The Water-Energy-Food Nexus

Global conflicts and possible solutions

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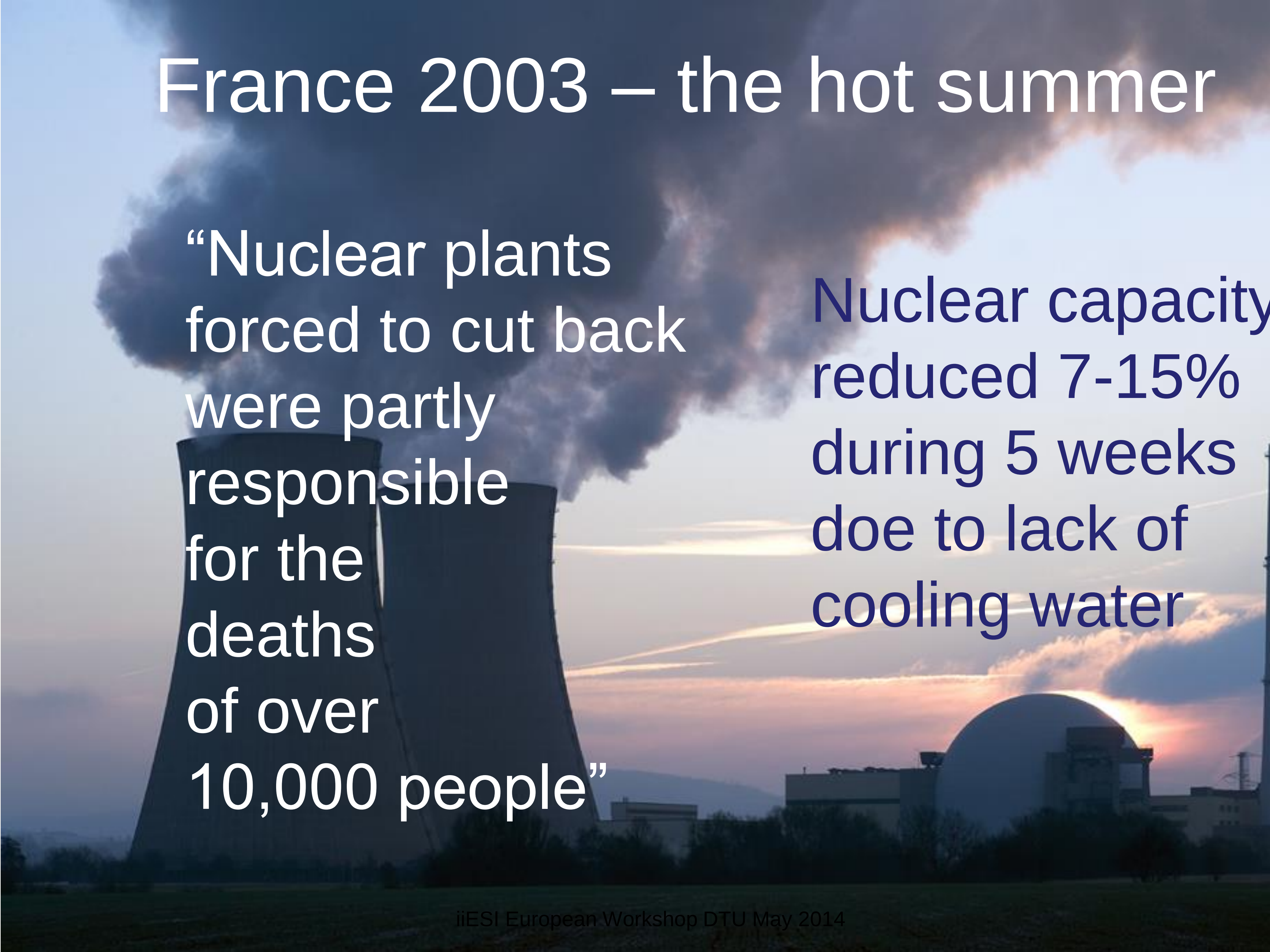
Content

- ***Setting the scene*** **–**
  the water- energy-food nexus
- ***Energy*** **for water supply and treatment**
- ***Water*** **for energy**
  - Fossil fuel extraction
  - Electrical power generation

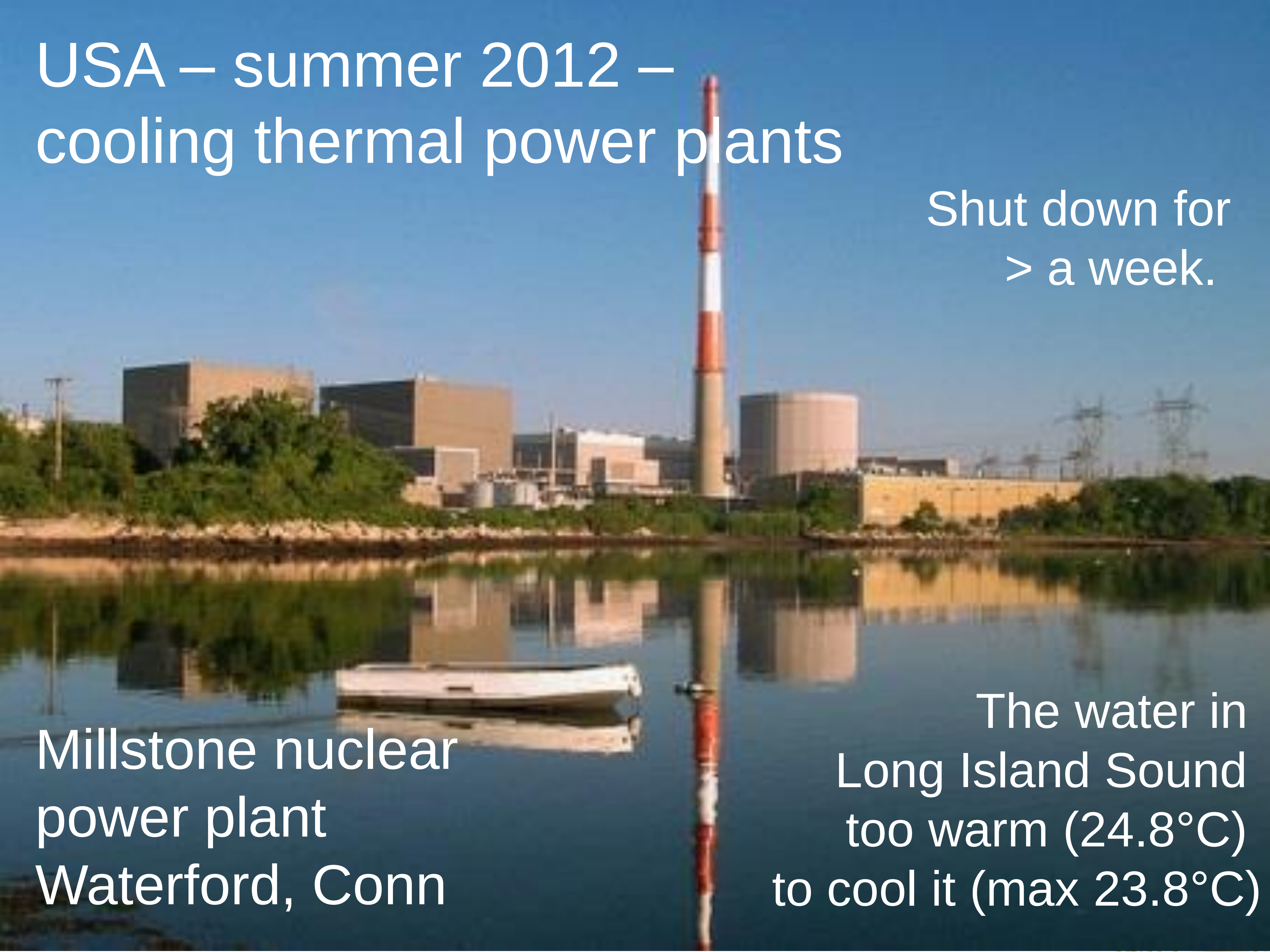

The global
energy challenge
depends on water!



France 2003 – the hot summer

“Nuclear plants forced to cut back were partly responsible for the deaths of over 10,000 people”

Nuclear capacity reduced 7-15% during 5 weeks doe to lack of cooling water


USA – summer 2012 –
cooling thermal power plants
Shut down for
> a week.
Millstone nuclear
power plant
Waterford, Conn
The water in
Long Island Sound
too warm (24.8°C)
to cool it (max 23.8°C)

Summer 2012 in USA –
worst drought since the 1950s -
80% of agricultural land was affected.

Price of corn soared

Corn for ethanol or for food?

USA - corn for ethanol production:
2000: 7% of supply
2014: 40% of supply

Food versus Feed and Fuel

Of the world food-crop calories:

- **55% to directly nourish people**
- **36% goes to feed cattle**
- **9% goes to fuel (biofuel and industrial products)**

We get another 4% indirectly by eating meat, dairy or eggs

Thermal power generation vs. water scarcity - China, 2010 and 2030

A 3-fold increase in water-intensive thermal power generation until 2030

Northern China
- 60% of China’s thermal power capacity
- 20% of China’s renewable freshwater supply

China’s ‘Big Five’ power utilities (500 GW) are all located in water scarce regions

Source: *Bloomberg New Energy Finance, National Bureau of Statistics of China.*

Planned dams in the Himalayas

Tibetan plateau, the source of the single largest collection of international rivers in the world.

