The Water-Energy-Food Nexus

Global conflicts and possible solutions

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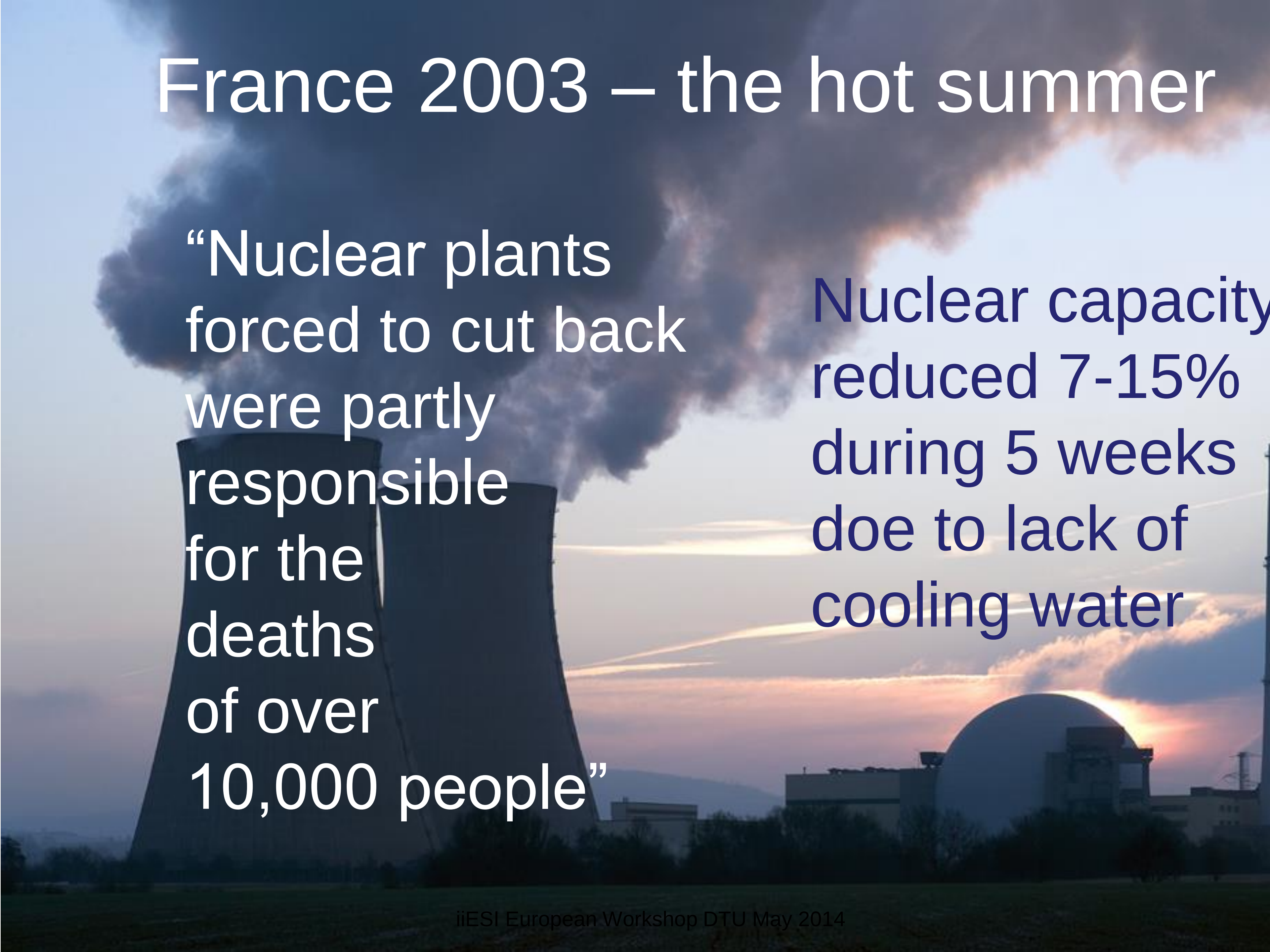
Content

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

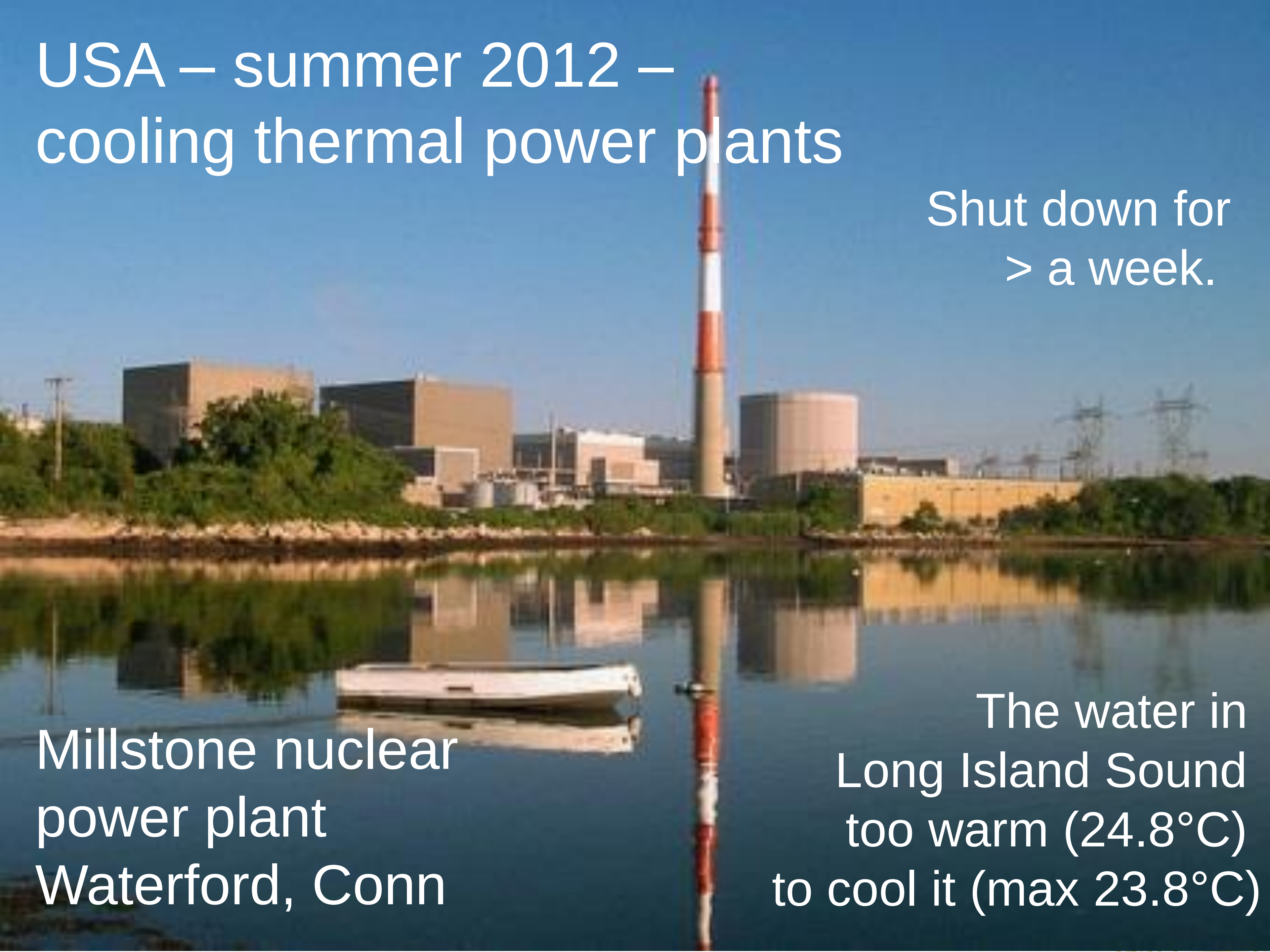

The global
energy challenge
depends on water!

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

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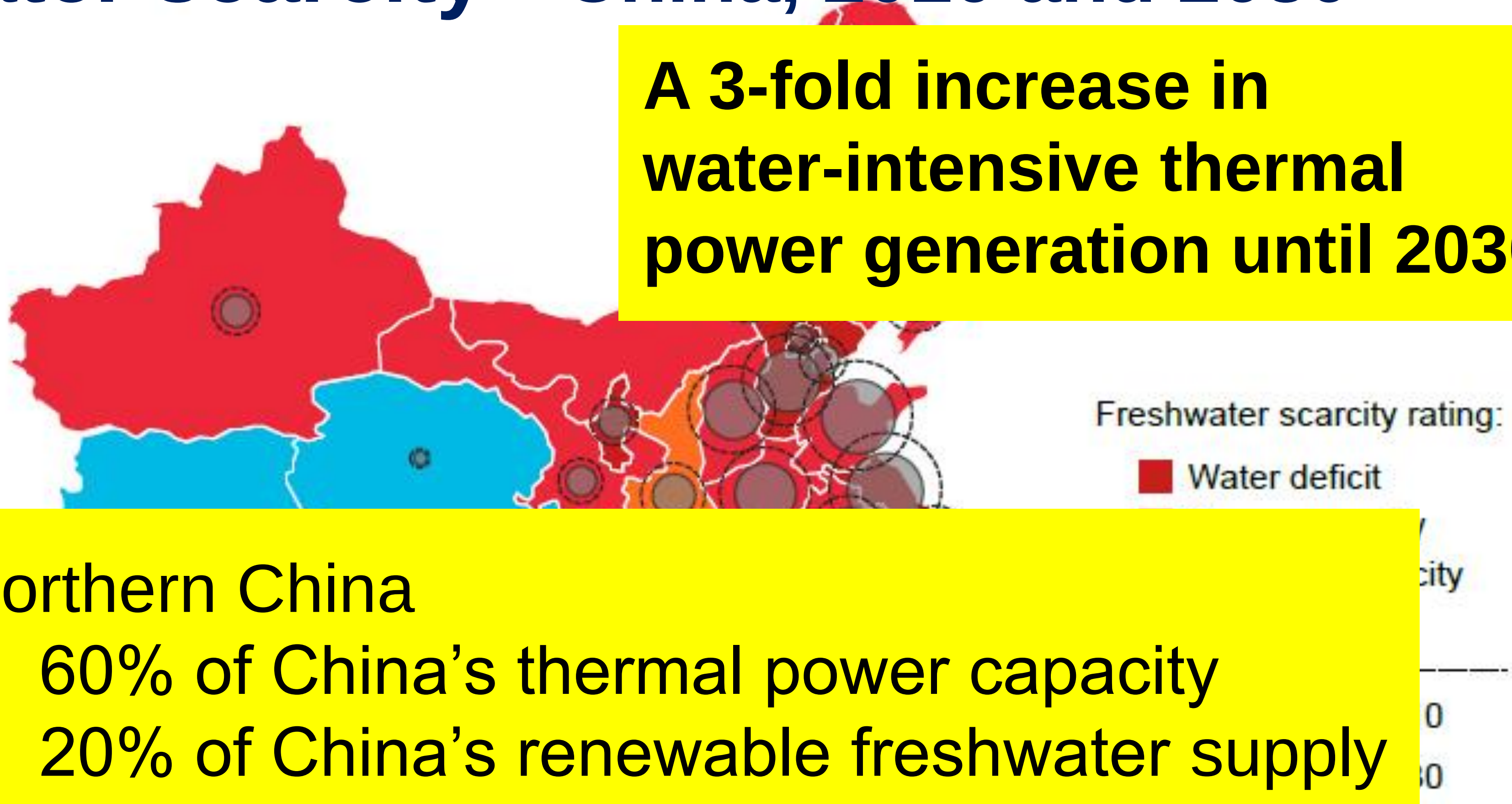
Of the world food-crop calories:

- **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

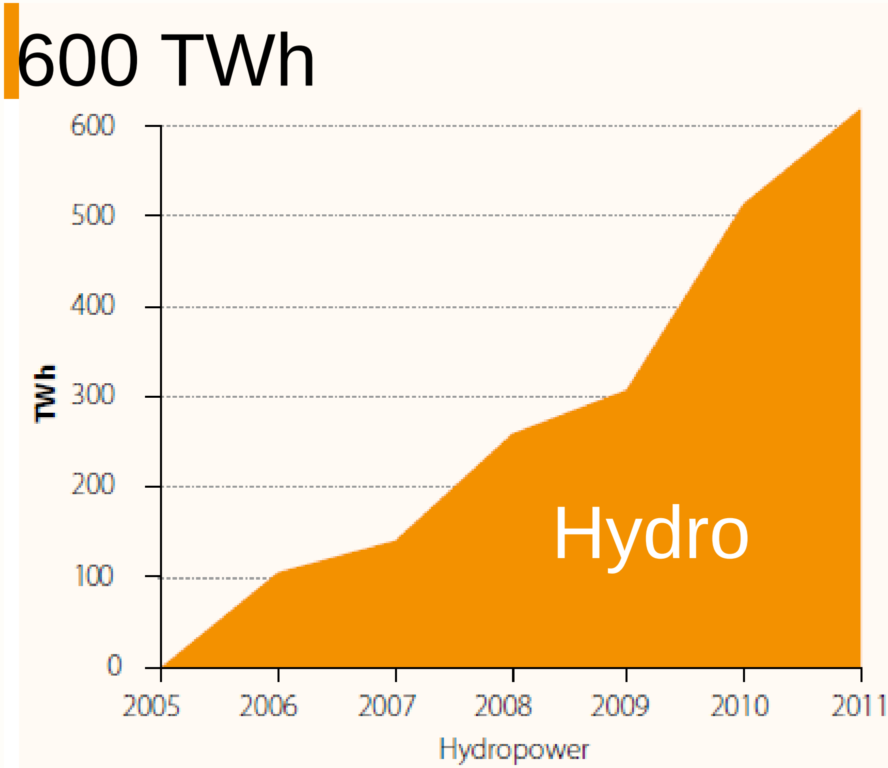
Tibetan plateau, the source of the single largest collection of international rivers in the world.

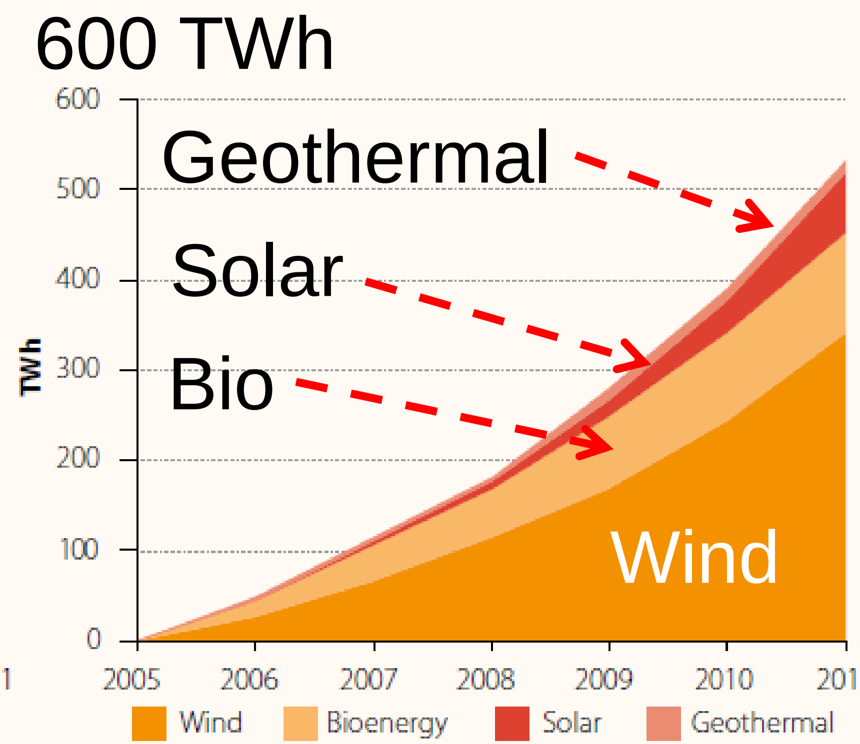
- **Indus – Ganges – Brahmaputra (Zangbo) - Irrawati – Salween**
- **Megong (Lancang) – Yangtse – Huang He (Yellow river)**
- **The headwater of rivers on which nearly half the world depends**
- **Half of India's water comes directly from China**

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

Electricity generation - recent additions to hydropower and other renewables





2005 ←-----------→ 2011

Source: IEA (2012)

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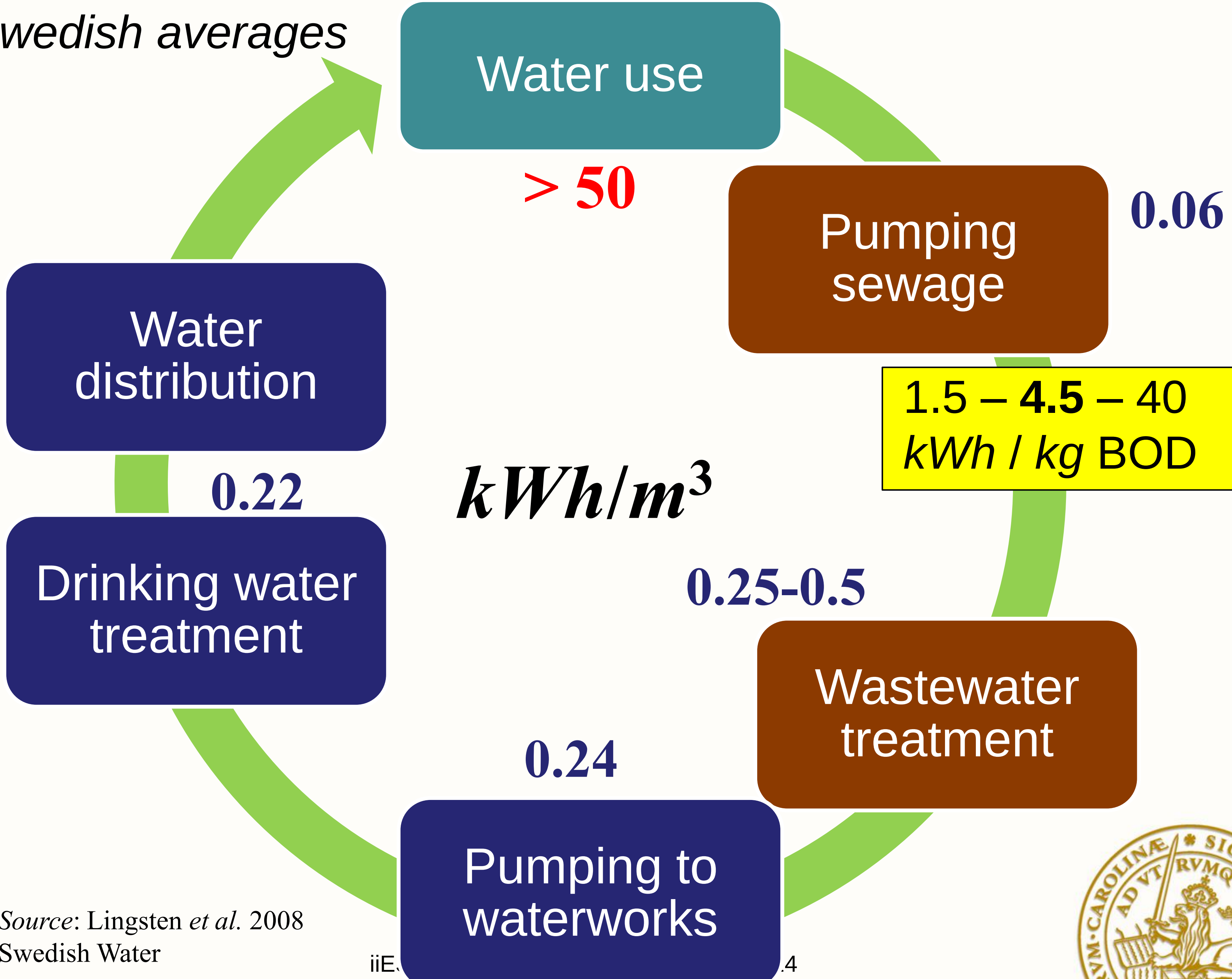
Swedish averages

