Sustainable or Not?
Impacts and Uncertainties of Low-Carbon Energy Technologies on Water

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The Issue

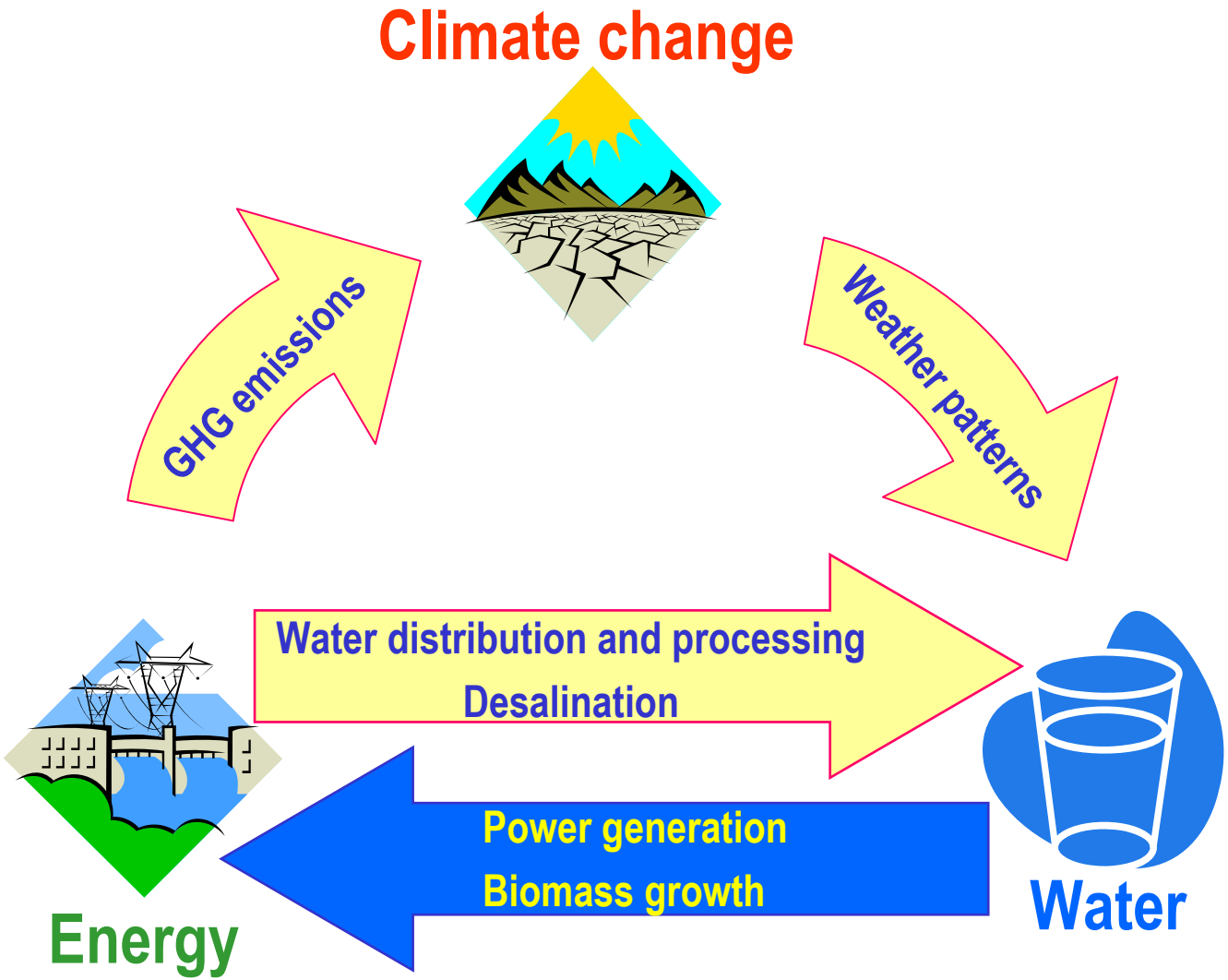
- There is a global effort to deploy energy technologies with a low carbon footprint as a means to mitigate climate change.
- Water resources are under strain – increased population, climate change…
- It is largely overlooked that the energy system also requires water.

The aim of the presentation

- Assessment of the impact of large scale deployment of low carbon technologies in the power system on freshwater usage - The case for Europe

