Water and Energy: Beyond the Nexus

QUANTIFYING THE TRADEOFFS OF THE WATER-ENERGY NEXUS

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World Water Week 2013, Stockholm

THE WORLD BANK

Why is this issue important?

90% of global POWER GENERATION is WATER-INTENSE

by 2035 GLOBAL ENERGY consumption will INCREASE 50%

... increasing WATER CONSUMPTION by 85%

But still...

2.8 billion PEOPLE live in areas of HIGH WATER SCARCITY

and 2.5 billion PEOPLE have UNRELIABLE or NO access to ELECTRICITY

CLIMATE CHANGE will impact both the ENERGY and WATER sectors

Sources: IEA, 2012 and UN, 2012

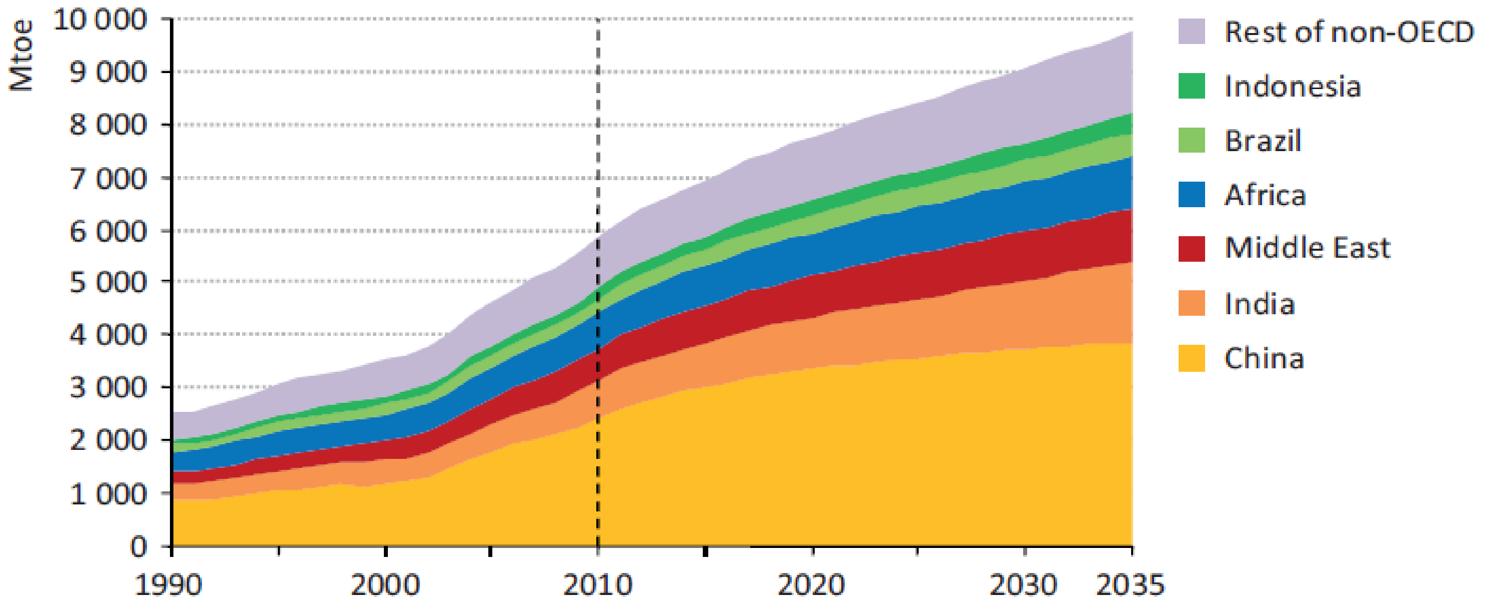
Outline

- Water Risks for the Energy Sector
- Water Needs of the Energy Sector
- Quantifying the Tradeoffs of the Water and Energy Nexus – a World Bank Initiative
- South Africa as a First Case Study

Water Risks of the Energy Sector

Rapid growth in energy demand in developing countries will drive a doubling of water demand for energy by 2035

Non-OECD primary energy demand by region in the New Policies Scenario *



- Africa's electricity generation will be **7 times** as high as nowadays by 2050
- Asia's primary energy production will almost **double**, and electricity generation will more than triple by 2050
- In Latin America, the amount of electricity generated is expected to increase fivefold in the next 40 years and the amount of water needed will triple

SOURCES: * WORLD ENERGY OUTLOOK. EIA, 2012

The energy-water nexus is already present and very real problem

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

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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

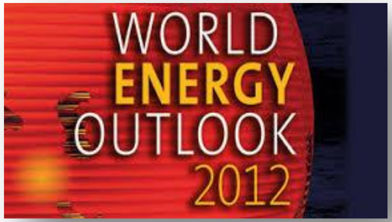
China, India Lack Water for Coal Plant Plans, GE Director Says

Impacts in the Energy Sector in the US

The US Department of Energy recently issued a report looking at water impacts on their energy sector

SOURCE: U.S. DEPARTMENT OF ENERGY

The Energy sector is starting to recognize the magnitude of the issue



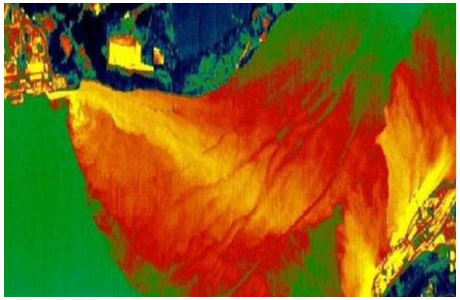
The **first time** that the IEA World Energy Outlook report has included a special section on the water needs and the possible future water constraints of the energy sector.

