International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

Introduction to the Energy-Water Nexus

An Energy Systems Perspective

Fricko, Oliver

Parkinson, Simon

Energy Program - IIASA

23 July, 2014

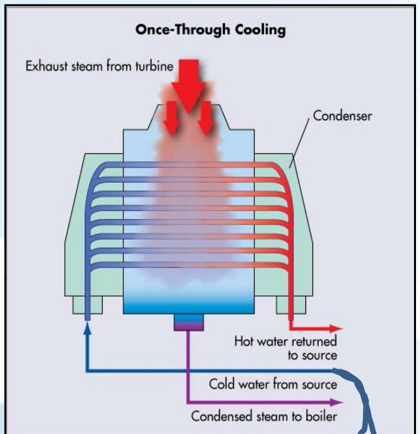
IIASA, Laxenburg

Water use in the energy system

- **Resource extraction**
- **Transformational processes**
- **Hydropower generation**
- **Bioenergy crop irrigation**
- **Power plant cooling**
  - *Currently requires more water than any other energy sector*

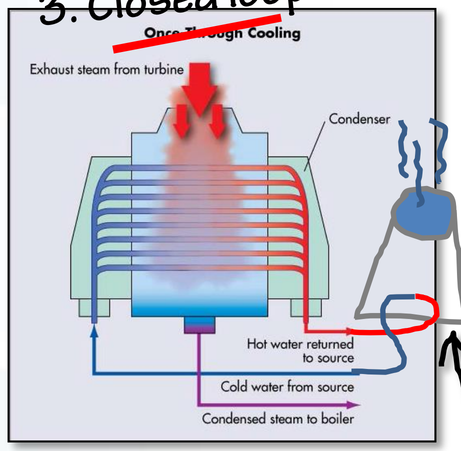
IIASA

Overview of cooling technologies

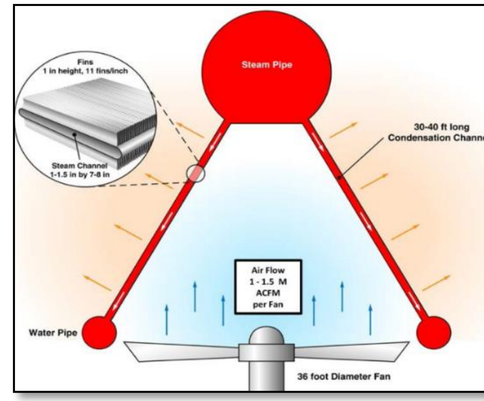


1. River 2. Sea Water

3. Closed loop



Cooling tower

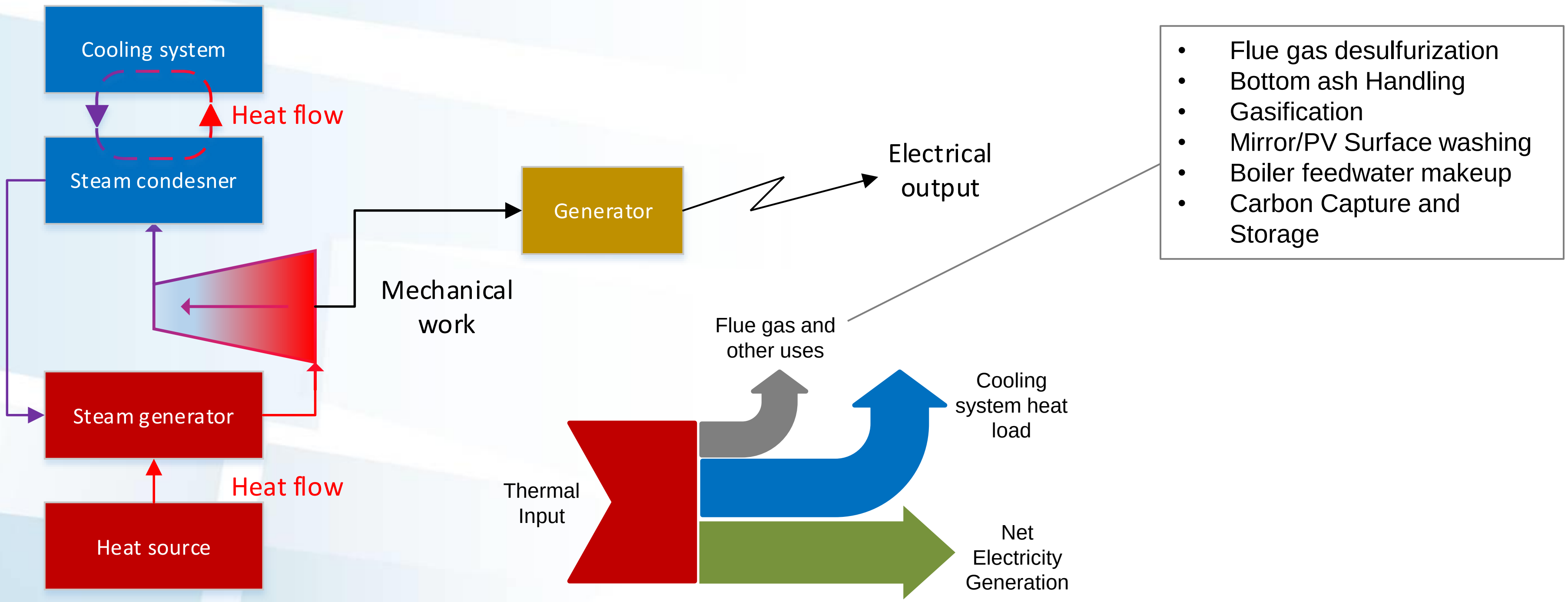


4 .Dry cooling using an air-cooled condenser

