Overview of the water-energy-CCS nexus

ADDRESSING THE ENERGY-WATER NEXUS THROUGH R&D PLANNING AND POLICIES

Experts' Group on R&D Priority Setting and Evaluation (EGRD)

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Greenhouse Gas R&D TCP

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iea Energy Technology Network

Established in 1991

Independent advisory body

Not advocacy or policy

Member-driven

strategic direction and programme

Governments, industry, IGOs

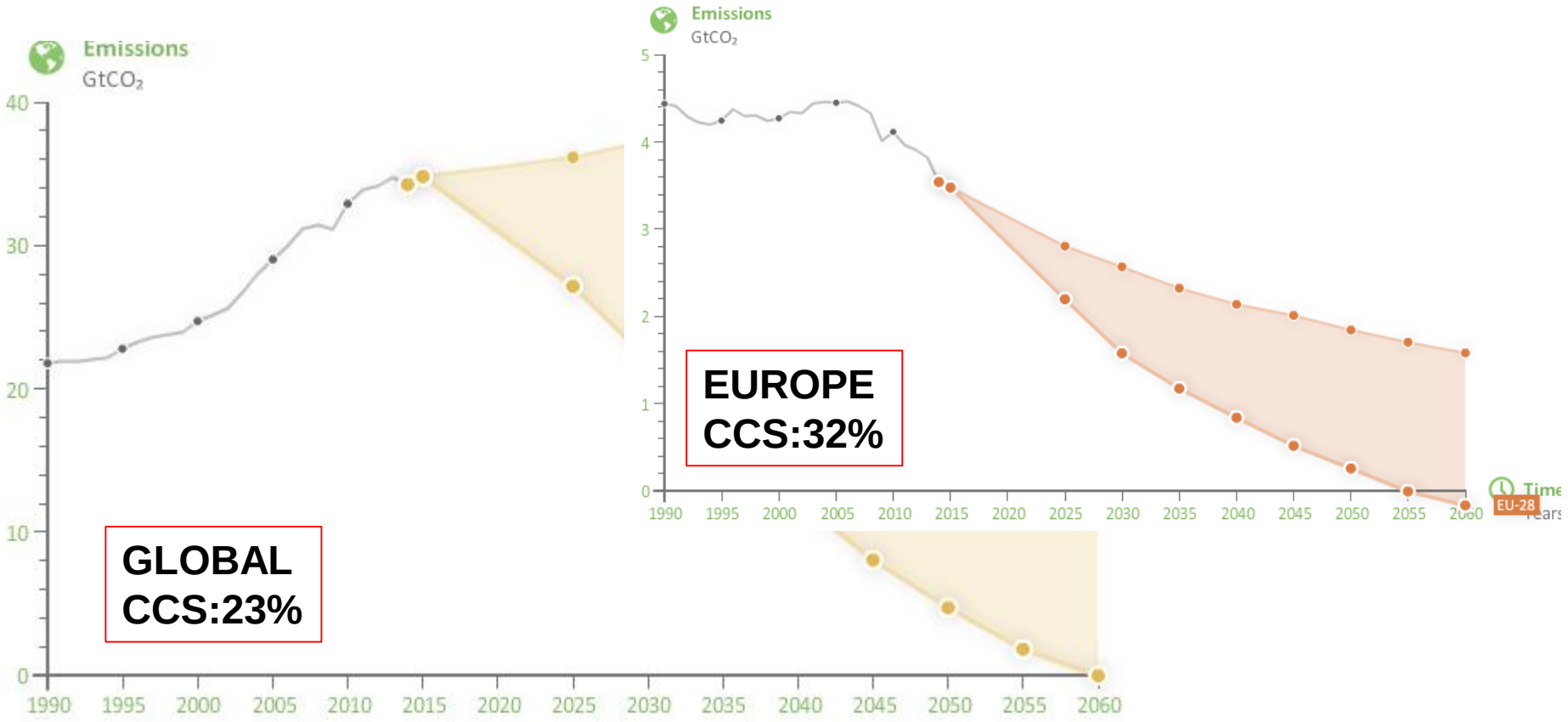
16 industries (Sponsors), 16 governments (Contracting Parties),
3 OPEC, EC, IEA Coal Industry Advisory Board

