Will Water Constrain

Our Energy Future?

thirsty energy

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Water – Energy Interdependence

energy needs
water

Energy production processes require water

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

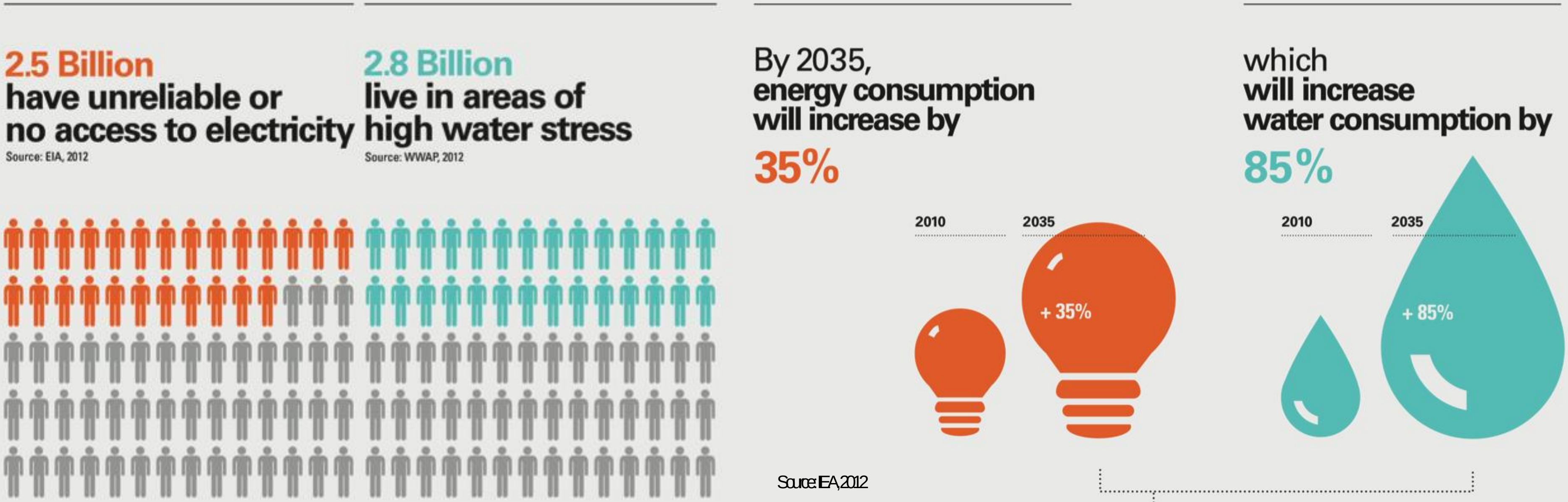
water needs
energy

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

- extraction
- treatment
- transportation

Why is the energy-water issue **important?**

Of the **7 Billion people on Earth today**,



Increasing pressure on **finite water resources**

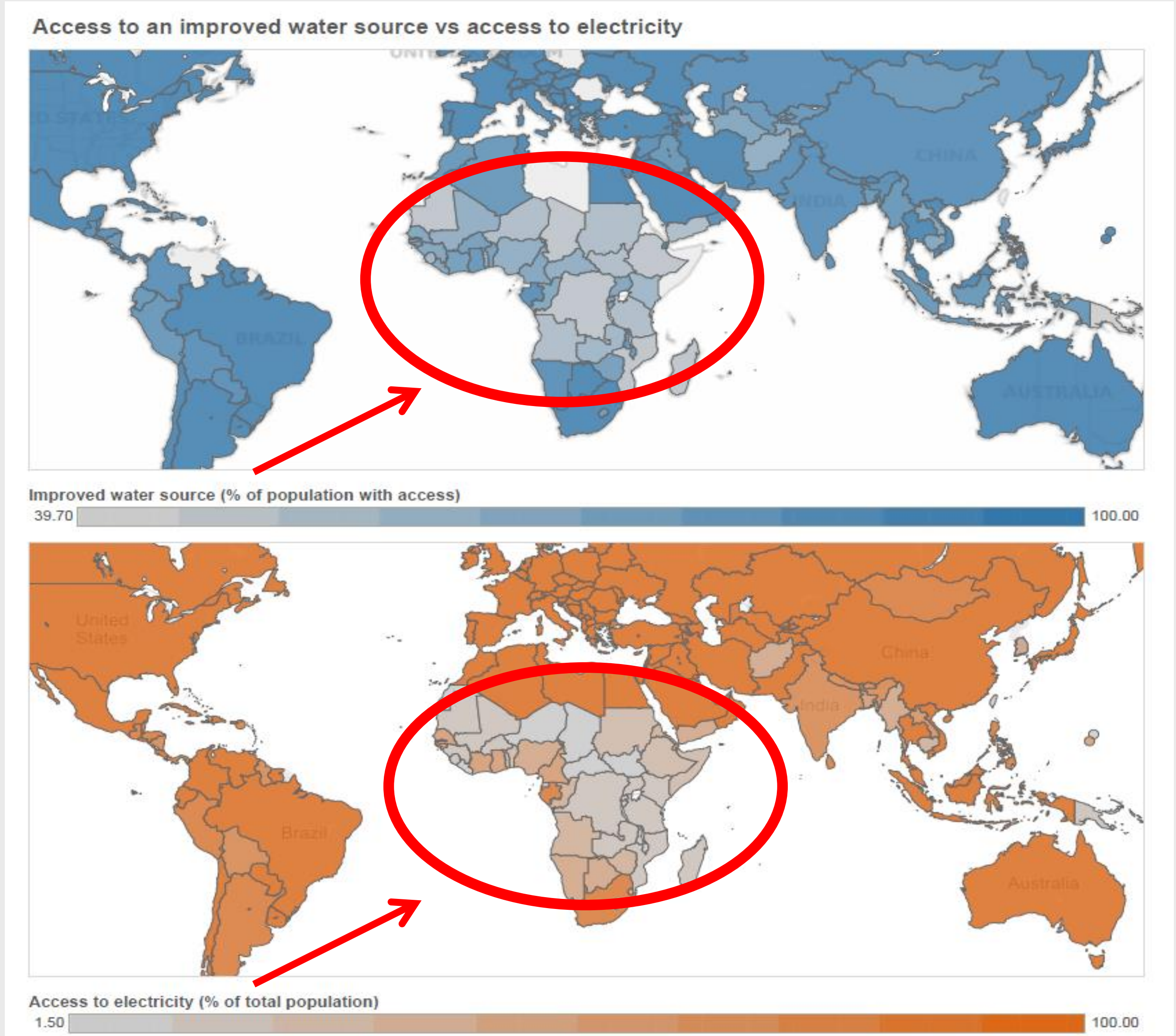
→ **Water scarcity is increasing** as demand for water intensifies with population and economic growth

→ **Climate change is exacerbating** water and energy challenges

the energy poor are often also water poor

Access to an improved water source (% of total population)

Access to electricity (% of total population)



Source: World Bank Data. http://bit.ly/improvedwatersource and "Access to Electricity" from http://bit.ly/SE4ALL

