Water and energy

How energy is used in water cycle operations
How water is used in energy production

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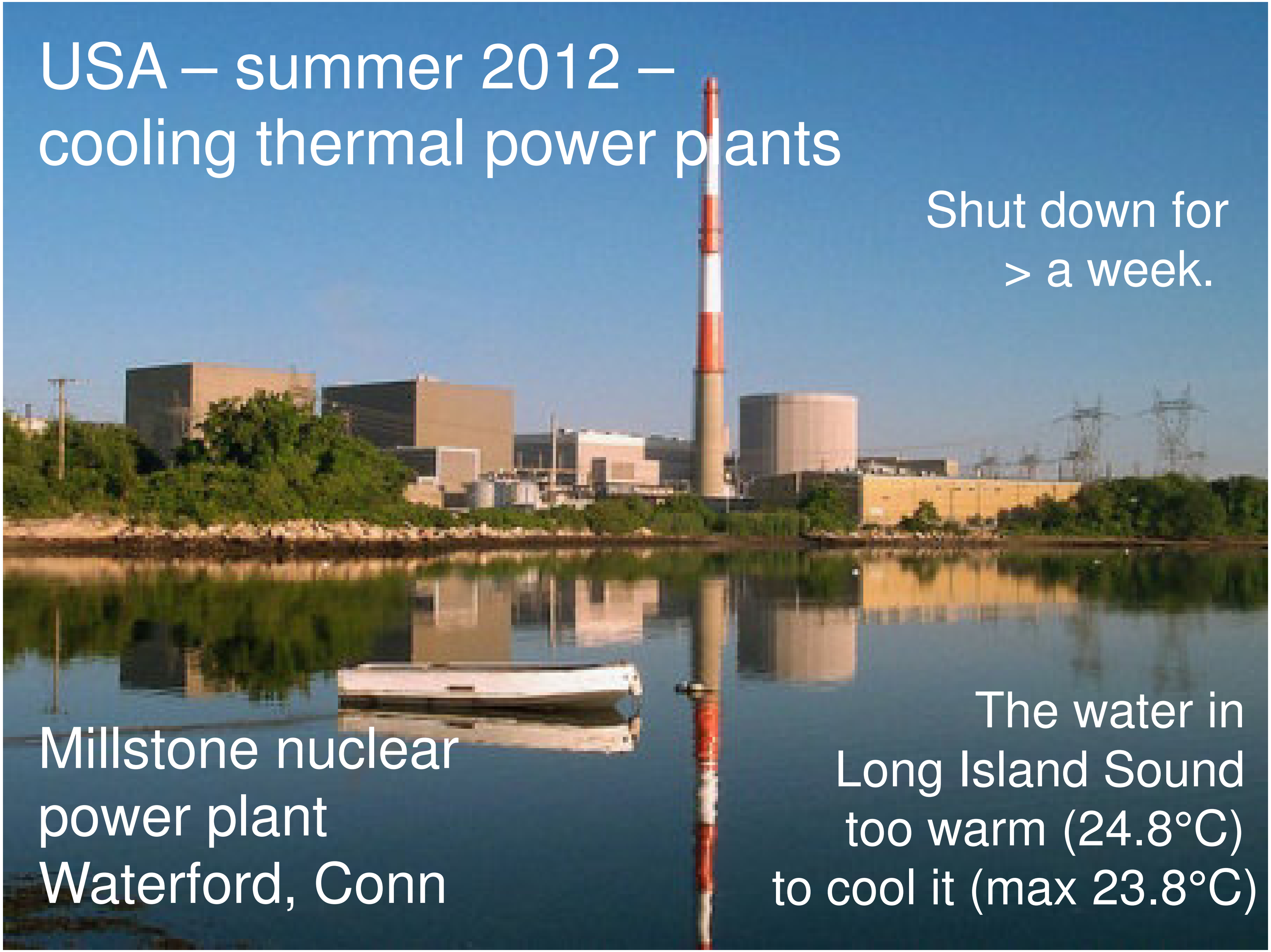
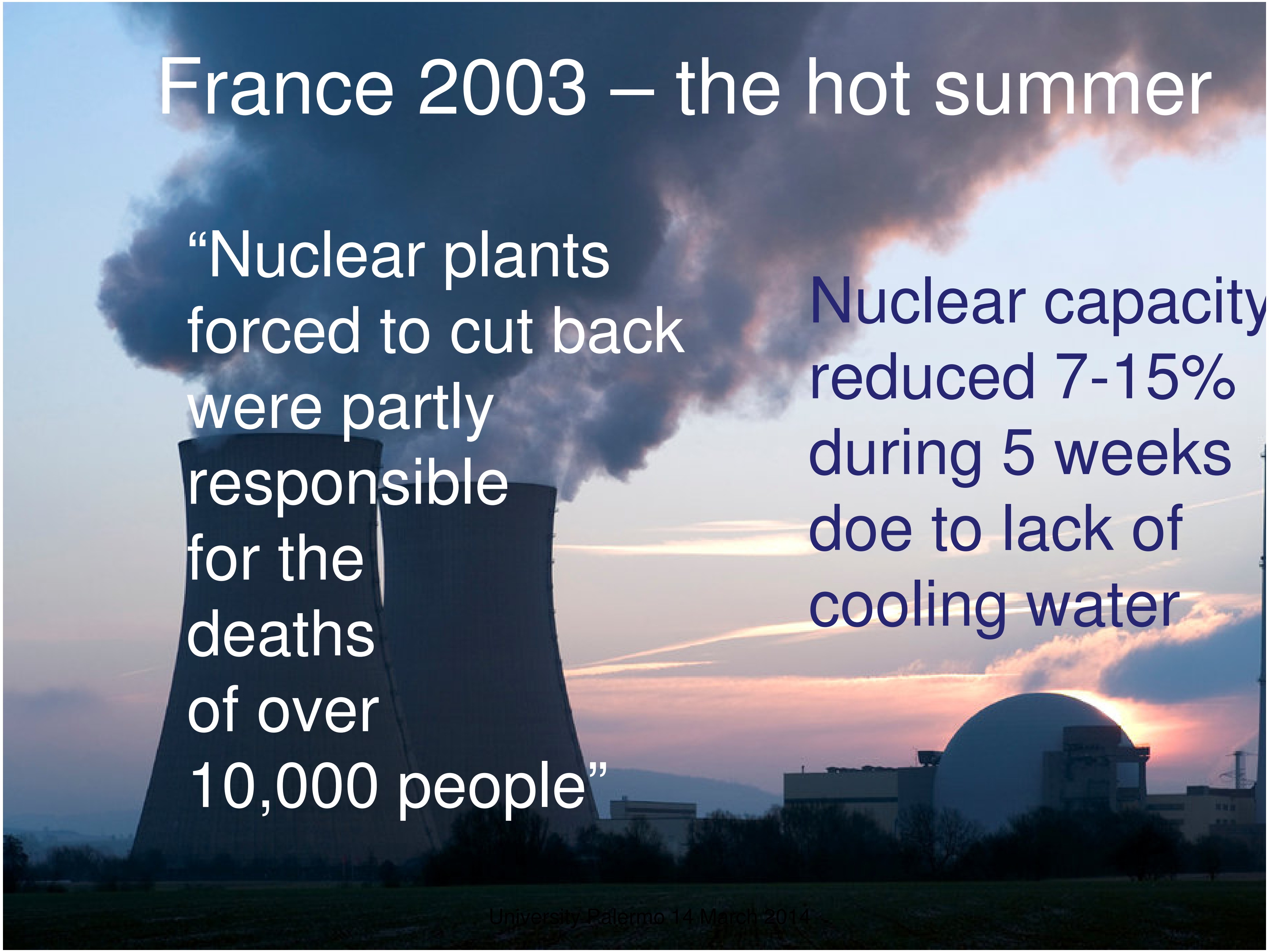
Università Degli Studi di Palermo, 14 March 2014

Content

- Setting the scene
- Energy in water operations
- Water in energy operations
  - Hydraulic fracturing
  - Cooling thermal power plants
  - Hydropower
- Out of the waterbox


The global energy challenge
depends on 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)


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
University Palermo 14 March 2014