Illustrations adapted from EPRI 2013

Additional, more common cooling technologies, include ***hybrid cooling systems*** which combine natural draft towers with mechanical fans, or cooling technologies using ***ponds*** as alternative water sources.

Understanding cooling requirements



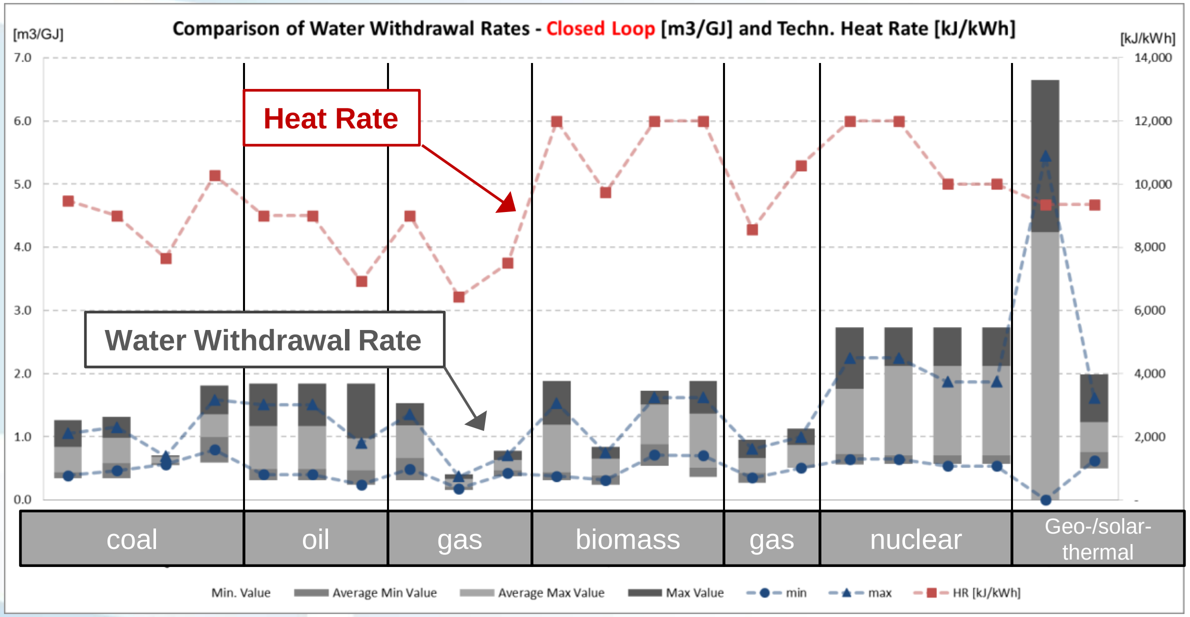
Any of the aforementioned cooling technologies could be applied in the above example. The decision as to which technology is implemented is based:

- technical feasibility
- geographical conditions
  - Water source & availability
  - Ambient air temperature
- operational parameters

	Water Withdrawal	Water Consumption	Investment Costs	Plant Efficiency	Ecological Impact
Once Through	high	med	low	low	high
Closed-Loop	med	high	med	low	med
Dry Cooling	low	low	high	high	low