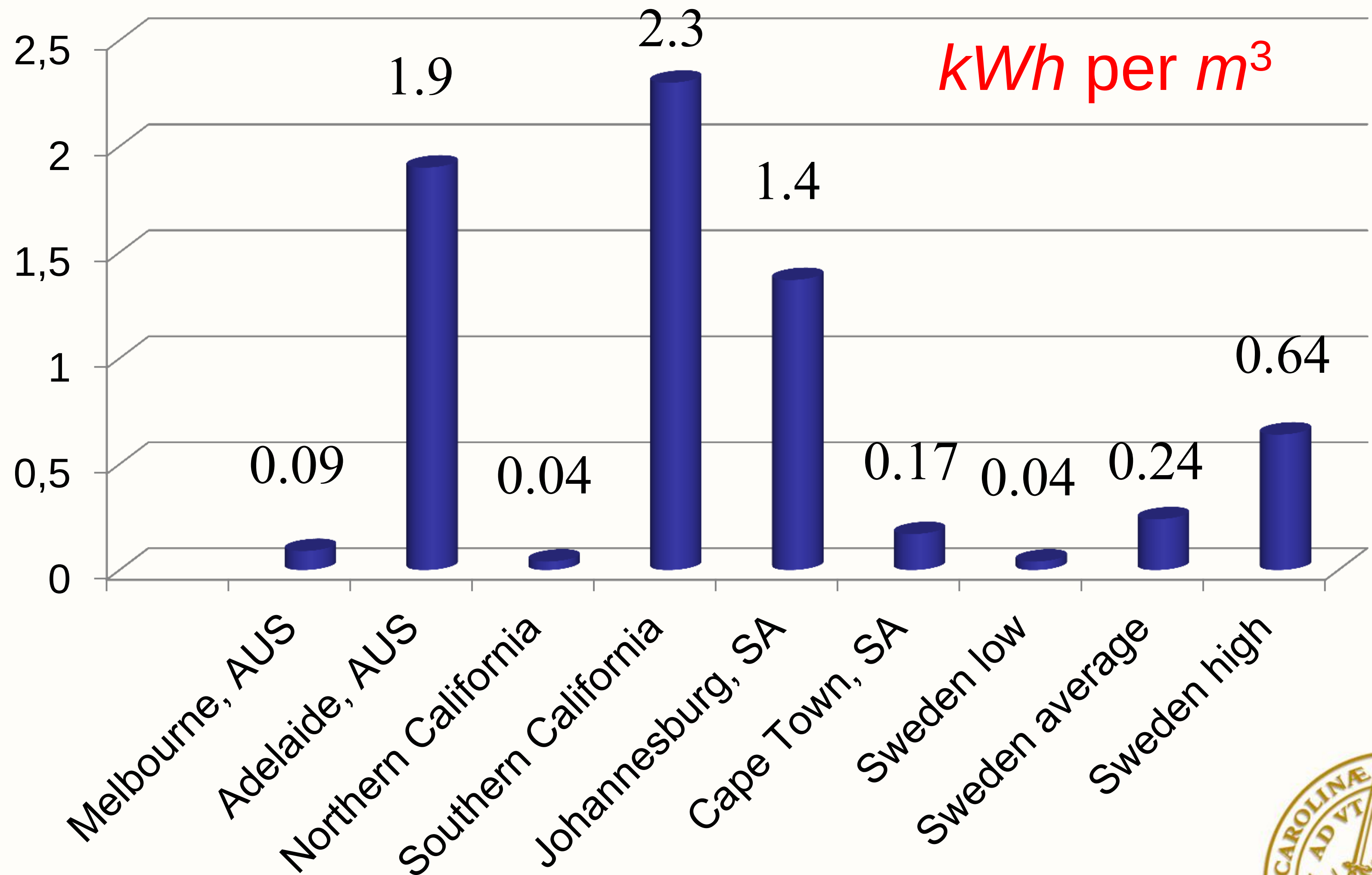


Source: Lingsten *et al.* 2008
Swedish Water

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



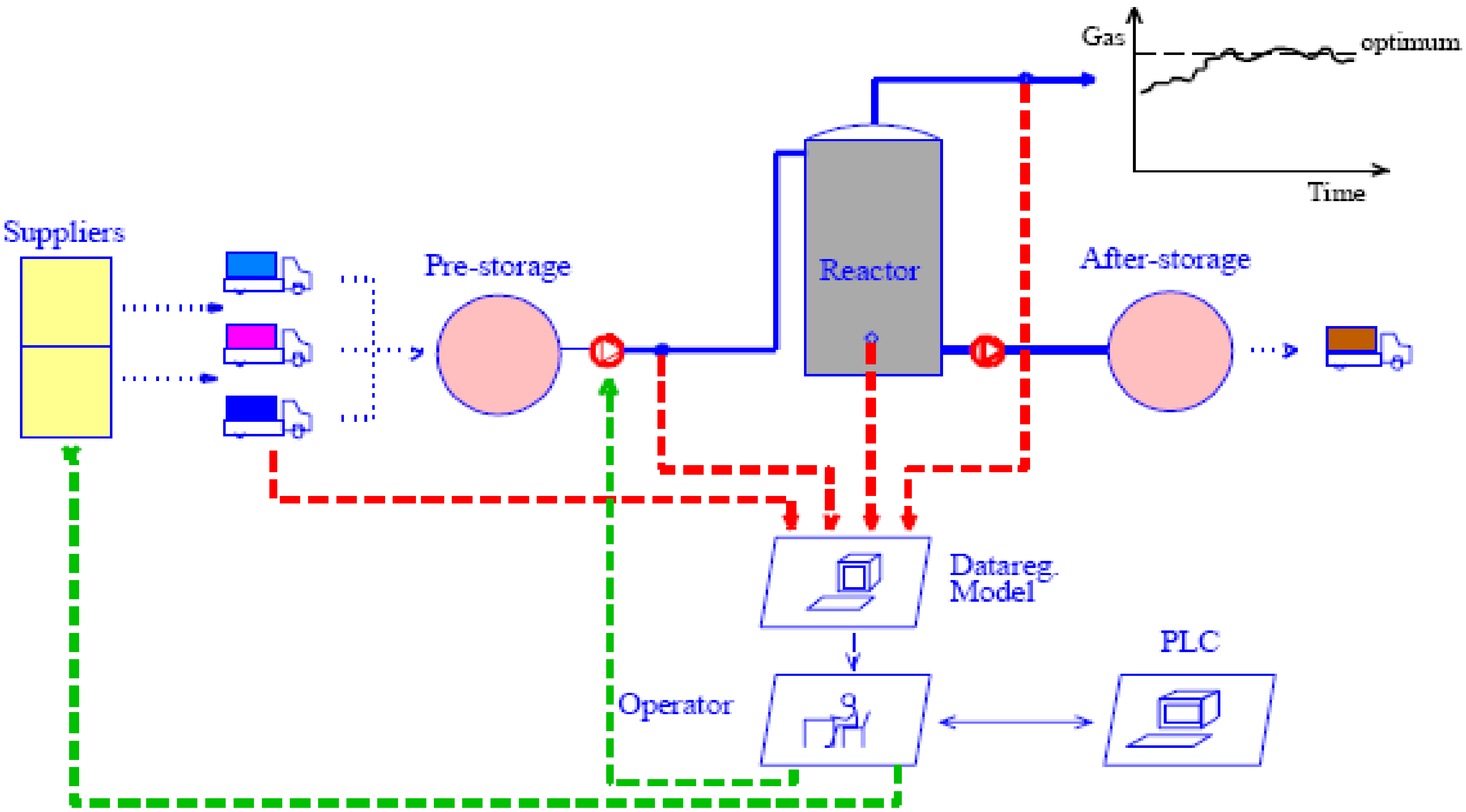
Water supply – energy efficiency

- **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



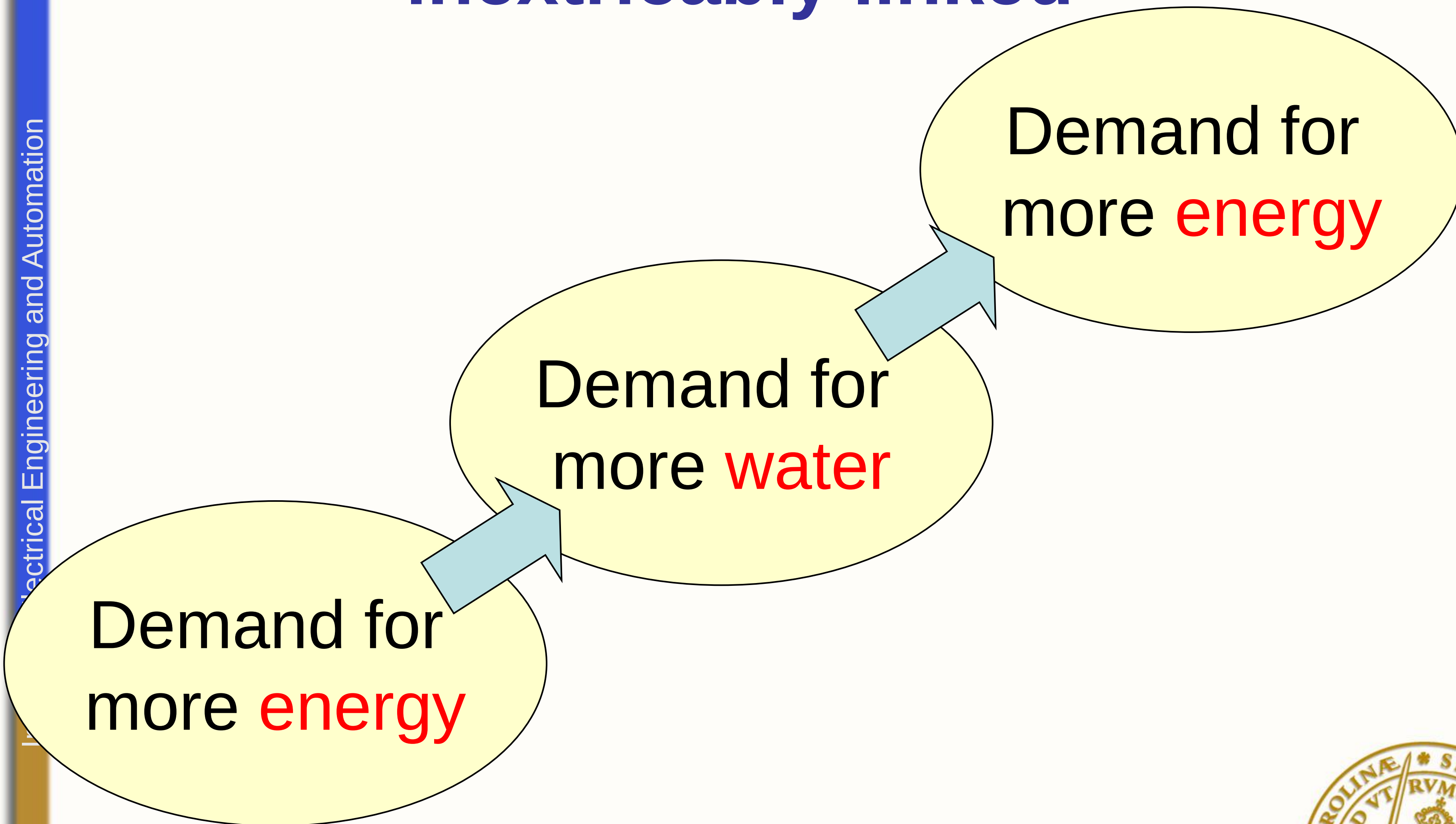
With increasing water scarcity….