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

Price of corn soared

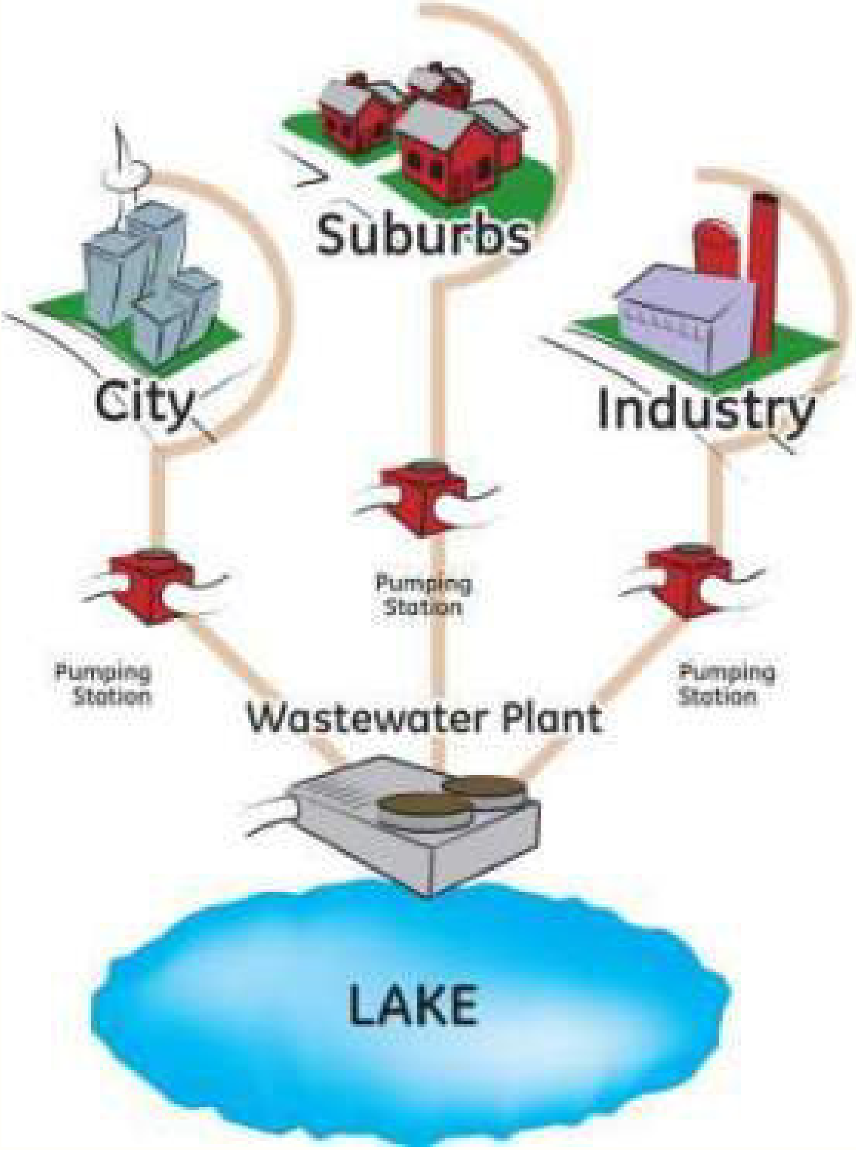
Corn for ethanol or for food?

World Energy Outlook 2012

International Energy Agency (IEA)

- ***The water need for energy production will be increasingly important***
- **15% of the water use is related to energy production (2010)**
- **55-60% of the water use for energy is related to coal**
- **Water availability – a limiting factor for electric power and for biofuel, for example in China, USA, Iraq, India and South Africa**

Energy for the urban water cycle



1-3% of a city's energy demand is used to produce, treat & transport water.