Greenhouse Gas R&D TCP (2)

- **Aims:** Evaluate technology options for greenhouse gas mitigation from energy and industrial systems
- **Focus:** Carbon dioxide capture and storage (CCS) and utilisation (CCS-US)
- **Activities**
  - **Technical studies:** >300 reports published on all aspects of CCS
  - **Industry conferences:** GHG Control Technologies, Post-Combustion Capture
  - **International research networks:** Risk Assessment/ Management, Monitoring, Modelling, Environmental Research, Social Research, Oxy-combustion, Solid Looping, Cost of CCS
  - **Advice:** Peer reviews (e.g. USDOE, USEPA, CO2CRC), international regulatory developments (e.g. UNFCCC, London Convention, ISO TC265)
  - **Collaborations:** IEA, CSLF, CCSA, EU ZEP, CSIRO, others
  - **International CCS summer schools**

Why do we need CCS- CCUS?

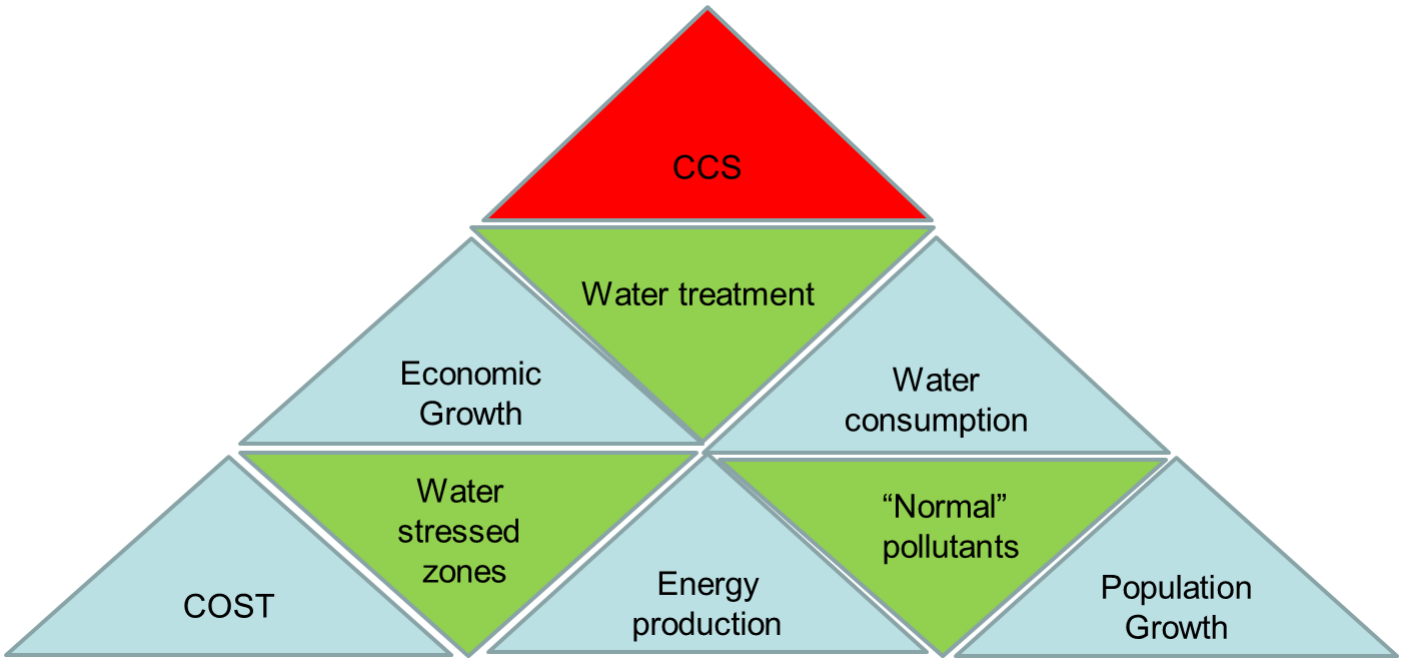
CO_2 emissions reductions potentials



Source: IEA below two-degree (B2DC) scenariohttps://www.iea.org/etp/explore/

The issues

- Water and energy are indispensable
- Environmental agreements are indispensable
- You need water to produce energy and energy to extract/produce water



Terminology

- **Water**
  - Usage
  - Consumption
  - Withdrawals

The evil is in the details!