Increased energy for pumping (deeper – longer)

Impaired, reused, brackish, sea water

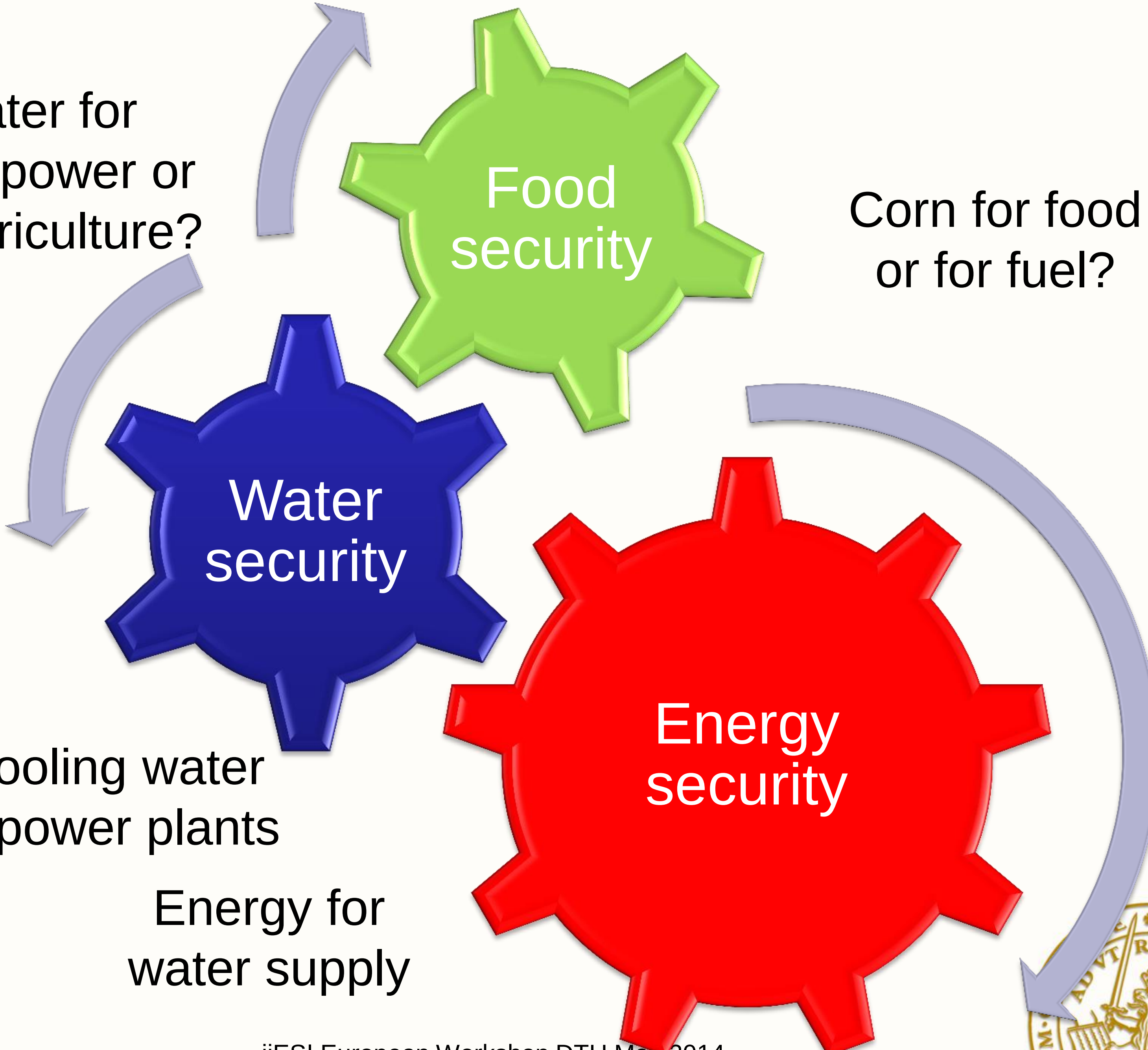
New technologies to access/treat water **will use more energy**

Water and Energy – inextricably linked



Water for
hydropower or
for agriculture?

Corn for food
or for fuel?



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

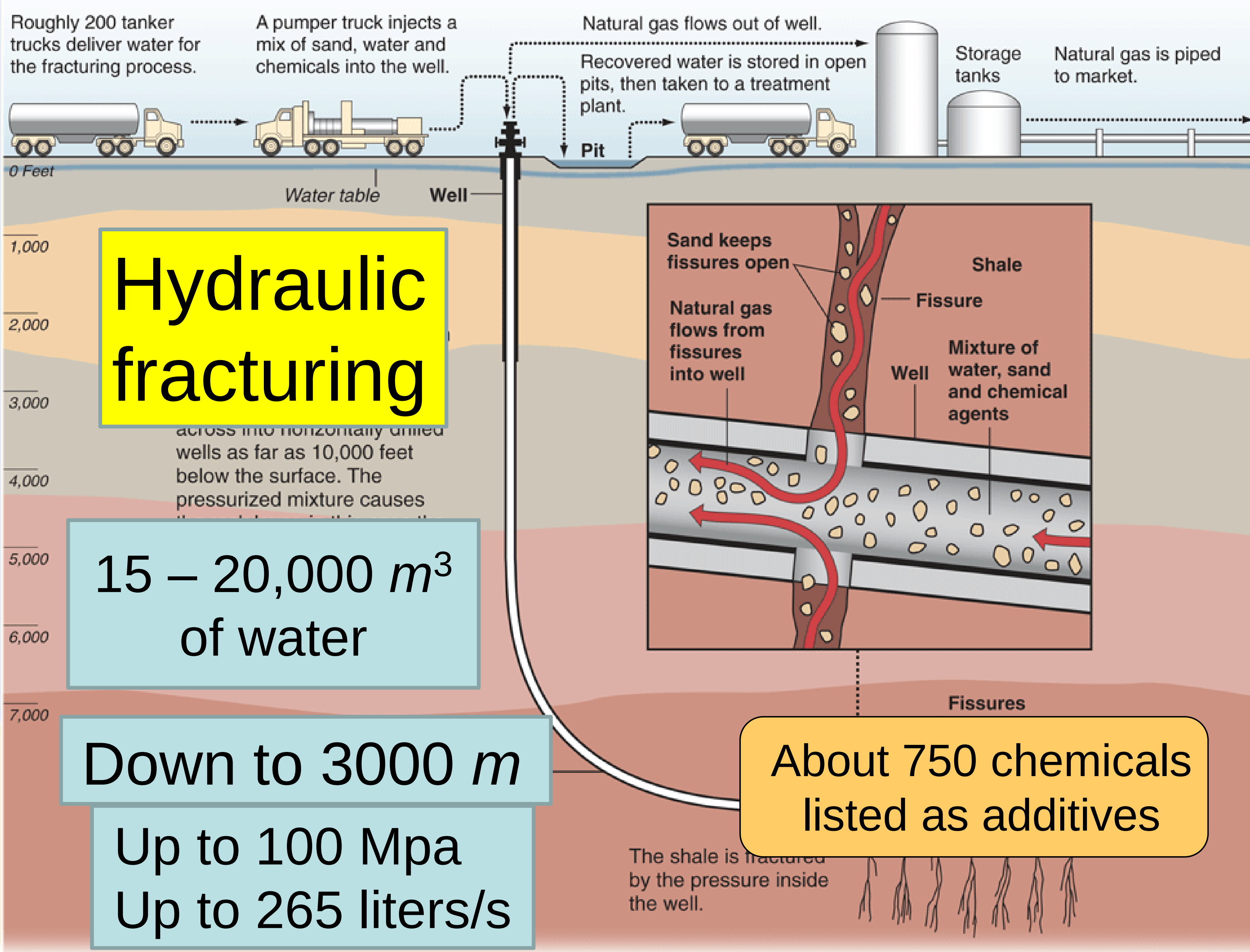
Hydraulic fracturing

15 – 20,000 m^3 of water

Down to 3000 m

Up to 100 Mpa
Up to 265 liters/s

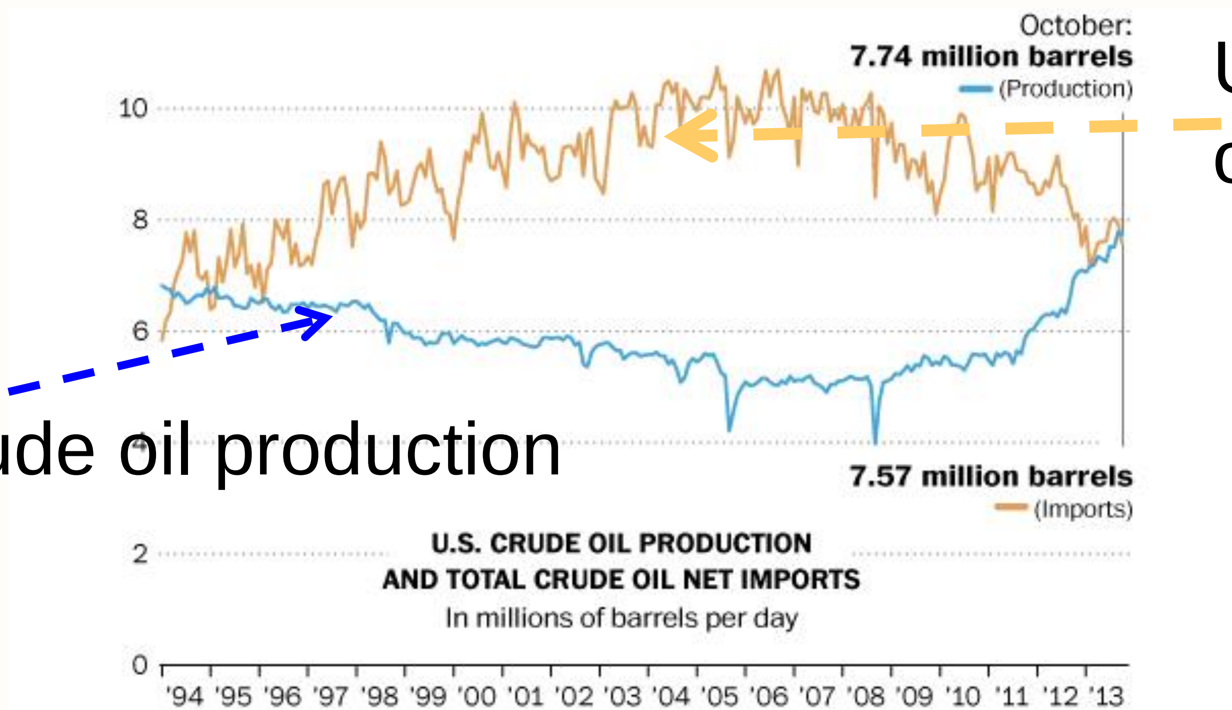
About 750 chemicals listed as additives



Graphic by Al Granberg

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

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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