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

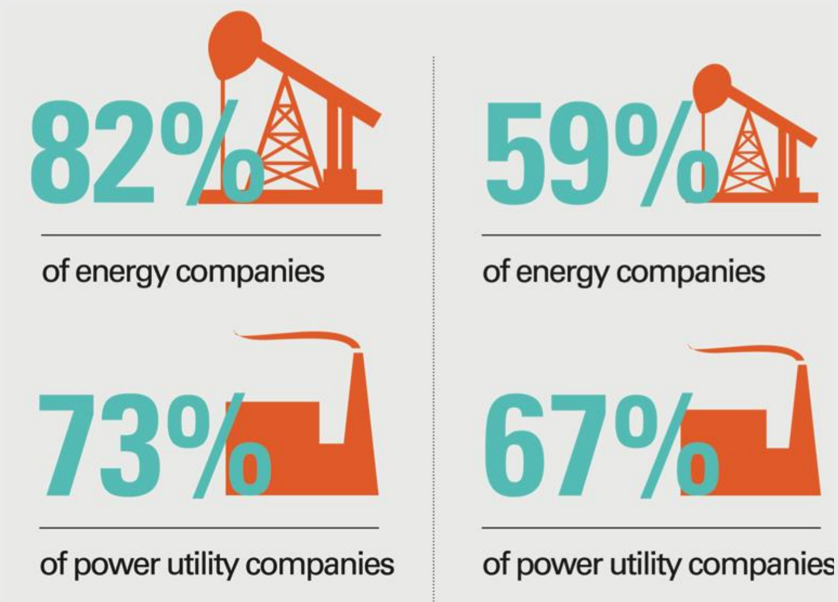
Financial losses CAPEX and operational costs increase

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



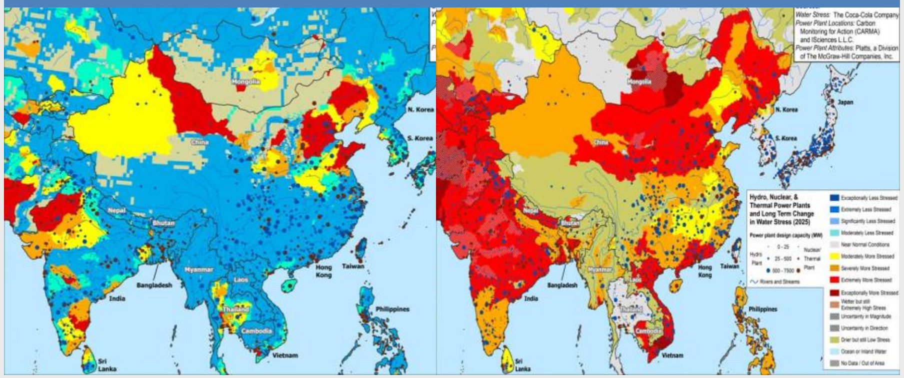
Indicate that **water is a substantive risk** to business operations

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

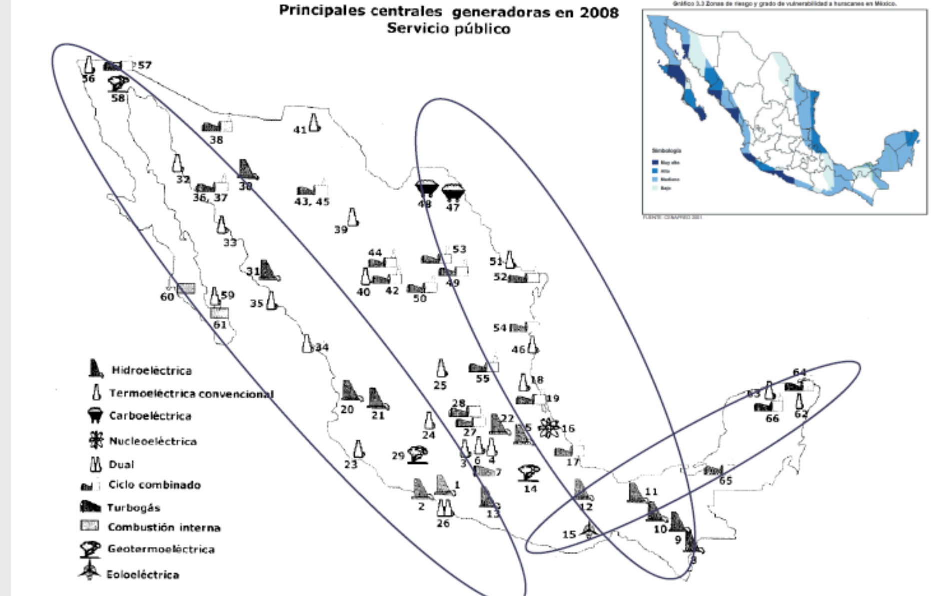
However, the majority of companies surveyed do not appear to be planning corollary increases in the breadth and scale of their water risk management practices

Energy Services will be increasingly affected by **the consequences of climate change**

Water scarcity changes is Asia



SOURCE: WRI, 2012. The baselines water stress is defined as the ratio of total annual freshwater withdrawals for the year 2000, relative to expected annual renewable freshwater supply based on 1950–1990 climatic norms.

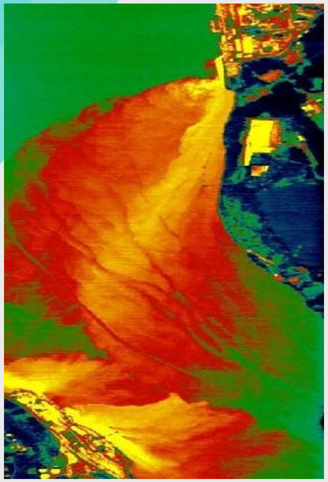


Relative location of power plants vs. hurricane/typhoon zoning areas in Mexico

SOURCE: ESMAP PRESENTATION ON CLIMATE IMPACTS ON ENERGY SYSTEMS. NOVEMBER 16, 2010

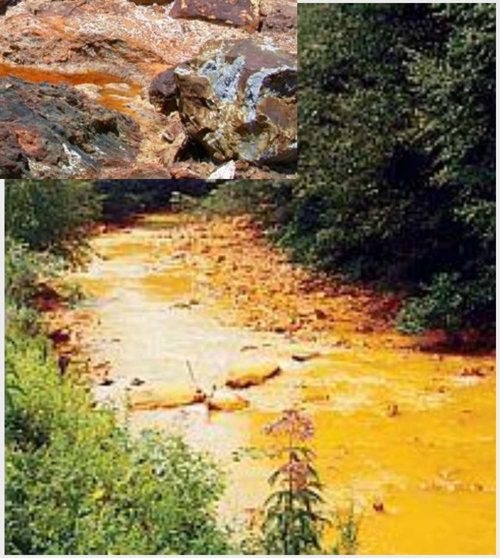
Projected changes in hydropower generation

Moreover…**water quality** can be an issue if not regulated/managed properly



Thermal pollution from once through cooling has adverse effects on ecosystem

Fracking requires large amount of water and also generates waste water that needs to be treated



Drainage from Abandoned coal mines

The energy-water challenge is **already present and very real**

Water shortages hit US power supply

Updated 10:54 20 August 2012 by Sara Reardon

OP-ED CONTRIBUTOR

Will Drought Cause the Next Blackout?