- Indus – Ganges – Brahmaputra (Zangbo) - Irrawati – Salween
- Megong (Lancang) – Yangtse – Huang He (Yellow river)
- The headwater of rivers on which nearly half the world depends
- Half of India's water comes directly from China

Planned dams in the Himalayas

- China
  - The Tibetan plateau - the source of water for nearly 40% of the world's population
  - 100 dams in Tibet
- India, Nepal, Bhutan, Pakistan:
  - >400 dams -- 160,000 MW
- Megong (Lancang) river:
  - 60 dams from Tibet to SE Asia
- 1 dam for every 32 km of river channel

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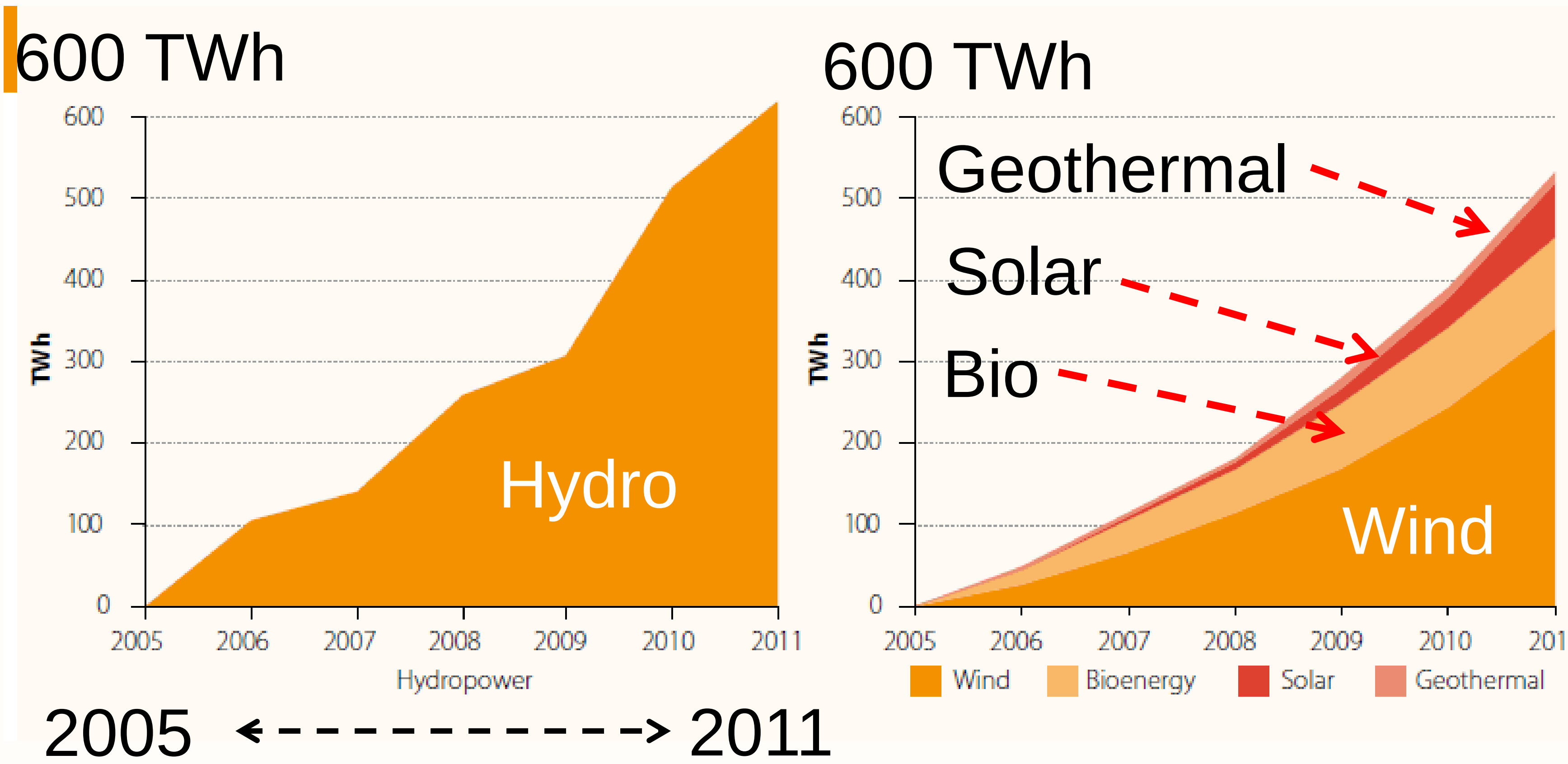
Electricity generation - recent additions to hydropower and other renewables



Source: IEA (2012)

Industrial Electrical Engineering and Automation

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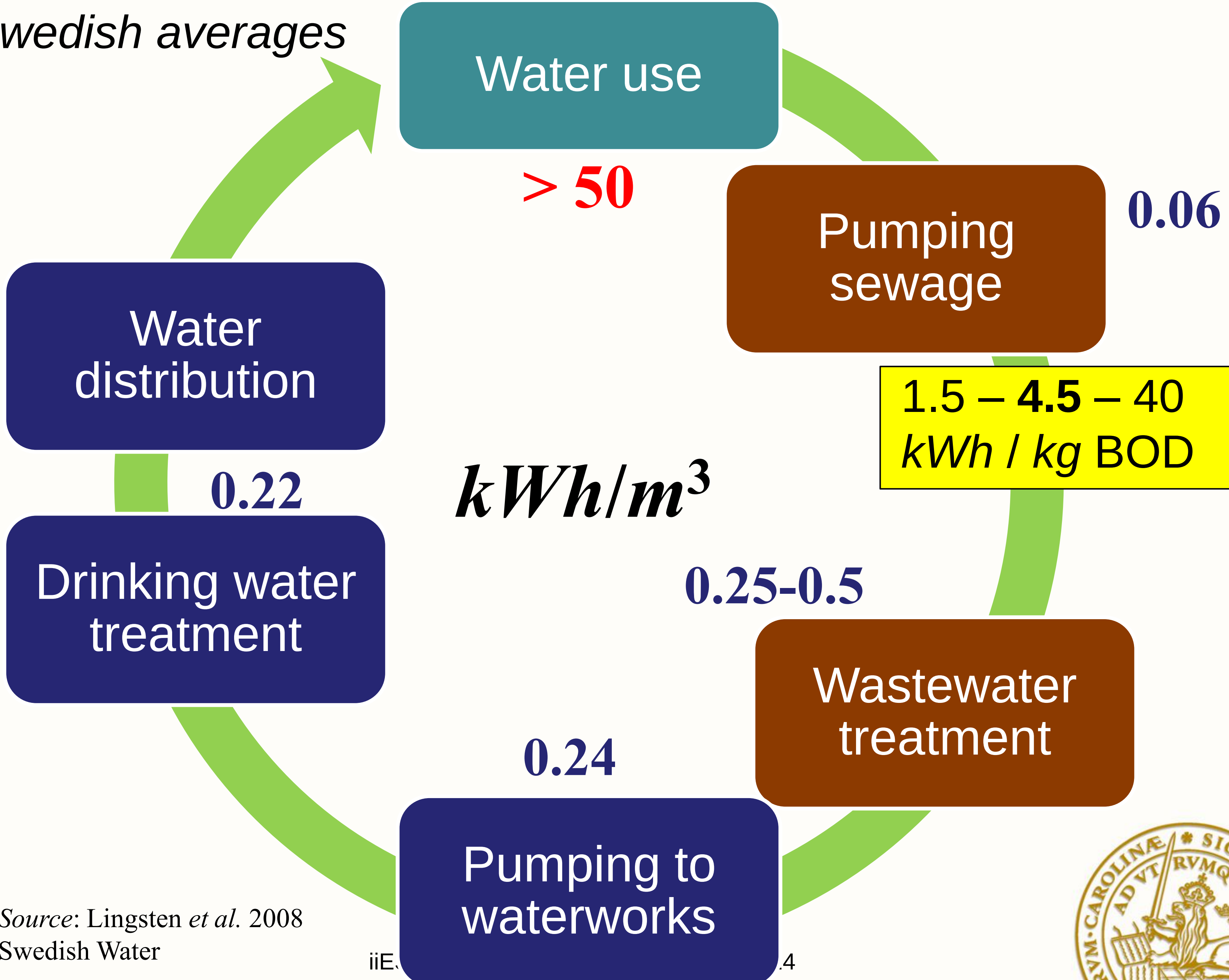
Swedish averages

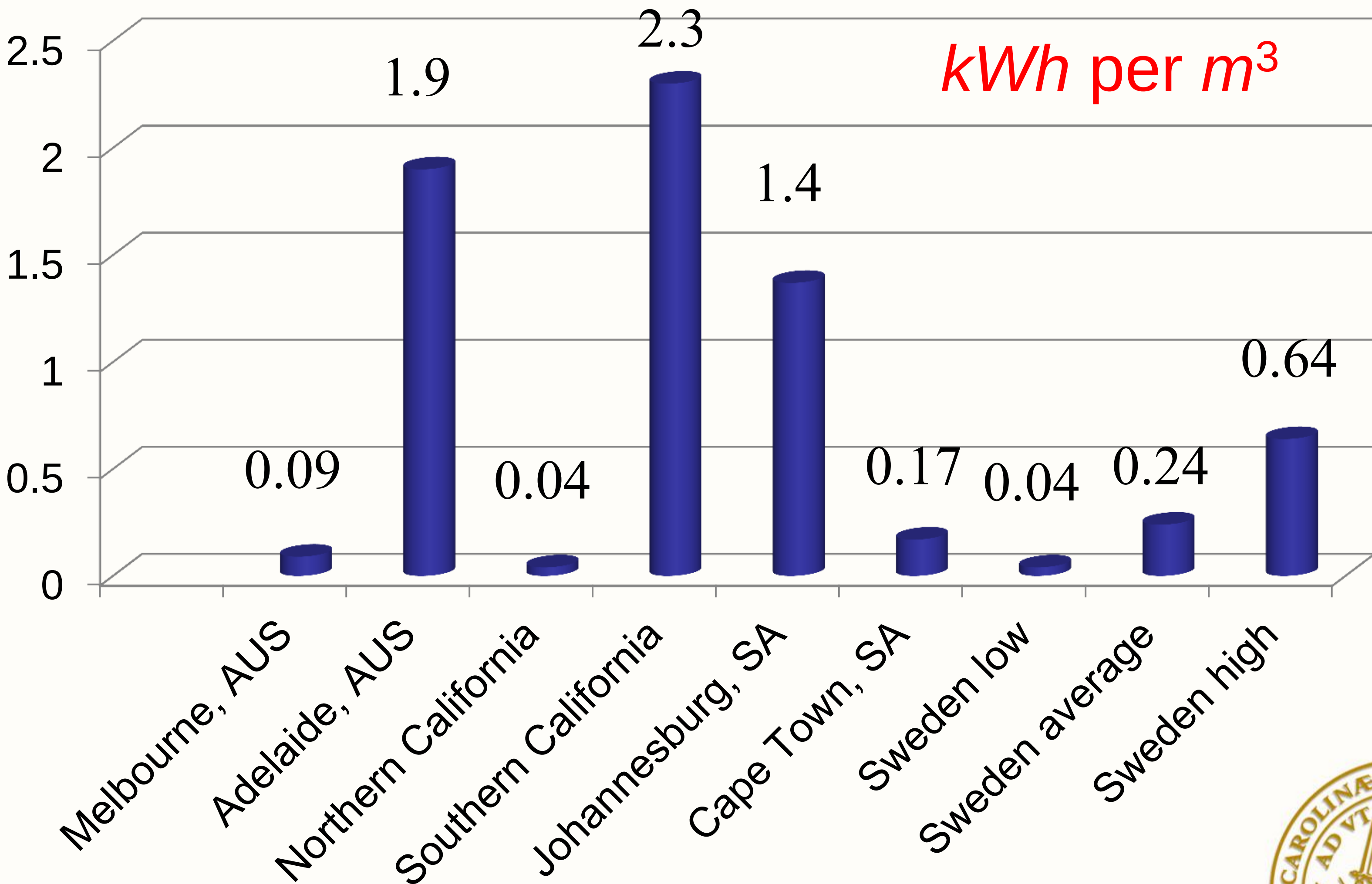


Source: Lingsten *et al.* 2008
Swedish Water

Energy cost to produce cold water

	kWh / m^3
Surface water	0.5 - 4
Recycled water	1 - 6
Desalination	4 - 8
Bottled water	1000 - 4000