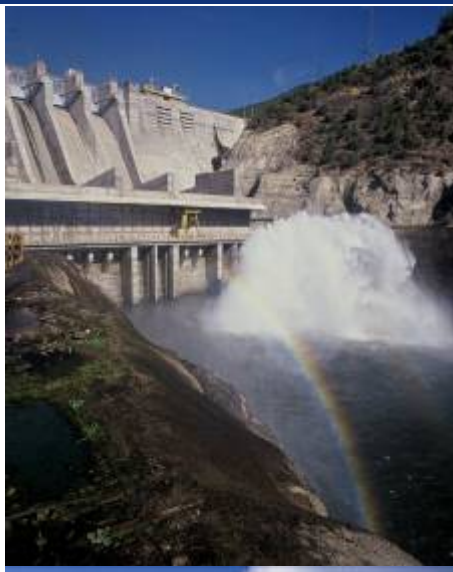
The link between energy and water

There are strong direct and indirect links between energy and water

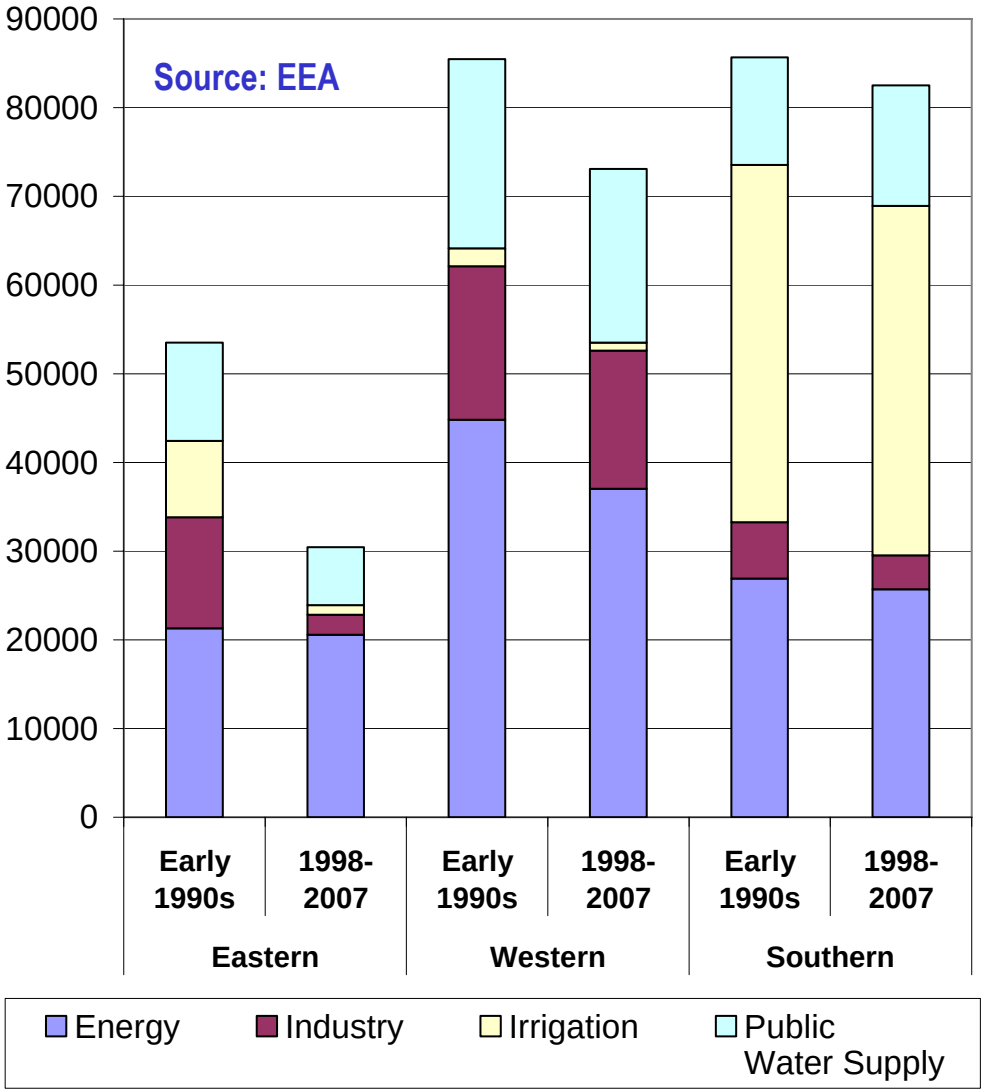


Water is essential for power generation

- **Hydropower**
  - EU: 143 GW - 10.6% of generation in 2008
- **Pumped Hydropower for electricity storage**
  - EU: 40 GW in 2008 – growing importance for grid stability
- **Extraction and processing of energy sources**
  - Coal and uranium mining, fuel processing
- **Fossil fuel and nuclear plants**
  - Steam generation to spin turbines and generate electricity
  - Condensing low pressure steam before reuse (75% - 95% of water use in a power plant)



Abstractions (million m^3 / year)



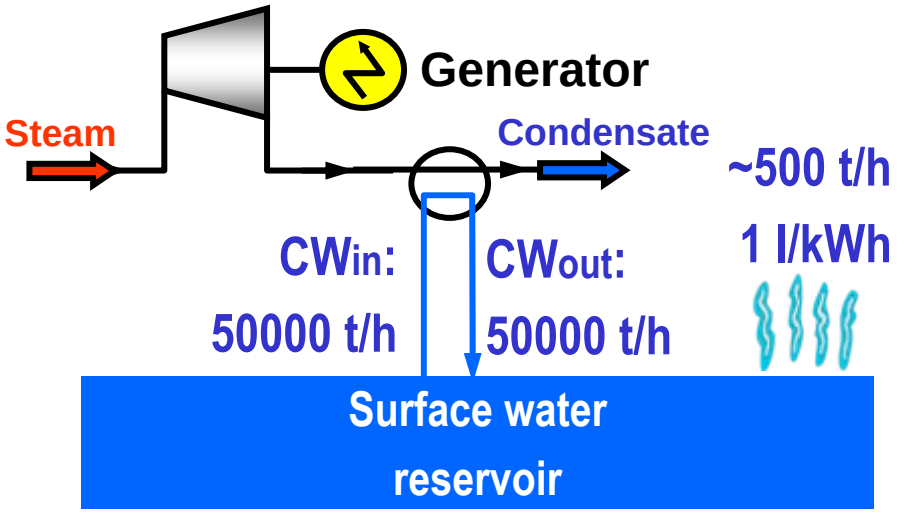
- Water abstraction for cooling in energy production accounts for 44.8 % of the total water abstraction in Europe (2007 data).
- Energy cooling water abstractions in Europe have decreased overall by 10 % over the last 10 -15 years, due to the adoption of advanced cooling technologies.
- Although significant amounts of water are abstracted, only a small fraction is consumed (i.e. removed from the immediate water environment). Most is returned albeit warmer.