By MICHAEL E. WEBBER
Published: July 23, 2012 | 150 Comments

Austin, Tex.

China power crunch to worsen as drought slashes hydro

Recommend | 6 people recommend this. Be the first of your friends.

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(Reuters) - The worst drought to hit central China in half a century has brought water levels in some of

as bayou floods
Tue, May 17 2011

Japan keeps Fukushima

Connecticut nuclear power plant shut down one unit due to hot water from Long Island Sound

Published: Monday, August 20, 2012

Maharashtra: Parli power plant shuts down after severe water crisis

Reported by Rashmi Rajput, Edited by Amit Chaturvedi | Updated: February 17, 2013 17:33 IST

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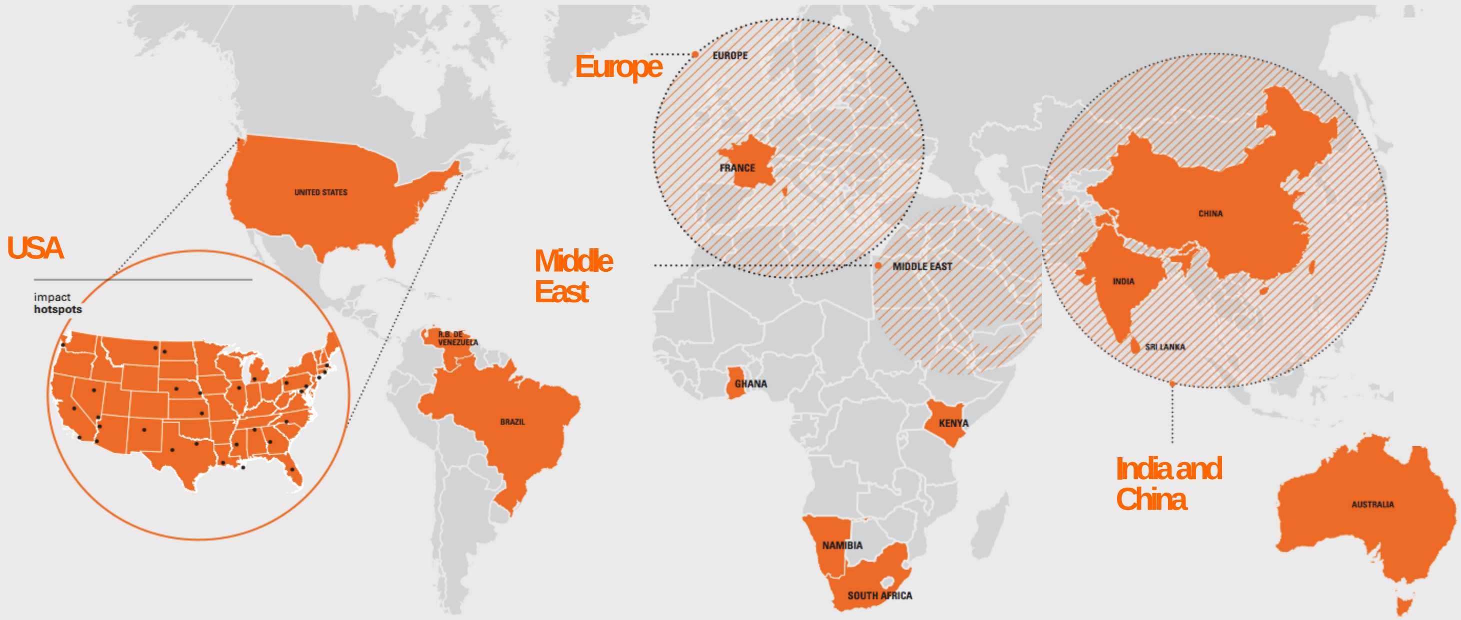
'Water becoming a serious constraint for power generation'

The power plant has an installed capacity of 1130 MW.

Bloomberg News

China, India Lack Water for Coal Plant Plans, GE Director Says

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



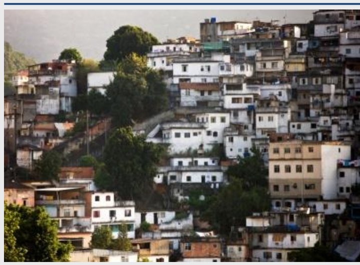
- In the **U.S.,** several power plants have had to shut down or reduce power generation due to low water flows or high water temperatures.
- **In India**, a thermal power plant recently had to shut down due to a severe water shortage.
- **France** has been forced to reduce or halt energy production 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.

Water is not an isolated sector
We need to understand and quantify tradeoffs

Climate impact: Major increases in climate variability expected, with increased frequency of droughts and floods. Heaviest impact will be borne by the poorest, who are already underinvested in adaptation to current climate

Major demand increases… / **…with the potential to derail growth**

Health and human settlements



- Changing settlement patterns, with a 2004-15 to see 40% increase in urban population without basic WSS access
- 80% of all people lacking WSS access in rural areas
- Half of urban water supplies are from groundwater with very little knowledge of hydrology
- Rapid urbanization

Lack of sanitation access can cost countries up to 6% of GDP

Food and agriculture

- 70% increase in food production will be required in 40 years (with it already 70% of withdrawals)
- Half the world's food is grown on groundwater, much of which is unsustainable
- Use of crops for biofuels affecting food prices

Unreliable water supply and farm-to-market access can deprive farmers of 2/3rd of their potential income

Energy and industry

- Global energy consumption expected to increase by ~35% from 2007-2035
- Water-intensive thermal and hydro account for 90% of current power generation
- Power outages caused by lack of cooling water already seen in many countries

Energy security is threat-ened by water challenges; 3% of Kenya's GDP from lost hydro production over 1998 - 2000

Environment

- Ecosystem damage largely coincides with high water stress (e.g., Indo-Gangetic Plain, North China Plain) and fertilizer runoff (dead zones)
- Over-consumption of water, water pollution and inadequate pricing of the resource results in loss of massive ecosystem benefits

Losses of biodiversity and ecosystem services with increasingly visible economic cost (e.g., China losing 5% GDP to pollution)

Competition for water allocation

Impaired water quality affecting all uses

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 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 problem
- We need specific solutions for each region and each problem

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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

the challenge: how do we plan & how do we 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 and economic growth and climate change

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

Improving Energy Efficiency

- **In the energy sector:**

Replacing old and inefficient power plants for new ones; achieving the same electricity output with less fuel, less water and less GHGs emissions.