Illustrations adapted from Rutberg, 2012

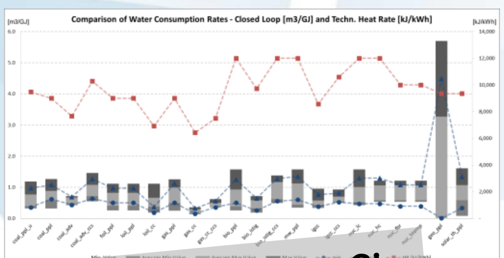
Overview of cooling technologies



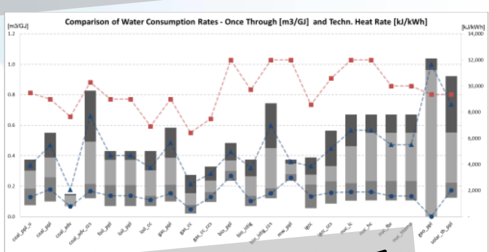
Even for **individual technologies** the spread between water withdrawal coefficients have a large spread.

The water withdrawal **rate between closed loop** and **once-through** systems can vary by factor 10-80.

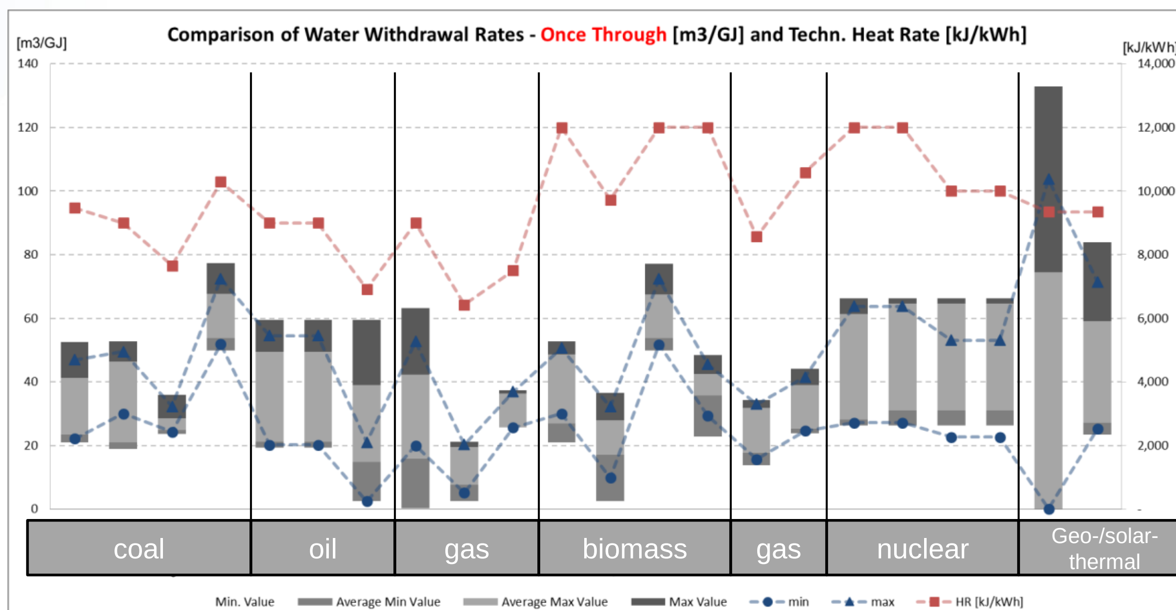
The choice of which factor is used in the model can therefore portray very different developments and need to be based on technological and regional characteristics, some of which are being developed on a finer granularity.