Water cooling in power generation

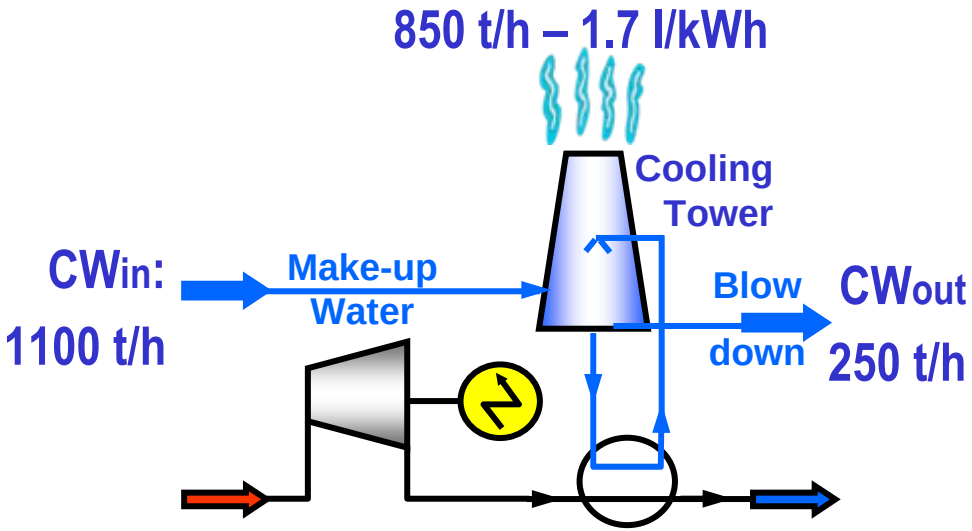
There are two major methods to cool power plants in the EU

The case for a 500 MW subcritical coal plant (η_{net} = 37%)

Once - Through (OT)



Open Recirculating (OR)



- Both options are considered Best Available Techniques
- New power plants typically use OR systems, e.g. in UCTE*:
  - (1978): 60% OT – 40% OR
  - (2007): 25% OT – 75% OR

*** Union for the Co-ordination of Transmission of Electricity**

Evolution of the European power system

- Security of energy supply and climate change drive the transition to a low carbon economy.
- The European Union has committed to reduce GHG emissions by 20% - 30%, improve efficiency by 20% and increase the share of RES by 20% in 2020 as a first step to the decarbonisation of the energy system in 2050.
- These targets can only be achieved via the large scale deployment of low-carbon technologies, especially in the power sector.
- The European Strategic Energy Technology Plan accelerates RD&D in:
  - Wind
  - Solar: Photovoltaics (PV) & Concentrating Solar Power (CSP)
  - Carbon Capture and Storage (CCS)
  - Bioenergy
  - Nuclear fission (Gen IV)
  - Electricity Grids

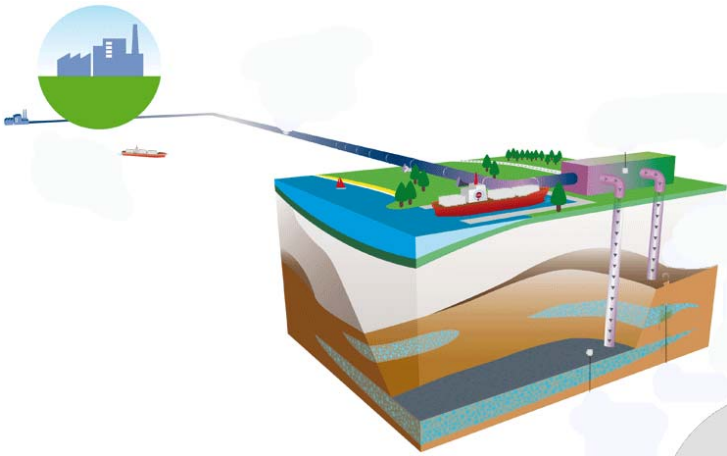
Not all technologies that generate power from Renewable Energy Sources (RES) require water

- Wind and PV installations require almost no water for their operation.
- Most CSP options require water for cooling and to a lesser extent for mirror washing (up to 2-4 l/kWh).
  - CSP is a technology proven at the utility scale – 1 GW installed capacity globally through numerous demonstration projects.
  - Air cooling is possible but more expensive.
- Biomass is combusted in electricity-only and in combined heat and power plants.
  - Water consumption:
    - Electricity plants: approx. 2 l/kWh
    - Cogeneration plants: negligible

Water use in CCS

- CCS technologies can be applied to all types of fossil fuel power plant (coal and gas) to reduce CO_2 emissions by 85-90%, albeit with an efficiency penalty (currently ~10 percentage points).

- CO_2 capture can increase significantly (1.6X – 4X) water use of a power plant.
  - Steam condensation, desulphurisation, boiler feed-water make-up
  - Solvent regeneration (post-combustion)
  - Water gas shift reaction (pre-combustion)
  - Additional ancillary services
  - Cooling of CO_2 compressors