Pumping from source to waterworks



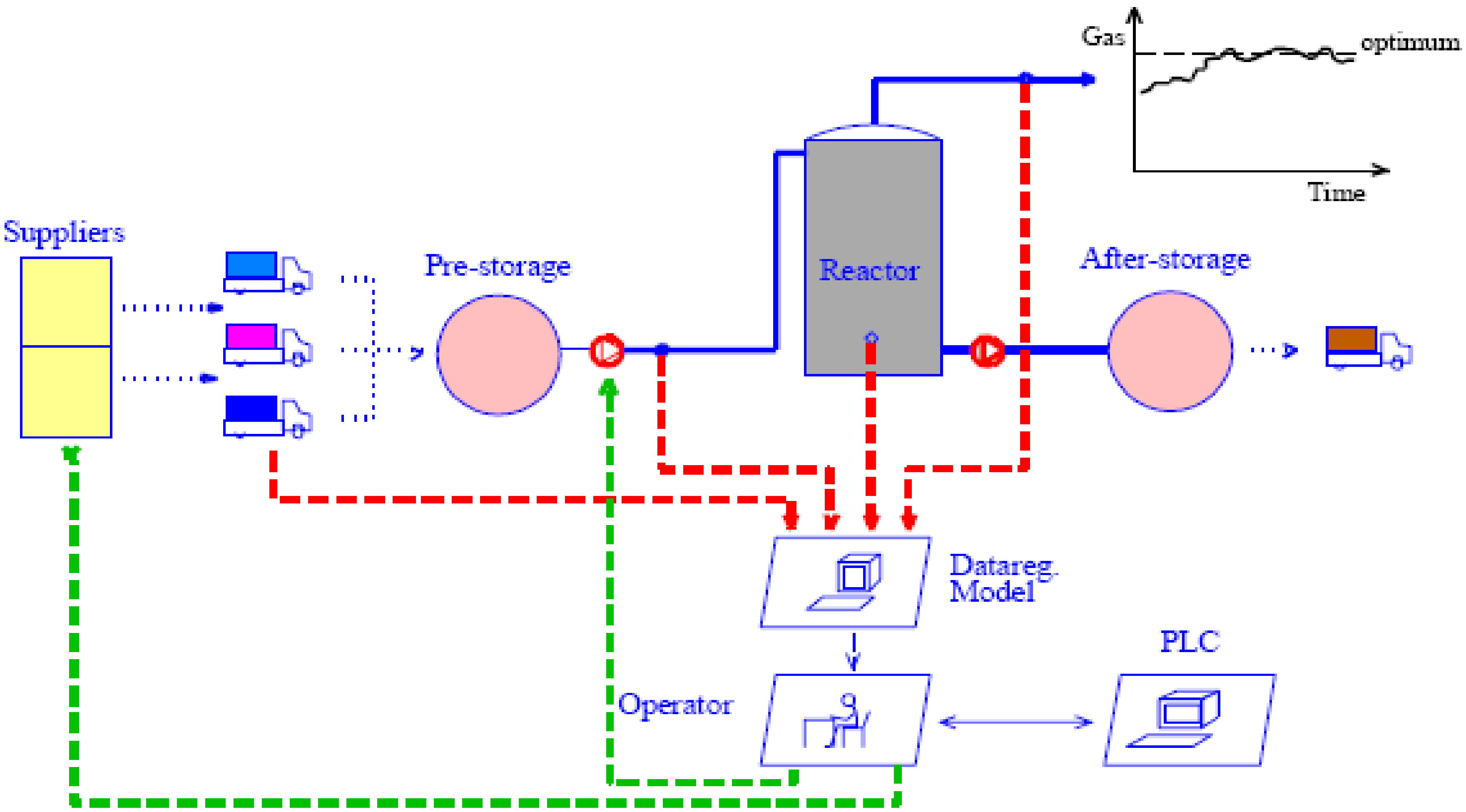
Water supply – energy efficiency

- Efficient pumping
- Variable pressure control
- Leakage
  - Detection
  - Localisation

Wastewater treatment – energy efficiency

- Pumping
  - Efficient pumps for adequate flows
  - Operating at dynamically changing flows and pressures
- Aeration in wastewater treatment
  - Adequate compressors
  - Controlling the air flow for variable loads

Anaerobic digester control



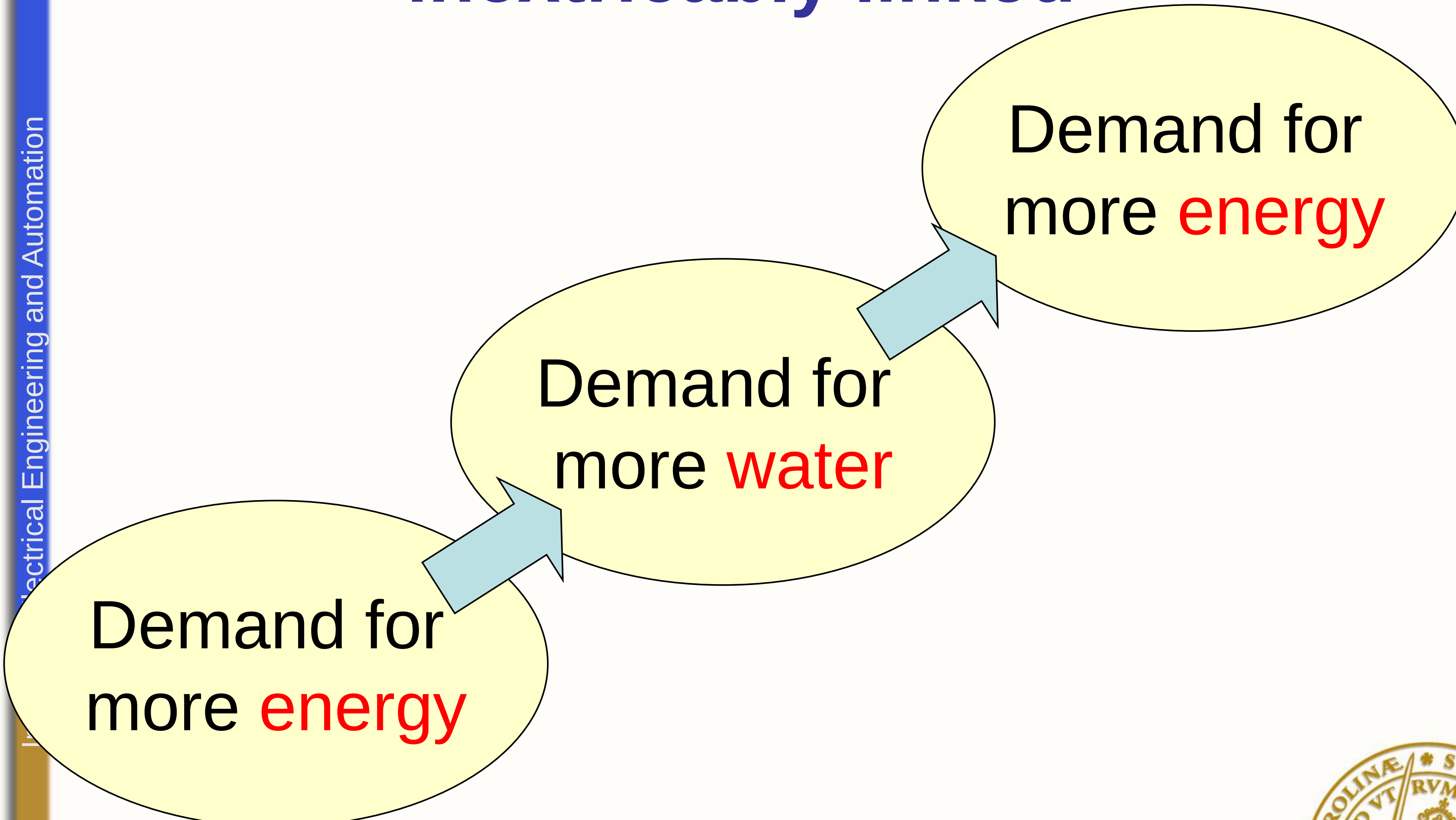
With increasing water scarcity….