Consumption - CL



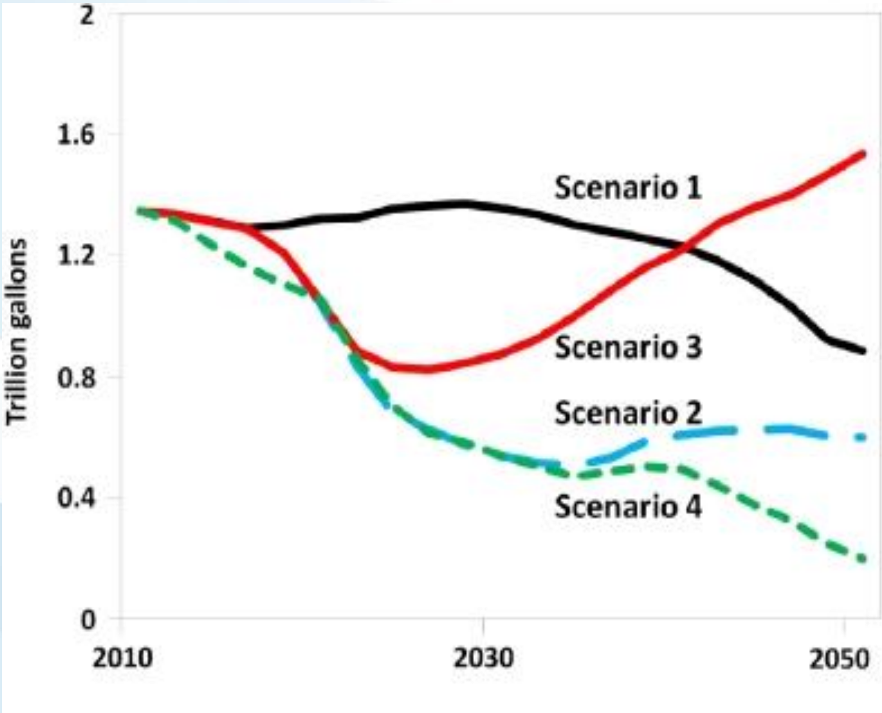
Consumption - OT



International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

Water-CO2 tradeoffs in Long-term Energy Scenarios



Scenario 1

Reference case

Scenario 2

Low-carbon, no technology targets

Scenario 3

Low-carbon, with coal CCS and nuclear

Scenario 4

Low-carbon, with efficiency and renewables

Figure: United States water consumption results for four electricity scenarios. [Source: Macknick et al, 2013]

Low-carbon does not always mean water-efficient

Water constraints are typically neglected during the energy planning process

Planning for the future

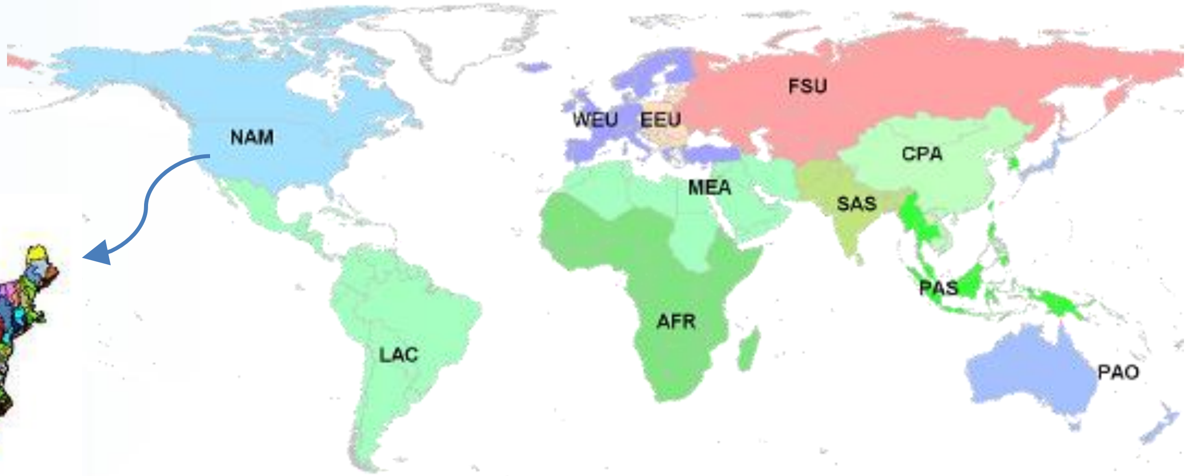
Global energy-water nexus analysis with IIASA's integrated assessment model

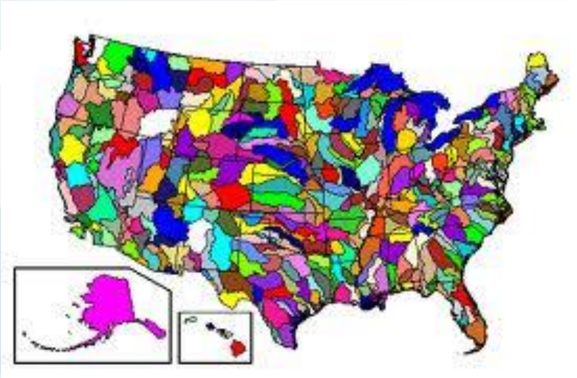
- Understand tradeoffs between energy technologies
  - Incorporate water use by technology options
  - Optimize technology configurations
- Where do critical water constraints occur and how might they be overcome?
  - Hydrologic modeling
    - *Water availability and temperature*
    - *Climate change impacts*

IIASA

Challenges: Spatial requirements

MESSAGE Model – 11 World Regions





United States – 221 Hydrologic Regions

How much water is available in a particular location?