* Word cloud (count) infographic of the IEA report

Energy Sector is vulnerable to Water Issues

MAIN WATER RISKS*

INCREASED WATER TEMPERATURE FOR COOLING – for thermal power plants



DECREASE IN WATER AVAILABILITY – for hydro, thermal power plants, fuel extraction and processing

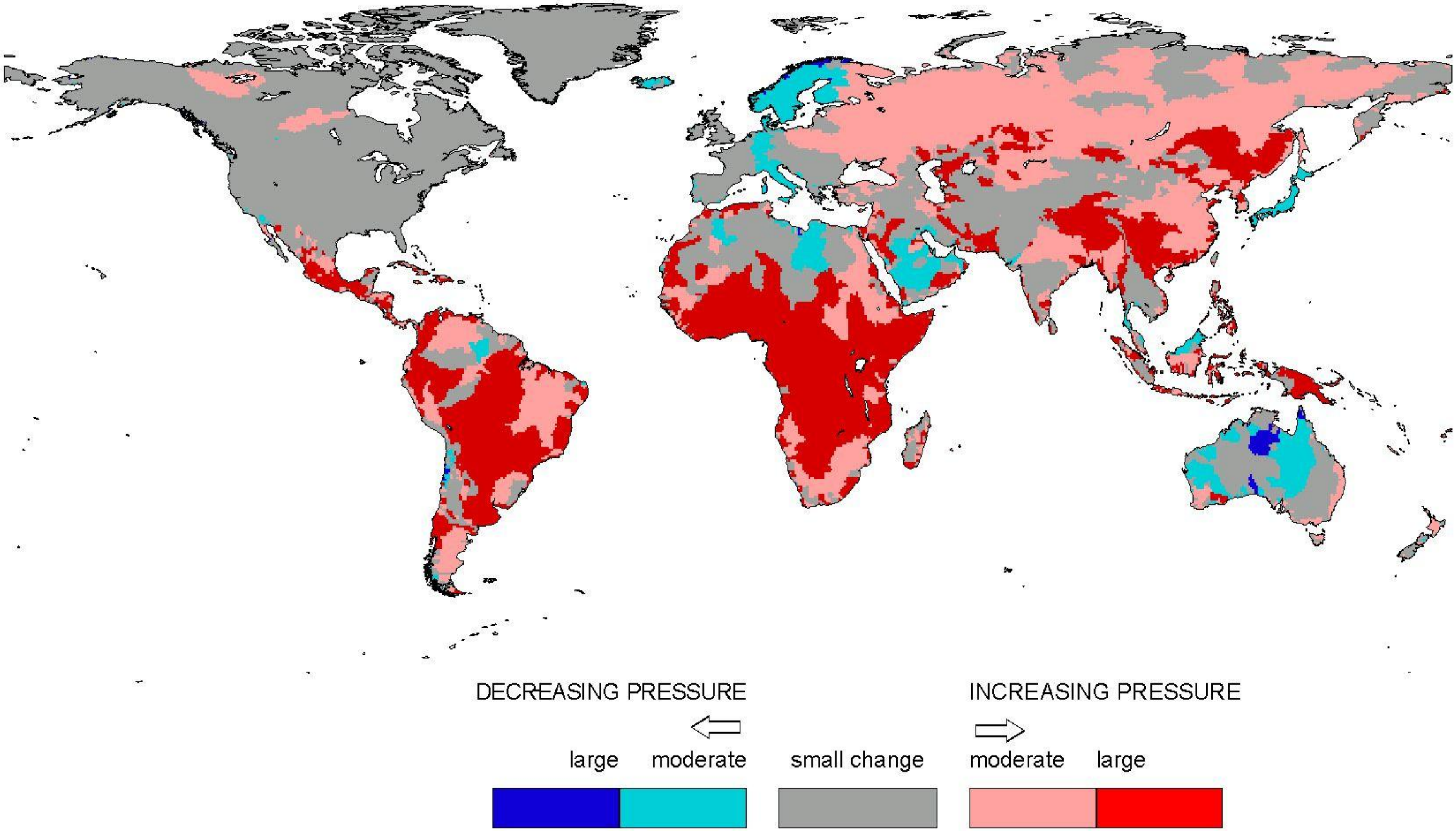
WORLDWATCH.ORG

WASHINGTON POST

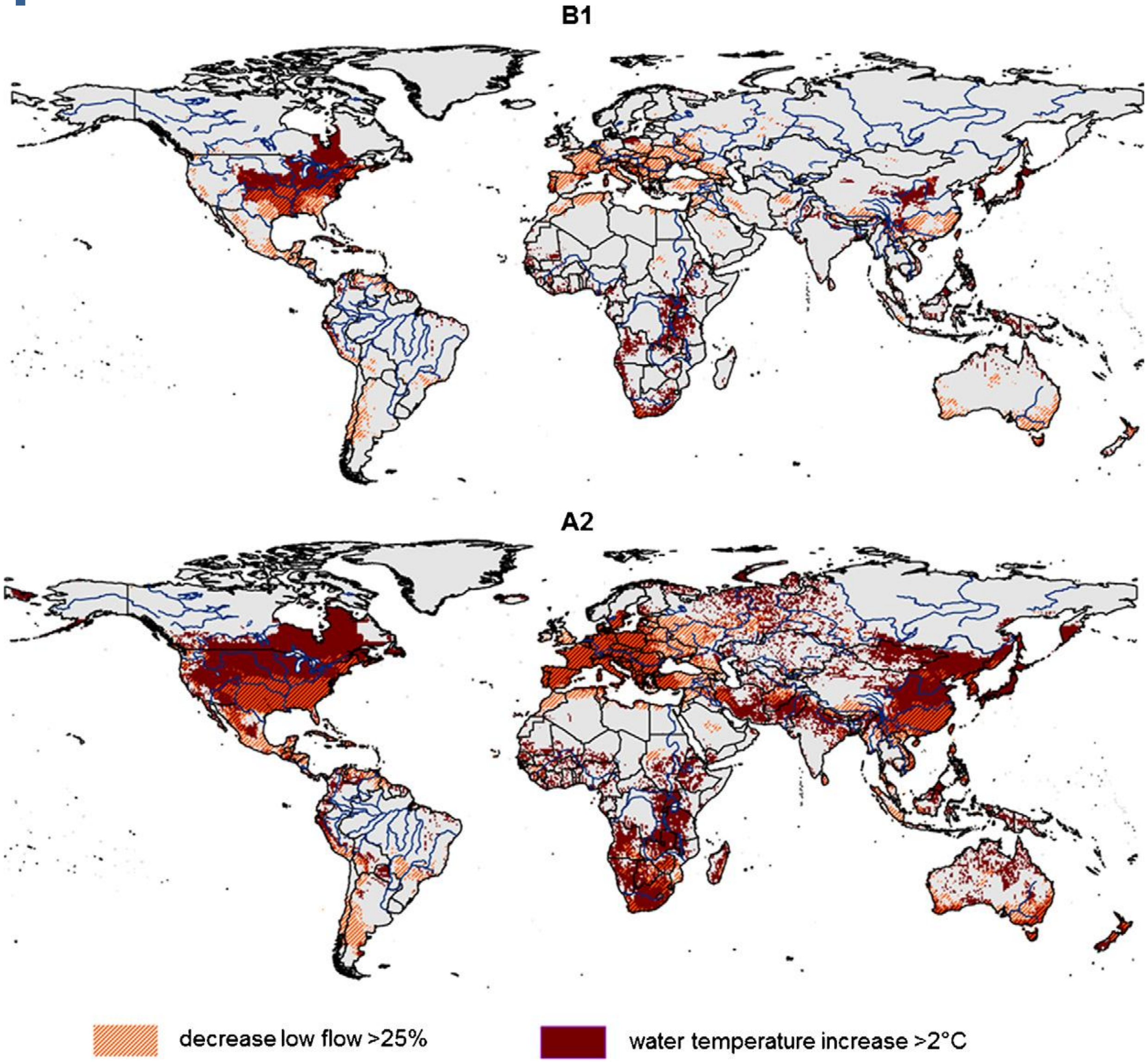
* Besides floods and other extreme events

Pressure on water resources is growing:

Key drivers include more people, growing economies, and climate change

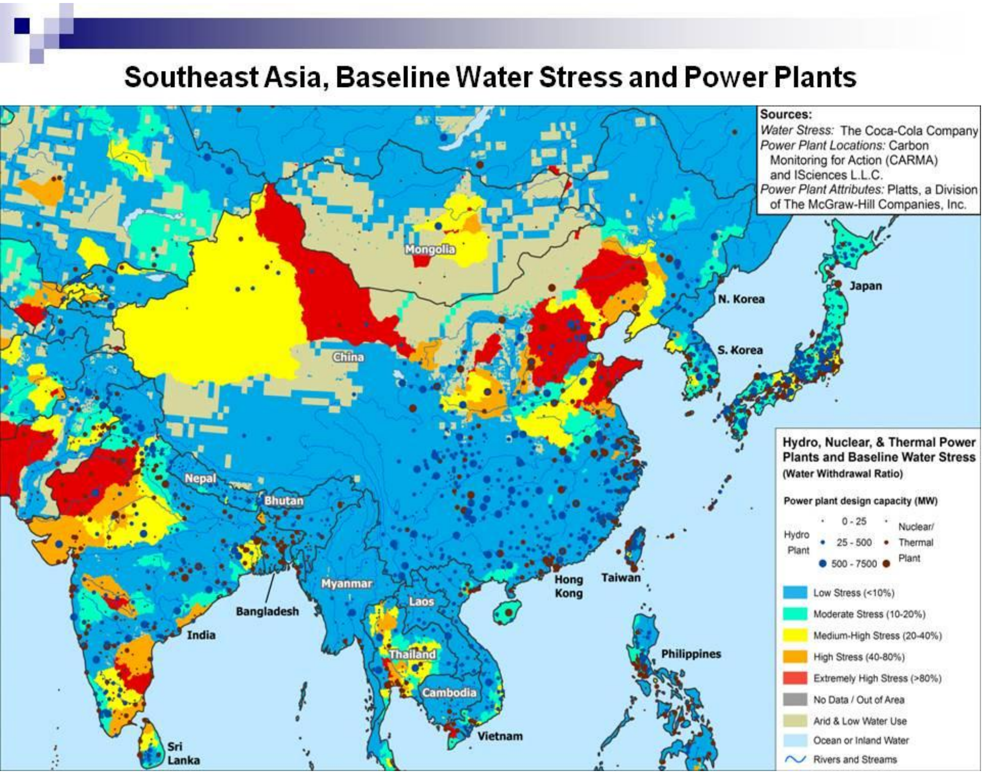


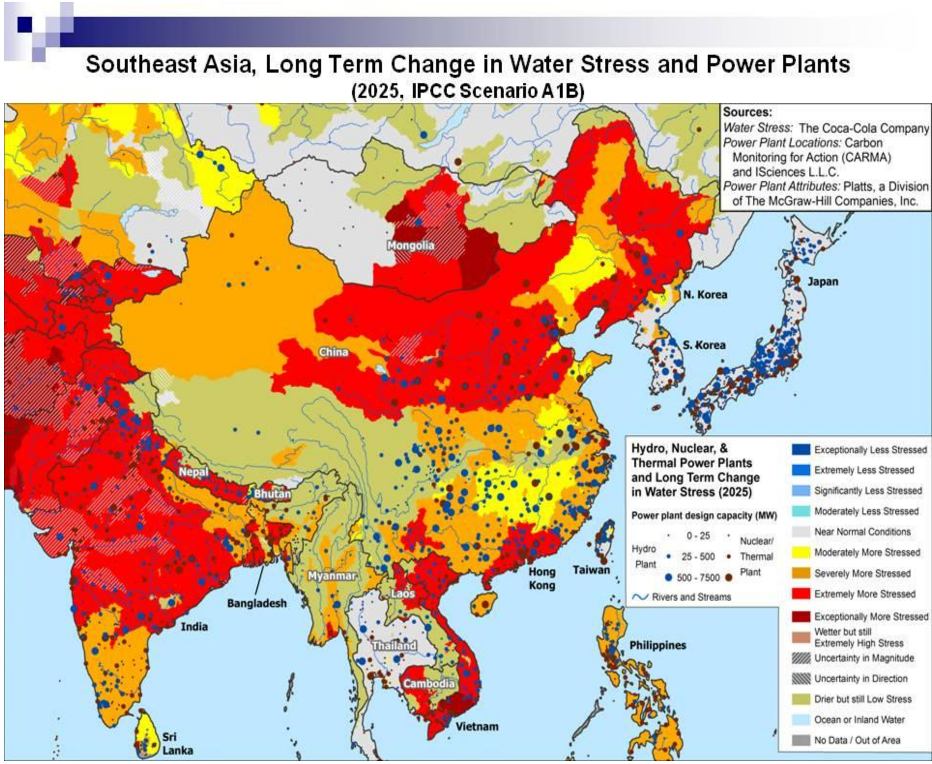
Hot Spots – where "low flows" and "water temperature increase" meet



Source: Vulnerability of US and European electricity supply to climate change. Michelle T. H. van Vliet1, John R. Yearsley2, Fulco Ludwig1, Stefan Vögele3, Dennis P. Lettenmaier2 and Pavel Kabat