- **In the water sector:**

In water and wastewater treatment plants:

- Electricity costs are usually between 5 to 30 percent of total operating costs (in developing countries it can go up to 40 percent or more).
- Many energy efficiency measures have a payback period of less than 5 years (ESMAP, 2013)
- Improving energy efficiency directly improves the financial health of the plants
- One example of improving energy efficiency is **Leakage detection and reduction**

Leakage detection and reduction to save water and energy

World Bank financed project in Vietnam:

- ✓ Performance based leakage contract
- ✓ Leakage was reduced from 54% to 29%
- ✓ **Water saved: 92,000 cubic meters a day** (equivalent to 36 Olympic pools)

- ✓ **Electricity saved: 23,000 kwh a day (**enough power for a community in rural Vietnam of 27,000 people -with average electricity consumption of 2009)

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

This WASTEWATER is used in the cooling towers instead of freshwater

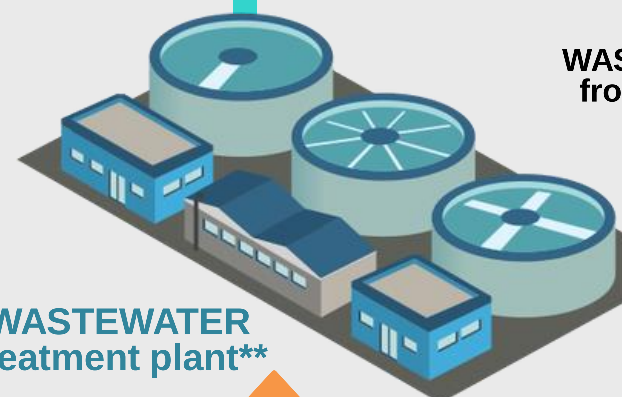
treated wastewater

treated WASTEWATER is piped to the power plant

Thermal POWER PLANT

net reduction of groundwater extractions of at least 48 million m3 in 6 years

WASTEWATER from the city



WASTEWATER treatment plant**

$

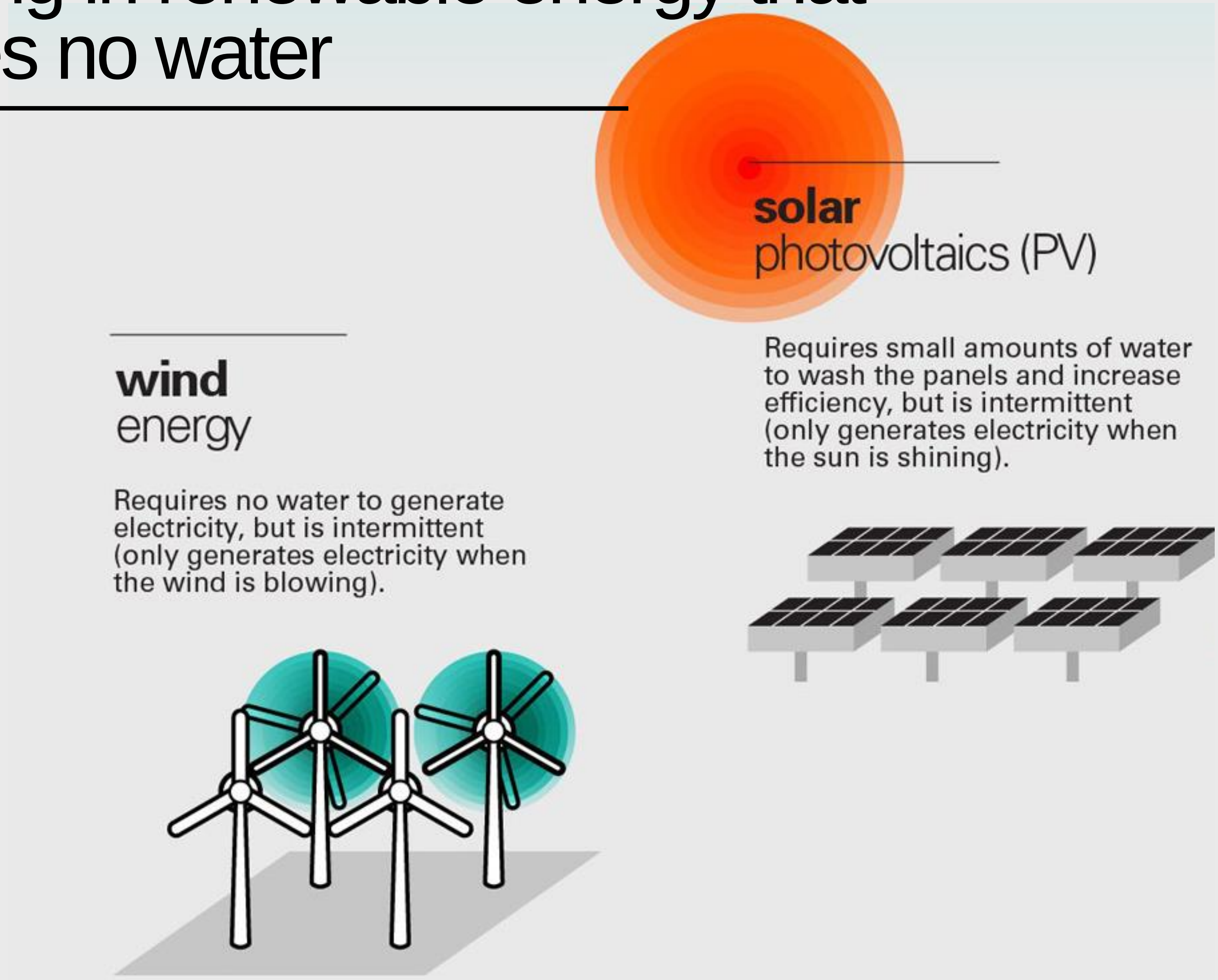
BENEFITS FOR THE WASTEWATER TREATMENT PLANT

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



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

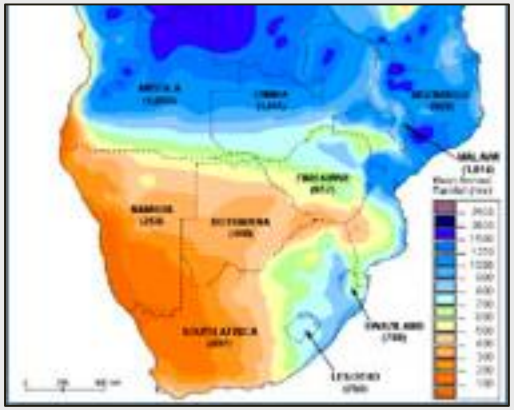
THIRSTY ENERGY: Methodological approach

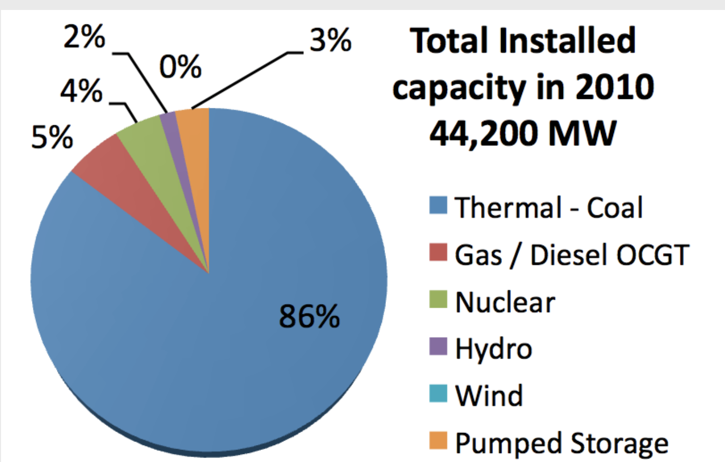
- **Demand Driven , Entry point is Energy Sector**
- **Engagement with relevant stakeholders from day 1**, involving local partners from energy and water sectors to identify potential constraints and synergies
- **Build on existing country knowledge and modeling tools** whenever possible to ensure continuity and sustainability of initiative
- **Flexible modeling framework** to facilitate tailored analyses over different geographical regions and challenges
- **Economic tools to assess the tradeoffs between competing sectors** and to provide policy recommendations to mitigate potential effects
- **Robust treatment of risk and uncertainty, incorporating the long-term effects of climate change**
- **Case studies or pilots to illustrate the different challenges** that are most relevant for client countries.