Where exactly are the technologies located?

Challenges: Uncertainty

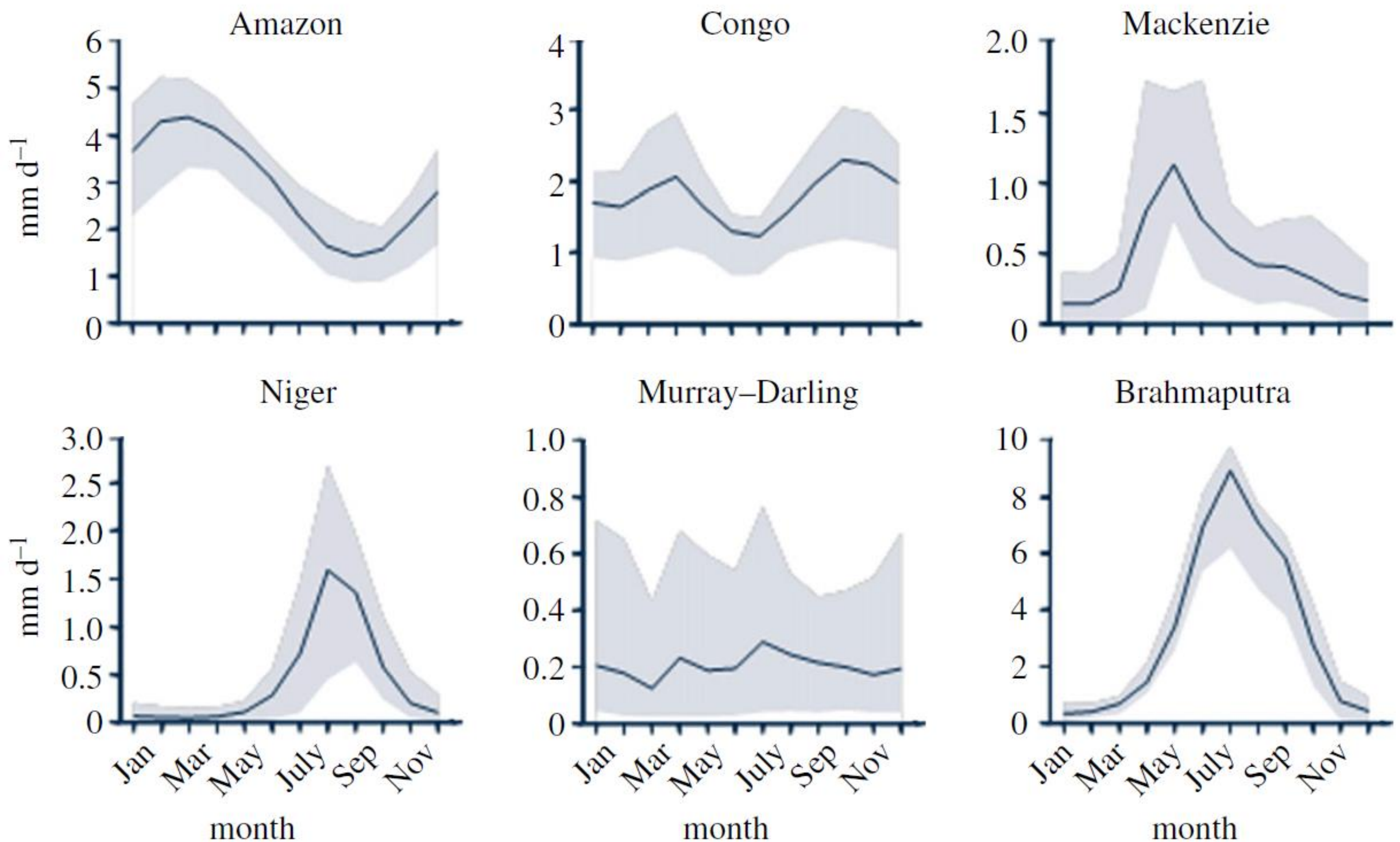


Figure: Multi-model total run-off for six major river basins for the period 1985-1999. Ensemble mean (solid line) and range (shaded area). [source: Dadson et al, 2013]