So the challenge is how do we plan and how do we design our investments

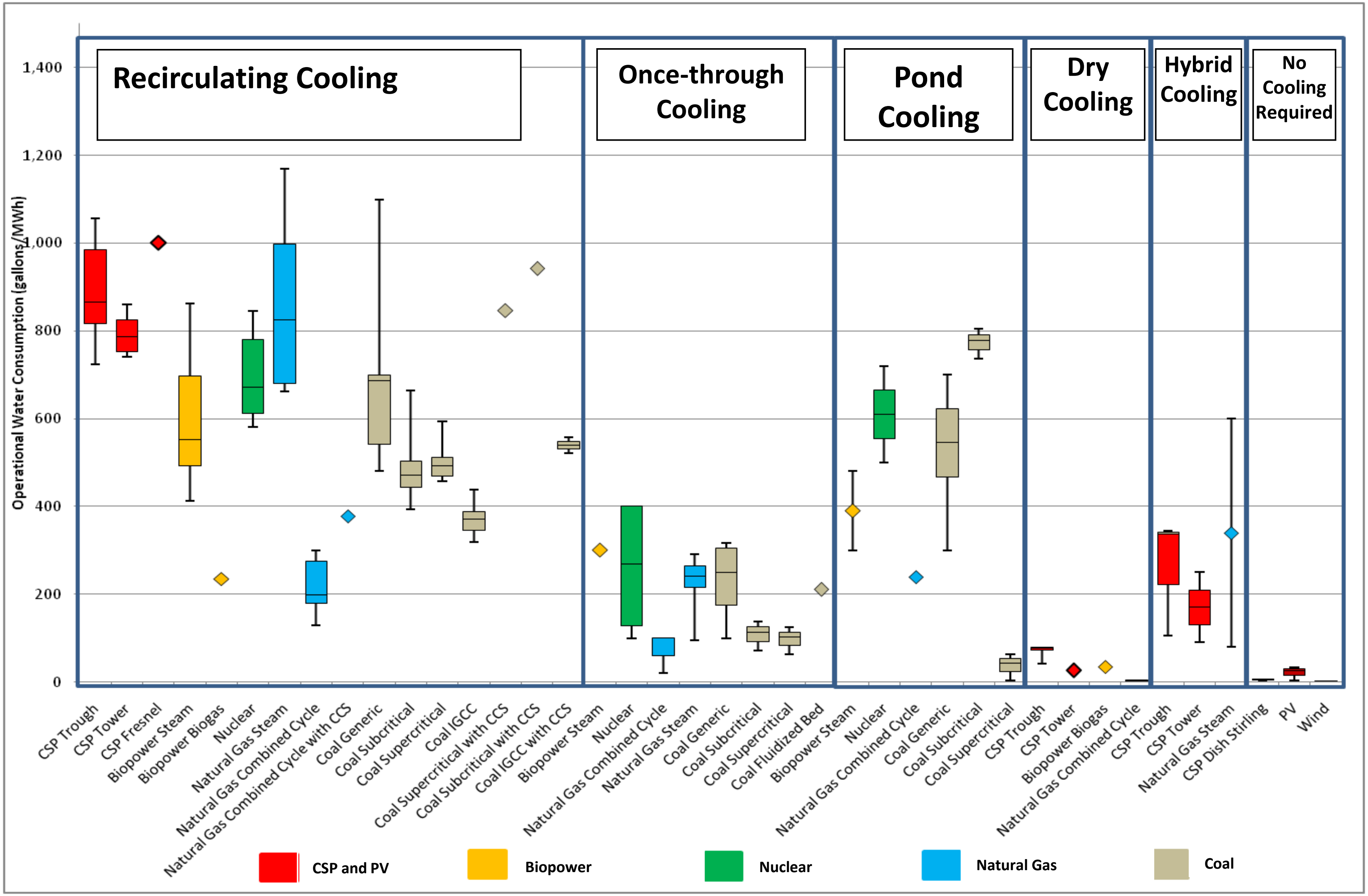




The baselines water stress is defined as the ratio of total annual freshwater withdrawals for the year 2000, relative to expected annual renewable freshwater supply based on 1950–1990 climatic norms.