15-20% to USE the water

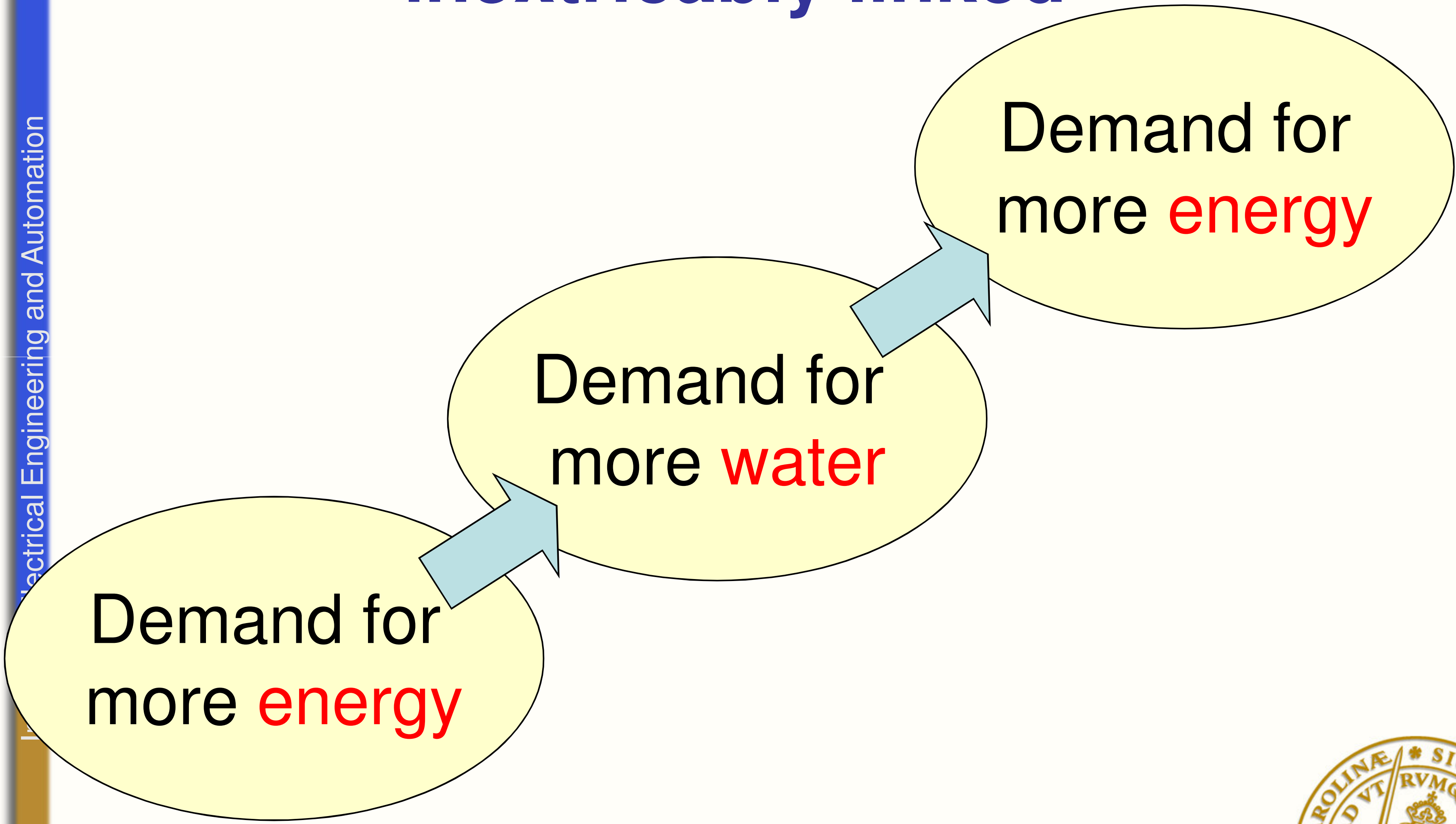
Source: General Electric

Energy - treating impaired water

Requires more advanced technology and more energy

Reused, brackish, sea water

Water and Energy – inextricably linked



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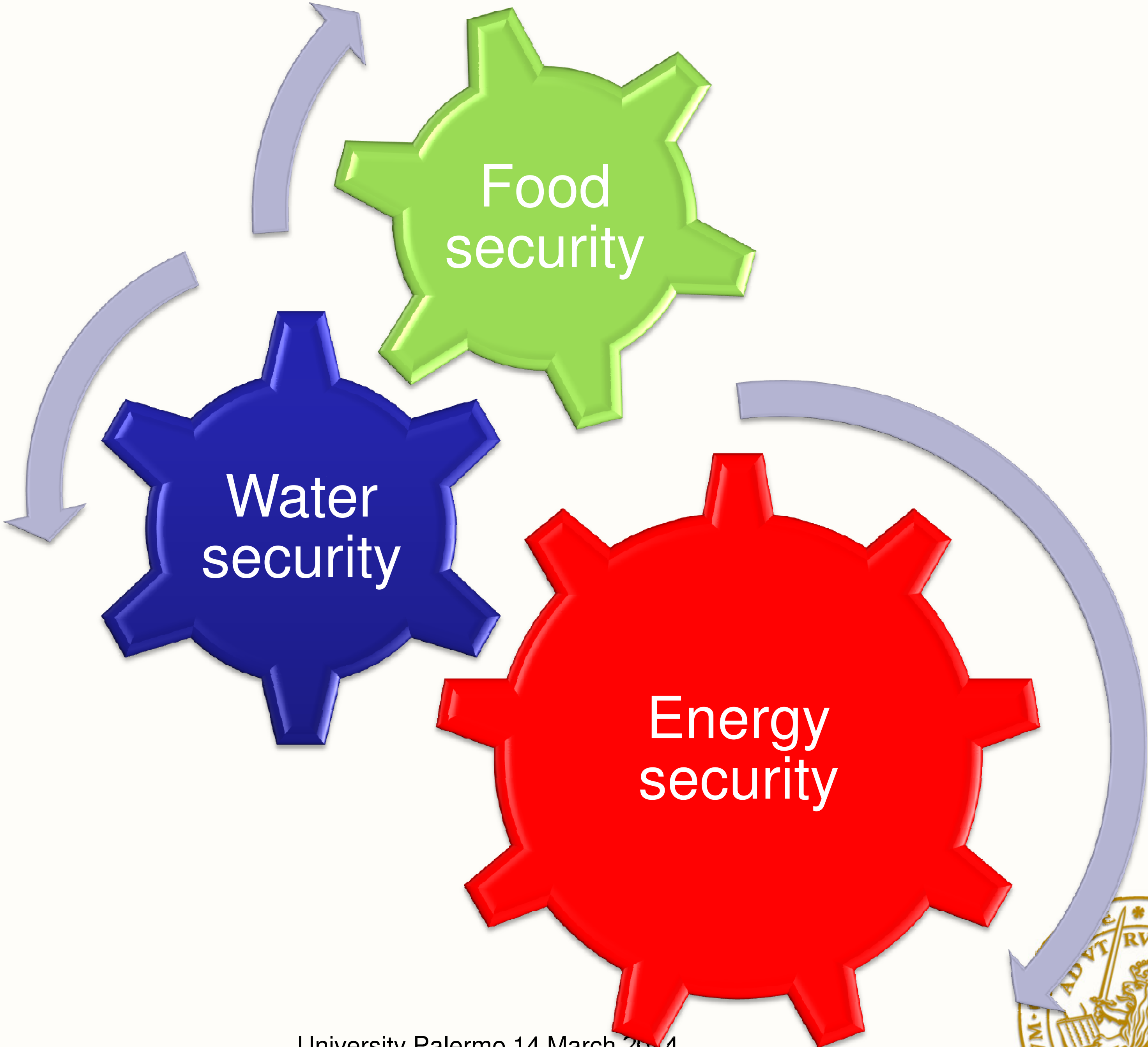

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- **Setting the scene**
- **Energy in water operations**
- **Water in energy operations**
  - **Hydraulic fracturing**
  - **Cooling thermal power plants**
  - **Hydropower**
- **Out of the waterbox**

Energy cost to produce cold water

	kWh / m^3
Surface water	0.25 - 3
Recycled water	1 - 6
Desalination	4 - 8
Bottled water	1000 - 4000

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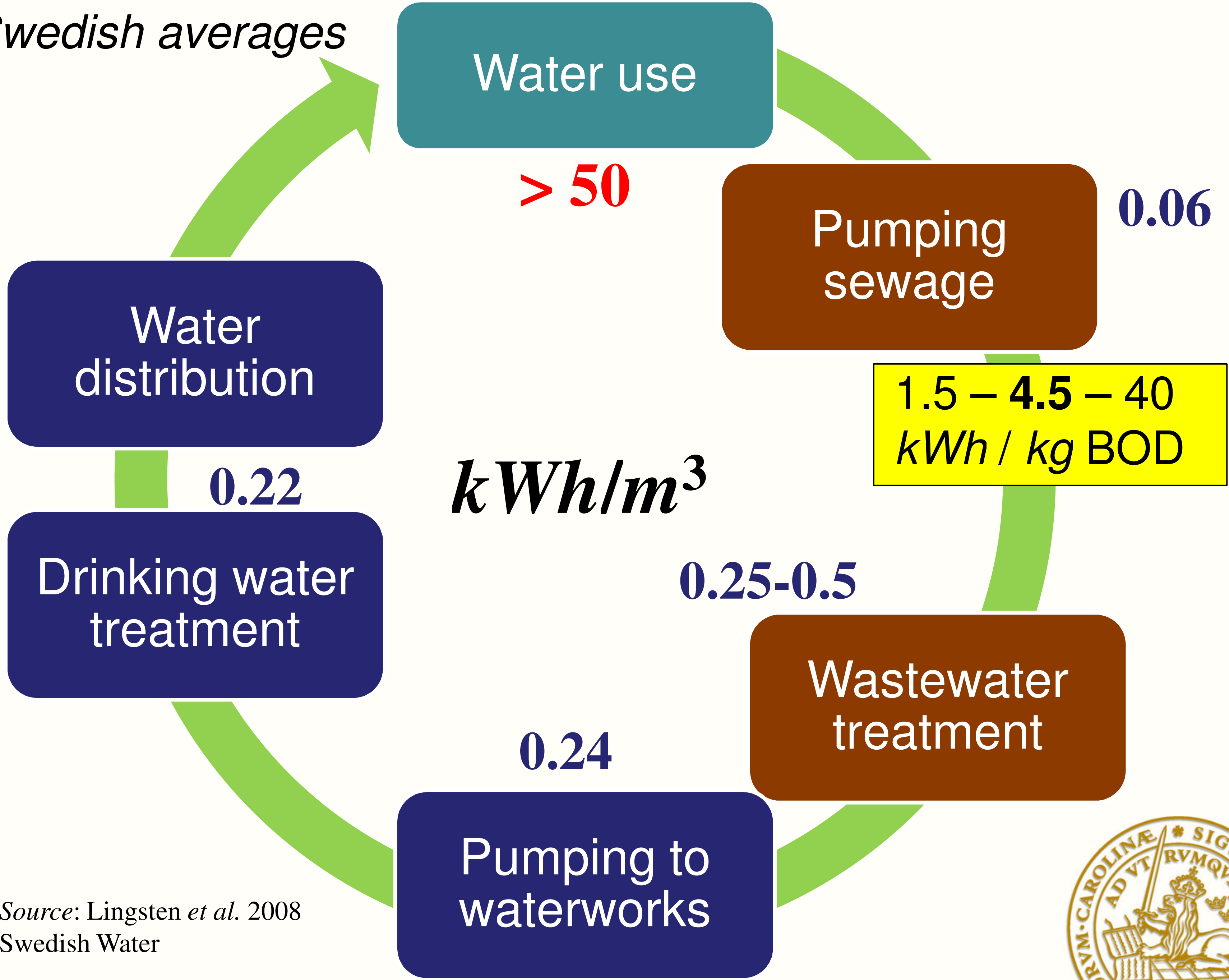
Swedish averages



Source: Lingsten *et al.* 2008
Swedish Water

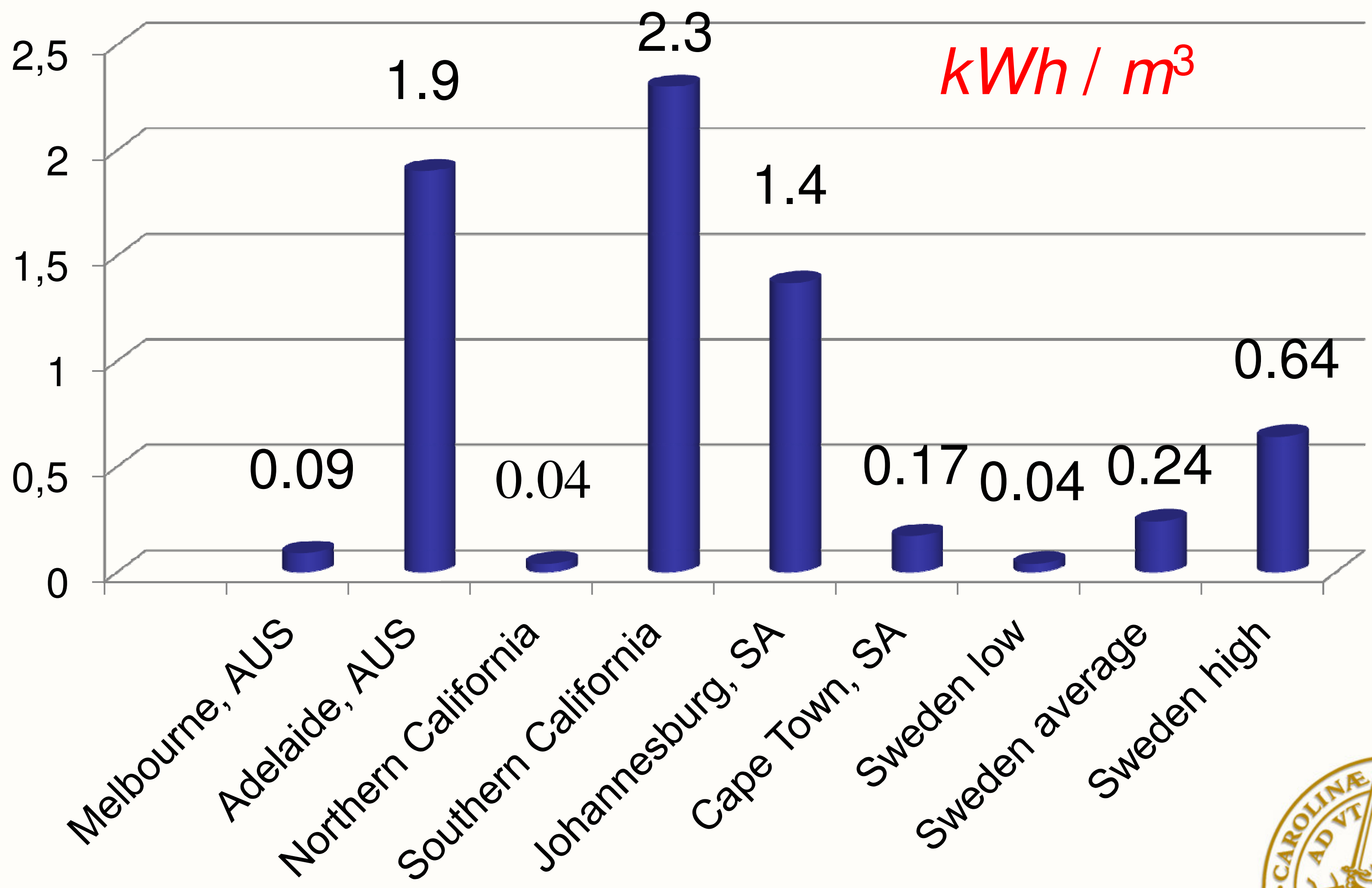
Clean Water Requires Energy!