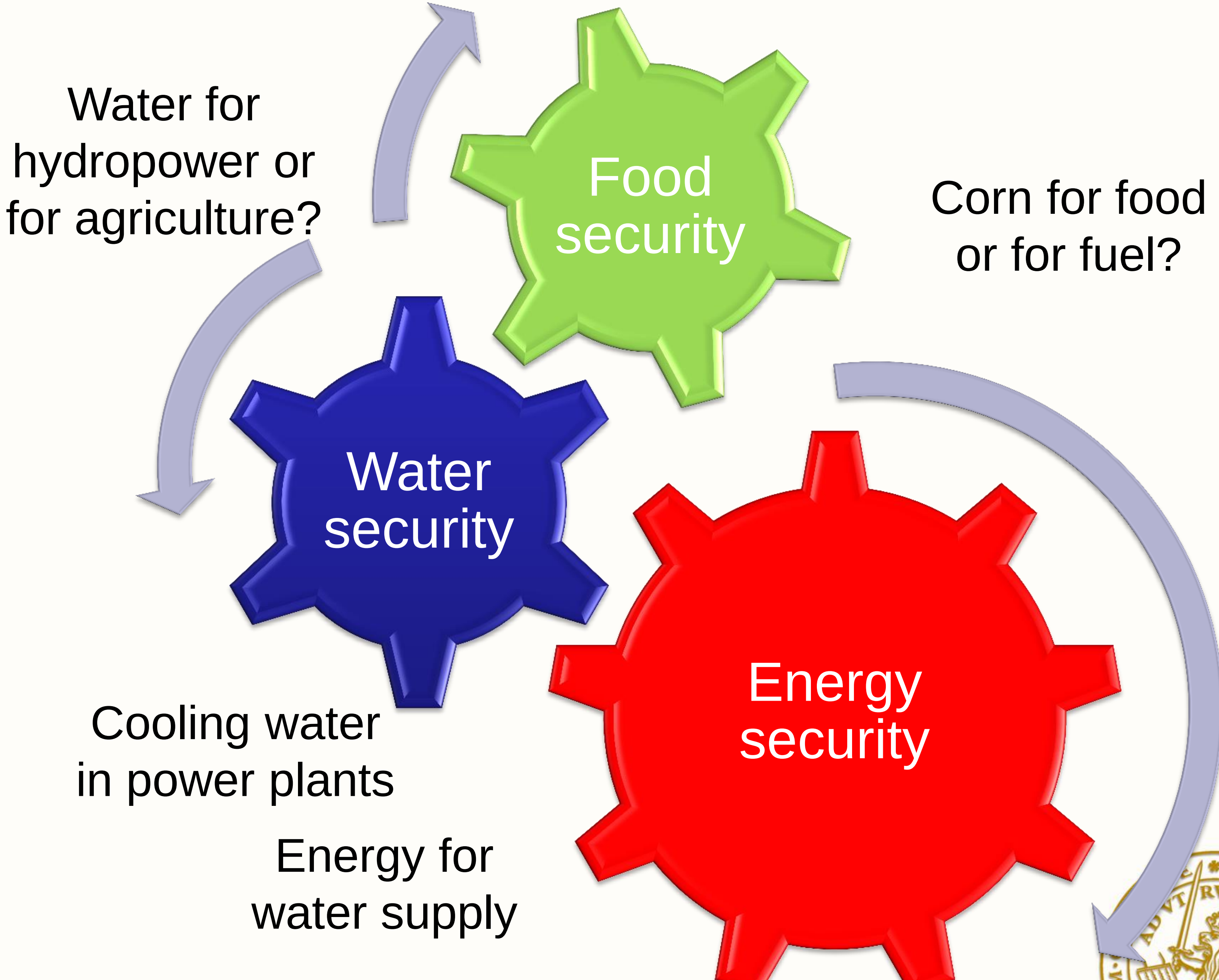
Increased energy for pumping (deeper – longer)

Impaired, reused, brackish, sea water

New technologies to access/treat water will use more energy

Water and Energy – inextricably linked




Water for
hydropower or
for agriculture?
Food
security
Corn for food
or for fuel?
Water
security
Energy
security
Cooling water
in power plants
Energy for
water supply

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Primary energy extraction

Shale gas – shale oil

Hydraulic fracturing

Source: National Geographic - N. Dakota

Hydraulic fracturing

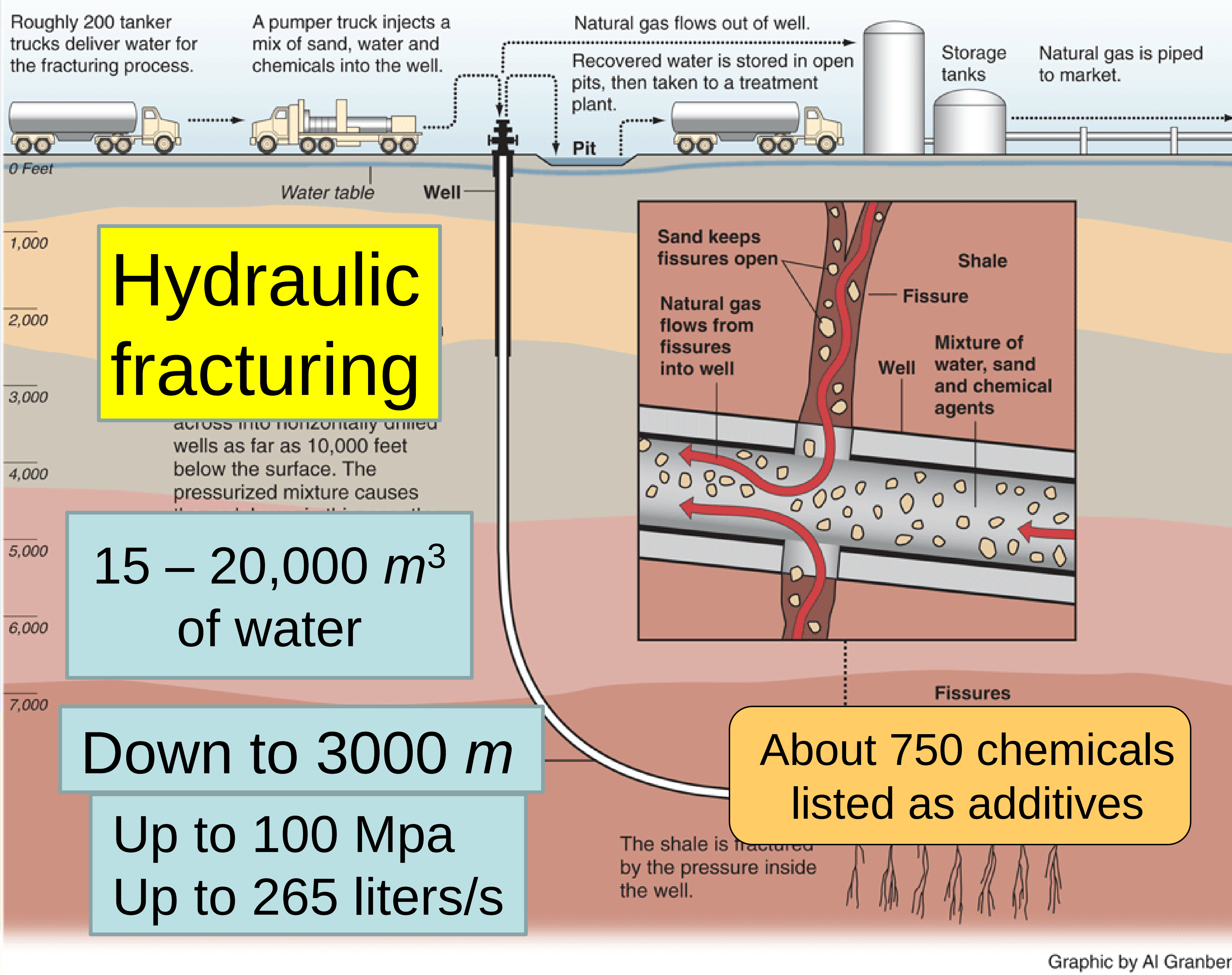
15 – 20,000 m^3 of water

Down to 3000 *m*

Up to 100 Mpa

Up to 265 liters/s

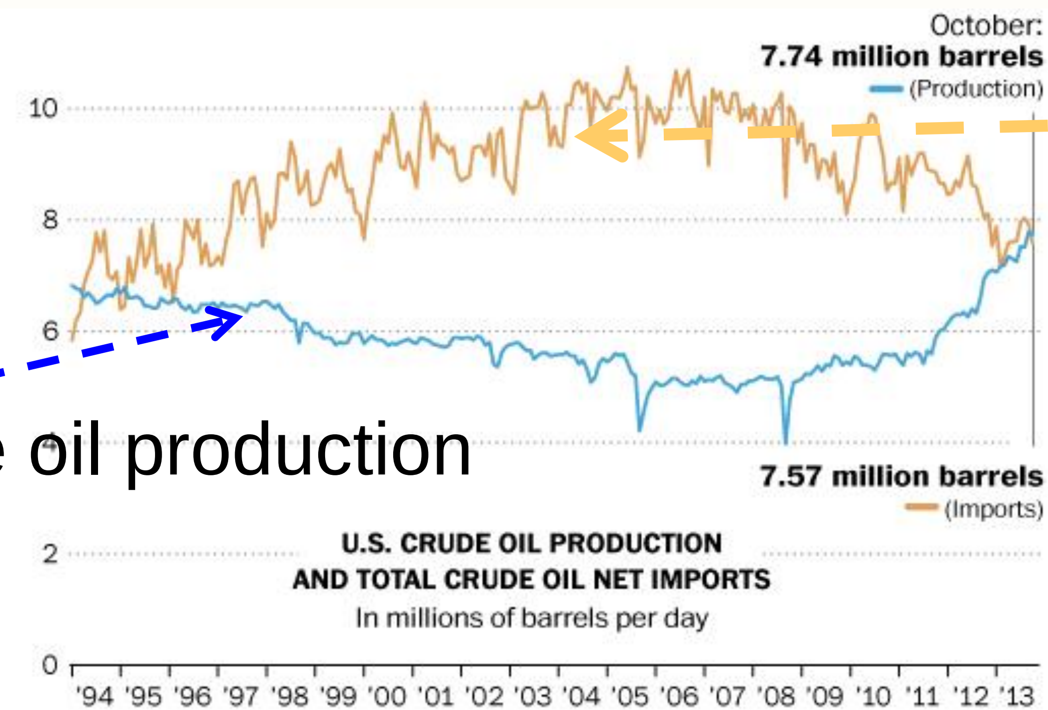
About 750 chemicals listed as additives



Fracking and U.S. Shale Oil Production

- **U.S. shale oil production by fracking has more than tripled in recent years to more than 1 million barrels/day and U.S. oil production now exceeds imports**

US net oil import



US crude oil production

Fracking fluid facts

- The fracking fluid
  - 80% water
  - 19% proppant – natural quartz + man made ceramics
  - 0.5% chemicals – additives (many toxic) – to inhibit bacterial growth, minimize friction, increase viscosity
- Volumes (during a life time of a well)
  - 25,000 – 500,000 m^3 water
  - Up to 2000 tons of proppant
  - 50+ m^3 (or 300+ barrels) of chemicals

Chemicals in fracking fluid

- **Purposes:**
  improve fluid viscosity,
  inhibit corrosion, and
  limit bacterial growth
- **Contain:**
  known carcinogens and air pollutants,
  BTEX: benzene, toluene, xylene, ethylbenzene

→ **Harmful effects on the central nervous system**

Risks in fracking

- Chemical content a trade secret
- Cement-casing failures
  methane and chemicals migrate to water sources
- Fracking fluid
  can leak into ground and surface water during the fracking process
- Accidental spills during truck transportation