Challenges: Resource Competition

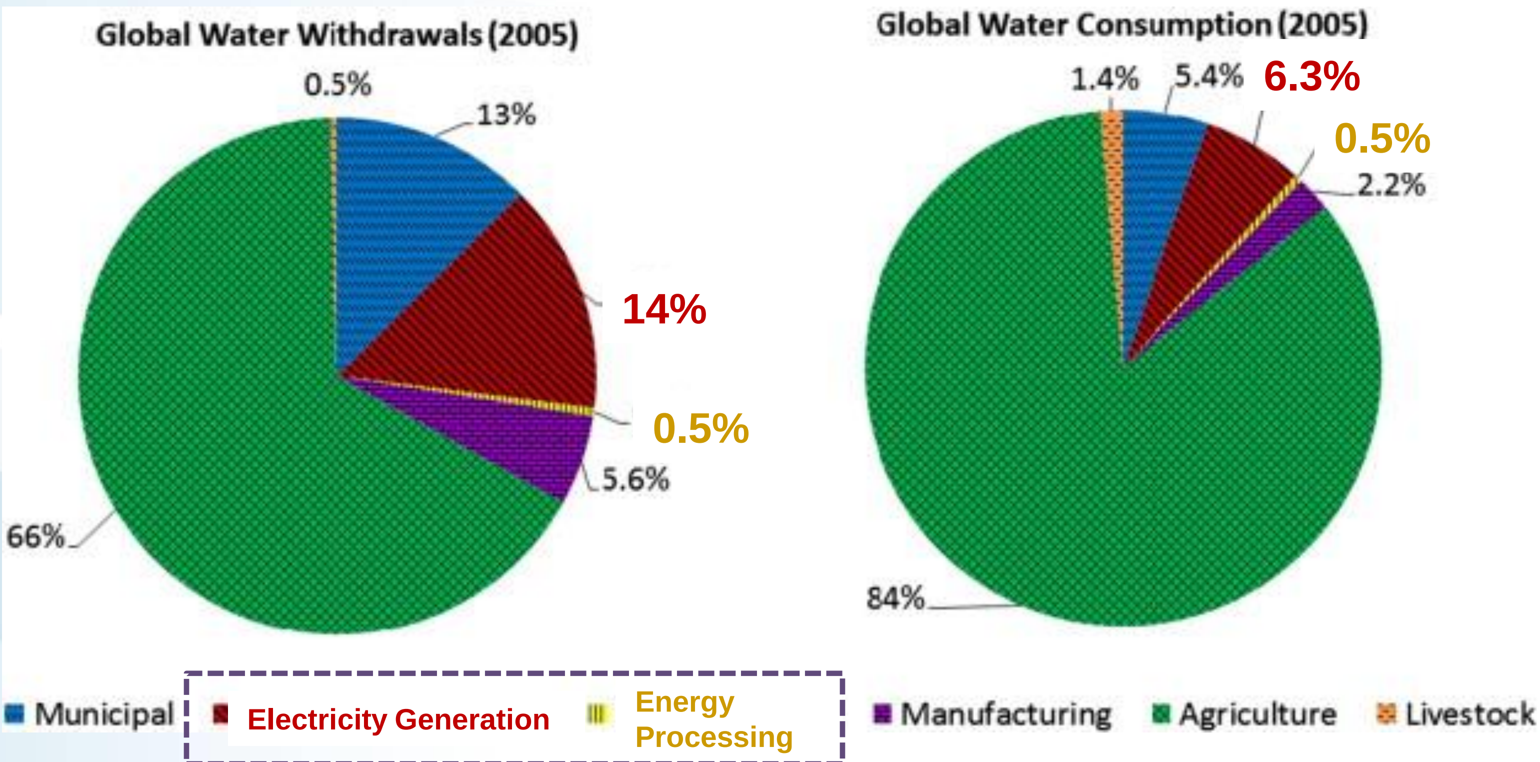


Figure: Distribution of global water consumption and withdrawals by sector in year 2005.
[Source: Hejazi et al, 2014]

How to partition supply between rivers, groundwater and synthetic (desalination) sources?

Opportunities

- **Increased access to hydro-climatic data**
  - Enables parameterization of uncertainties
  - Help to identify resilient technology configurations
- **IIASA's integrated assessment model provides unique capabilities**
  - Energy and land-use pathways
  - Harmonized socioeconomic and climate scenarios

IIASA

Conclusions

- Many energy technologies require access to water
- Tradeoffs exist between efficiency, water use, and cost
- Modeling the energy-water nexus is a challenge
- Significant future research opportunities exist in this field