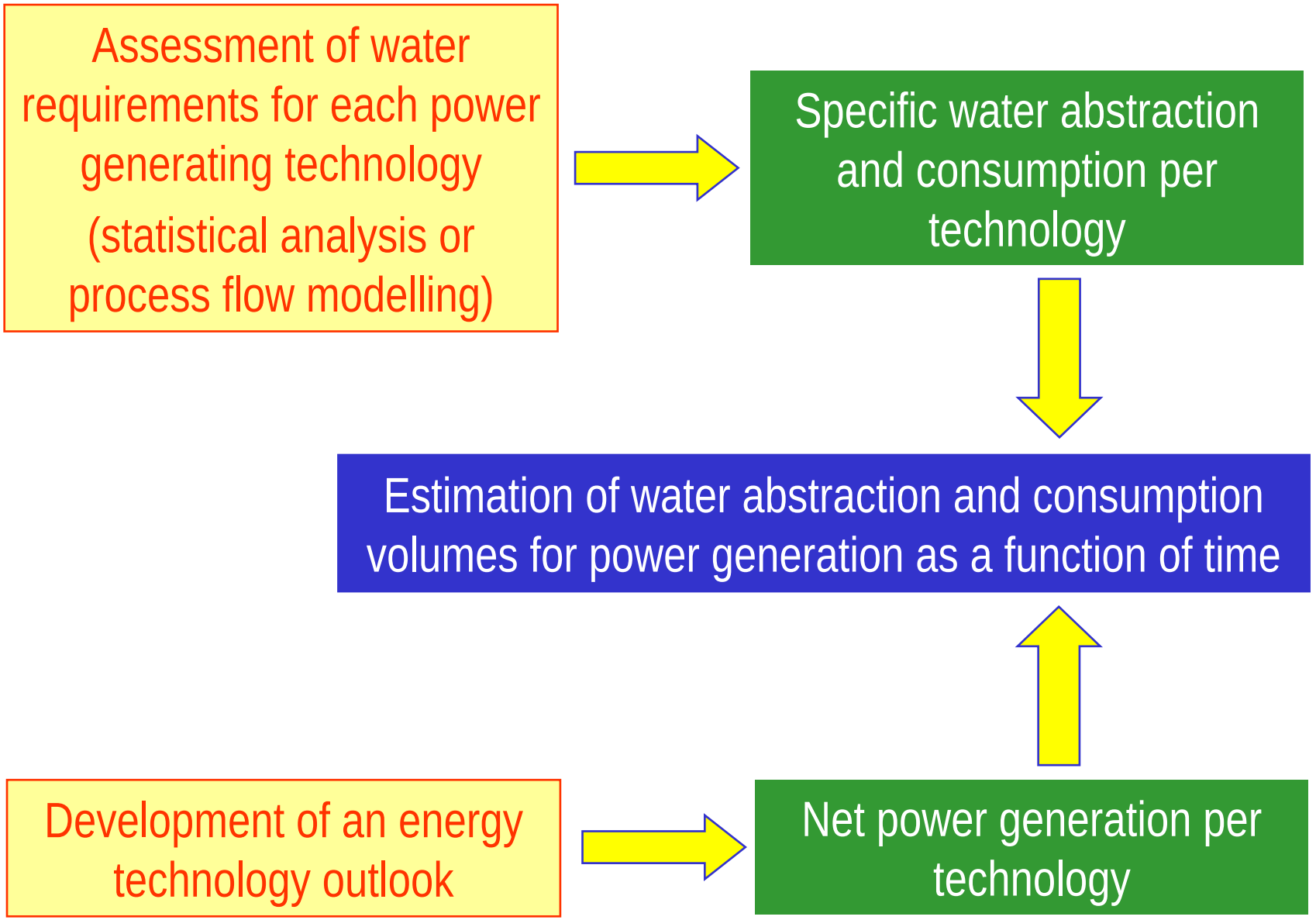
Water use in nuclear plants

- In general, nuclear power plants require more water for cooling than coal plants of the same capacity since they operate at reduced steam conditions. A typical LWR has a 33% thermal efficiency.

- Today's state-of-the-art: Gen III European Pressurised Reactors with 36 - 37% efficiency (12% reduced water usage).

- 2040 and beyond: Gen IV Lead-cooled Fast Reactors (42% efficiency), Very High Temperature Reactors (~50% efficiency)… will come with proportional reductions in water usage.