Fracking often in dry regions

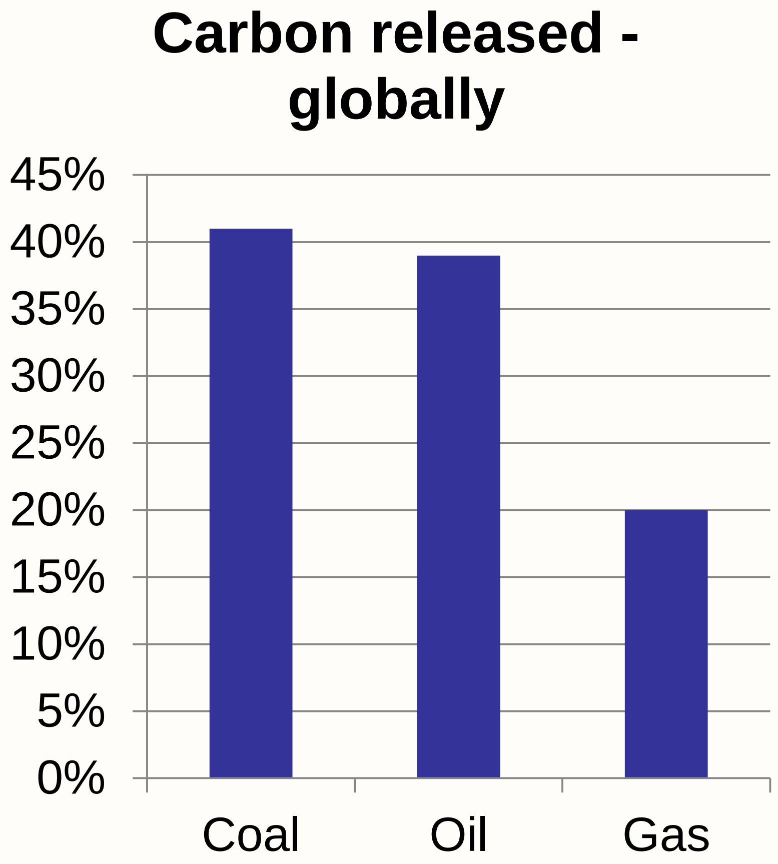
- **Groundwater is sold to the oil company instead of being used for irrigation**
- **Conflict between energy and food!**

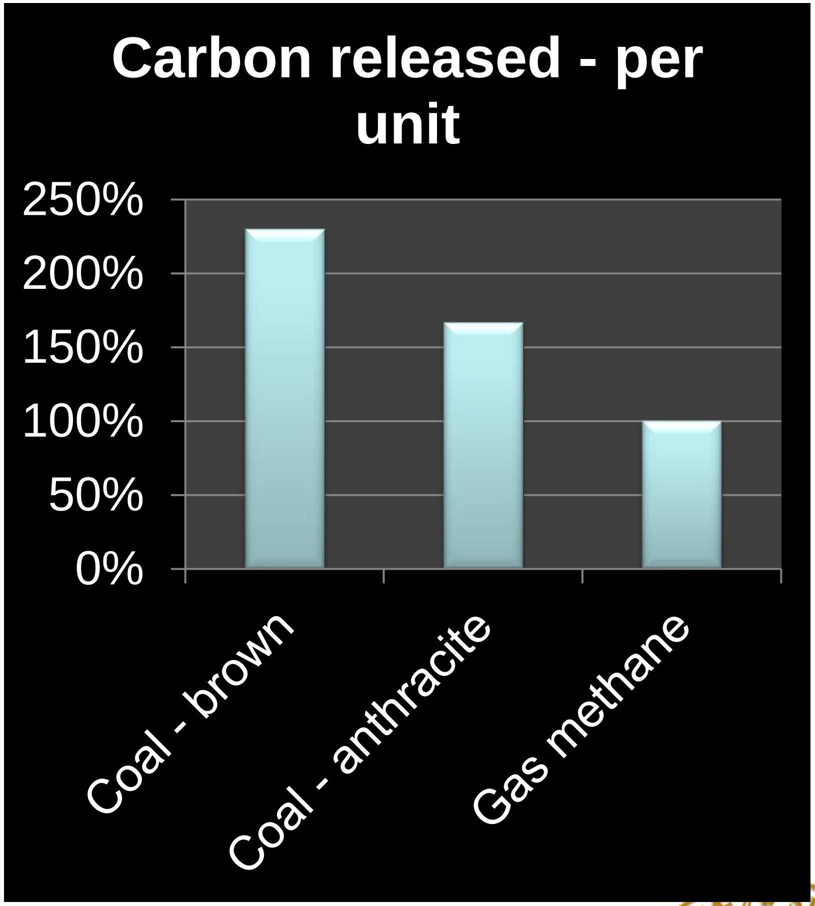
In the Barnett Shale (Texas) drillers paid 0.06 cents/m^3

The fracking controversy

Pennsylvania, USA 2011
Source: Nat. Geographic

Coal vs. natural gas





Oil Sand

Athabasca,
Alberta
Canada

Alberta Tar Sands

Oil sand (1)

- **Alberta – every day**
  - **1 million ton sand**
  - **200,000 m^3 water**
  - **Heat the water to 80° C (washing out the bitumen)**
  - **Heat up the bitumen to 500° C**
  - **Compress to 100 bar – crack the carbohydrate molecules**

Oil sand (2)

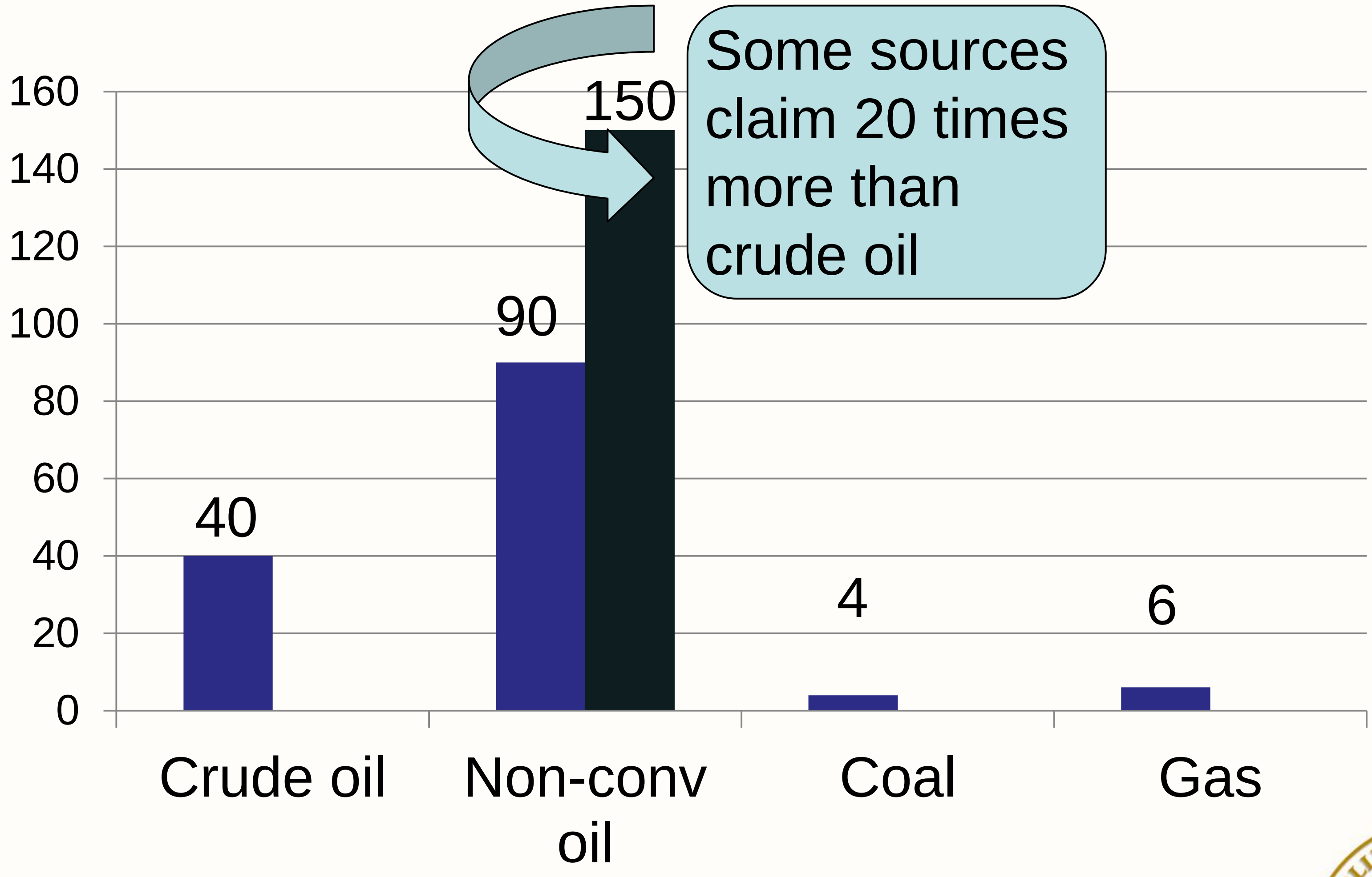
- Water consumption 3 times larger than crude oil
- Energy for production from natural gas

"Clean energy is used to make dirty energy"

The tailing lakes (”ponds”)

- The toxic tailing lakes in Northern Alberta - one of the largest human-made structures in the world: 176 km^2
- An accident related to the failure of one of the oil sands tailing lakes could have catastrophical impact on the aquatic ecosystem of the Athabasca - Mackenzie River Basin

Water consumption per *liter* or *kg*



Source: World Energy Council, 2010

Remember some oil accidents

- **Exxon Valdez, Alaska 1979 – 43 000 m^3**
- **Mexican Gulf, Deepwater Horizon 2010 – 780 000 m^3**
- **Nigeria, the Niger Delta during 50 years – 1.4 – 2.1 million m^3**