Where are we?

- **Officially launched initiative** at the World Future Energy Summit 2014
  - Rachel Kyte (VP), Vivien Foster (Manager, Energy Anchor), William Rex (Manager, Water Anchor), VP Alstom, VP Abengoa, Executive Director IEA
  - Ideal timing and place:
    - same venue Water International Summit
    - UN Water 2014 theme Water&Energy, a lot of traction from media

South Africa:
the case of A Water Scarce Country





Sources - Top: CSIR, Bottom: ESKOM and Department of Energy of South Africa

- Water scarce country with very stressed basins in terms of water allocation
- 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

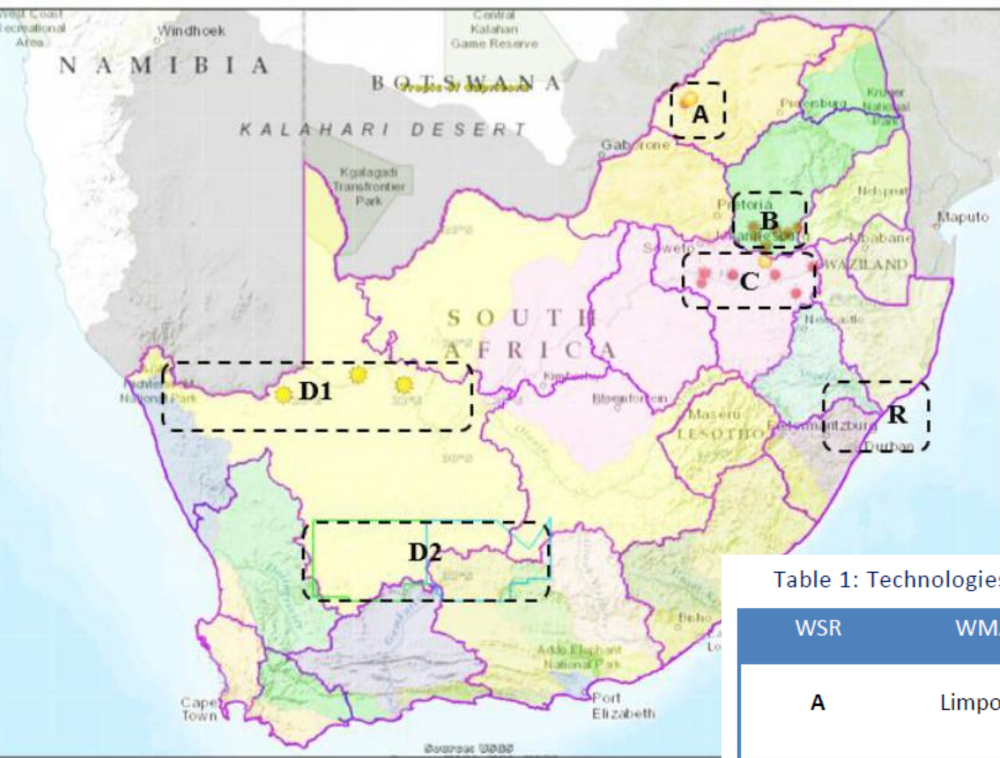
Water already represented in the model but…

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



1. Needed 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

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.

South Africa: Marginal Cost of Water Supply

2. Needed to add the cost of supplying water to the energy facilities:

by calculating the marginal cost of water supply for each basin

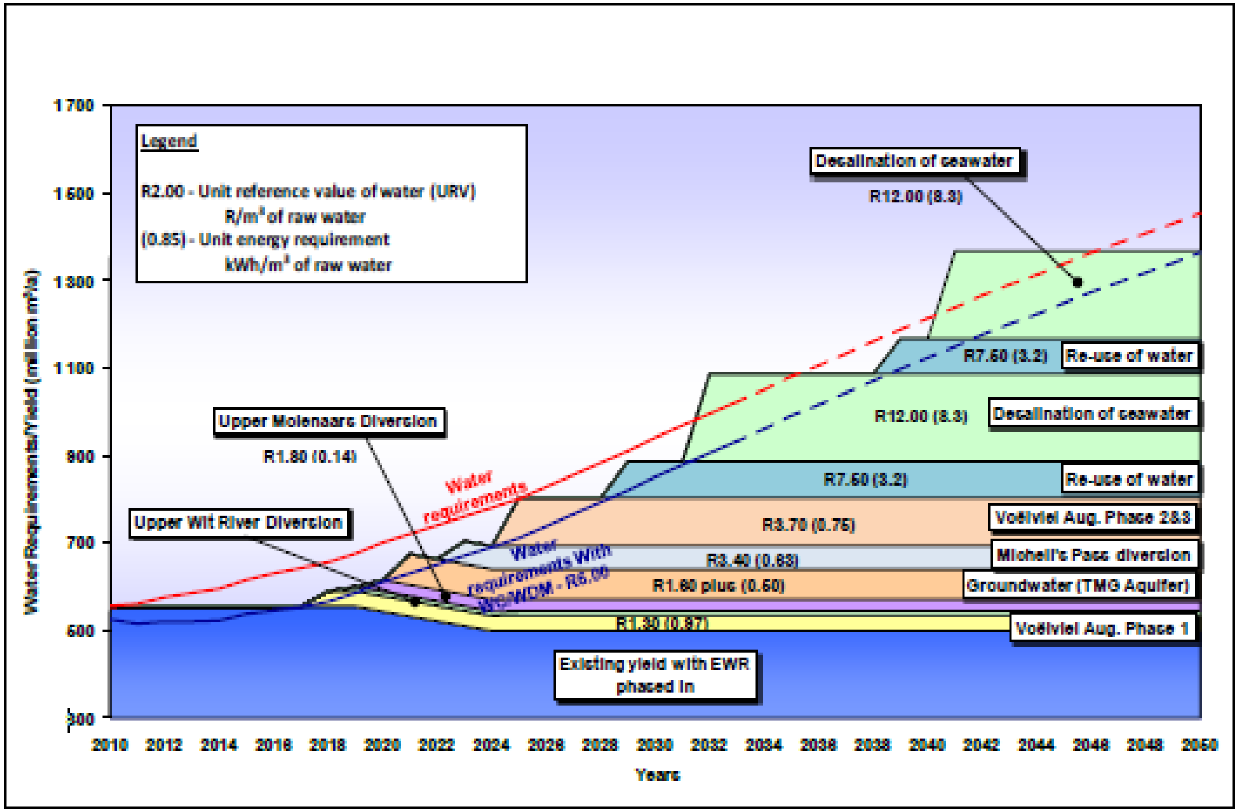


Figure 4.10 (a) Western Cape Augmentation Options (without climate change)

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.

- Preliminary draft assessments of the current status of the water and energy sectors were prepared

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.