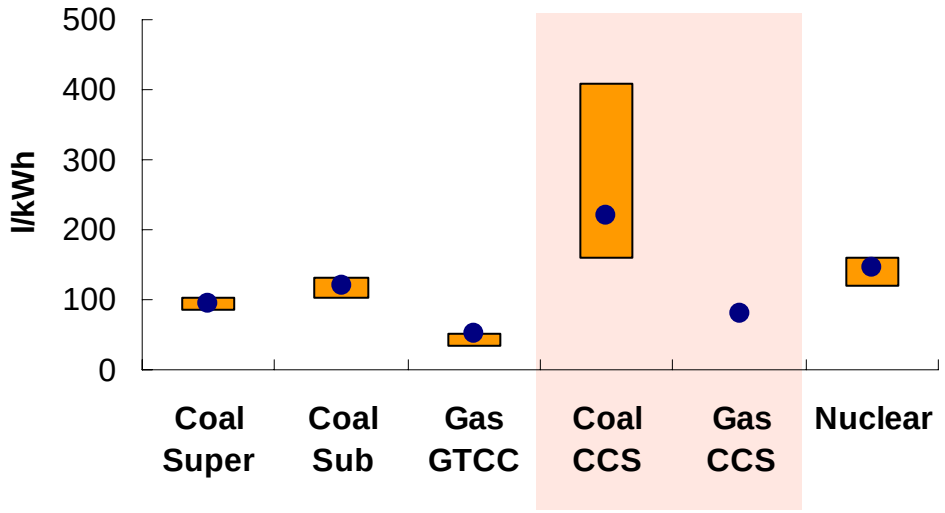
Methodology for estimating water usage



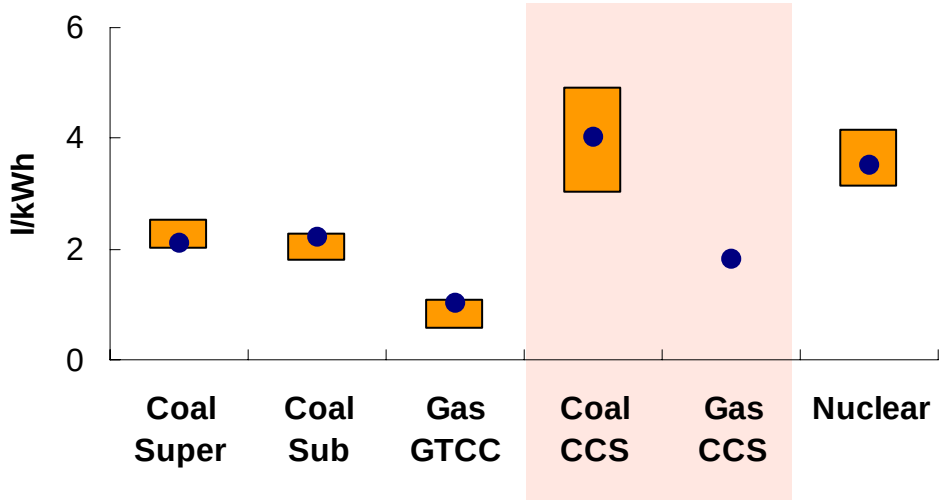
Water requirements for power generation

Abstraction

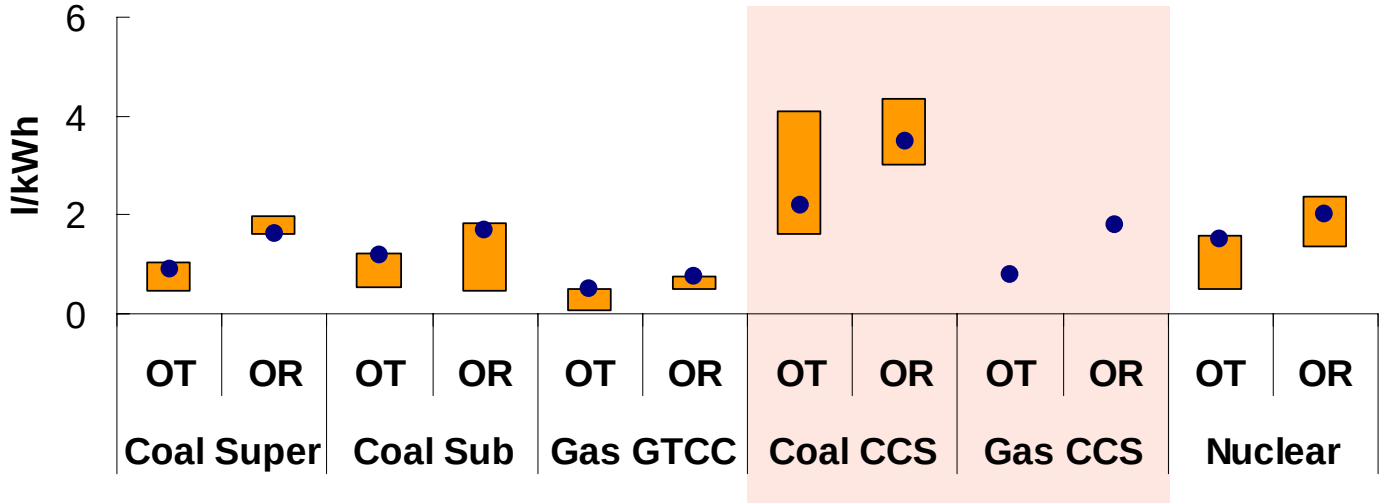
Once-Through



Open Recirculating



Consumption



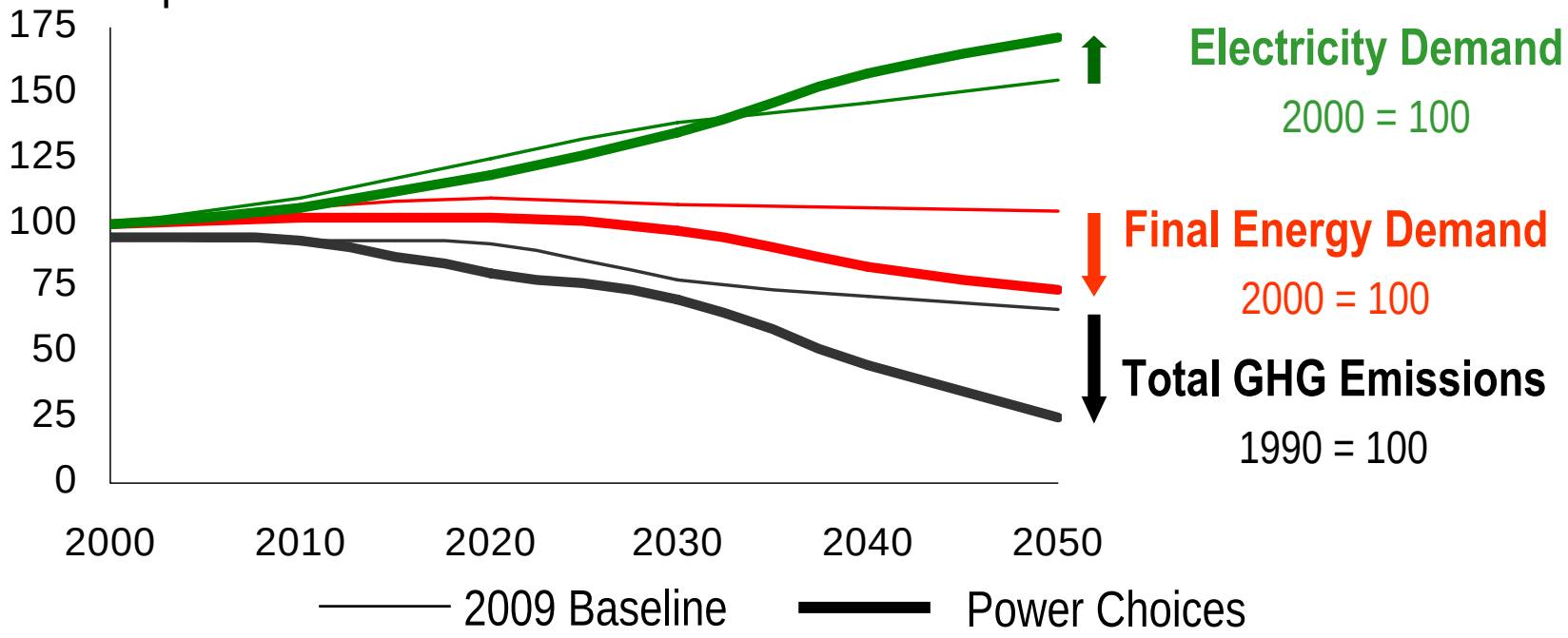
There is significant uncertainty on water usage in CCS plants