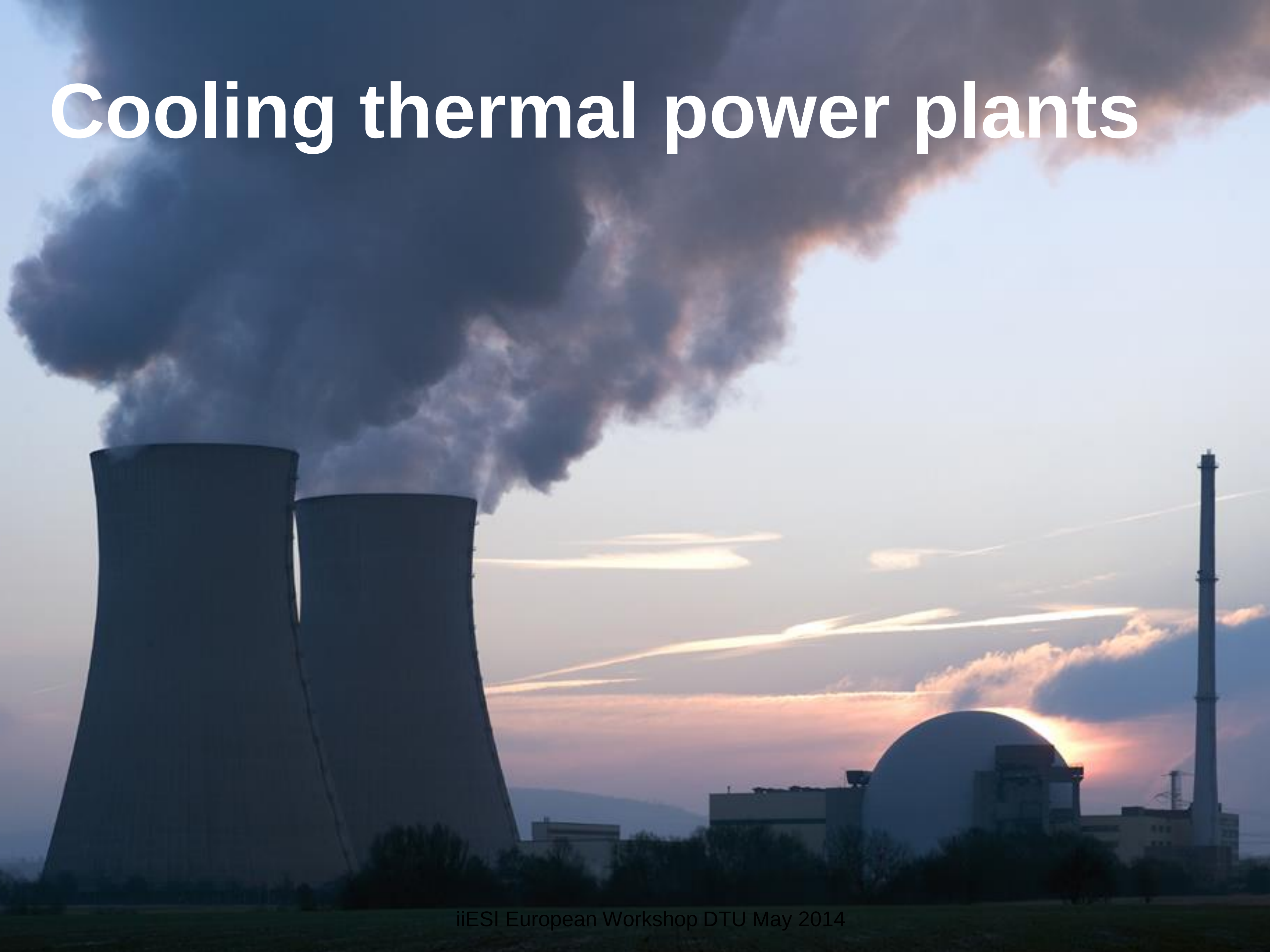
(one Exxon Valdez every year….)

Niger Delta wetland

Sivibilagbara swamp
before oil spill

Dr. Nenibarini Zabbey, Univ. of Port Harcourt

Cooling thermal power plants



Water withdrawal - once-through cooling

- **Nuclear power plants**
  - **Typical temp. increase USA 16.5°C**
  - **1000 MWe requires 33 m^3/s**
  - **Rule of thumb for 1000 MWe: 25 – 43 m^3/s**
- **Coal fired plants**
  - **Typical temp. increase USA 9.5°C**
  - **1000 MWe requires 50 m^3/s for ΔT=10°C**

**Source*: Richard Bozek,
Edison Electric Initiative, 2011

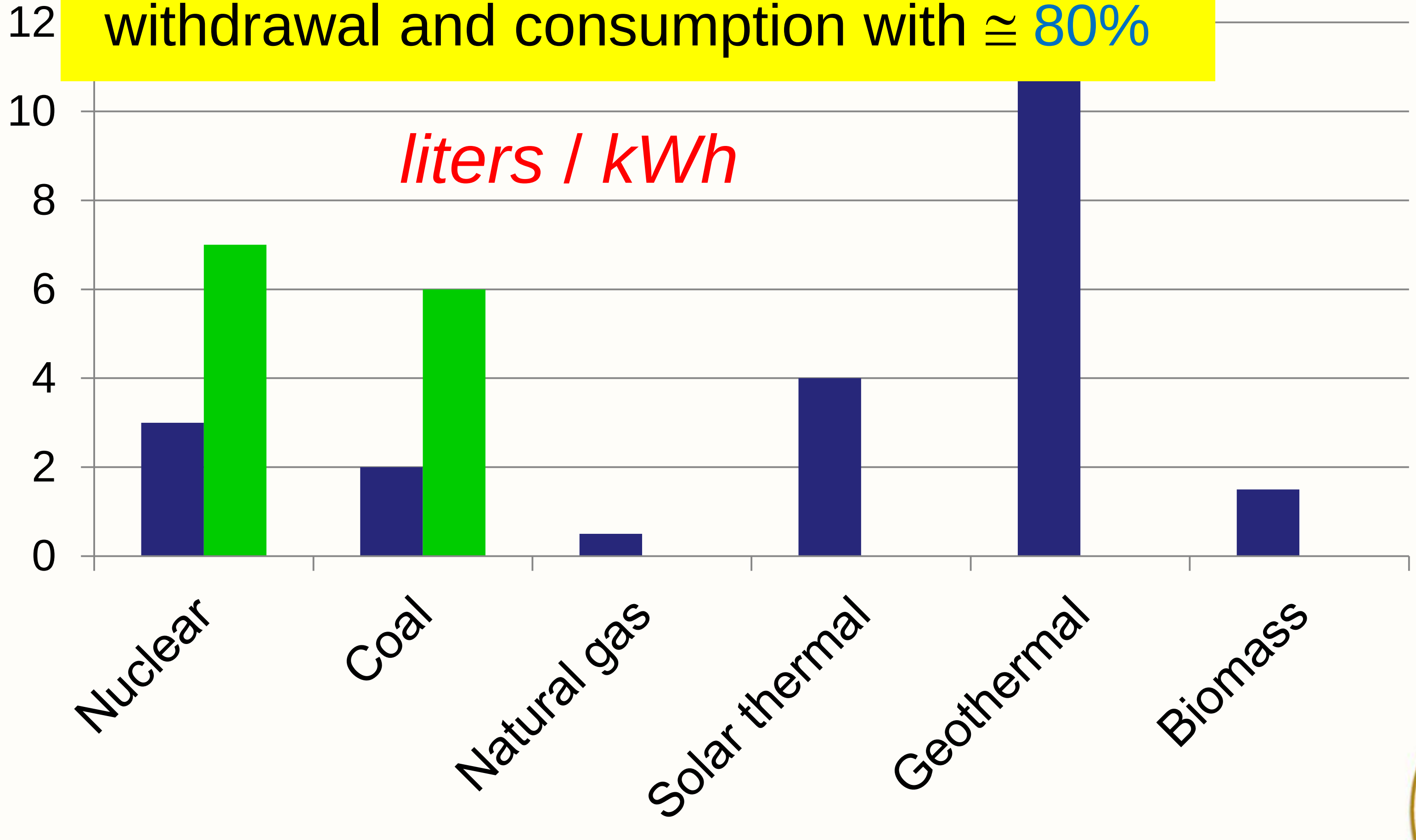
Out of the 33 m^3/s around 0.5 m^3/s is **consumed** (evaporated)

In Sweden we use
around 150 liters/day/person

The evaporated cooling water would be sufficient for about 300,000 persons

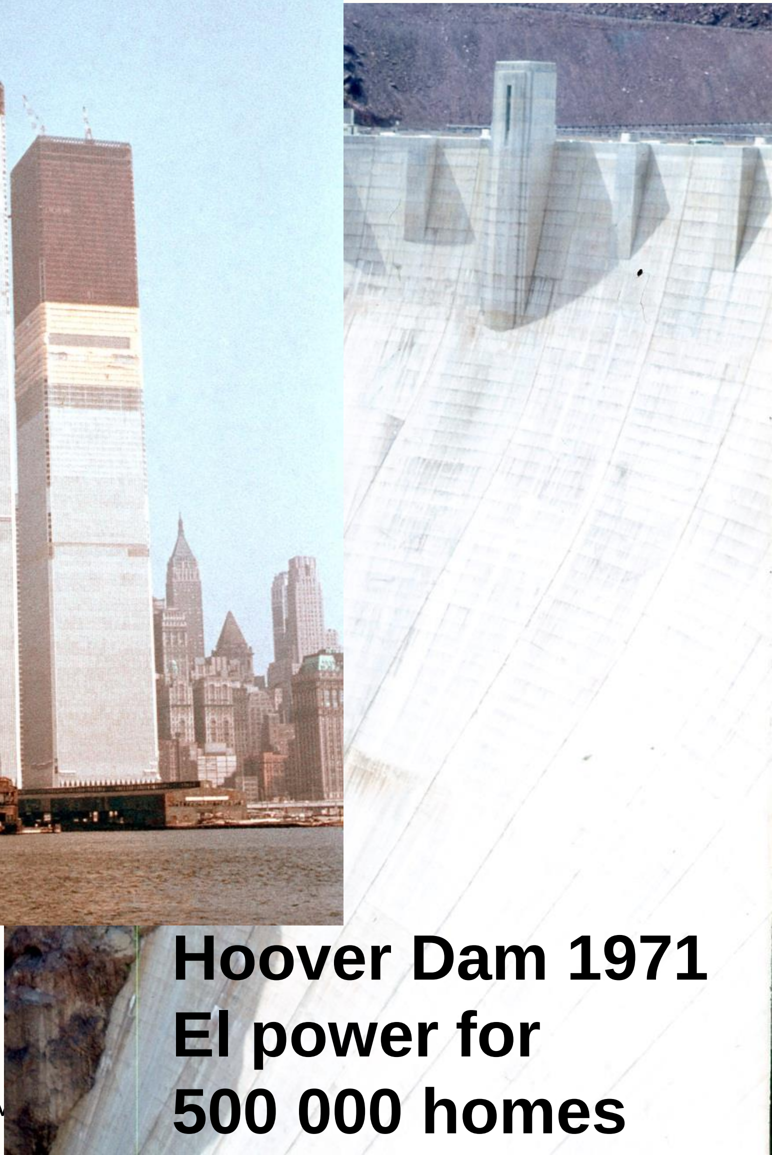
Water consumption in electrical generation