SOURCE: WORLD RESOURCES INSTITUTE

But we must acknowledge the complexities of the energy sector



SOURCE: National Renewable Energy Laboratory, US, NREL Technical Report, NREL/TP-6A20-50900

WATER NEEDS OF THE ENERGY SECTOR

Almost all forms of electricity generation require water

HYDROPOWER

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

THERMAL POWER PLANTS

Geothermal

Pulverized Coal

CSP (Tower)

Water is required mainly for cooling purposes

NGCC

Nuclear

CSP (Parabolic Trough)

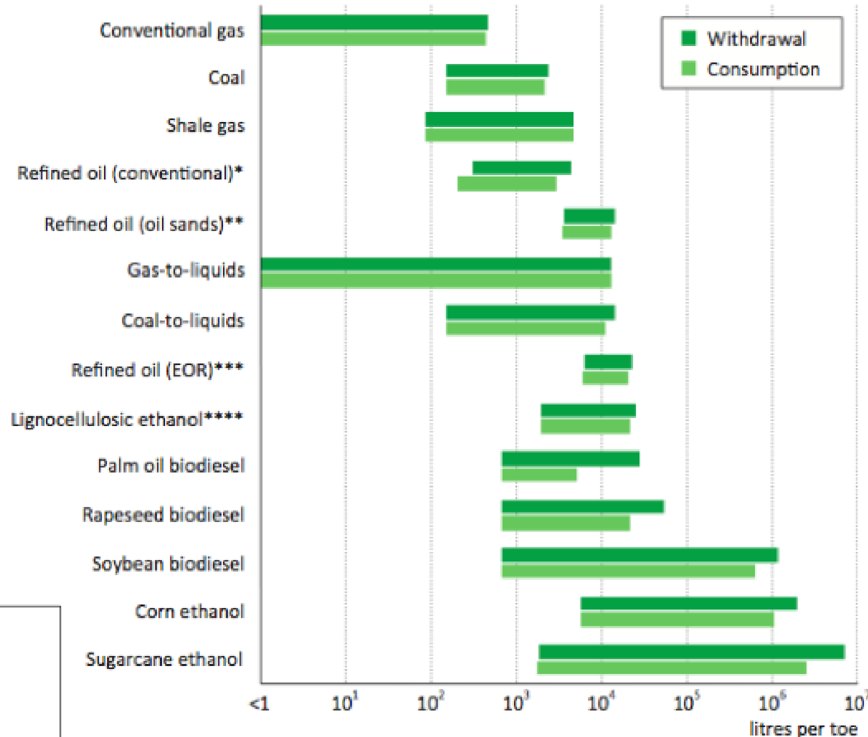
Thermoelectric power plants account for **40%** of the freshwater withdrawn every year in the US and for **43%** in Europe*.

* Source: Vulnerability of US and European electricity supply to climate change. Michelle T. H. van Vliet1, John R. Yearsley2, Fulco Ludwig1, Stefan Vögele3, Dennis P. Lettenmaier2 and Pavel Kabat

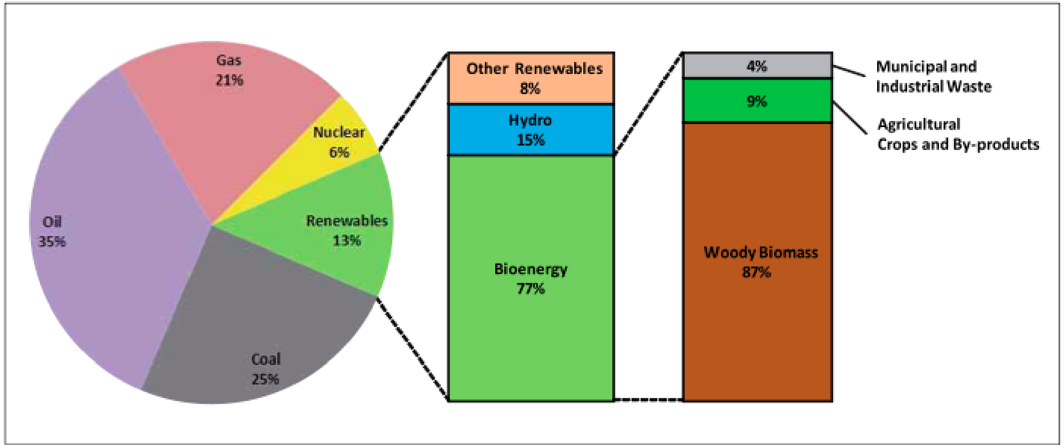
Water is also needed to extract and process fuels

- Water consumption for fuels such as oil, coal or gas can seem minor compared to other sectors, however, its development can be very water intensive locally and temporally.

- Biofuels is the single largest renewable energy source in use today, and will increase in the future, increasing also water consumption