- **Pumping**
  - **Having 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**

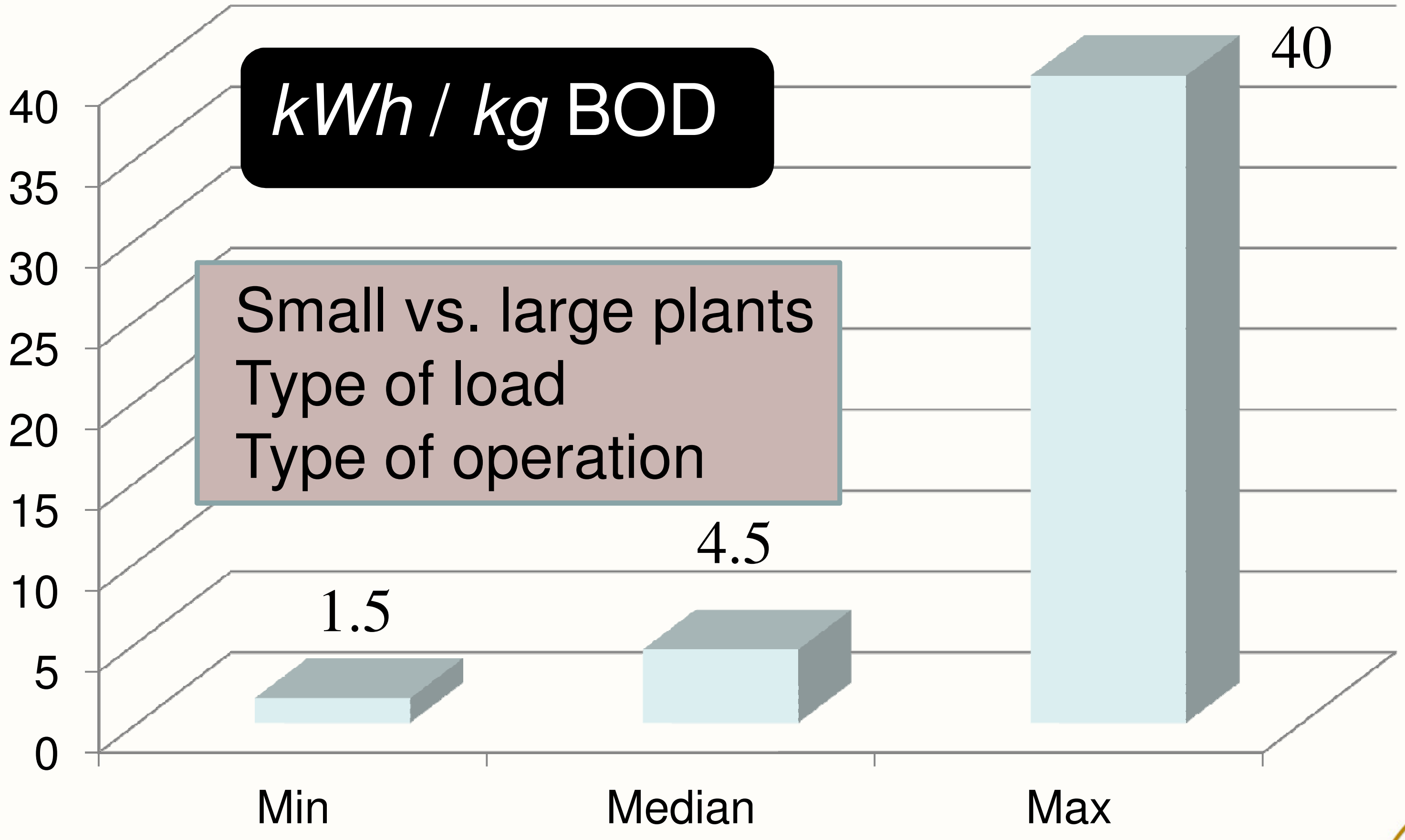
Increase efficiency!

Minimize air flow!