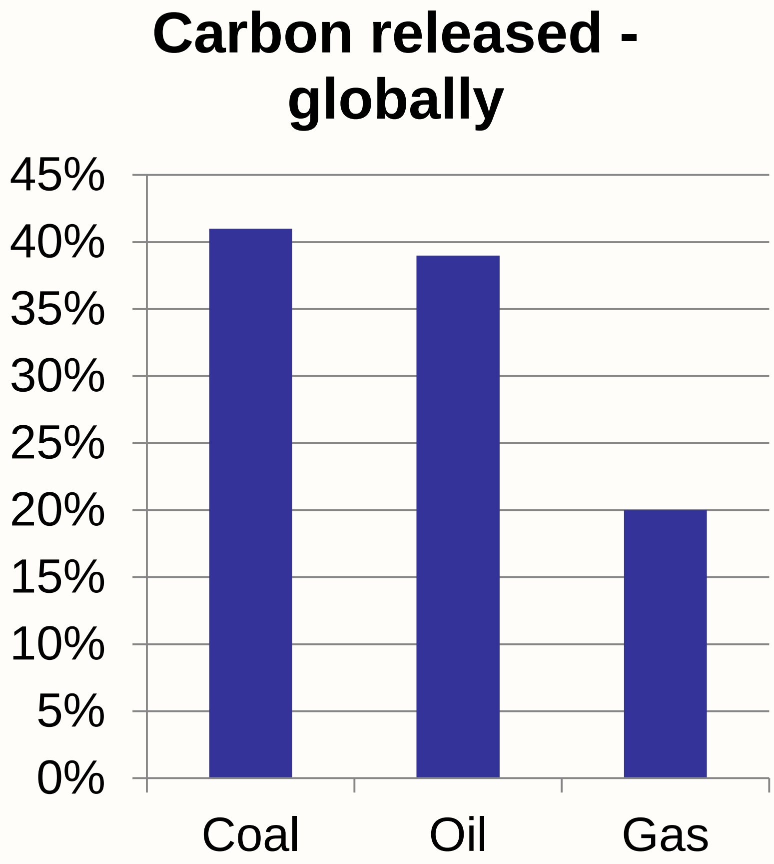
- **Groundwater is sold to the oil company instead of being used for irrigation**
- **Conflict between energy and food!**

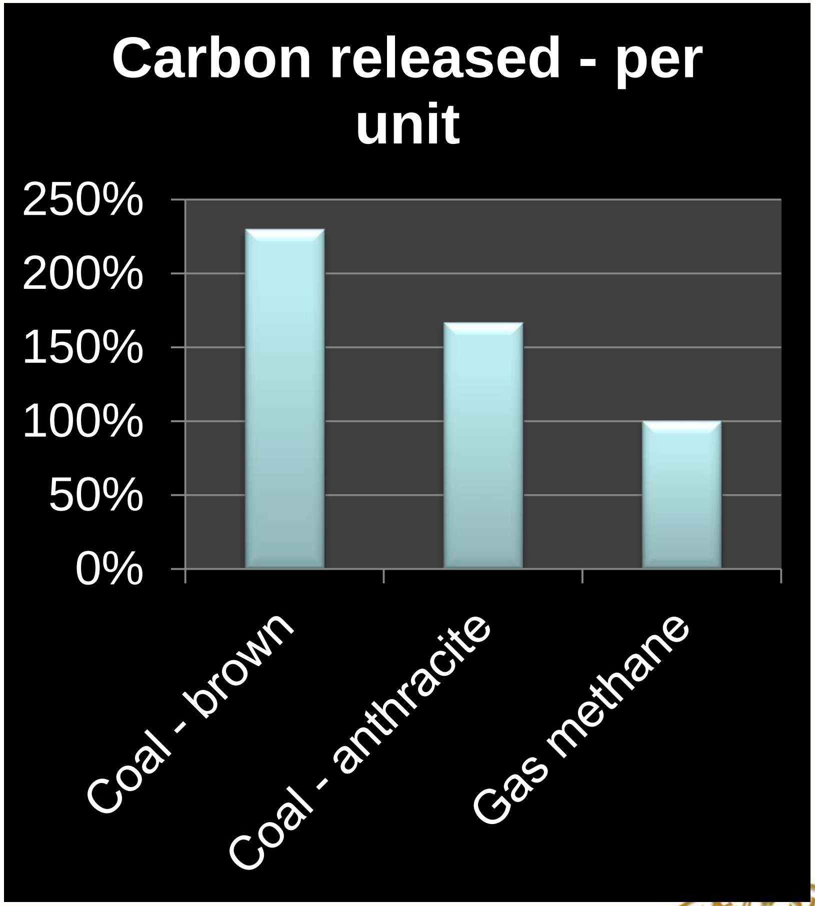
In the Barnett Shale (Texas) drillers paid 0.06 cents/m^3

The fracking controversy

Pennsylvania, USA 2011
Source: Nat. Geographic

Coal vs. natural gas





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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)

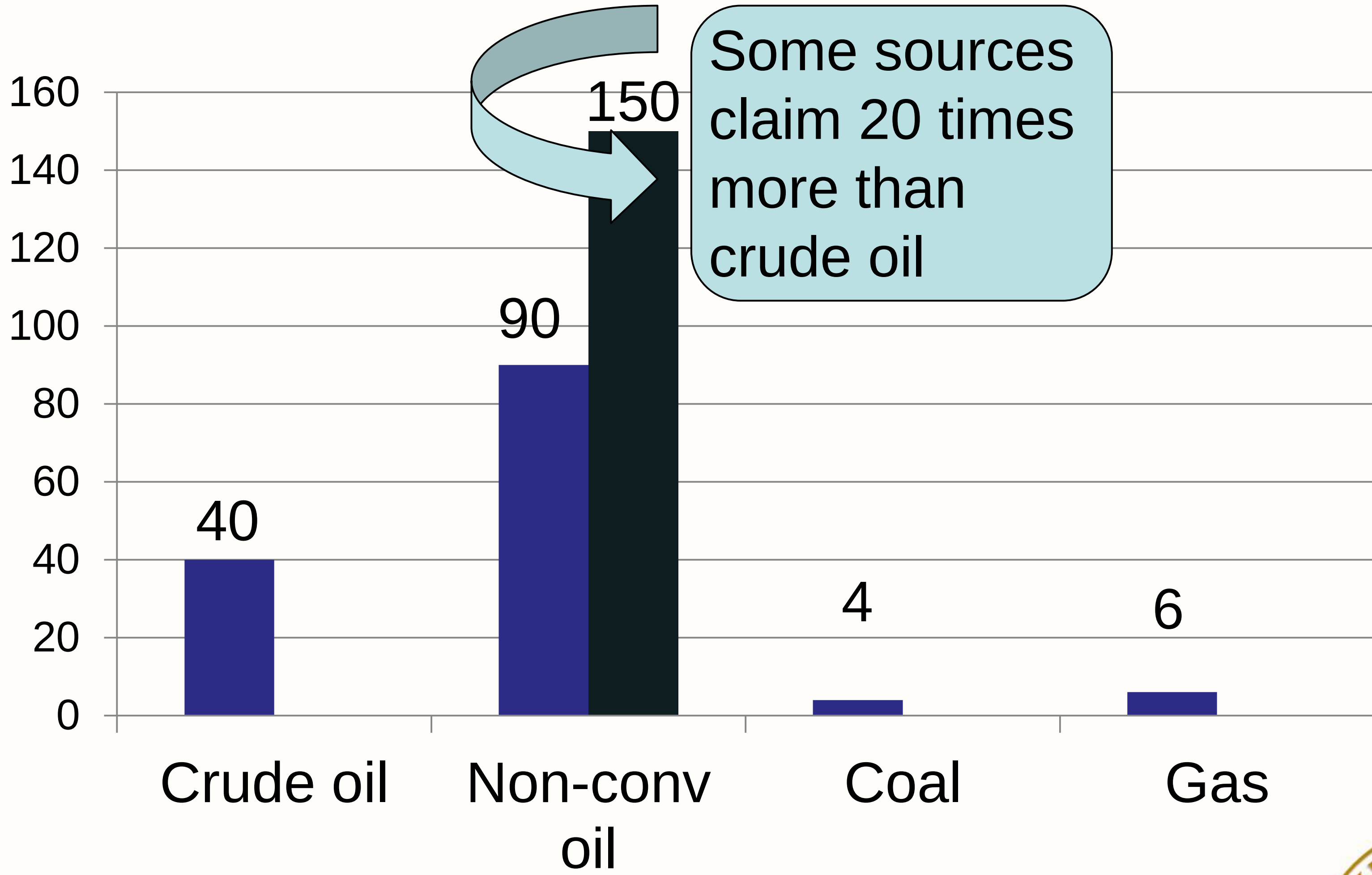
- Water consumption 3 times larger than crude oil
- Energy for production from natural gas

”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

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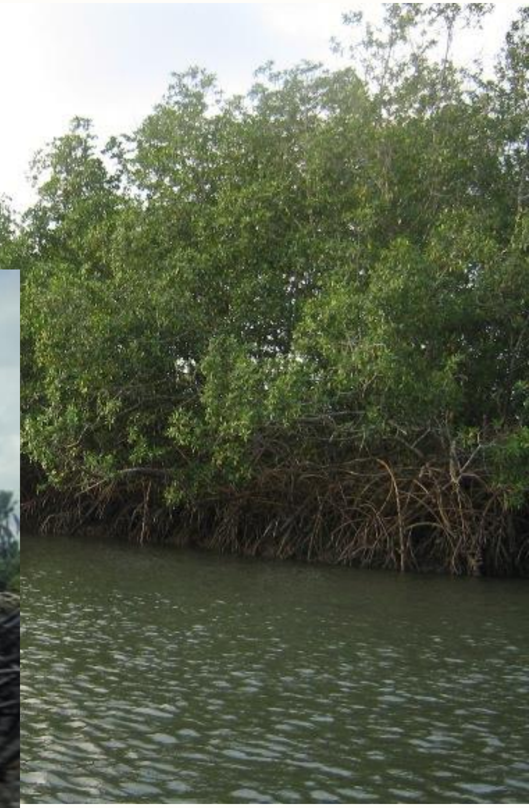
Remember some oil accidents

- **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….)