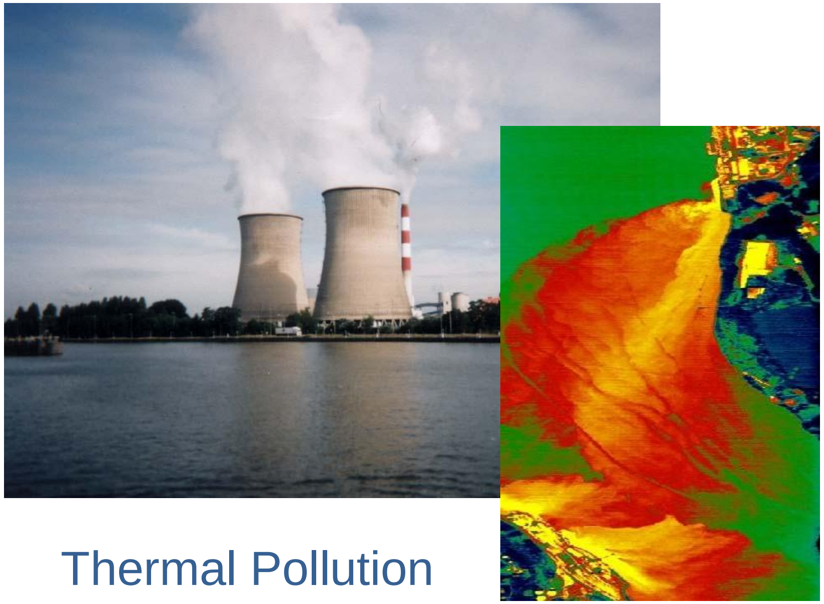


Source: IEA 2012

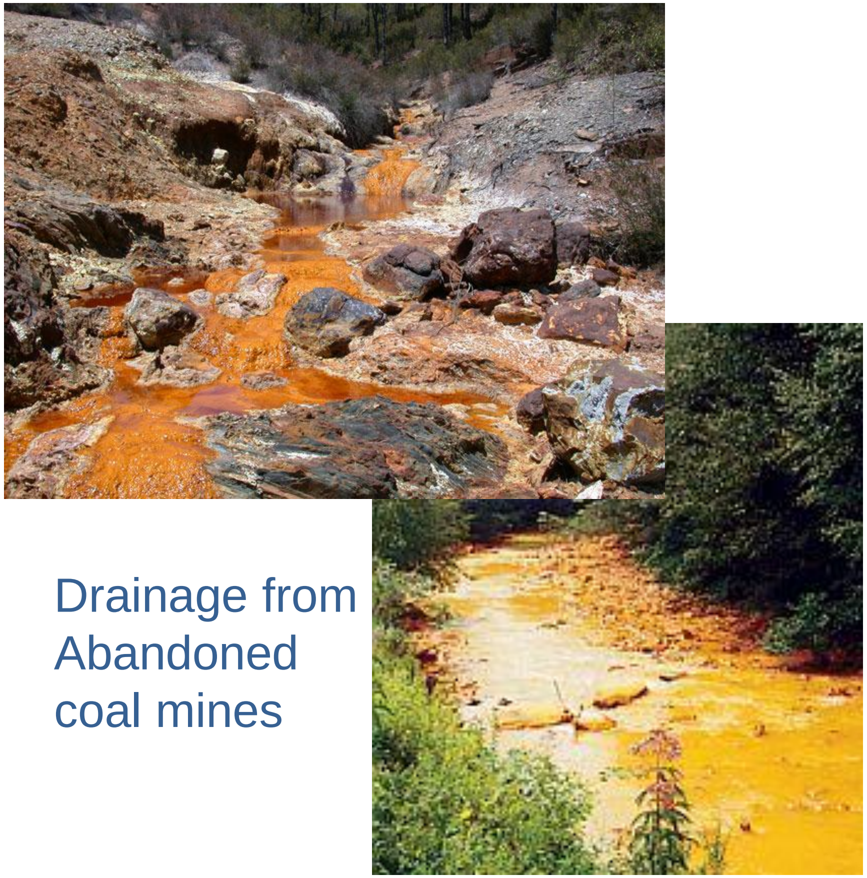


Share of Bioenergy in World Primary Energy Mix; IEA report, "Bioenergy– A sustainable and reliable energy source" (2009)

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



Thermal Pollution



Drainage from Abandoned coal mines

Fracking waste water

Quantifying the Tradeoffs of the Water-Energy Nexus
A World Bank Initiative

The World Bank Initiative

Objective: The main objective of the initiative is to contribute to a sustainable management and development of the water and energy sectors by incrasing 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**

Methodological Approach 1/2

- **Entry point is Energy Sector:** we acknowledge that it is very difficult to change energy planning from water organizations
- **Engagement** with relevant **stakeholders** from day 1, involving local partners from energy and water sectors work to identify and assess possible case studies based on their current energy and water sector situation and trends and constraints.
- **Flexible modeling framework** to facilitate tailored analyses over different geographical regions and challenges
- Build on **existing** country knowledge and modeling tools whenever possible to ensure continuity and sustainability of initiative and **lower costs** **Client ownership** and **capacity building** are crucial to ensure the success of the initiative.
- Robust treatment of **risk** and **uncertainty**
- Incorporate the long-term effects of climate change

Methodological Approach 2/2

- **Economic tools** to assess the tradeoffs between competing sectors and to provide policy recommendations to mitigate potential effects

- **Case studies** or pilots to illustrate different types of situations in that are most relevant for client countries
  - Water scarce country
  - Country with abundant water but with seasonal variability - tropical
  - Country with in-house capacity and good data
  - Country with lack of data (small-poor)

- Forming **stronger alliances** is also priority of this initiative. The challenge presented by the nexus is too large for any country, region, development finance institution or implementing agency to tackle alone.

- It will also **collaborate** with partners to leverage efforts of other countries, the international community, and partners in the nonprofit and private sectors for more success in moving the nexus agenda forward both at the global policy level and at the country level.

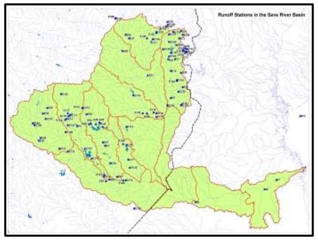
Methodological approach: Building on existing energy tools – start small

MARKAL / TIMES

- Application on regional or country level for long-term energy planning
- Improved integration of water dynamics and economy of water