- JRC Ref. Values

Data from literature sources and JRC analysis

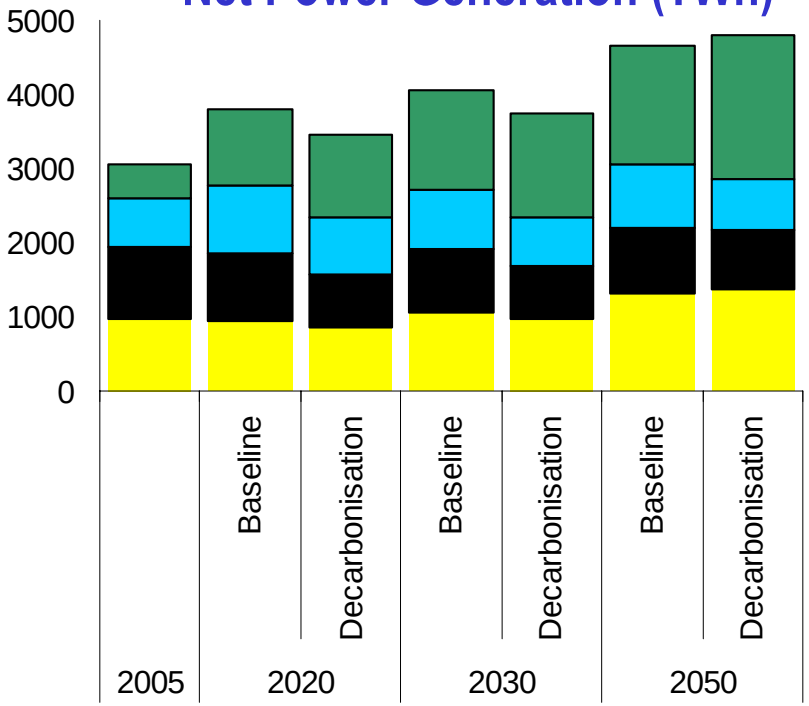
An energy scenario for 2050

- The EU has set a target to reduce GHG emissions by 80-95% by 2050.
- The development of a 2050 decarbonisation scenario by the European Commission is currently ongoing.
- The 'Power Choices' scenario by EURELECTRIC sets a 75% GHG emission reduction target.
  - Decarbonisation is achieved through electrification of the energy system, incl. transport.

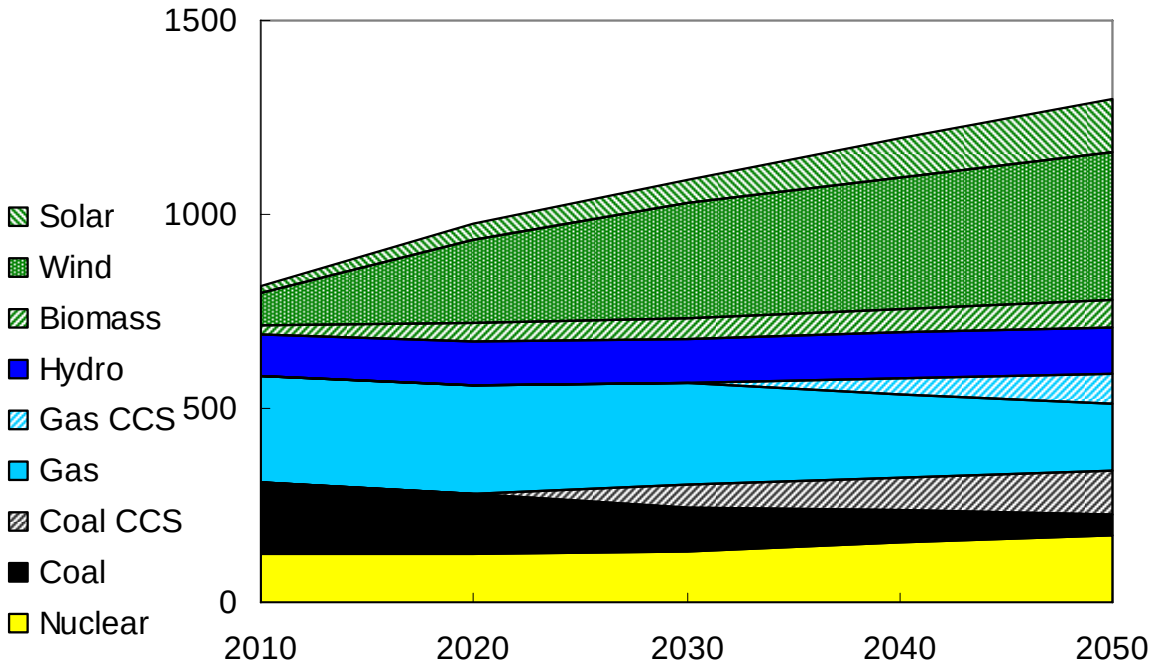


Low carbon technology deployment

Net Power Generation (TWh)