Pumping from source to waterworks



Wastewater treatment Sweden



Source: Lingsten *et al.* 2008
Swedish Water

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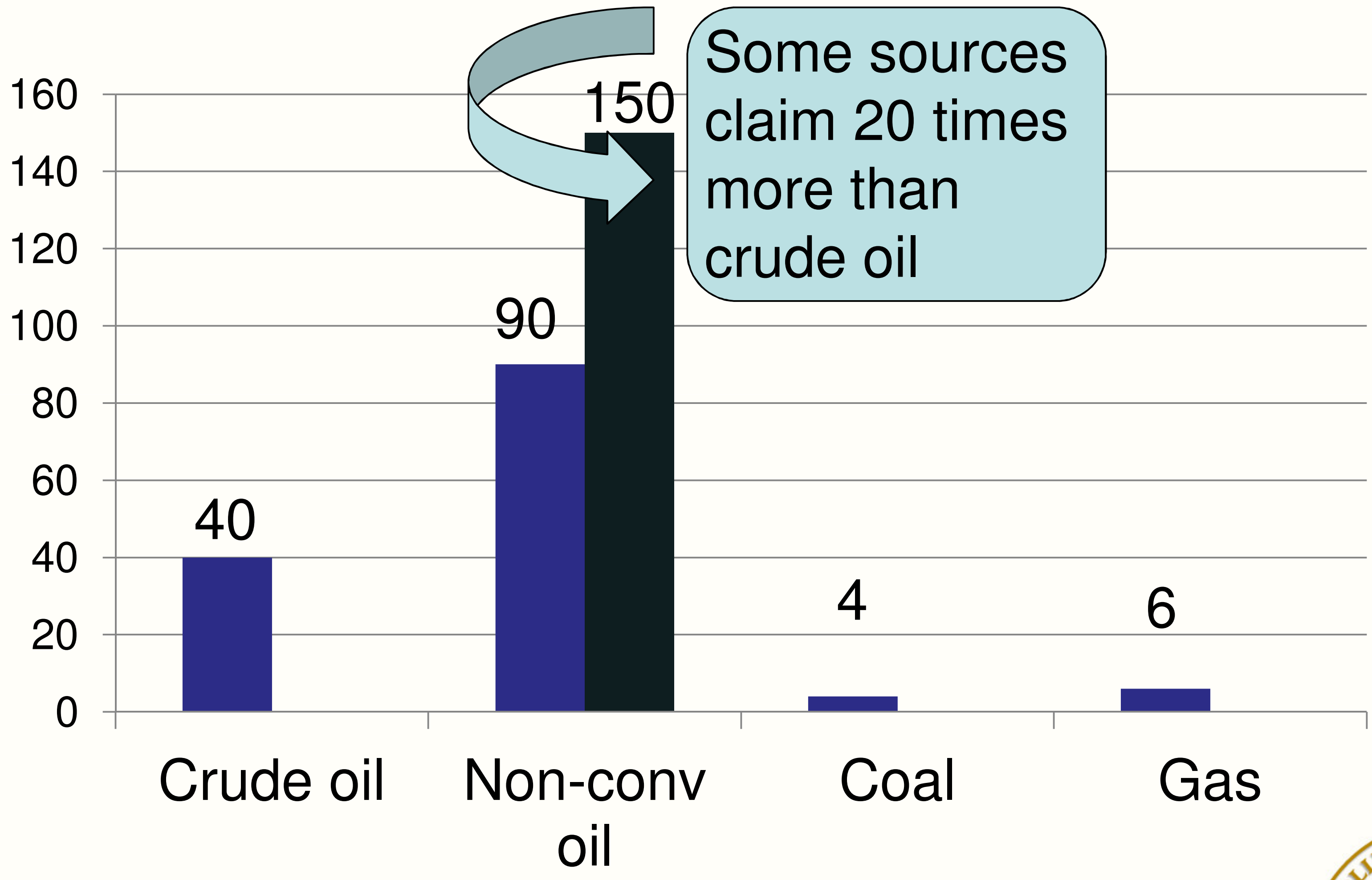
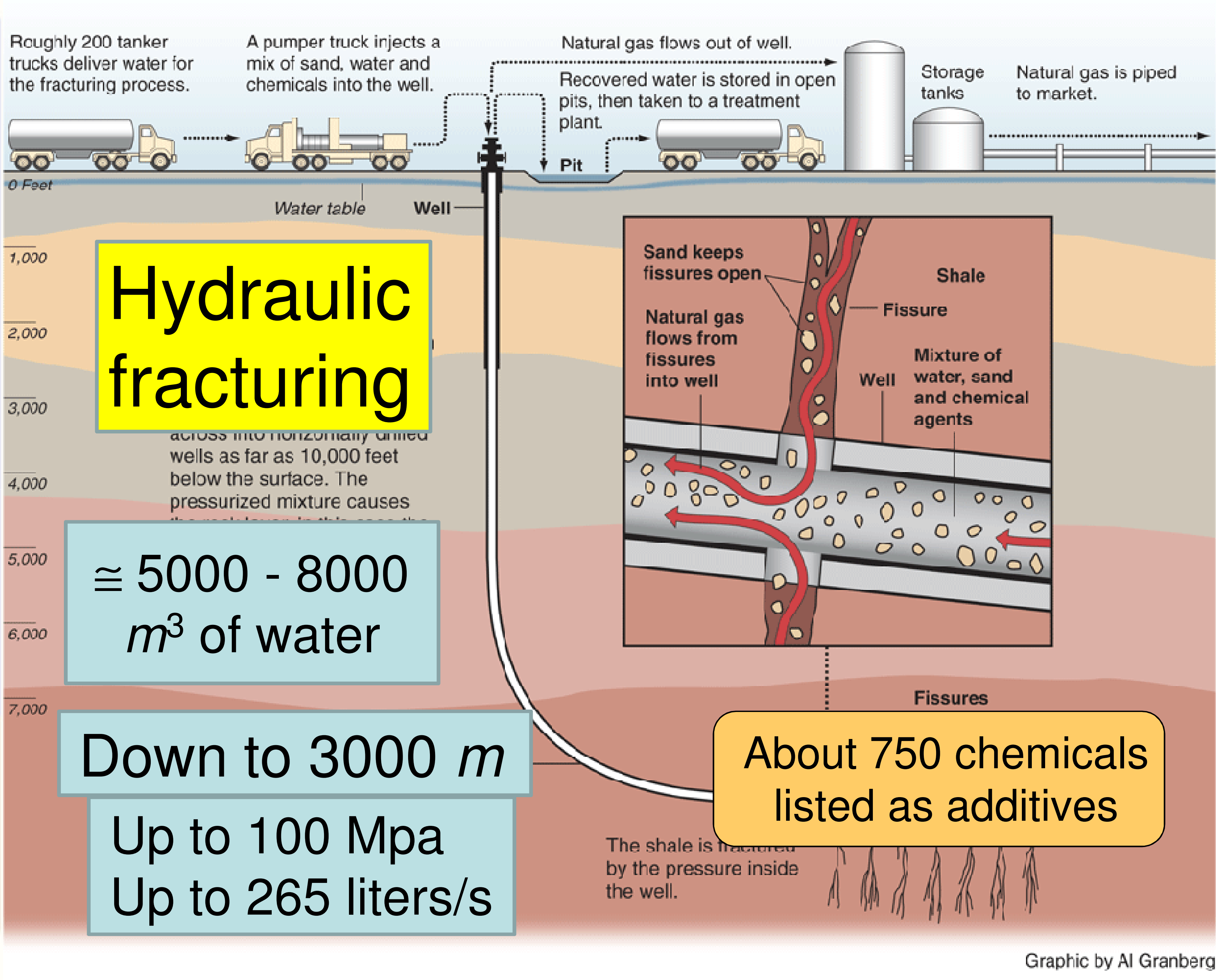
Water consumption per *liter* or *kg*



Source: World Energy Council, 2010

Hydraulic fracturing



≅ 5000 - 8000 m^3 of water

Down to 3000 *m*

Up to 100 Mpa

Up to 265 liters/s

About 750 chemicals listed as additives

Fracking 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)**
  - **Up to 8000 m^3 water**
  - **Up to 2000 tons of proppant**
  - **50+ m^3 (or 300+ barrels) of chemicals**

Risks in fracking

Water contamination:

- accidental spills during truck transportation
- leakages through cracked or corroded cement casing of the wells
- fugitive gas through the rock fractures

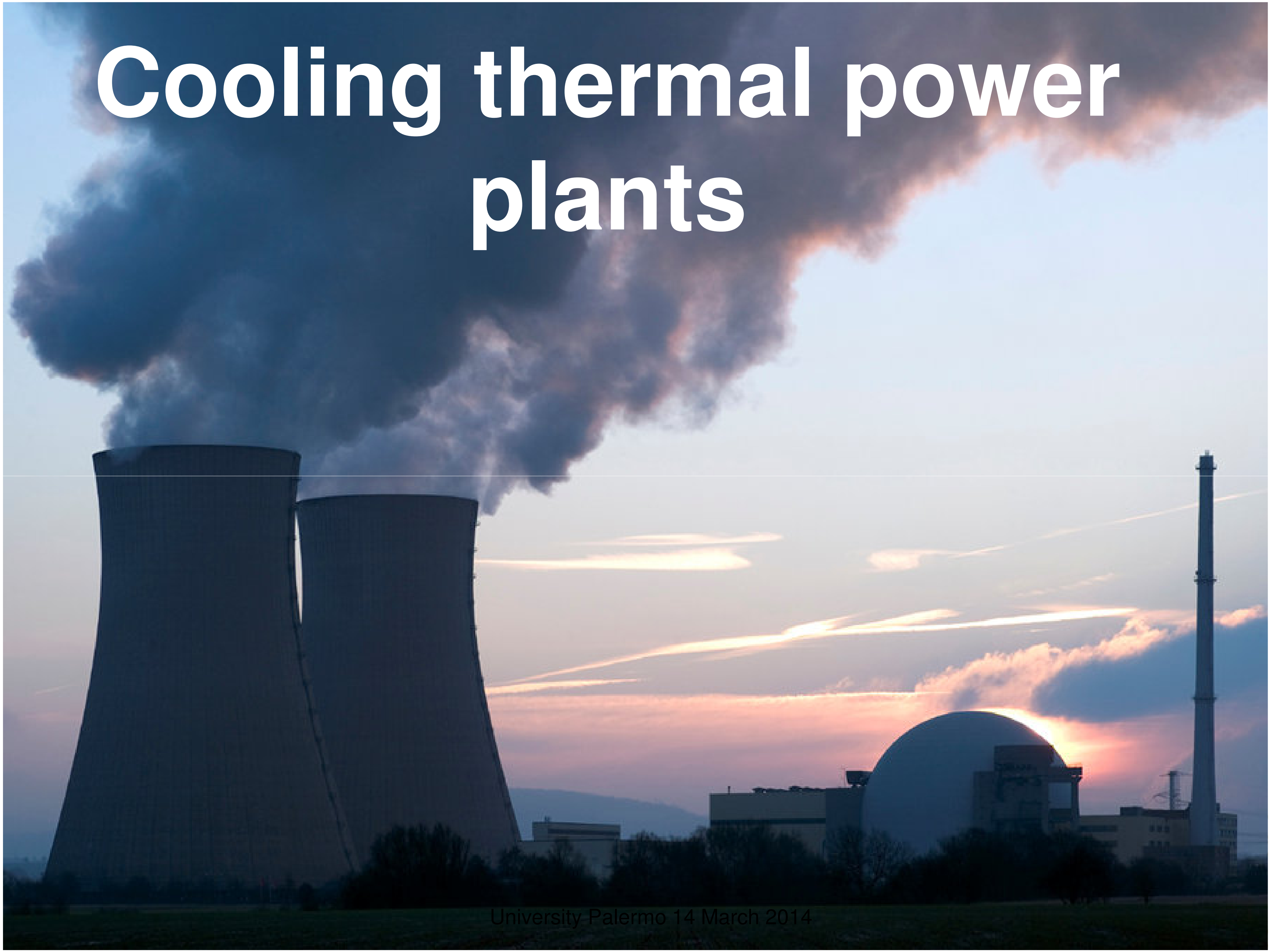
Wastewater ("produced water") - serious risks:

- 20-40% will be returned back to the surface

Bringing

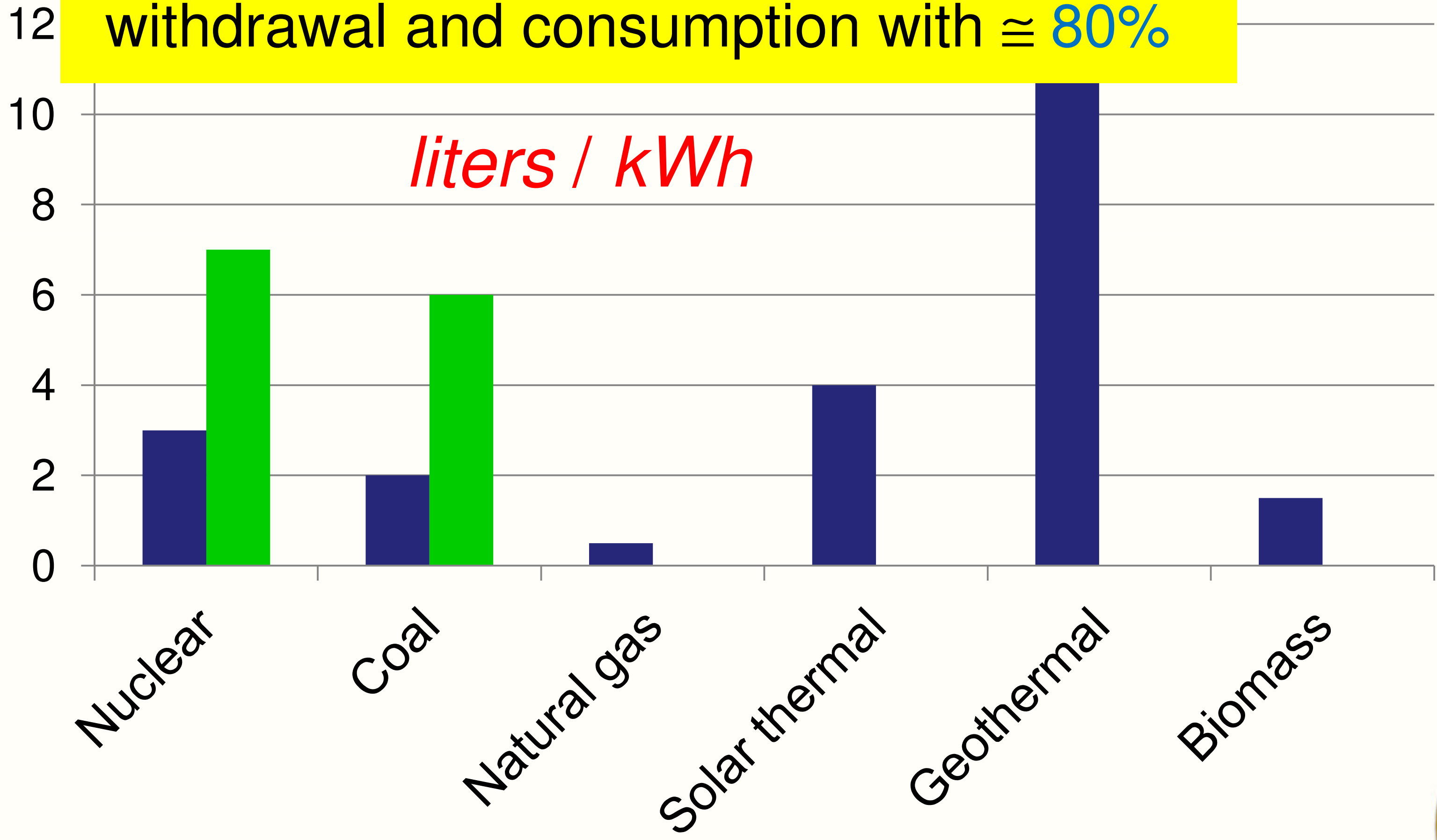
- chemicals, traces of oil-laced drilling mud,
- iron, chromium, salt,
- radioactive materials including Radium 226

Cooling thermal power plants



Water consumption in electrical generation

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



Water withdrawal - once-through cooling

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- **Nuclear power plants**
  - Typical temp. increase USA 16.5°C (30°F)
  - 1000 MWe requires 33 m^3/s for ΔT=15°C
  - Rule of thumb for 1000 MWe: 25 – 43 m^3/s
- **Coal fired plants**
  - Typical temp. increase USA 9.5°C (17°F)
  - 1000 MWe requires 50 m^3/s for ΔT=10°C

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

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Of the 33 m^3/s ~0.5 m^3/s are consumed (evaporated)

In Sweden we use some 150 liter/day/person

The evaporated cooling water could supply water for some 300 000 people

Cooling system tradeoffs

	Water with-drawal	Water consump-tion	Capital cost	Plant effi-ciency	Ecol-ogical impact
Once-through	80-200	0.8-1.2	good	good	Down-stream temp
Evapo-rative	1.2-2.4	1.2-2.0	ok	good	ok
Dry (direct air)	good	good	3-4 times wet cool	Up to 25% loss	good

Hydropower

Hydropower operation

No other energy source, thermal or renewable, can start up or change output as quickly as hydro in response to load demands – or can store energy on the same level as hydro to meet upcoming demand

Potentially sustainable

Large dams –
impacts to consider 1

- **Flooded area**
  - **Persons requiring resettlement**
    - Number of peoples displaced/MW
  - **Cultural property affected**
  - **Biomass flooded**
  - **Critical natural habitats affected**
  - **Floating aquatic vegetation**

Large dams – impacts to consider 2

Water loss due to evaporation

- Temperature
- Reservoir surface area
  - Hectares per megawatt (ha/MW)
  - Power per area unit (MW/km^2)

Evaporation

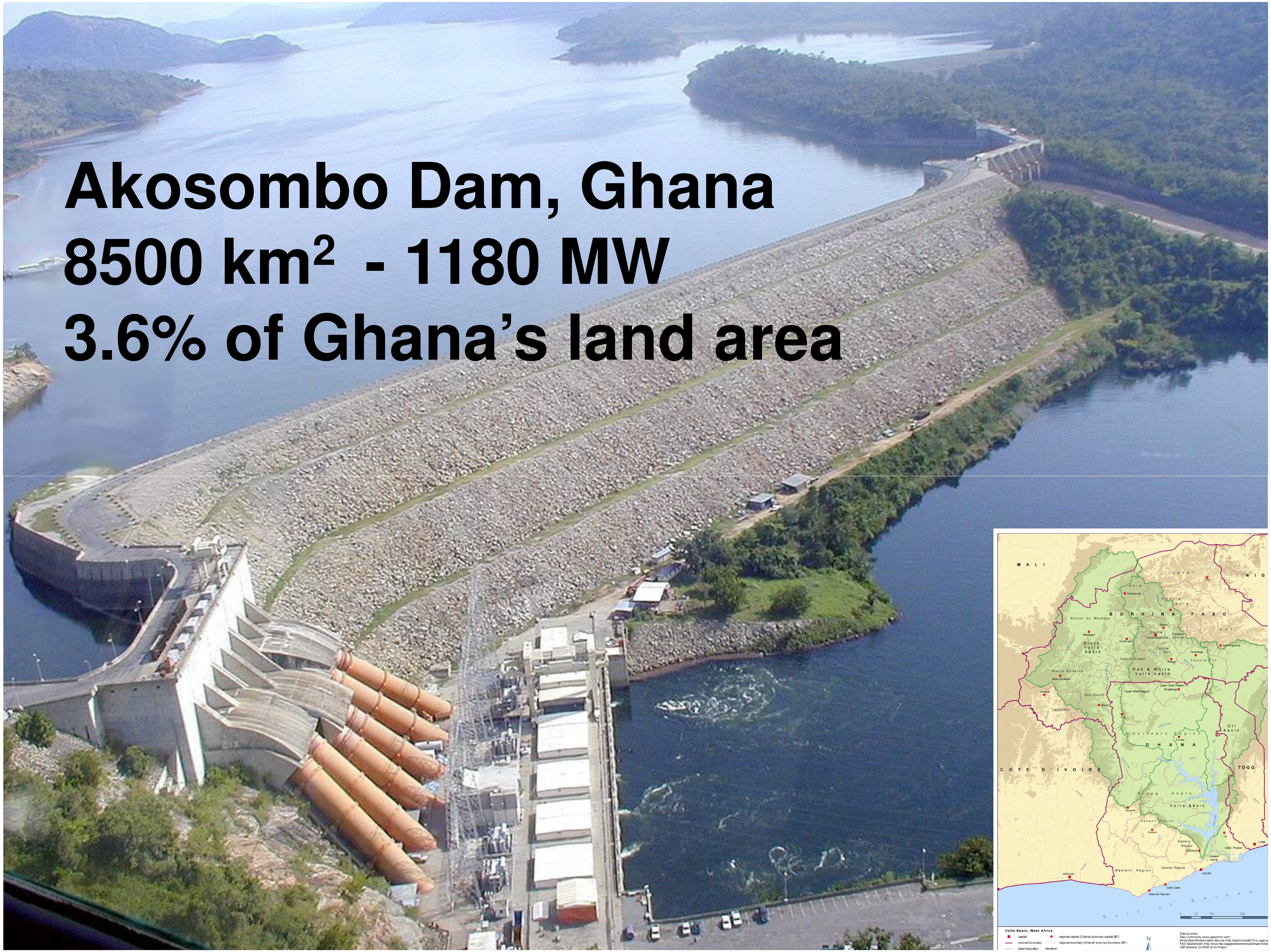
	ha/MW	Evaporation mm/year	Evaporation Gm^3/year	liters/kWh
Akosombo **Ghana**	720	2185	19	3000
Sobradinho, **Brazil**	400	2841	12	1430
Bayano, **Panama**	233	2156	0.75	1370
Itezhi Tezhi, **Zambia**	62	2572	0.95	338
Robert Bourossa, **Canada**	36	586	1.7	30
San Carlos, **Colombia**	0.26	1726	0.01	1