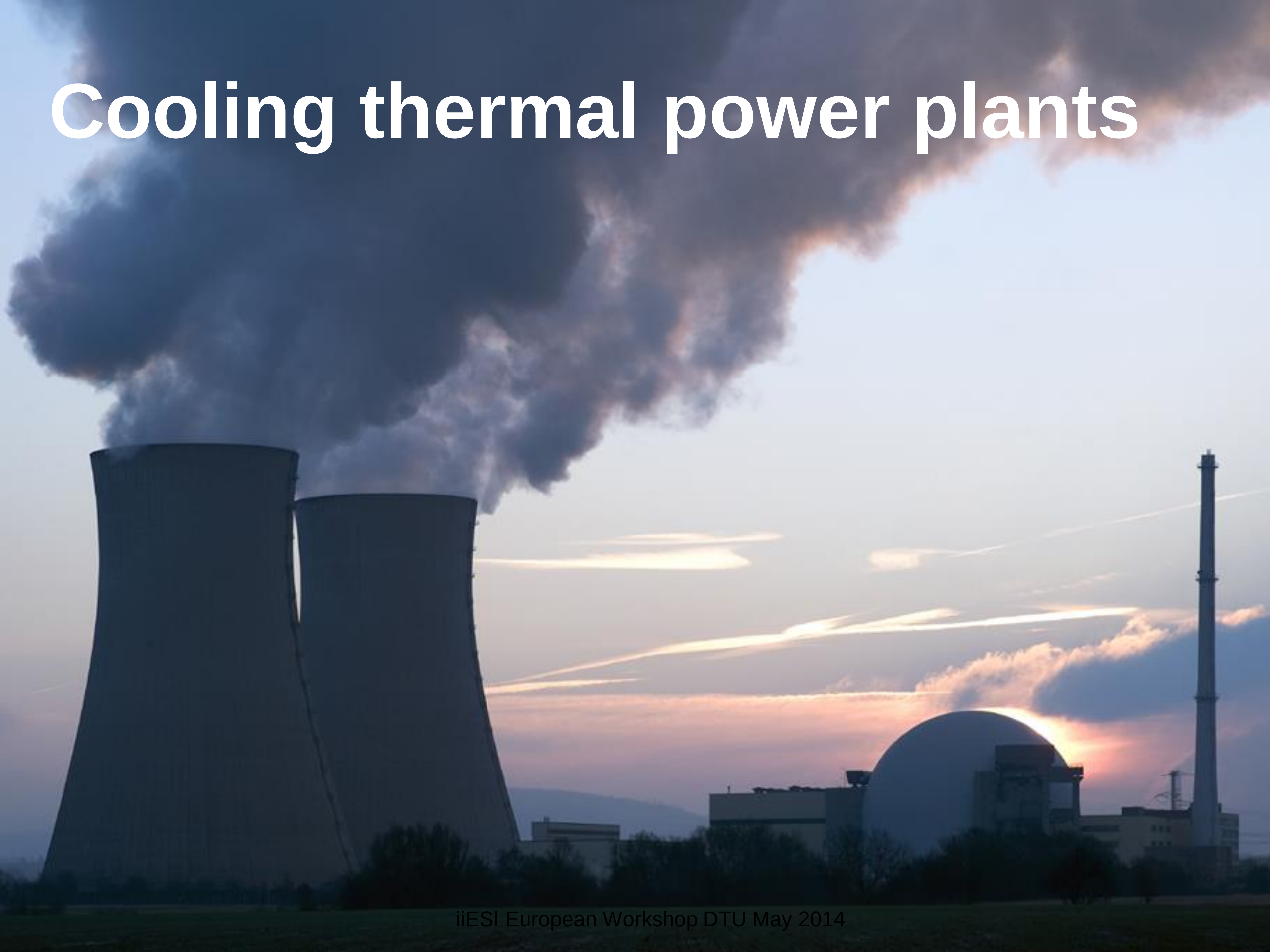
Niger Delta wetland



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

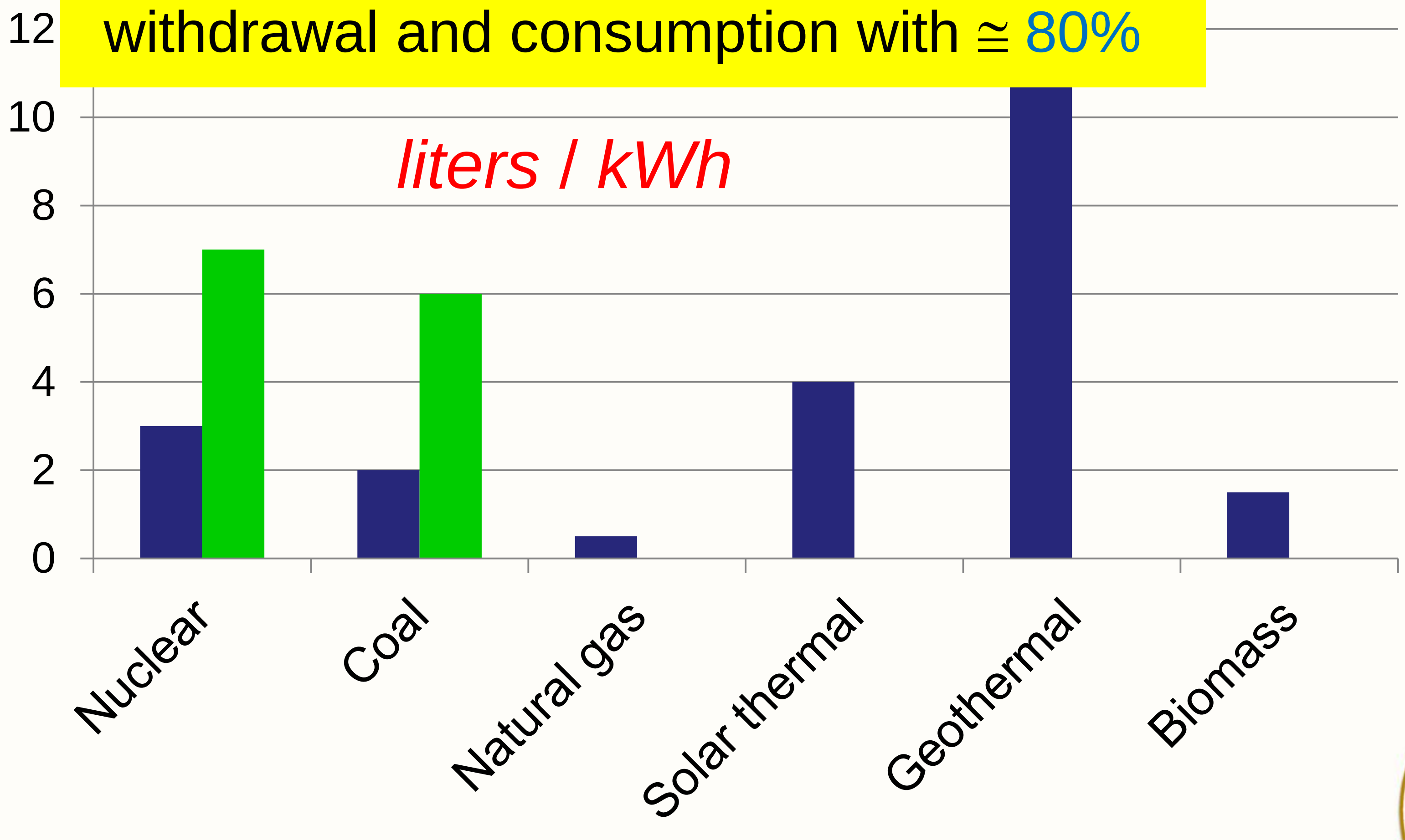
Out of the 33 m^3/s around 0.5 m^3/s is **consumed** (evaporated)

In Sweden we use around 150 liters/day/person

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

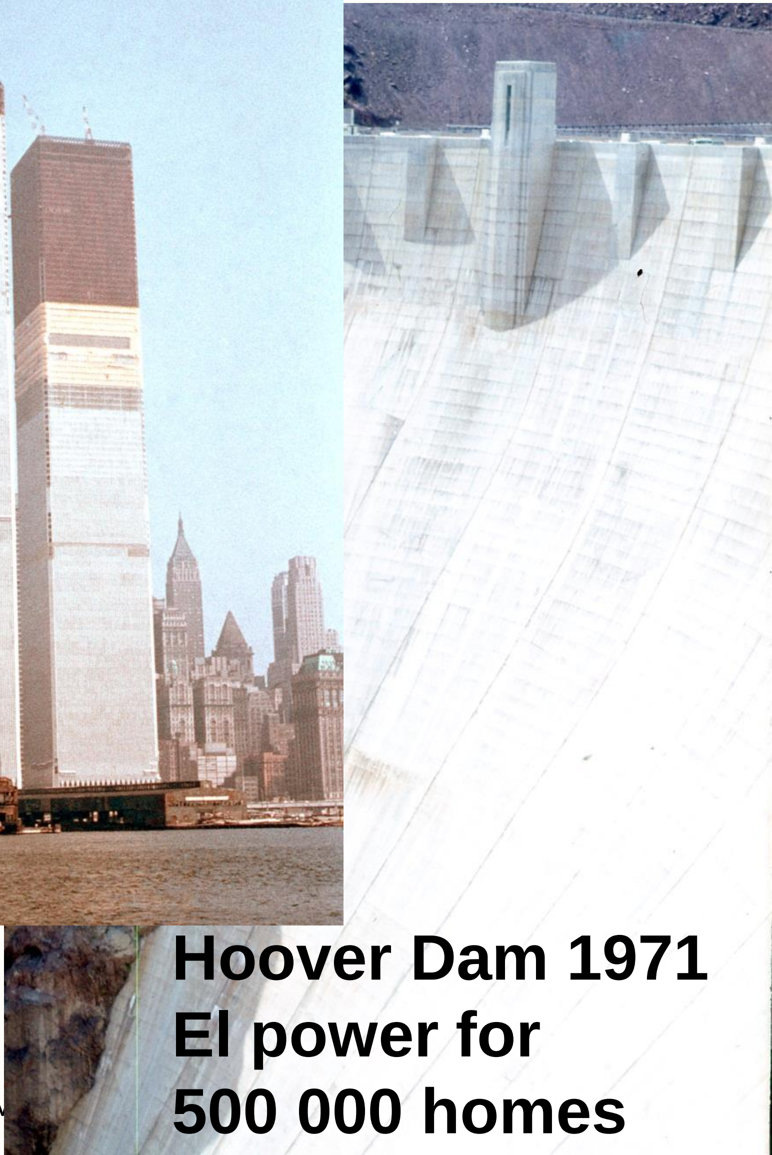
Water consumption in electrical generation