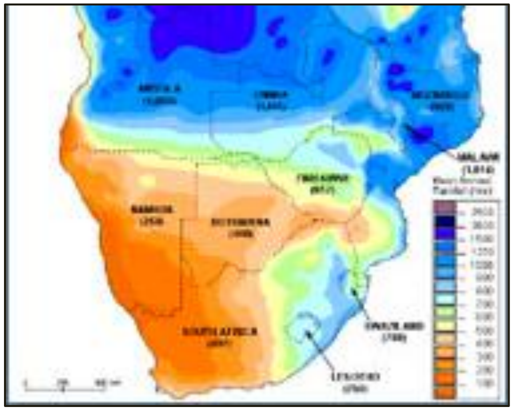
LEAP - WEAP

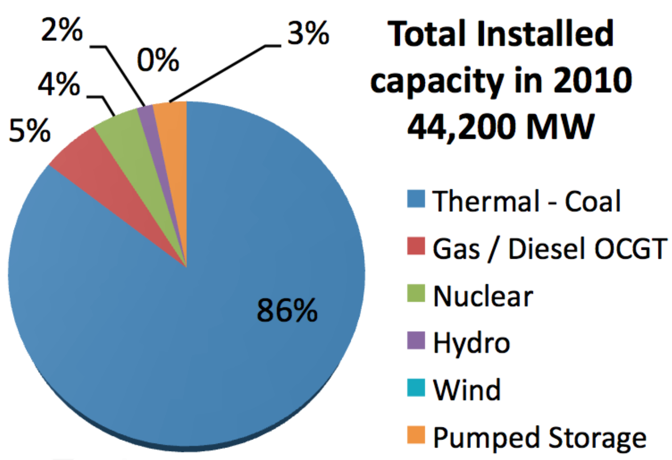
- Improved LEAP optimization
- Application of LEAP-WEAP on country or national river basin level for joint energy and water master planning
- Improved integration of economics for water



South Africa as a Case Study

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

Using what already exist and is currently used : Improvement of existing TIMES model

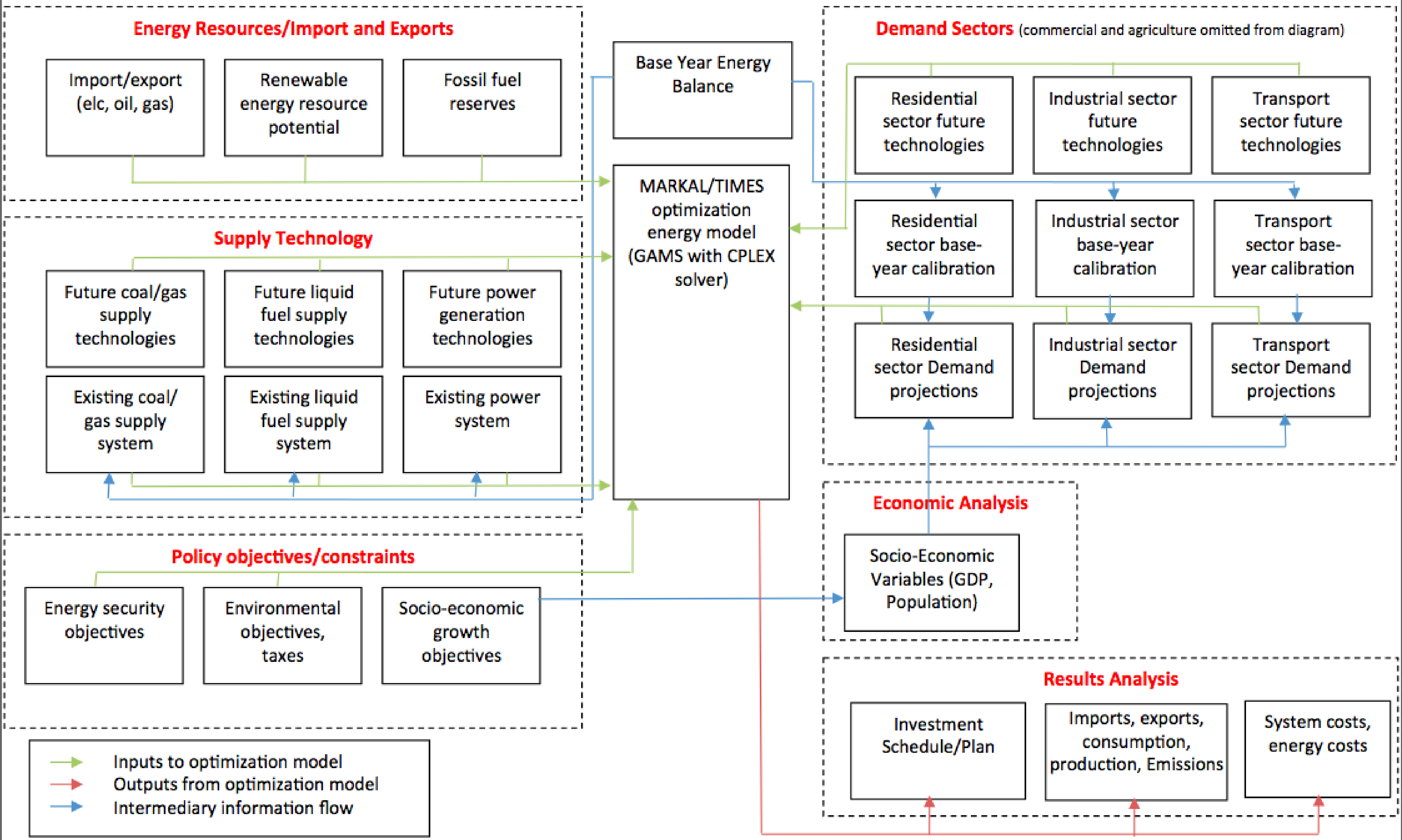
South Africa TIMES (SATIM) used by the Energy Research Center:

- Partial equilibrium linear optimization model capable of representing the whole energy system, including its economic costs and its emissions
- Five demand sectors – industry, agriculture, residential commercial and transport - and two supply sectors - electricity and liquid fuels
- The model is capable of solving for a variety of constraints

PHASE 1 of CASE STUDY:

1. Develop marginal water supply cost schedules
2. Develop the “water smart” SATIM
3. Energy-Water Model Simulations : run different scenarios to assess how energy sector development strategies change relative to the reference scenario depending if water is constraint, if water has a price, etc.