Carbon sequestration for fossil energy generation will increase water withdrawal and consumption with ≅ 80%



Hydropower

World Trade Center 1971



Lake Mead 1971

Elevation May 2014
332 m above sea
Full = 372 m

Volume = 42% of full pool

Hoover Dam 1971
El power for
500 000 homes

Industrial Electrical Engine

Rationale to build dams

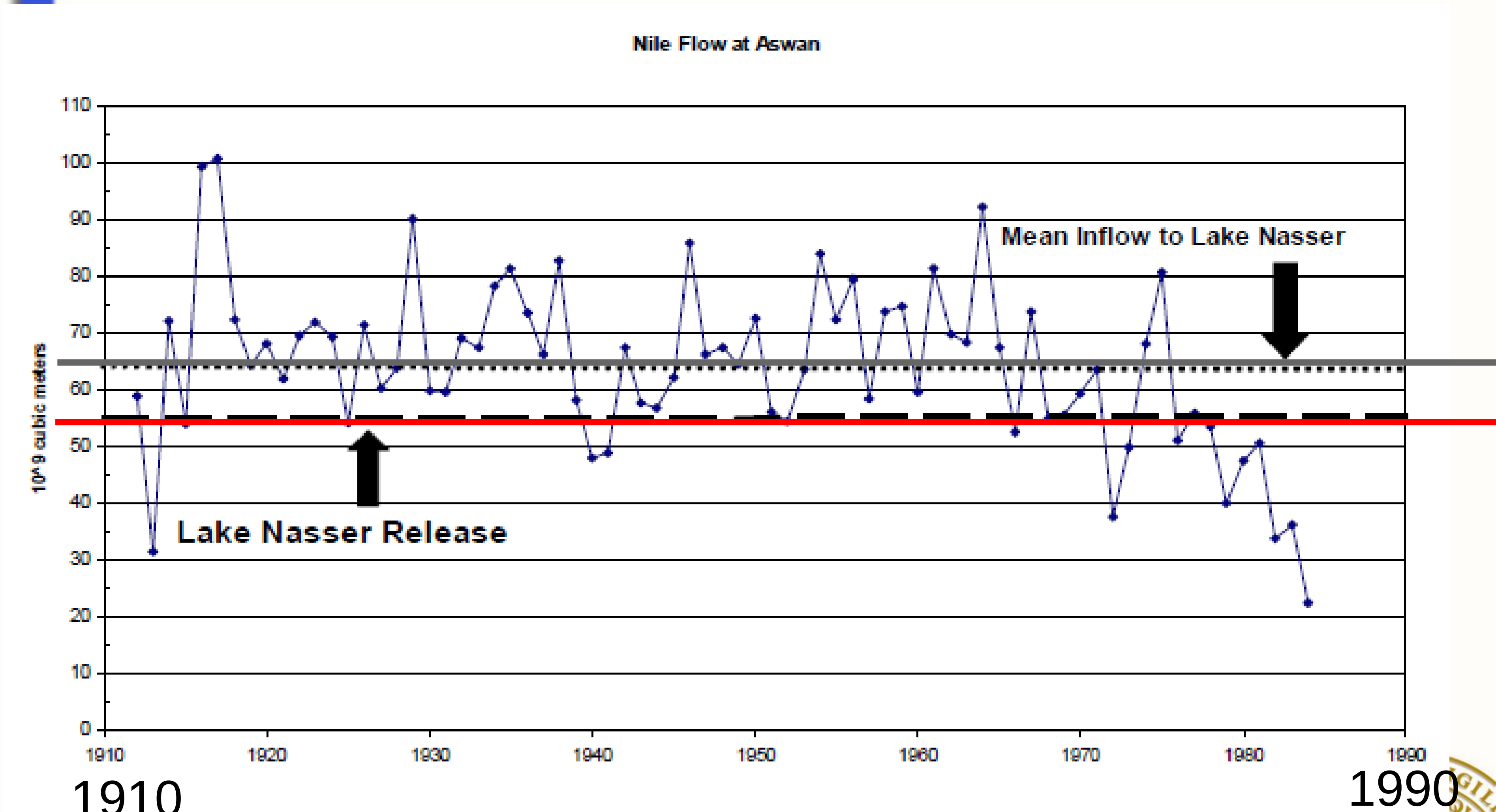
- **Hydropower generation**
- **Flood control**
- **Water storage for irrigation etc.**
- **Navigation**

Today 45 000 dams
≅10% are 60 – 300 *m* high

Large dams – impacts to consider

- Flooded area
- Water loss – evaporation
  - Power per reservoir area unit (MW/km^2)
  - Temperature
- Hydropower vs. flood control operation
  - Economy vs. risk
- Sedimentation
- Water quality
  - Public health
  - Ecology

Nile flow at Aswan



Source:
Strzepek et al. 2013

Evaporation (total)

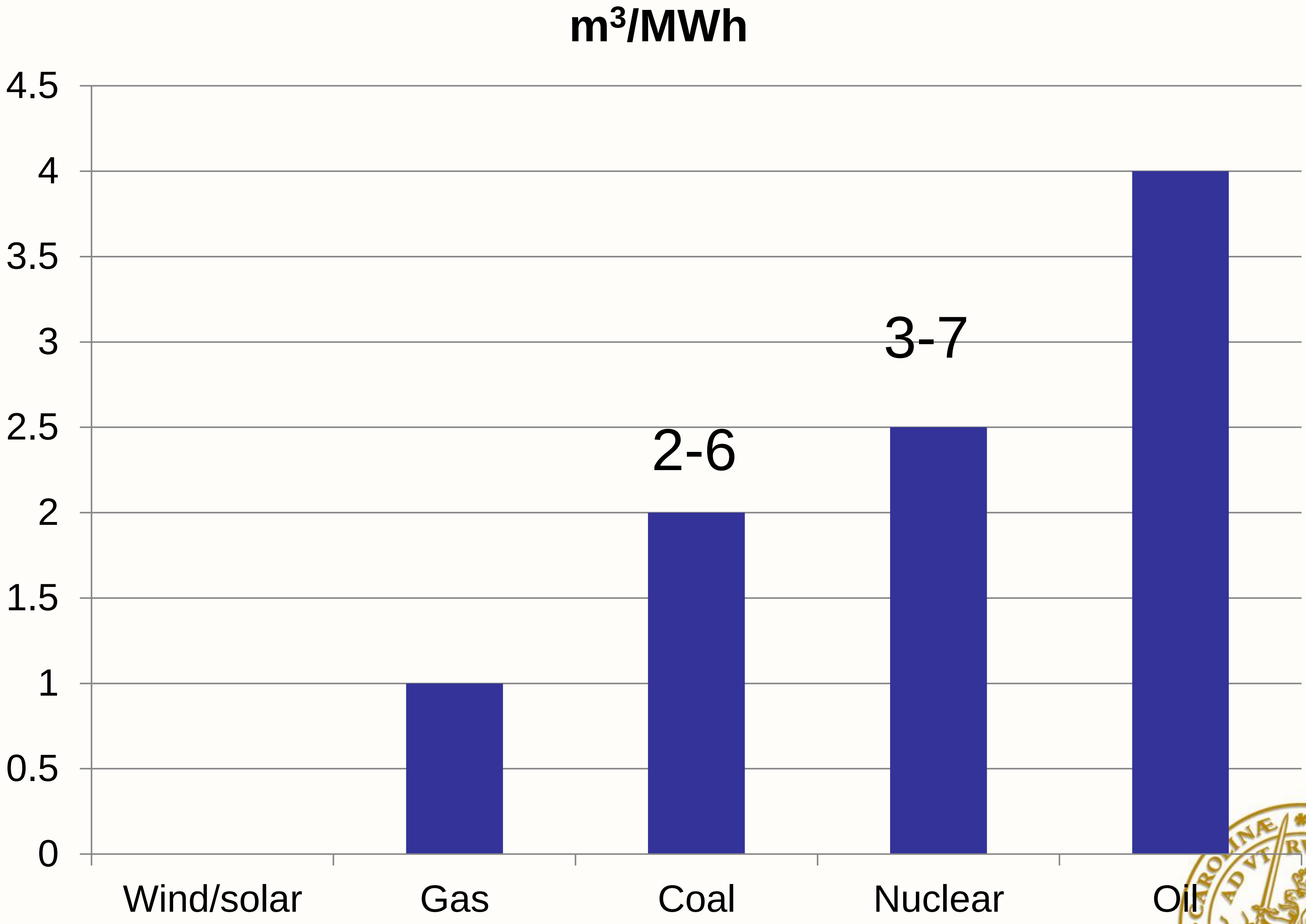
	ha/MW	Evaporation mm/year	Evaporation Gm^3/year	liters/kWh
Akosombo **Ghana**	720	2185	19	3000
Sobradinho, **Brazil**	400	2841	12	1430
Bayano, **Panama**	233	2156	0.75	1370
Itezhi Tezhi, **Zambia**	62	2572	0.95	338
Robert Bourossa, **Canada**	36	586	1.7	30
San Carlos, **Colombia**	0.26	1726	0.01	1

Source: Mekonnen & Hoekstra 2012

Range of evaporation

Locations	Range liters/kWh	Average liters/kWh	Reference
Selected 35 plants globally	1-3000	240	Mekonnen-Hoekstra 2012
New Zealand	3 – 115		Herath *et al*. 2011
California	0.04 – 200	5.4	Gleick (1993) DOE (2006)
USA, Switzerland, Tanzania	1 – 610		Pfister *et al.* 2011
USA average	---	17	Atlantic Council 2011
Estimated global average	---	80	Gerbens-Leenes 2009