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




Hydropower

World Trade Center 1971



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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

Rationale to build dams

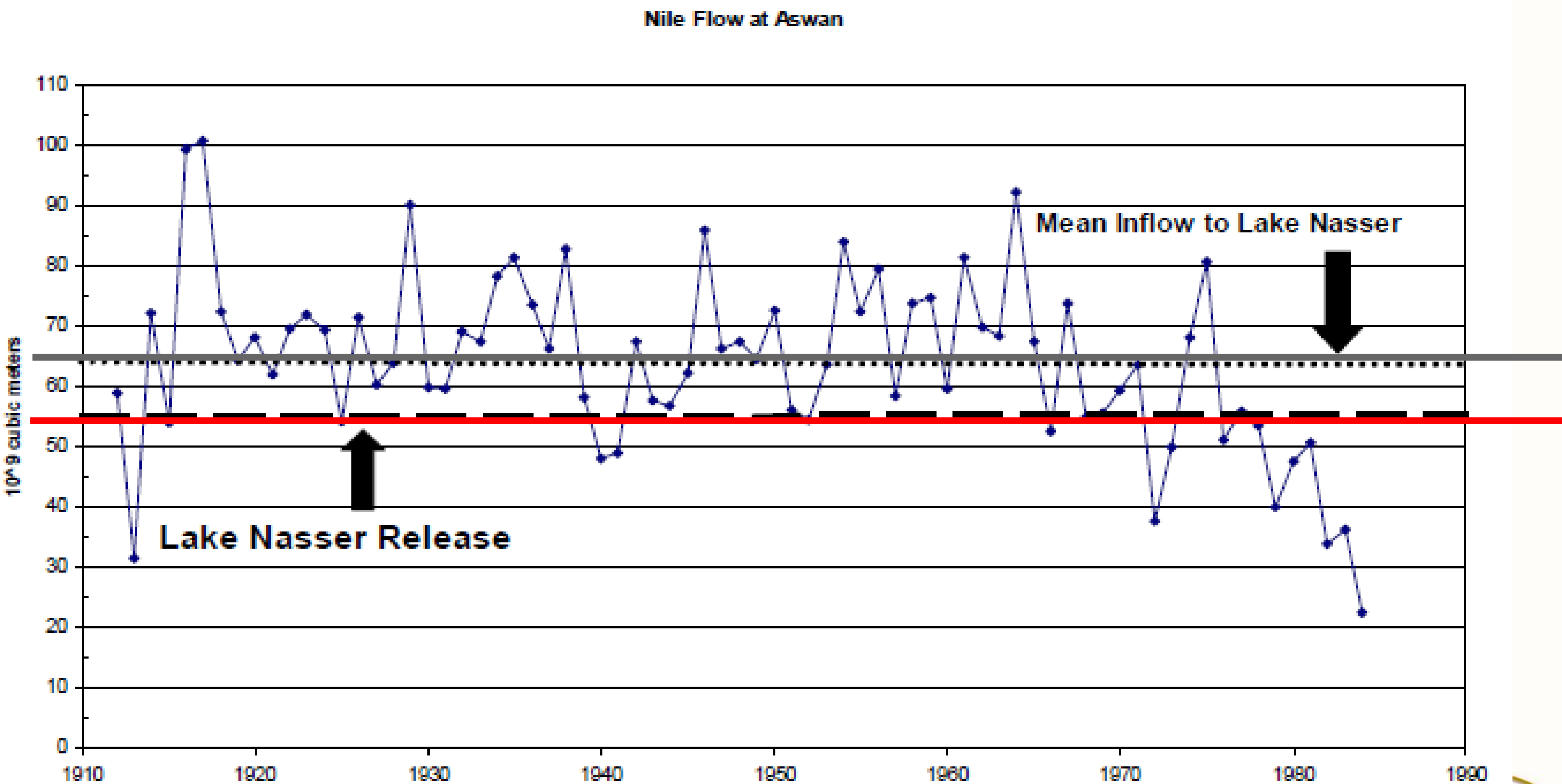
- **Hydropower generation**
- **Flood control**
- **Water storage for irrigation etc.**
- **Navigation**

Today 45 000 dams
$\cong$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



1910

1990

Source:
Strzepek et al. 2013

Evaporation (total)

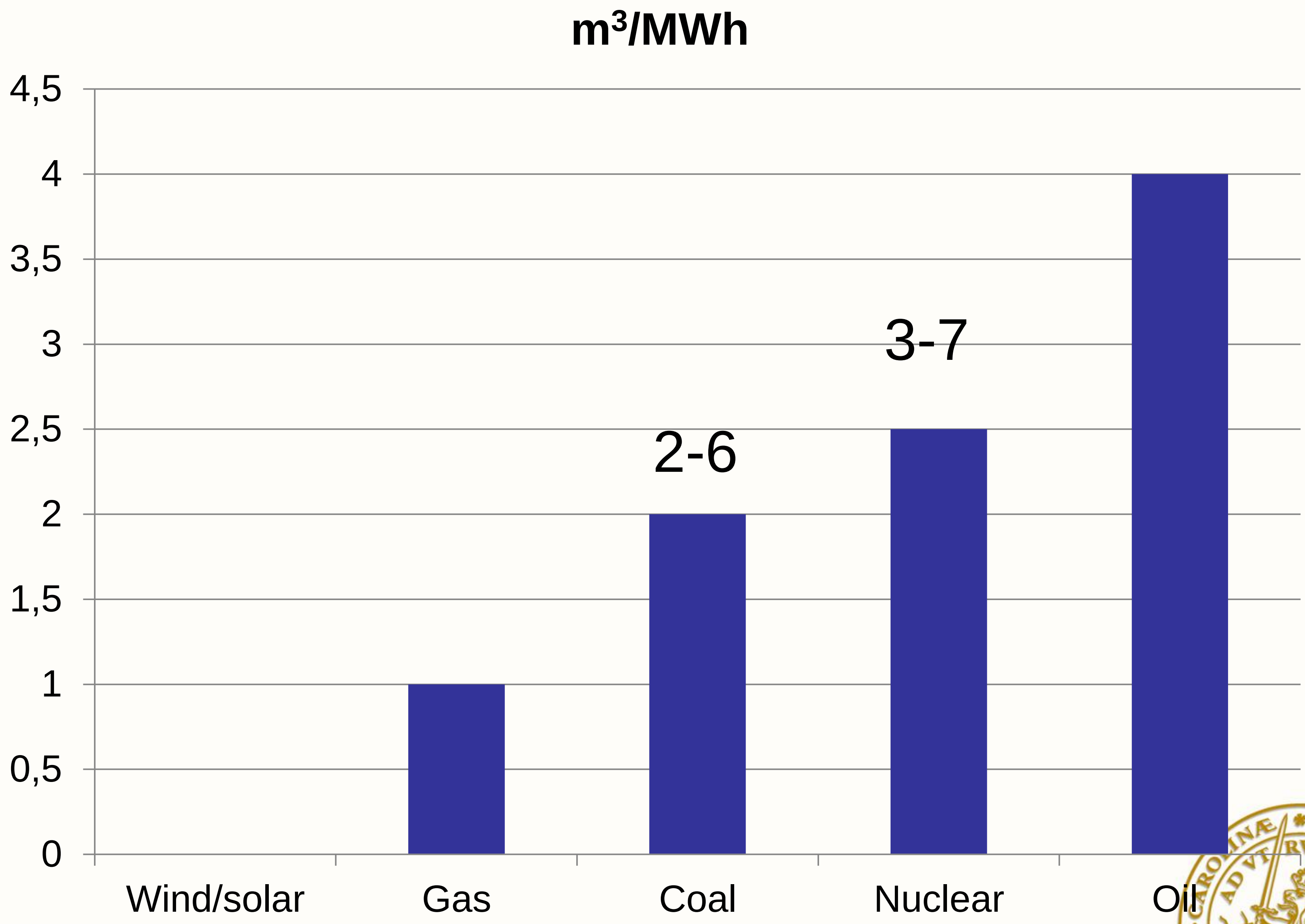
	ha/MW	Evaporation mm/year	Evaporation Gm^3/year	liters/kWh
Akosombo **Ghana**	720	2185	19	3000
Sobradinho, **Brazil**	400	2841	12	1430
Bayano, **Panama**	233	2156	0.75	1370
Itezhi Tezhi, **Zambia**	62	2572	0.95	338
Robert Bourossa, **Canada**	36	586	1.7	30
San Carlos, **Colombia**	0.26	1726	0.01	1