Net Power Capacity (GW) - Power Choices



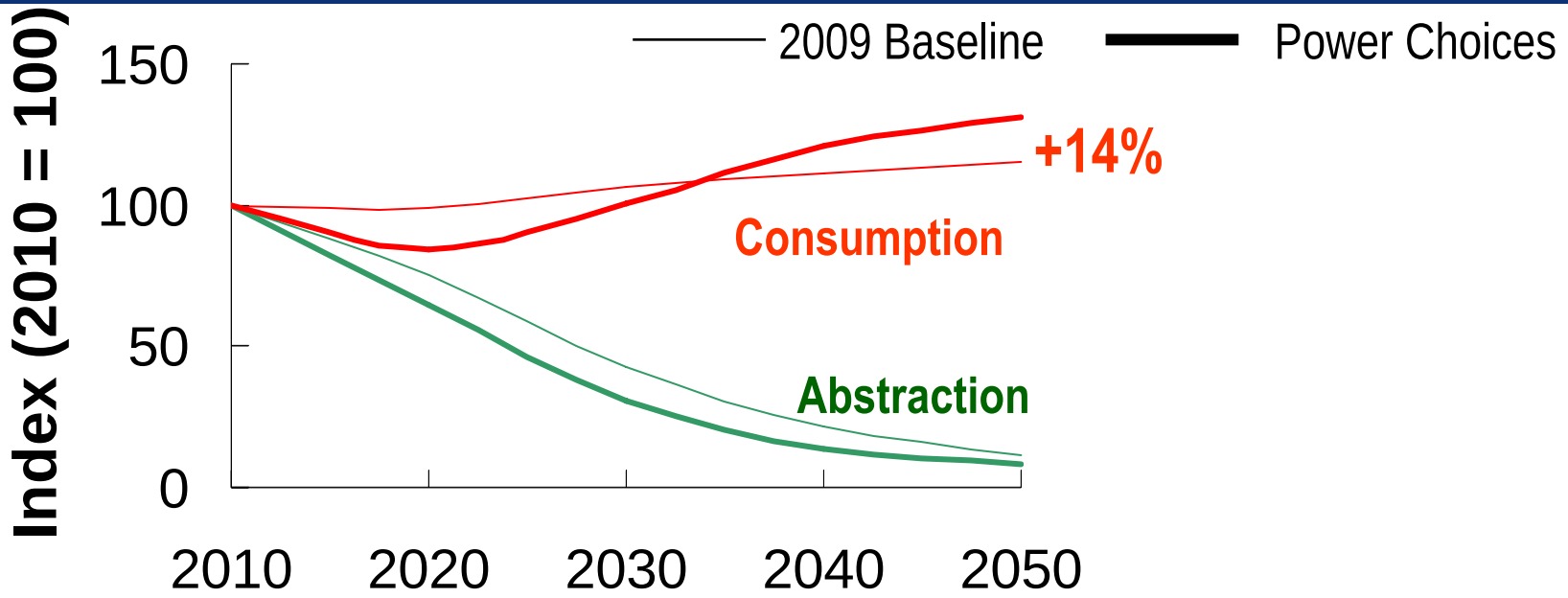
Power generation in the Decarbonisation Scenario (2050)

Compared to 2005	Compared to Baseline (2050)
RES: +330%	RES: +22%
Coal: -17%	Coal: -10%
Gas: +4%	Gas: -19%
Nuclear: +41%	Nuclear: +4%

Assumptions for estimating freshwater usage

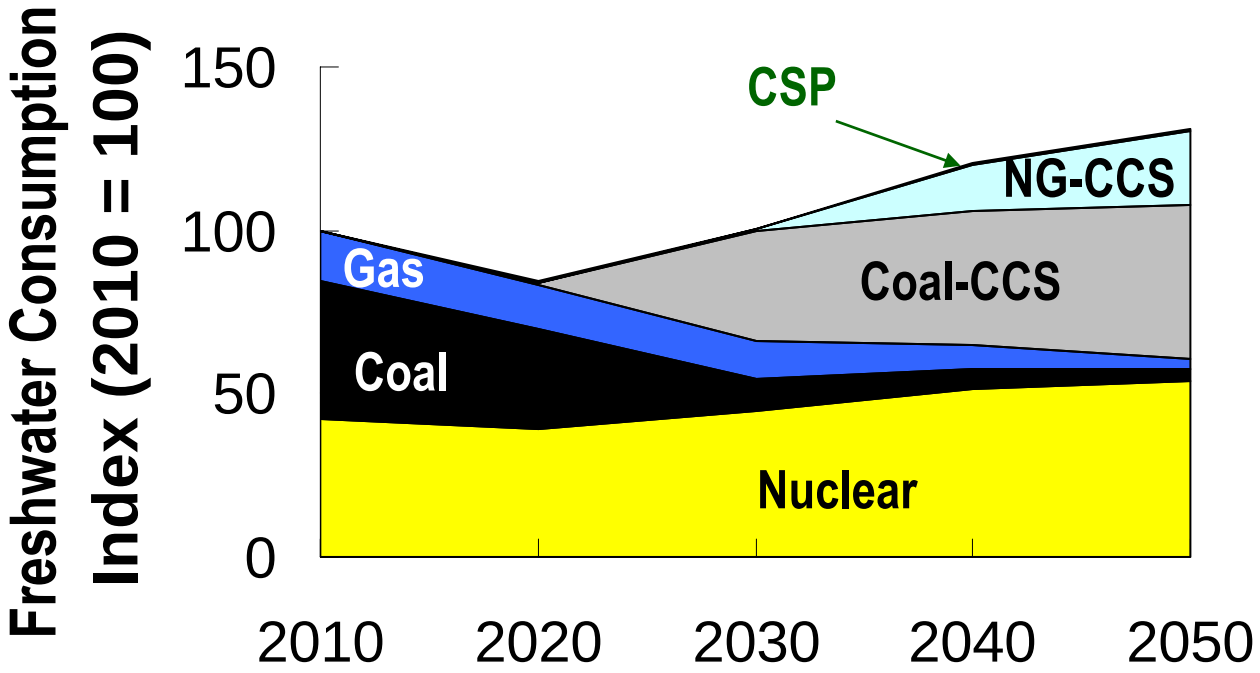
- Constant fraction of plant capacity that uses seawater for cooling
- Gradual increase of share of plants located inland that use OR
  - Retrofit of existing plants at end of life from OT into OR
  - New plants located inland use OR cooling
  - There is no deployment of dry & hybrid wet/dry systems
- Declining water abstraction and consumption coefficients for nuclear and fossil fuel plants (linked to efficiency improvements)
- All CCS plants use post-combustion capture technology
- Biomass plants are of the cogeneration type