Source: Mekonnen & Hoekstra 2012

Akosombo Dam, Ghana

$8500\ km^2$ - 1180 MW

3.6% of Ghana’s land area



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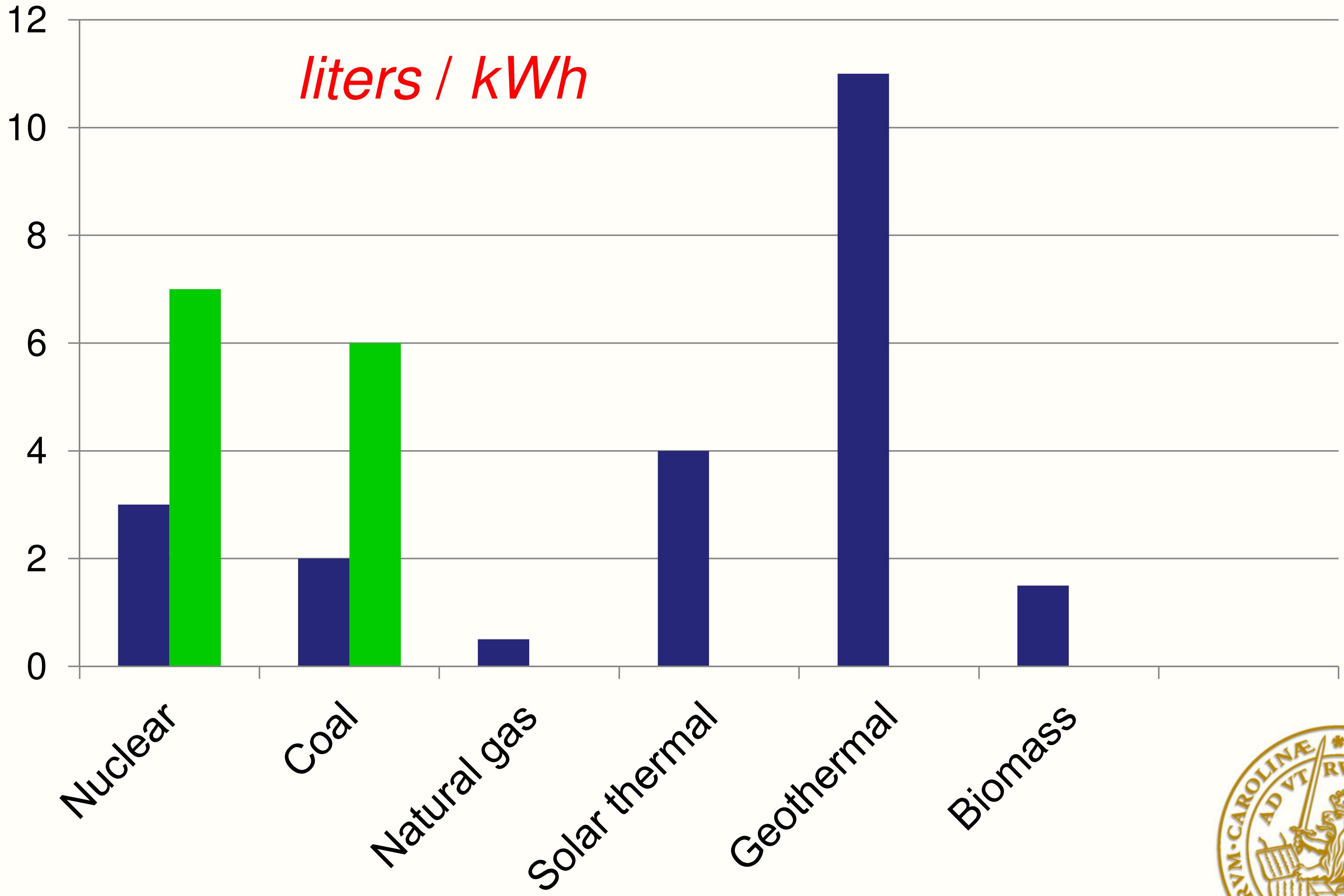
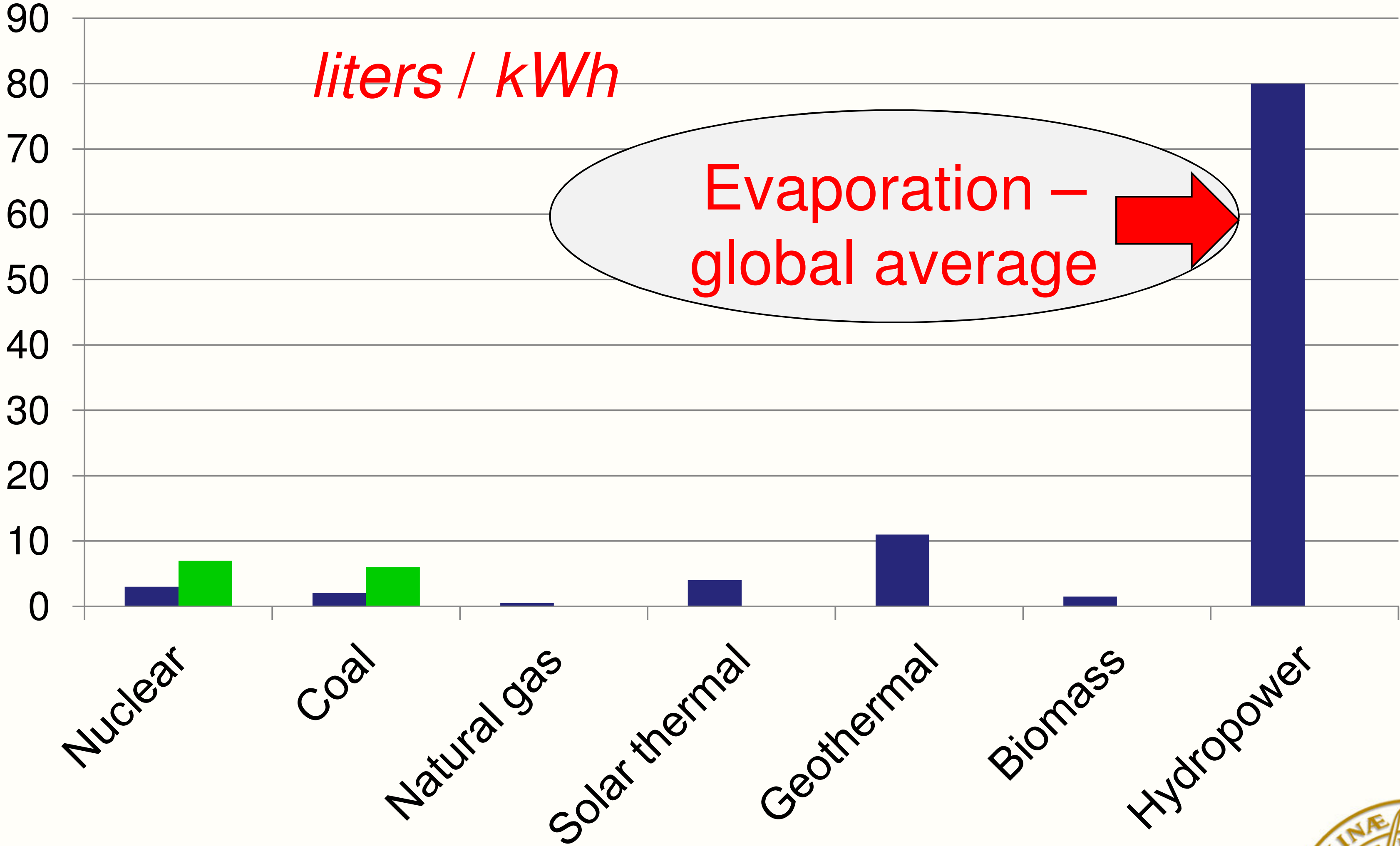
Range of evaporation