<u>Next Steps:</u>

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

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

CASE STUDIES: MOROCCO

Background

- Recent merge of power and water utility (ONEE) → **potential for synergies and integrated planning**
- **Water constraints can impact growth,** increasing competition for water across sectors (esp. irrigation); ambitious renewable targets for 2020 to meet 7% annual growth in electricity consumption; **Climate change vulnerability**

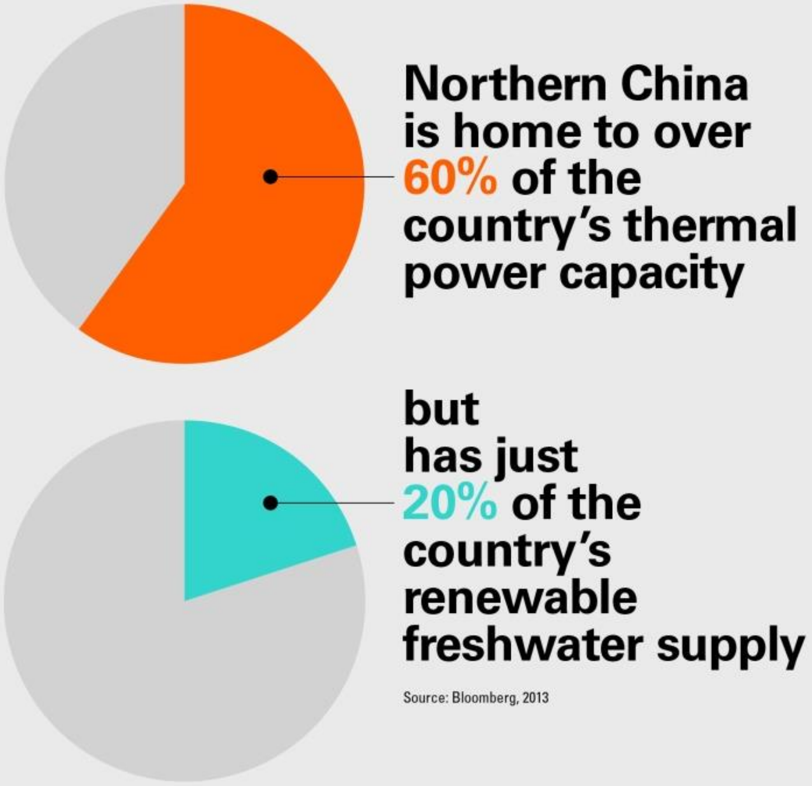
Status

- **First Stakeholder Workshop has been convened.** It was preliminarily decided, that two activities will be undertaken:
  - **at the national level,** focusing on the first national integrated energy and water vision, flagging potential future constraints, and including all relevant stakeholders in the government, private sector and others.
  - **at the utility level (ONEE),** focusing on identifying synergies and integrated strategies to improve the efficiency of the utility
    - **Optimized Planning of ONEE Water and Power Needs**
    - **Wastewater Reuse for Power**
    - **Power Transmission Lines vs Water Transfer**

Next Steps: Second Stakeholder Workshop

CASE STUDIES: CHINA

- 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**, sectoral growth increasing due to population growth, climate change
- **Pollution problems & degraded resources**
- **expansion plans for coal power plants in China** might not be feasible due to water scarcity issues (Bloomberg, 2013)



CASE STUDIES: CHINA

Background

- Recent efforts by the National Energy Agency (NEA) to assess water needs by the energy sector & integrate water resource constraints into the upcoming five-year energy plan

Status

- **First Stakeholder Meetings: March 2014:** with NEA, Energy Research Institute, Institute of Water Resources and Hydropower Research, and Tsinghua University
- The main objective of the initiative is to support the NEA in its planning process and in its effort to integrate water resources in the five-year energy plan, and to assess the long term sustainability of the plan

Next Steps

Start Implementation
Expected outputs:

May 2015: workshop/meeting to discuss progress and the technical inputs
June 2015: Preliminary Assessments to be shared with NEA
January 2016: Final Results and Report

Knowledge dissemination, advocacy and capacity building

- Implemented strategy from day 1
- Created Communication and Awareness package:
  - Infographics
  - Working Paper as Background on the topic
  - Blogs
  - Brochure
  - Twitter
  - Collaborating with partners on key messages
- Capacity building in case study countries
- South to South Knowledge Sharing

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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
- 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

What next?

- **Ongoing initiative:** Interest growing from several countries and regions
  - Brazil: Sao Francisco Basin
  - Indonesia
  - Mexico
- **Outcomes:**
  - Innovative tools, approaches and solutions developed and implemented to help Bank teams and countries 'green' their growth
  - Policy guidance and Improved design of investments, strategies and plans in energy
  - Knowledge deepened in the water and energy nexus
  - Energy-water integrated planning practice enhanced
  - Water mainstreamed in the energy sector
  - Improve interdisciplinary collaboration among sectors

A World Bank Initiative

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Thank You

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www.worldbank.org/thirstyenergy

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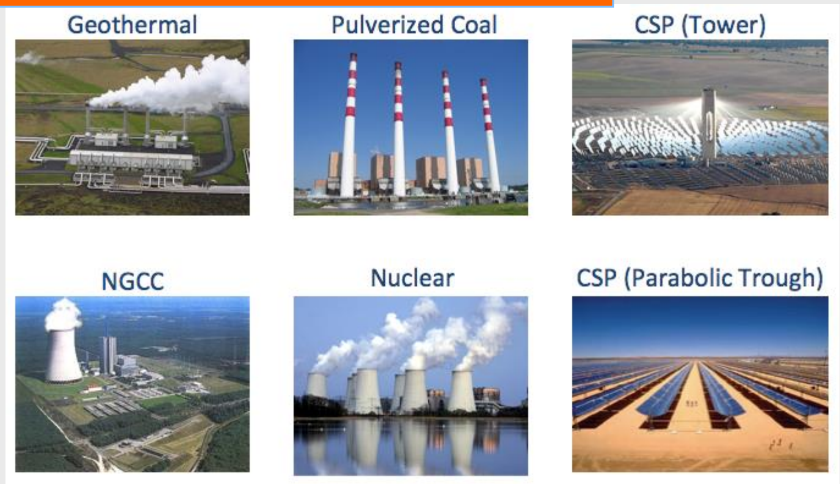
EXTRA SLIDES

