange River region.</td>
</tr>
<tr>
<td>Dry Climate</td>
<td>Regional water supplies and non-energy water demands are adjusted to reflect a drier climate (increasing water demand and decreasing water supply), affecting the unit water supply cost of regional schemes.</td>
</tr>
<tr>
<td>Water Quality</td>
<td>Quality of the water transferred between regions is lower than that of local supplies, requiring additional treatment.</td>
</tr>
</tbody>
</table>

### Environmental Compliance
- Retrofitting existing coal power plants with wet flue-gas desulfurization (FGD);
- Fitting existing and new coal-to-liquids refineries with semi-dry circulating fluidized bed (CFB)-FGD technology;
- Operating all combined-cycle gas turbines with wet control of nitrogen oxides;
- Coal mines fully treating water discharged into the environment, and
- Inclusion of the Water Quality scenario.

### South Africa Scenario
- Dry Climate + Environmental Compliance: Water demands and costs rise across sectors. Includes the Water Quality scenario.
- CO₂ Cumulative Cap 14GT: Cumulative national GHG emissions limited to 14 Gt by 2050 (in line with the country’s NDC).
- CO₂ Cumulative Cap 10GT: Stricter carbon budget limiting cumulative national GHG emissions to 10 Gt by 2050.

### China Study

<table>
<thead>
<tr>
<th>Policy Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>With and without cost for water, no CO₂ limit but with other 13th FYP core policies</td>
</tr>
<tr>
<td>Reference</td>
<td>13th FYP core policies and CO₂ limit of 9.5 billion tons in 2020 and 11.0 billion tons in 2030, and cost of water</td>
</tr>
<tr>
<td>Non-Fossil energy</td>
<td>Implement government Plans for nuclear and renewables by 2020, extended until 2030</td>
</tr>
<tr>
<td>Coal utilization (peak)</td>
<td>Limit coal production to 2.85 Btce in 2020 and 1.5 Btce in 2050</td>
</tr>
<tr>
<td>Coal chemicals</td>
<td>Coal-to-liquid (CTL) capacity increases to 2400 Kt/a by 2020, and the coal-to-gas capacity grows to 3.1 bcm/yr by 2030</td>
</tr>
<tr>
<td>Shale gas</td>
<td>Shale gas projected to be 30/60 BCM in 2020/2030</td>
</tr>
<tr>
<td>Combined scenario</td>
<td>Combining Reference, Non-Fossil Plan, Coal (Peak), and Shale gas</td>
</tr>
</tbody>
</table>
Regional Impact on Water Infrastructure Investment across Core Scenarios in South Africa

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Impact across Core Scenarios & due to Climate Change in China

Shift to renewables moves generation out of northern Energy Bases (except Ordos) when limits imposed on CO₂ & fossil fuels

Only minor impact seen on water availability in the Energy Bases under varying RCP scenarios

Air quality emissions trajectory

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Impact of Water Costs & Policies on Coal Use (and CO₂) in South Africa

As role of coal fades water intensity of the energy system improves

Abandon CTL Existing Coal-fired Power Plants

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\[\text{CO}_2\text{ Emissions}\]

\[\begin{align*}
\text{New Wet} & \quad \text{New Dry} & \quad \text{Existing Wet} & \quad \text{Existing Dry} \\
\text{2030} & \quad \text{2035} & \quad \text{2040} & \quad \text{2045} & \quad \text{2050}
\end{align*}\]

\[\begin{align*}
\text{Difference between Dry Climate and BAU (GW)} \\
\text{2030} & \quad \text{2035} & \quad \text{2040} & \quad \text{2045} & \quad \text{2050}
\end{align*}\]
Take Away Messages

- The **cost and availability of water supply** matters in energy planning as demonstrated in the case studies. **Regional impacts** are very important.

- Decision makers must consider the **interconnected nature of resources**, and how decisions ripple across sectors in order to simultaneously achieve all SDGs in a sustainable manner.

- Cross-sectoral solutions and practical tools are needed to address complex challenges, focusing on minimizing tradeoffs and fostering synergies. Otherwise gains in one goal (SDGs, NDCs) may have negative impacts on another.

- A forgotten aspect: planning, design and implementation of water **needs coordination** with energy. Planning is more effective that addressing synergies downstream after infrastructure is in place.

- Specific energy **sector policies can have significant implications** for new investment in water supply infrastructure and, in some cases, can strand water supply investments (and vice versa), reinforcing the importance of planning in an integrated manner.
Thank You!

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