Overview of SATIM



SOURCE: ERC - UCT

Example: the Power Sector

SATIM PARAMETERISATION OF POWER PLANT TECHNOLOGIES

PARAMETERS
Energy input commodity or fuel
Water consumption[1]
Efficiency
Output commodity
Energy availability
Capacity availability
Capacity credit
Fixed operating and maintenance cost
Variable operating and maintenance cost
Refurbishment/retirement profile
"Season" & "Daynite" operating categories

ADDITIONAL PARAMETERS FOR CHP PLANTS
Industrial process heat
Operation in back pressure
Additional input fuel

ADDITIONAL PARAMETERS FOR NEW PLANT TECHNOLOGIES
Limits on capacity
Investment cost
Technology life
hnology lead-time
er bound on new capacity
er bound on capacity factor
nds on wind classes
intermittency
Capacity credit of wind
Diurnal production of solar with and without storage by timeslice

…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

Links to CGE model (E-SAGE)

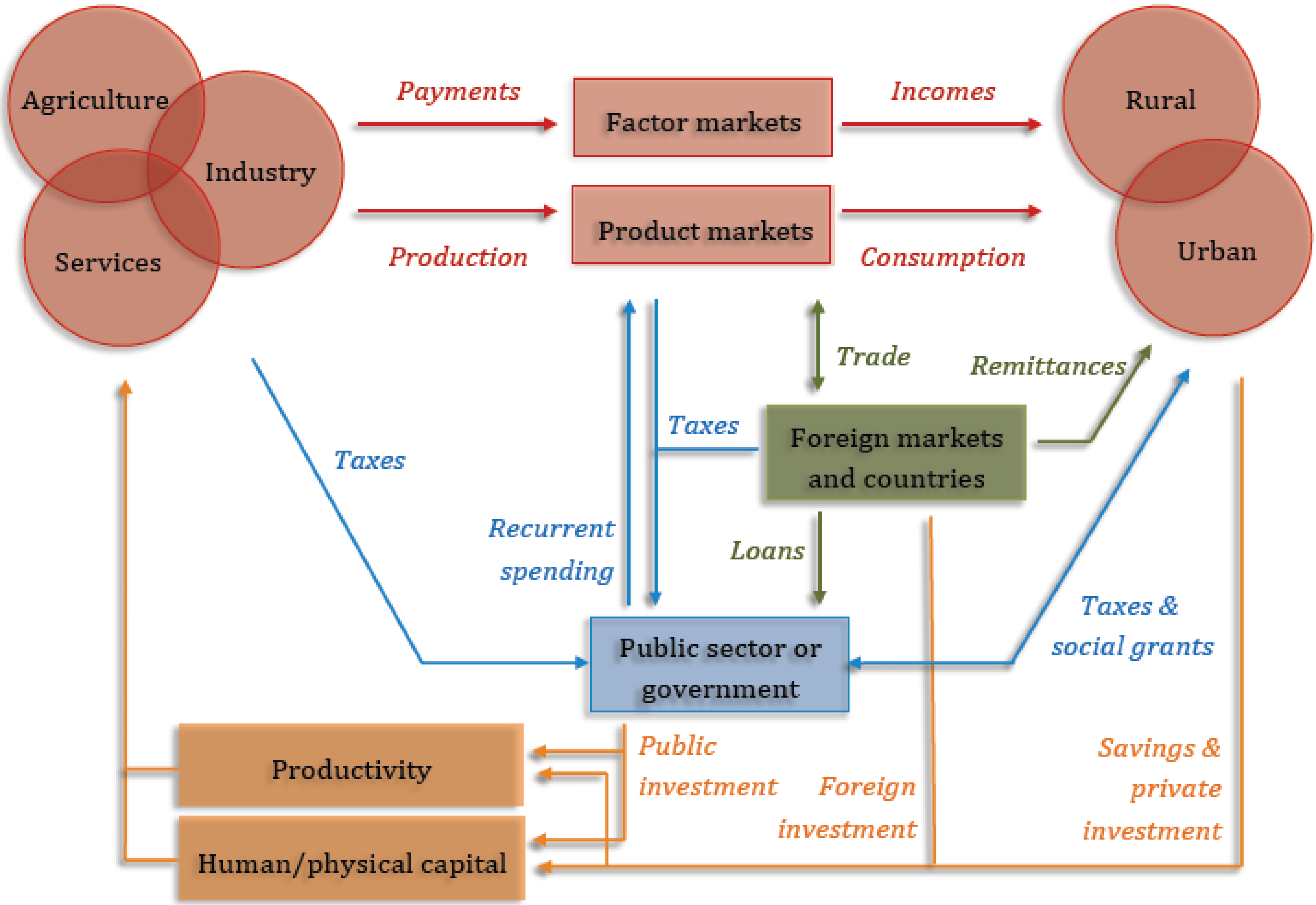
E-SAGE: Energy---extended South African General Equilibrium model

PHASE 2 of CASE STUDY:

- Run the CGE model to establish reference scenario demand projections for energy.
- Run SATIM with these given demand projections to produce a new Reference case, and then run a new EW-Nexus case that allows for reduced energy demands from economy-wide adjustments when energy prices rise to reflect water scarcity.
- Pass SATIM findings on increased energy production costs back into the CGE model in order to evaluate the economy-wide impact of accounting for water scarcity in energy sector development.
- Compare these reference and EW-Nexus scenarios.
- Compare the incremental water supply costs for energy expansion across the different water management areas in the model to other figures for water shadow prices by water management area. Using such comparisons, highlight where increased demands on water sources from energy sector expansion may particularly pose challenges to efficient water management across sectors and water management areas.

E-SAGE Model

Economywide framework



SOURCE: THURLOW, UNU--WIDER

First publication:

“Thirsty Energy”

is available at the World Bank Booth and online at: www.worldbank.org/water

It introduces the energy-water nexus, examines the water requirements of power generation and outlines some potential technical and institutional solutions for improving the management of the nexus.

THANK YOU

Questions?

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