Number of m^3 to produce 1 *MWh*



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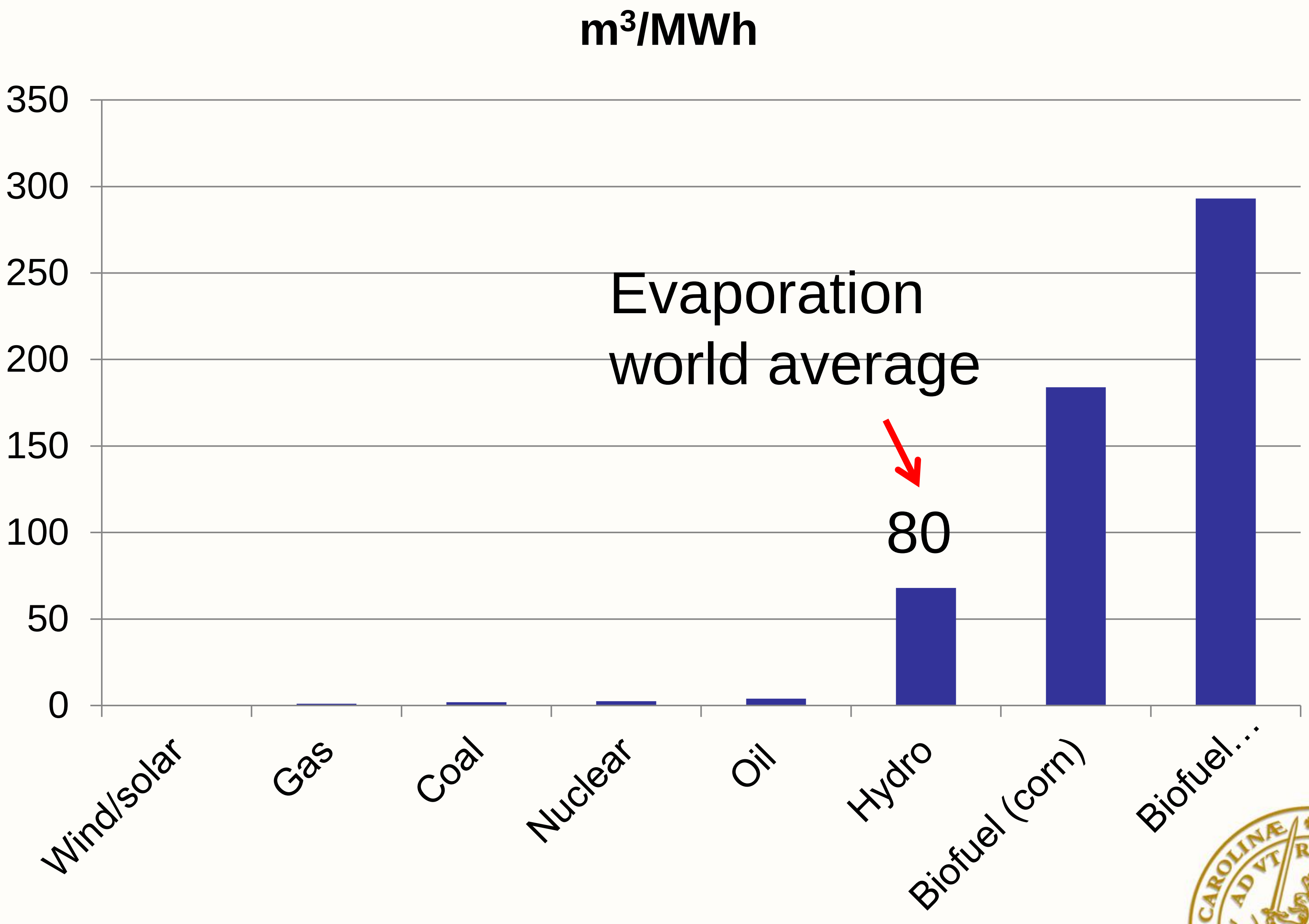

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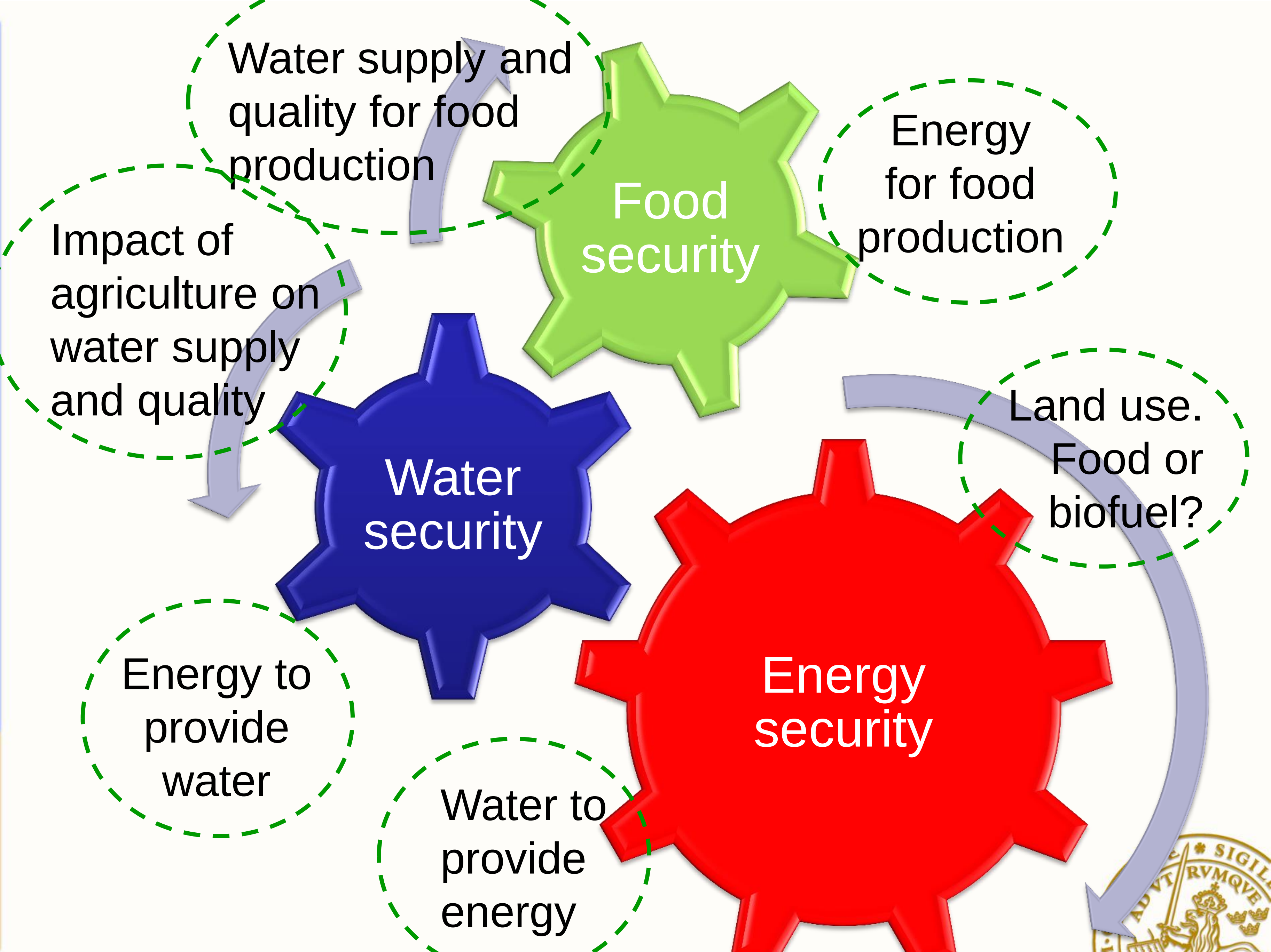


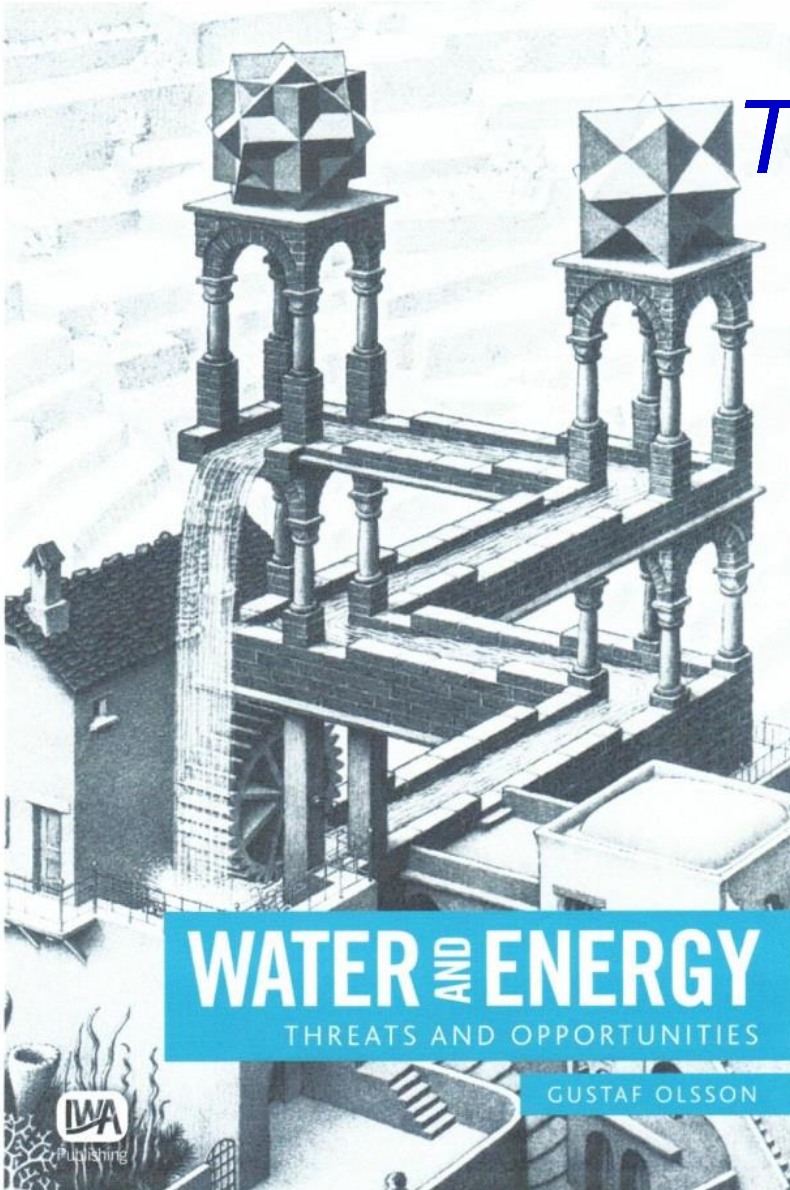
The demand side

From *supply* oriented to *demand* side oriented

- More focus on the demand side
- Understanding how demand works
  - Habits
  - Life style
  - Pricing
- Water economy needs radical changes
- Understanding regulators and rules

Water – energy considerations

- **Saving energy ↔ saving water**
- **Fracking methods need to be transparent**
- **Increase wind & solar to reduce thermoelectric withdrawal and consumtion**
- **Minimize once-through cooling**
  - **will decrease withdrawal but may not decrease consumption**
- **Review operation of multi-purpose dams**
- **What would happen if the water will have a cost (”opportunity cost”, ”society cost”)?**



Thank you!

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