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

Water use in electrical generation



Water use in electrical generation



Large dams – impacts to consider 3

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- Reservoir sedimentation
  - Useful reservoir life - before ”dead storage” is filled
  - Reduction in sedimentation reaching the mouth
  - A growing risk of landslides and reservoir induced seismicity

Large dams – impacts to consider 4

- **Water quality**
  - Temperature increase
  - Public health – water related diseases
  - Fish species diversity and endemism
  - Greenhouse gases
  - Deterioration of water quality

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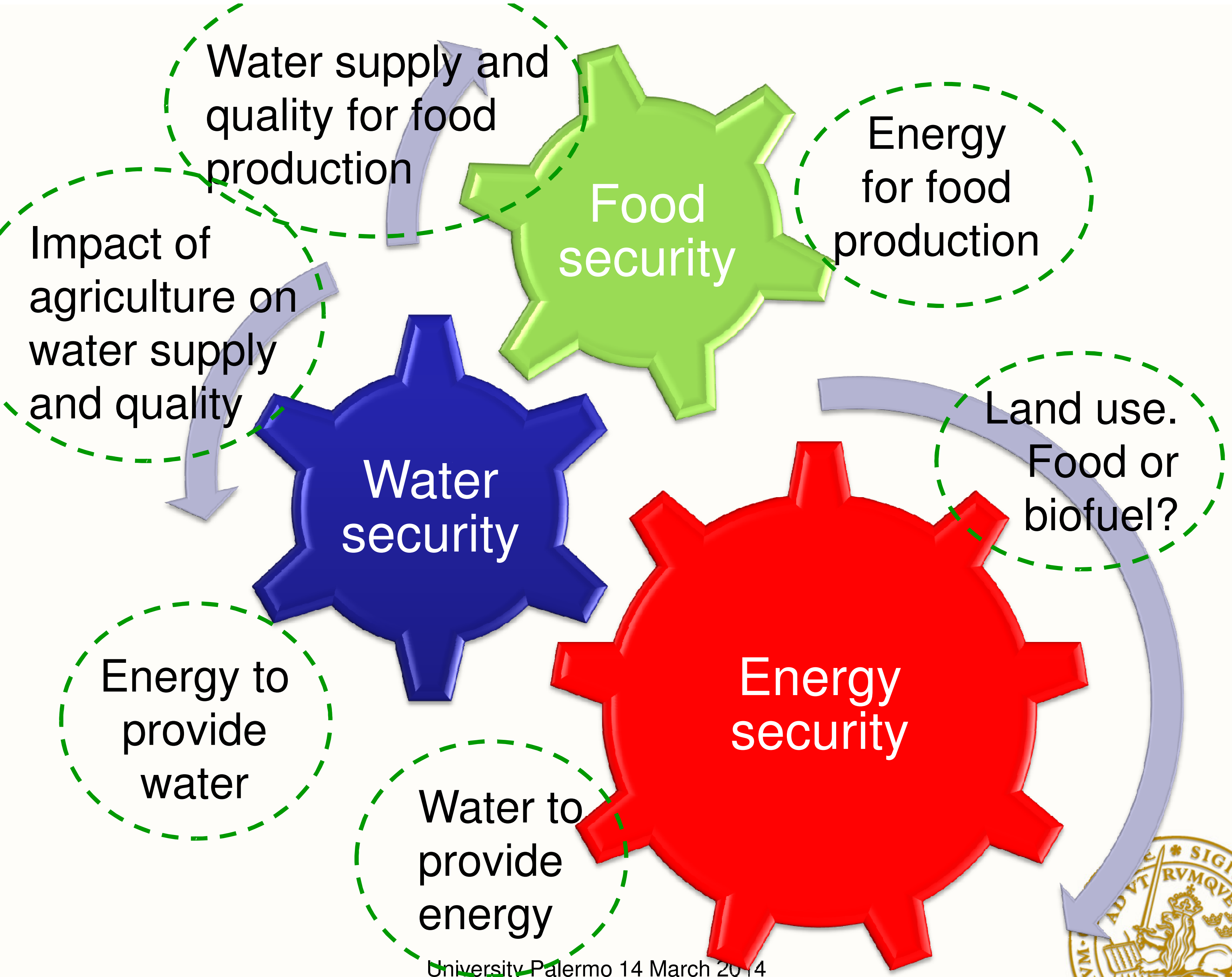
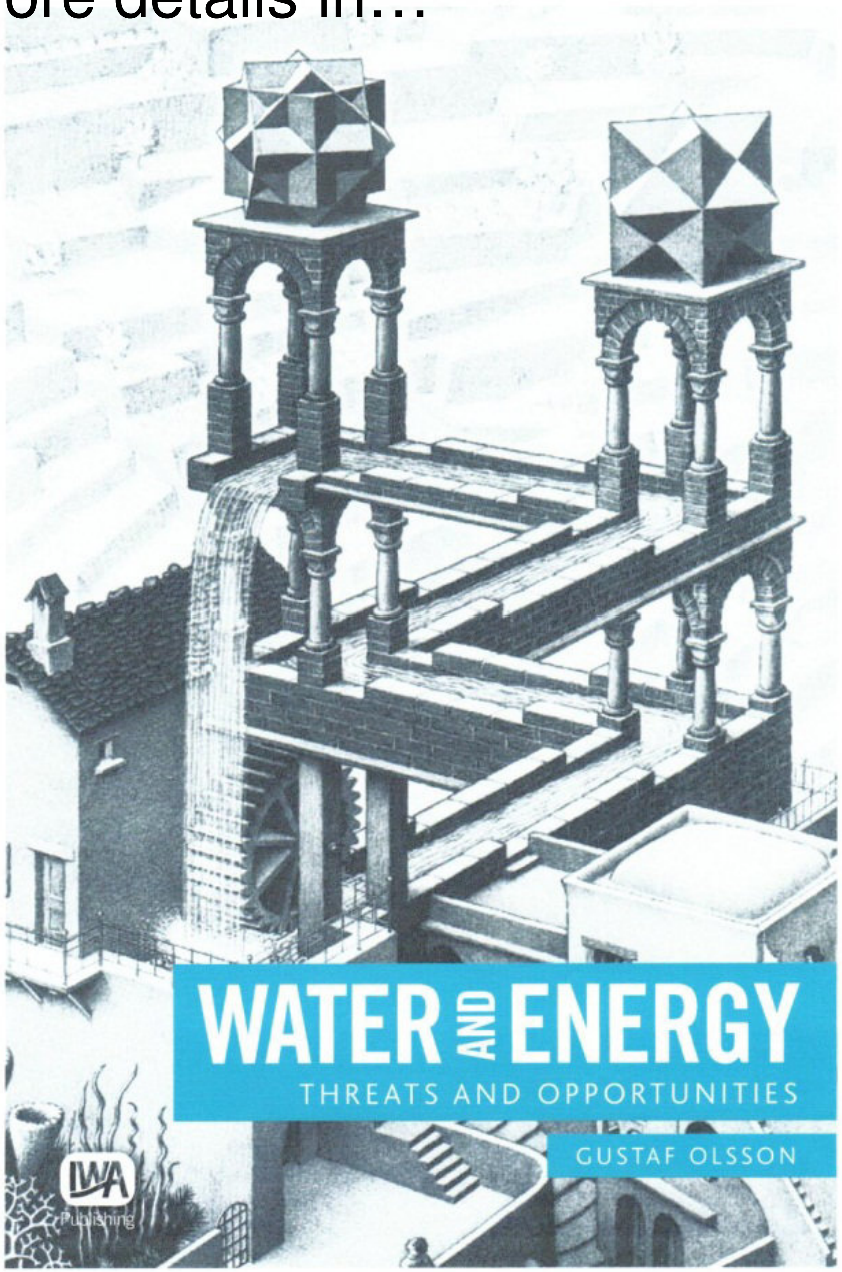
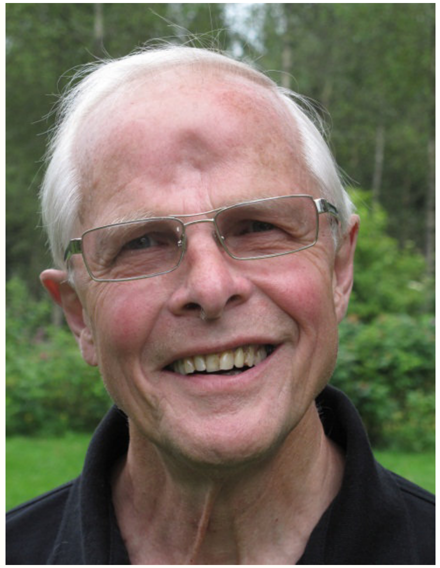
Saving water

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


Water supply and quality for food production
Food security
Energy for food production
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

More details in…





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Thank you!

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