Source: Mekonnen & Hoekstra 2012

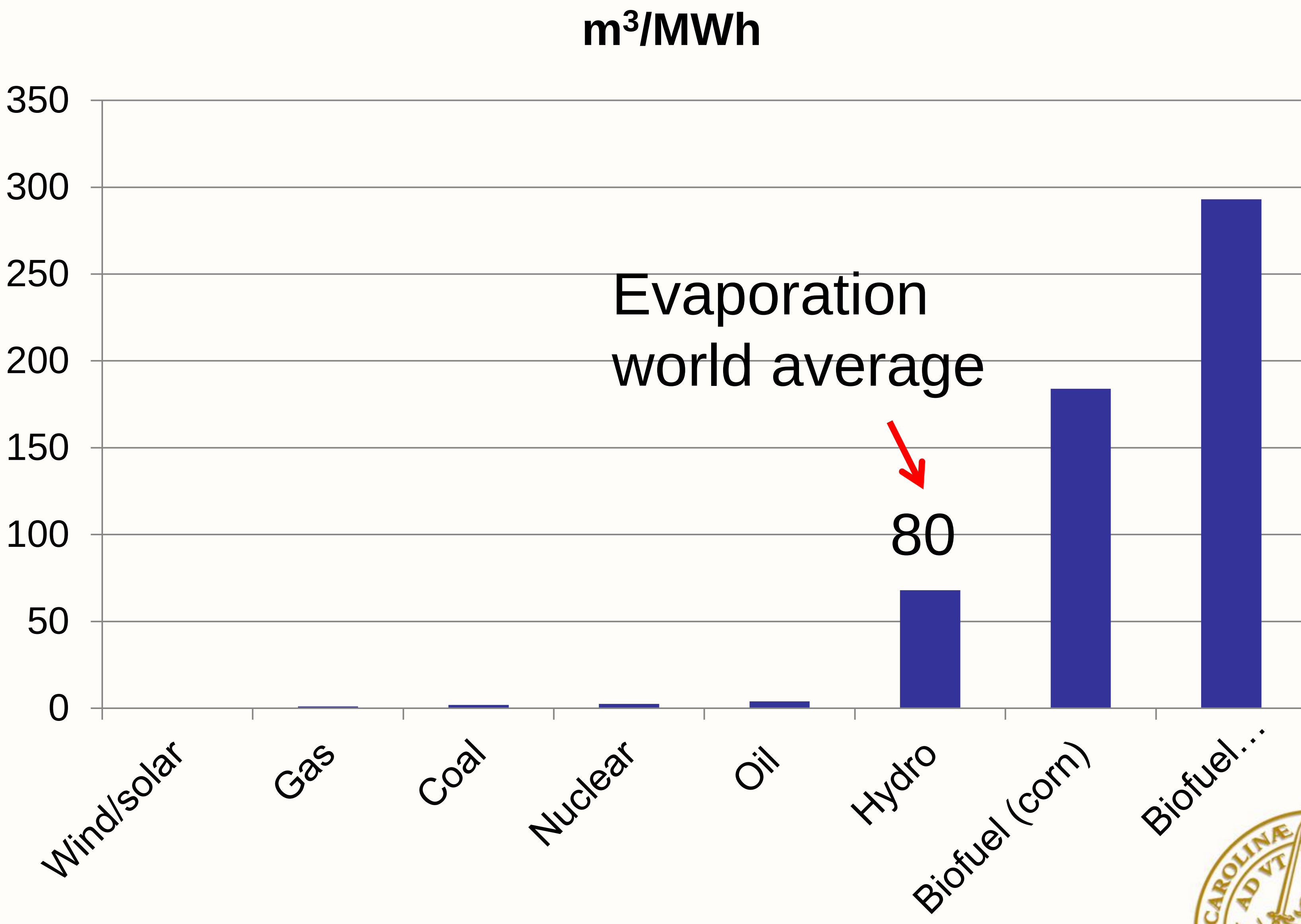
Range of evaporation

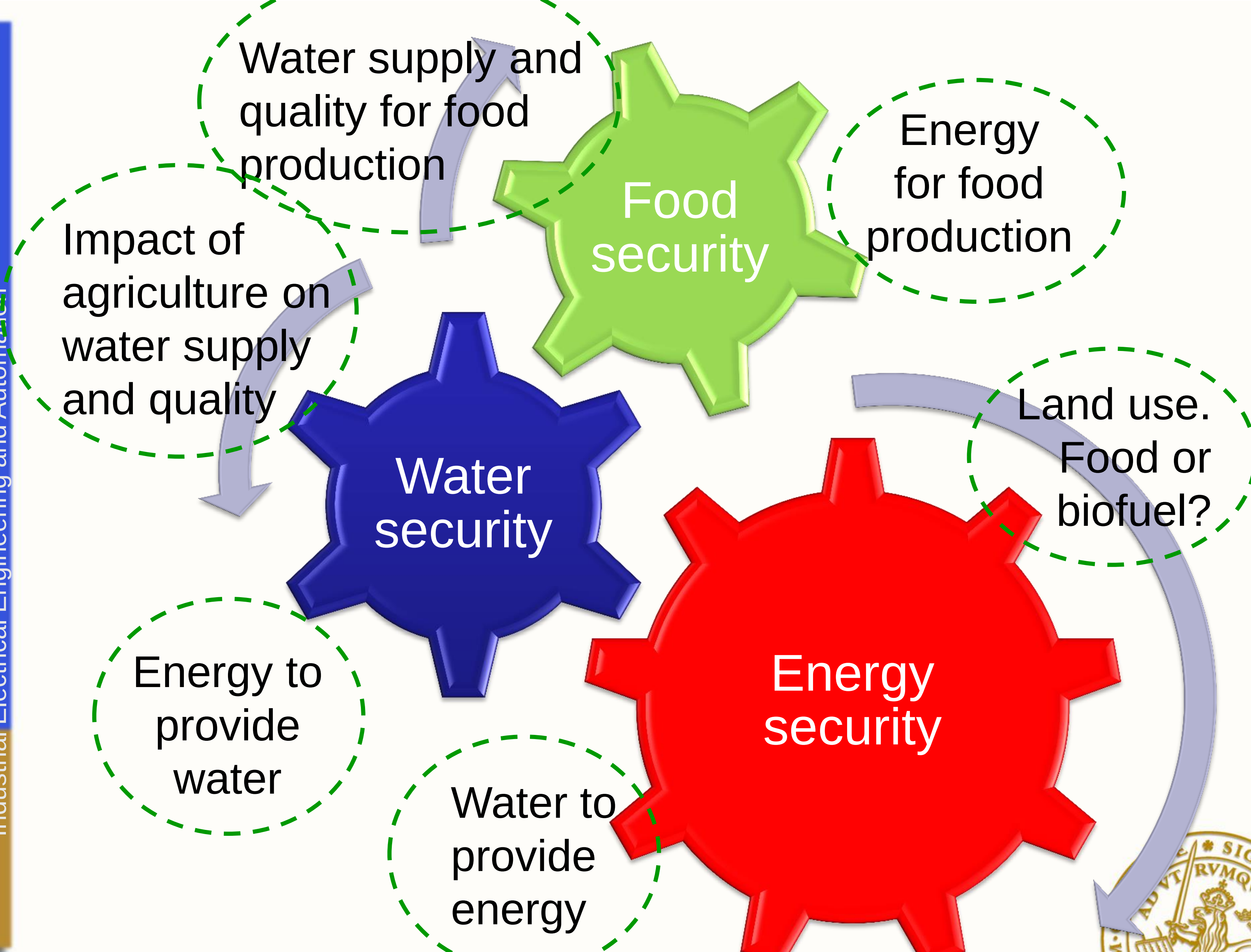
Locations	Range liters/kWh	Average liters/kWh	Reference
Selected 35 plants globally	1-3000	240	Mekonnen-Hoekstra 2012
New Zealand	3 – 115		Herath *et al*. 2011
California	0.04 – 200	5.4	Gleick (1993) DOE (2006)
USA, Switzerland, Tanzania	1 – 610		Pfister *et al.* 2011
USA average	---	17	Atlantic Council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

Number of m^3 to produce 1 *MWh*



Number of m^3 to produce 1 *MWh*




Water supply and quality for food production
Energy for food production
Food security
Impact of agriculture on water supply and quality
Water security
Land use. Food or biofuel?
Energy security
Energy to provide water
Water to provide energy

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”)?

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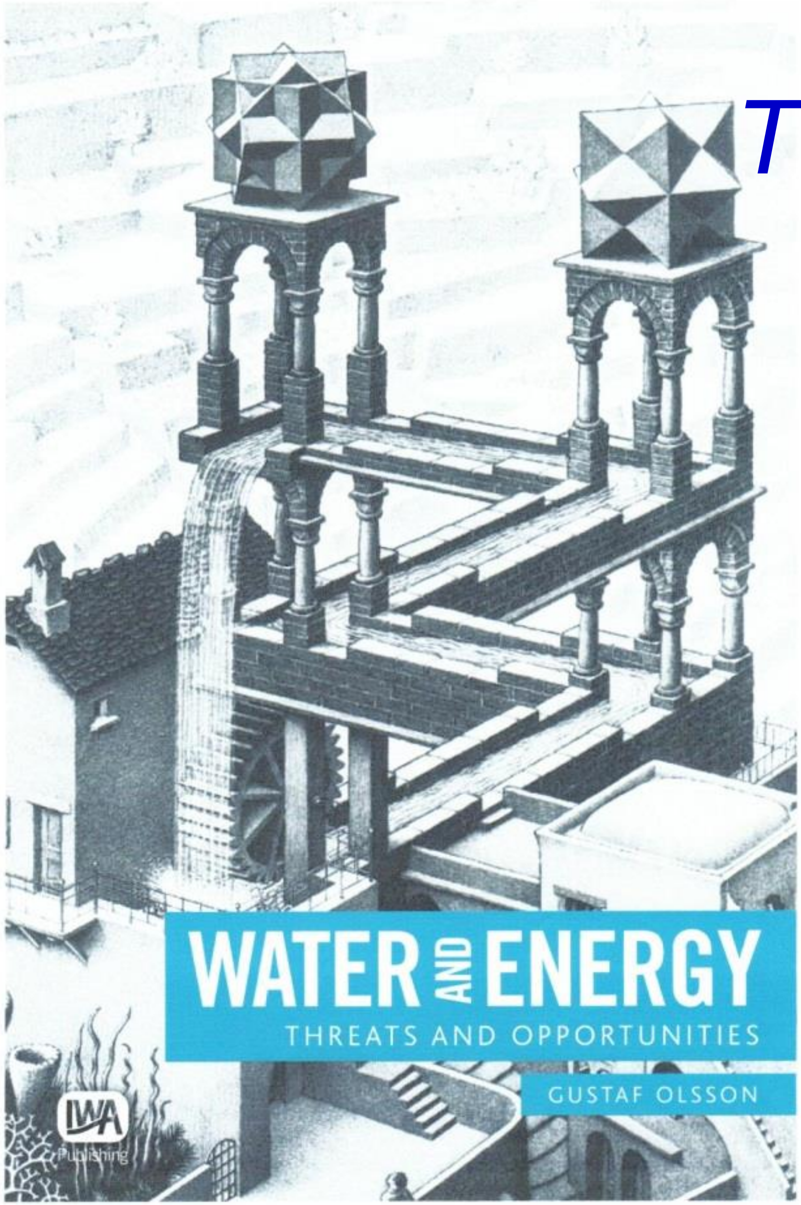

Thank you!

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