Almost all forms of electricity **generation require water**

HYDROPOWER

THERMAL POWER PLANTS

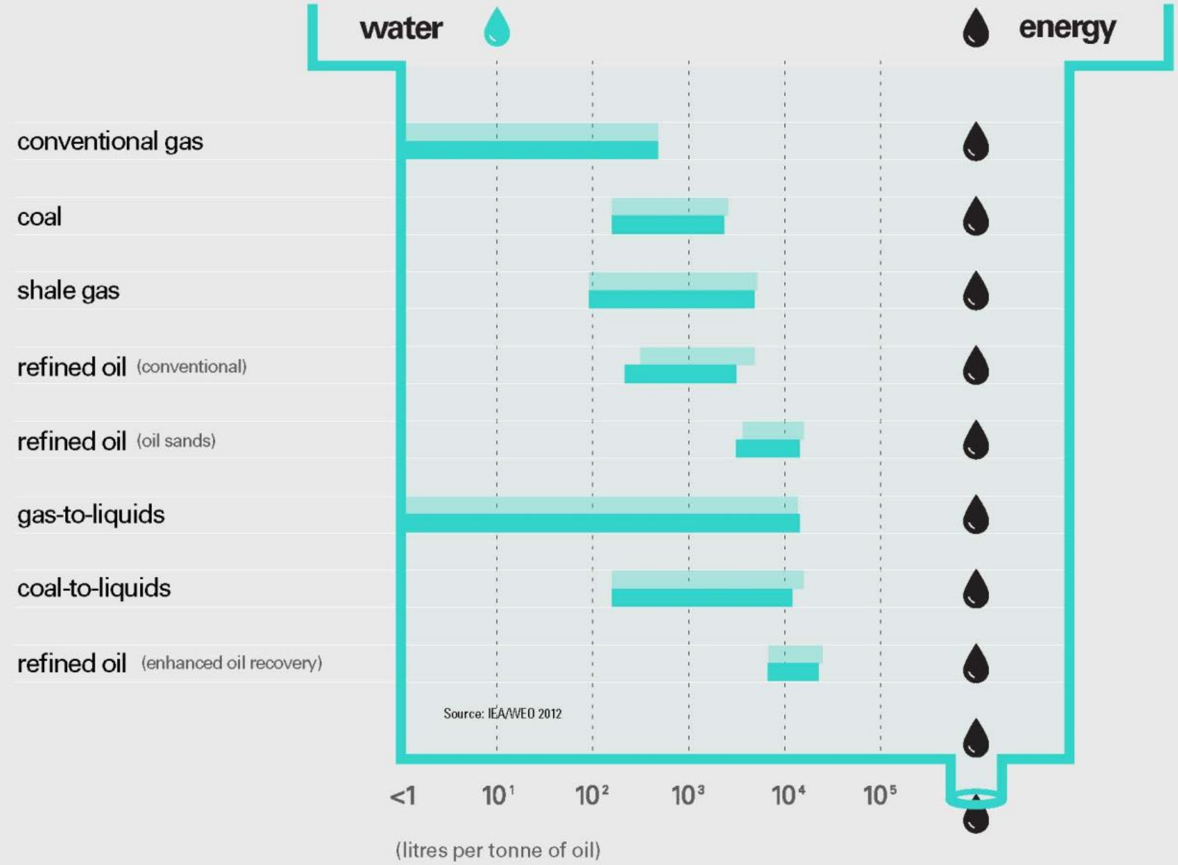


Wind and **Solar PV** have a negligible impact on water resources

But they are intermittent

energy **extraction**

Water use in energy development not only varies by fuel type, but also can vary a lot within fuel types, depending on the development method and the site conditions.



legend

- water withdrawal (in litres)
- water consumption (in litres)
- = 1 toe (tonne of oil equivalent)*

* tonne of oil equivalent (toe) is a unit of energy defined as the amount of energy released by burning one tonne of crude oil. It is approximately equal to 42 gigajoules (GJ)

Source: OECD/IEA

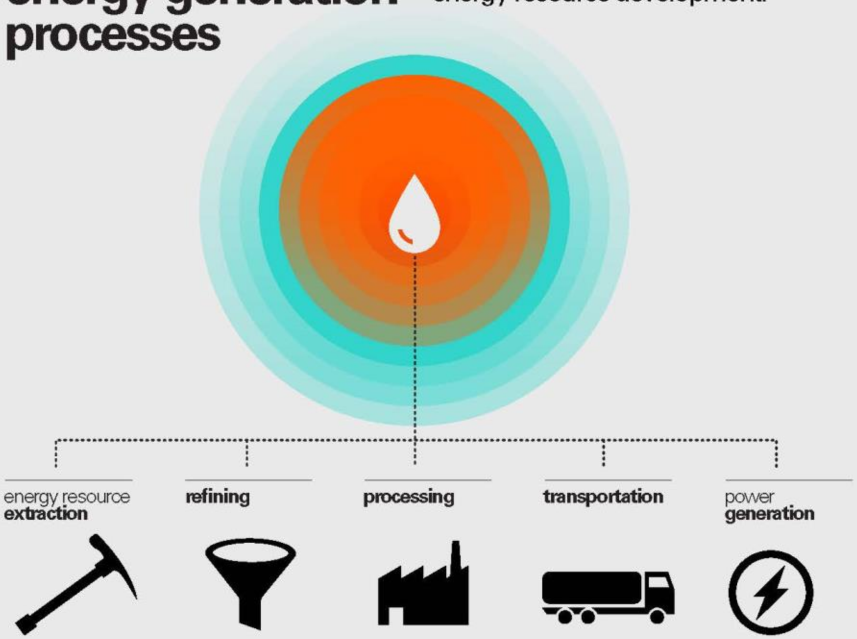
Energy production can adversely impact water resources and the environment if not managed properly.

Biofuels' water needs and environmental impact depend on the crop, and whether it is rain-fed or irrigated.

why does the energy sector **need water?**

water is used throughout **energy generation processes**

Constraints on water availability influences the choice of technology, siting, energy facility selection, and energy resource development.