Freshwater usage in the EU power system



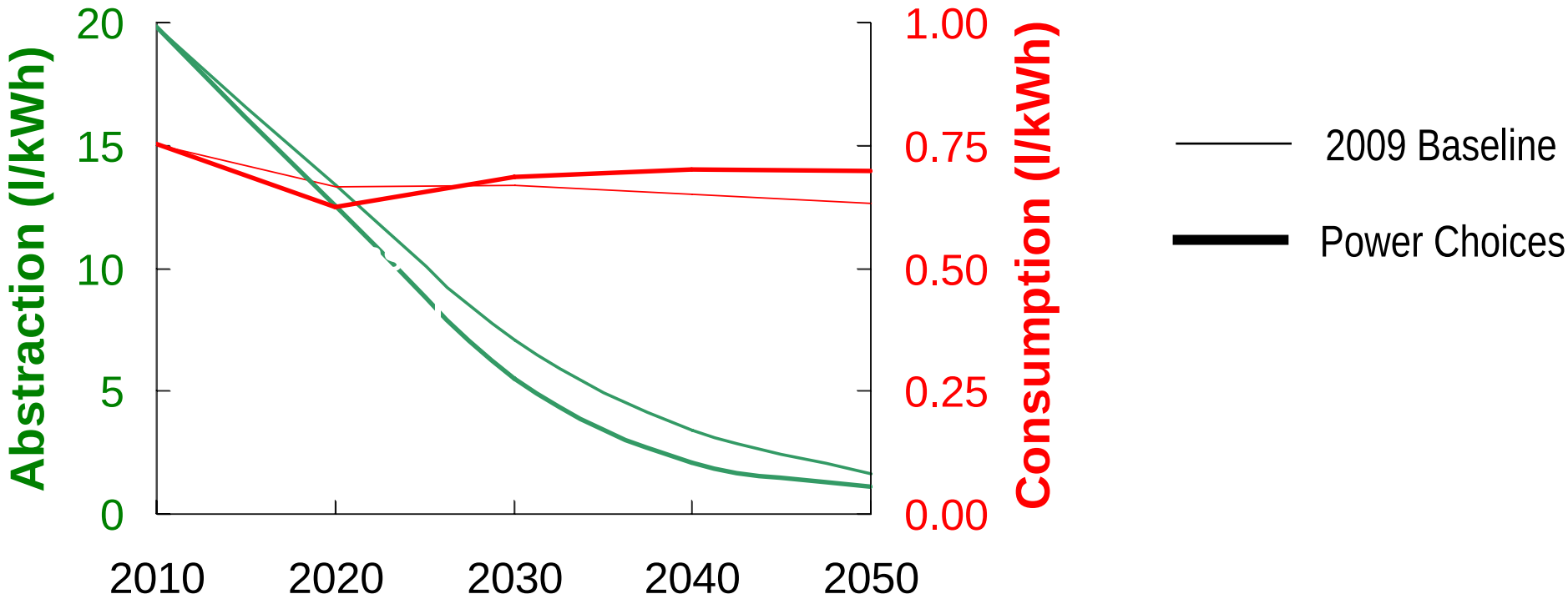
- While power generation in Europe in 2050 is increased by ~50% above the 2010 level:
  - Freshwater abstraction is reduced by 90% in both scenarios, due to the shift to OR systems and efficiency improvements.
  - Freshwater consumption is increased by 15% in the Baseline scenario and by 31% in the Decarbonisation Scenario.
- Freshwater consumption in 2050 in the decarbonisation scenario is 14% higher than in BAU.

Freshwater consumption in a decarbonised power system



- The deployment of CCS plants is the main contributor to the increase in freshwater consumption, cancelling any benefits arising from the retirement of conventional fossil fuel plants and the penetration of RES.
- Nuclear energy is the largest consumer of freshwater, but technology developments decouple freshwater consumption from nuclear power generation.
- CSP deployment does not affect freshwater consumption at the European level.

Freshwater consumption intensity



The deployment of low carbon technologies:

- accelerates the reduction in specific water abstraction due to the replacement of fossil fuel plants with a low carbon fleet (RES and CCS) that requires less water.
- decreases specific consumption until 2030 due to the larger contribution of RES.
- Increases specific water consumption after 2030 mainly due to CCS deployment.

Uncertainties

- **The formulation of the energy scenario has a strong impact on the results of the analysis and depends on:**
  - Energy, climate and economic policy targets
  - Nuclear energy policy
  - CCS acceptance & technology development
  - RES technology development incl. costs
  - Use of electricity in sectors of the economy
- **The adopted methodology provides rough & 'global' estimates only. Uncertainties include:**
  - Future power plant performance and cooling system choice
  - Developments in cooling system technology
  - Technology choices (biomass, cogeneration, CCS options, etc.)

Measures to reduce freshwater consumption

Strategic technology development

- Optimisation and further development of CO_2 capture systems
- Increase in fossil fuel power plant efficiencies
- Development of Gen IV nuclear reactors

SET-Plan

Regulation

- Use of best available cooling technologies as a condition for plant permit
- Promotion of cogeneration where there is a heat market

EU legislation

Cooling technology development

- Development of cost competitive alternative cooling technologies (wet/dry hybrid systems, dry cooling, …)
- Increase of water usage efficiency (separation technologies, materials and inhibitors for increased OR cycles, …)
- Use of alternative water sources (waste water, lignite water, water recovery from flue gases, etc.)

Conclusions

- The decarbonisation of the European economy will have an impact on freshwater requirements and consumption. Based on the assumed decarbonisation scenario, the power sector in 2050 will demonstrate:
  - 75% reduction in GHG emissions, compared to 1990
  - 90% reduction in freshwater abstraction, compared to 1990
  - 30% increase in freshwater consumption, compared to 1990
- The power sector in 2050 will be emitting 63% less GHGs compared to a BAU scenario but will be consuming 14% more freshwater.
- The European Strategic Energy Technology Plan through its focus on RES, Gen IV nuclear reactors and CCS can bring about the technologies that will ensure both GHG emission and freshwater consumption reductions.
  - Freshwater consumption should be among the criteria for setting R&D and demonstration priorities.

THANK YOU!

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