today 15% of global water withdrawals are for **energy production.**

Source: IEA/WEO 2012

by 2035, **energy consumption will increase by**

increasing **water consumption by**

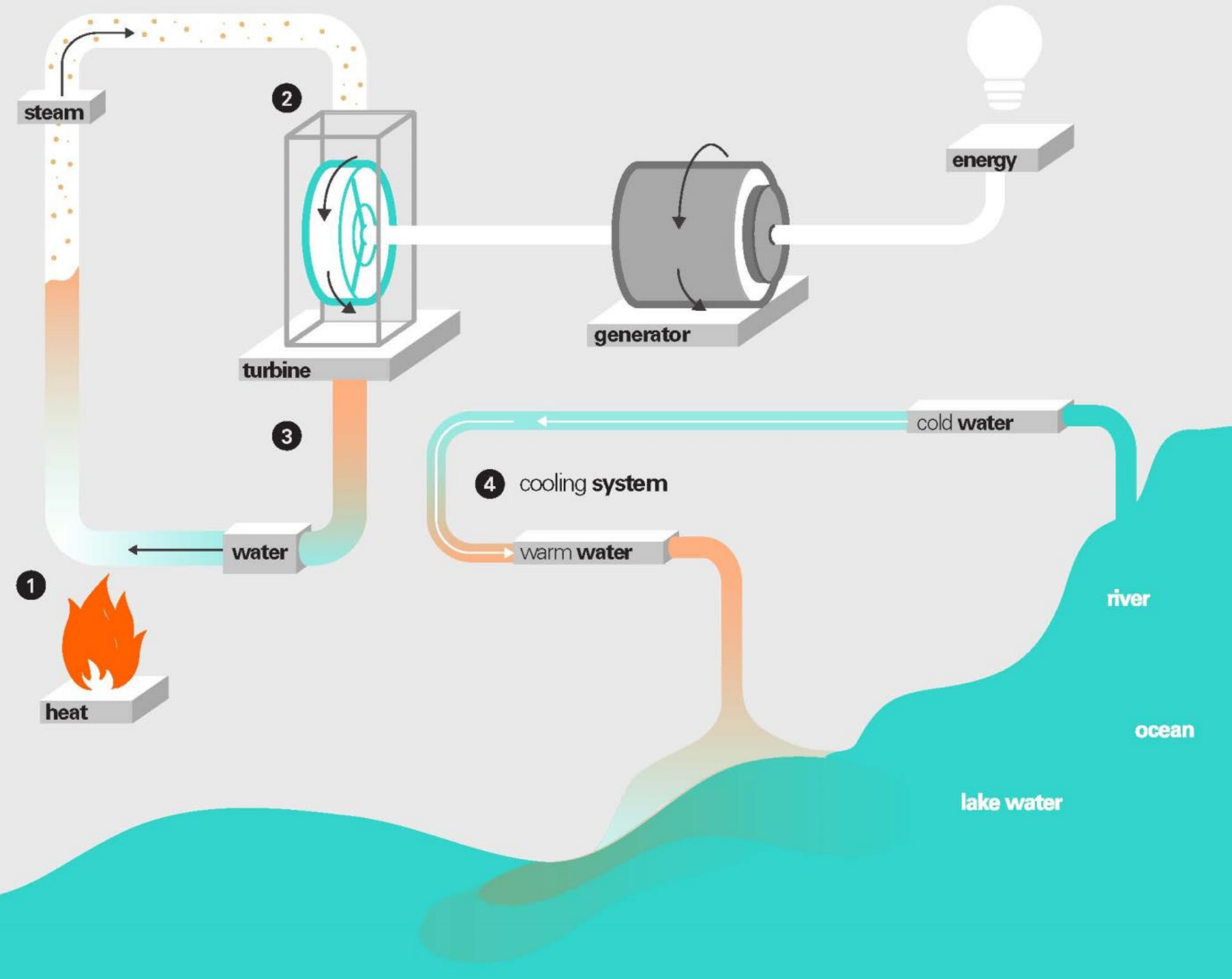
increasing **water withdrawal by**

Source: UN 2014

thermal **power plants**

Once the energy resources are refined and processed, some are used as fuel in thermal power plants to generate electricity.

1. The water is heated with different energy sources (coal, oil, natural gas, uranium, solar energy, biomass, geothermal energy) depending on the sub-type of power plant, but the principle is the same.
2. The steam spins the turbine, which is connected to a generator that produces electricity.
3. After passing through the turbine, the steam is cooled down and condensed to start the cycle again.
4. Thus, most thermal power plants require a cooling system to convert the steam back to water and close the cycle.



cooling **systems**

The type of **cooling system** used will determine the amount of water required by the thermal power plant.

Water is also needed in smaller quantities for other processes, generating waste water streams that can have a negative impact on the environment.

main types of cooling systems	use	water withdrawal	water consumption	efficiency	cost	environmental impact
once through	water				$ small	bad
cooling towers	water				$$ medium	moderate
dry cooling	air	0	0		$$$ high	none

Note on water withdrawal and consumption: this is an approximate representation to show the difference in magnitude for types of cooling systems. The exact amount of water will vary depending on the efficiency of the power plant, but the ratios will remain constant.This table shows an approximate calculation for a power plant with an efficiency of ~35%, and each drop ≈ 1000 liters/MWh

Knowledge dissemination, advocacy and capacity building

- From January 17-31 (during and after launch), the online package received
  - over 23,000 pageviews (an average of over 1,500 pageviews/day)
  - more than 500 publication downloads.

IEA @IEA · Feb 11
Infographic: **Thirsty Energy** -- **Energy** and Water's Interdependence buff.ly/1edpPAw #**energy** #climate
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World Bank's Announcement of 'Thirsty Energy' Initiative Signals Growing Importance of Energy-Water Nexus

Kate Zerrenner, Contributor

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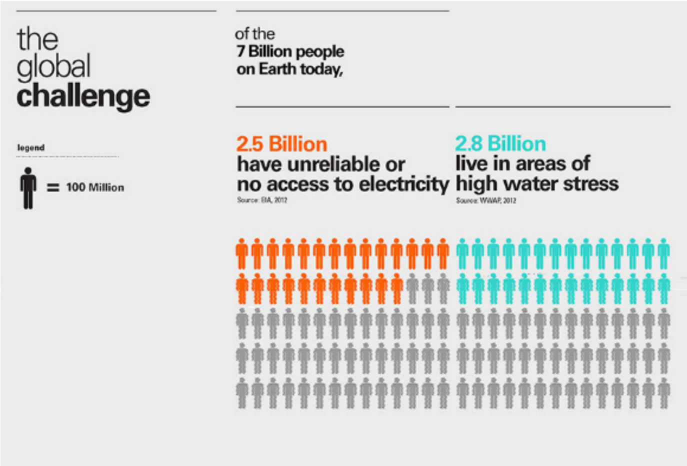
Energy and water, two of our most important global resources, are inextricably linked. And yet when it comes to planning, the regulatory agencies in charge of managing these precious resources are often separate and uncoordinated in their decision-making. With the World Bank's recent unveiling of its Thirsty Energy initiative, it seems that the energy-water nexu is finally being taken seriously- and on a global scale.

This new initiative aims to address the interconnection between energy and water head-on by providing countries with "assessment tools and management frameworks" to help governments "coordinate decision-making when planning for future energy and water infrastructure. Fortunately, this kind of guidance couldn't come soon enough. Here's a cool infographic from the Thirsty Energy website to illustrate where we are and where we're headed



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Terry Slavin

Thursday 6 February 2014 12.01 EST

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By Kate Zerrenner
Published February 06, 2014
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Energy and water, two resources, are inextrica comes to planning, the charge of managing th often separate and unc making. With the Worl its Thirsty Energy initia energy-water nexus fin and on a global scale.

This new initiative aims interconnection betwee by providing countries management framewo "coordinate decision-making" when planning for future energy and water infrastruct guidance couldn't come soon enough. Here's a cool infographic from the Thirsty E where we are and where we're headed.

To further complicate things, climate change is expected to make the management resources exceptionally challenging "by causing more water variability and intensifi severe floods and droughts," says the website.

Another key point from this initiative is that while a global water crisis is looming, m facing challenges to their electricity supplies.

Several areas in the United States that are not considered water-stressed already have been experiencing rolling

World Bank's Thirsty Energy Initiative Signifies Growing Importance of Energy-Water Nexus

Richard Meryn | Feb 12, 2014 | Comments 0

Two of our highly important global resources, Energy and water are intricately linked. However, when it comes to organising, the regulatory agencies, who manage these valuable resources, are often disunited and uncoordinated in their decision-making. With the World Bank recently launching its Thirsty Energy initiative, it appears that the energy-water nexus is finally being given a serious thought and also taken on a global scale.

thirsty energy

World Bank's Thirsty Energy Initiative

World Bank's latest initiative intends to address the interconnection between energy and water head-on by offering countries with assessment tools and management frameworks to assist governments coordinate decision-making while planning for future energy and water infrastructure.

According to the Thirsty Energy website climate variation is expected to make the management of water and energy resources anomaly challenging by causing more water variability and extreme weather conditions, such as severe floods and droughts. Adding to it, the global water crisis is emerging and many countries are already facing challenges to their power supplies.