- **Carbon Capture and Storage (CCS)**
  - Post-plant combustion using liquid solvents
  - Xx Add more here???

The water-energy-CCS nexus

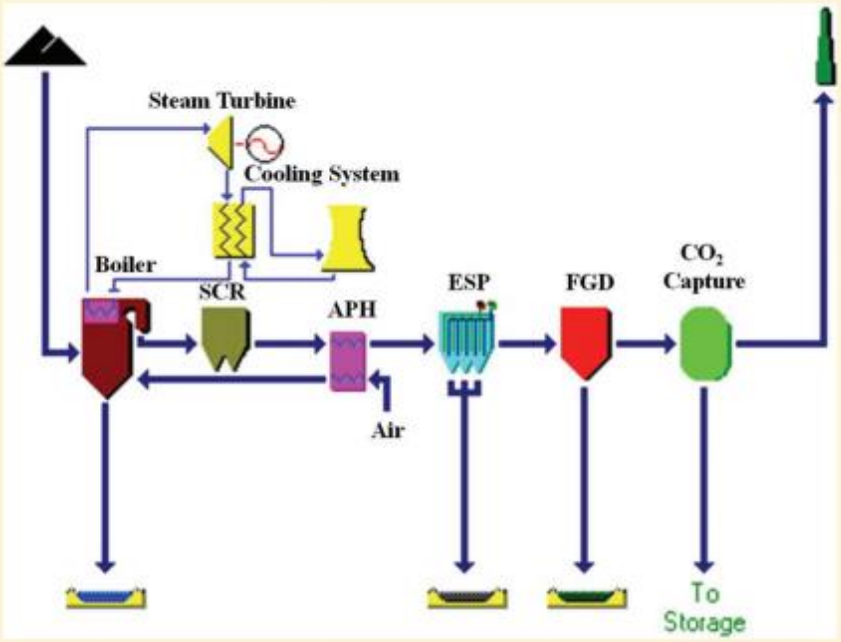
- How are these connected?
- What are the boundaries?

Electricity generation
- Boiler
- Steam turbine
- Condenser
- Wet cooling tower

Environmental control
- SCR
- ESP
- FGD
- NO_X removal
- SO_2 removal
- CO_2 removal

Site specific, age of plant

Coal power plant with CCS



Source: Zhai, Rubin and Versteeg (2011), *Environmental Science and Technology.*

The effects of CCS on water use

Water distribution in a supercritical power plant

Operation Unit	Without carbon capture				With carbon capture			
	Water withdrawals		Water consumption		Water withdrawals		Water consumption	
	(Liters/MWh)	(%)	(Liters/MWh)	(%)	(Liters/MWh)	(%)	(Liters/MWh)	(%)
Boiler	230.9	9.6	0	0.0	333.1	7.6	0	0.0
SCR	3.8	0.1	0	0.0	3.8	0.1	0	0.0
FGD	234.7	9.8	234.7	14.0	340.7	7.8	340.7	11.1
Carbon capture system	0	0.0	0	0.0	83.3	1.9	30.3	0.9
Cooling system[a]								
steam cycle cooling	1930.6	80.5	1449.8	86.0	1676.9	38.3	1260.5	40.9
carbon capture cooling	0	0.0	0	0.0	1938.1	44.3	1453.5	47.1
Total plant water use	2400.0	100.0	1684.5[b]	100.0	4379.9	100.0	3085.0[b]	100.0

Source: Zhai, Rubin and Versteeg (2011), *Environmental Science and Technology.*

Water use increases by >80% with carbon capture

Issues for consideration

- Other plant configurations
- Water-stressed locations
- Impacts of regulation
- Associated costs

Examining the water-energy-CCS nexus

- **GHG TCP studies**
  - *Extracting formation water from CO_2 Storage* (2012)
  - *Evaluation and analysis of water usage of power plants with CO_2 Capture* (2010)
  - *Understanding the cost of reducing water usage in coal and gas fired power plants with CCS* (2019)
  - Collaborative project with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

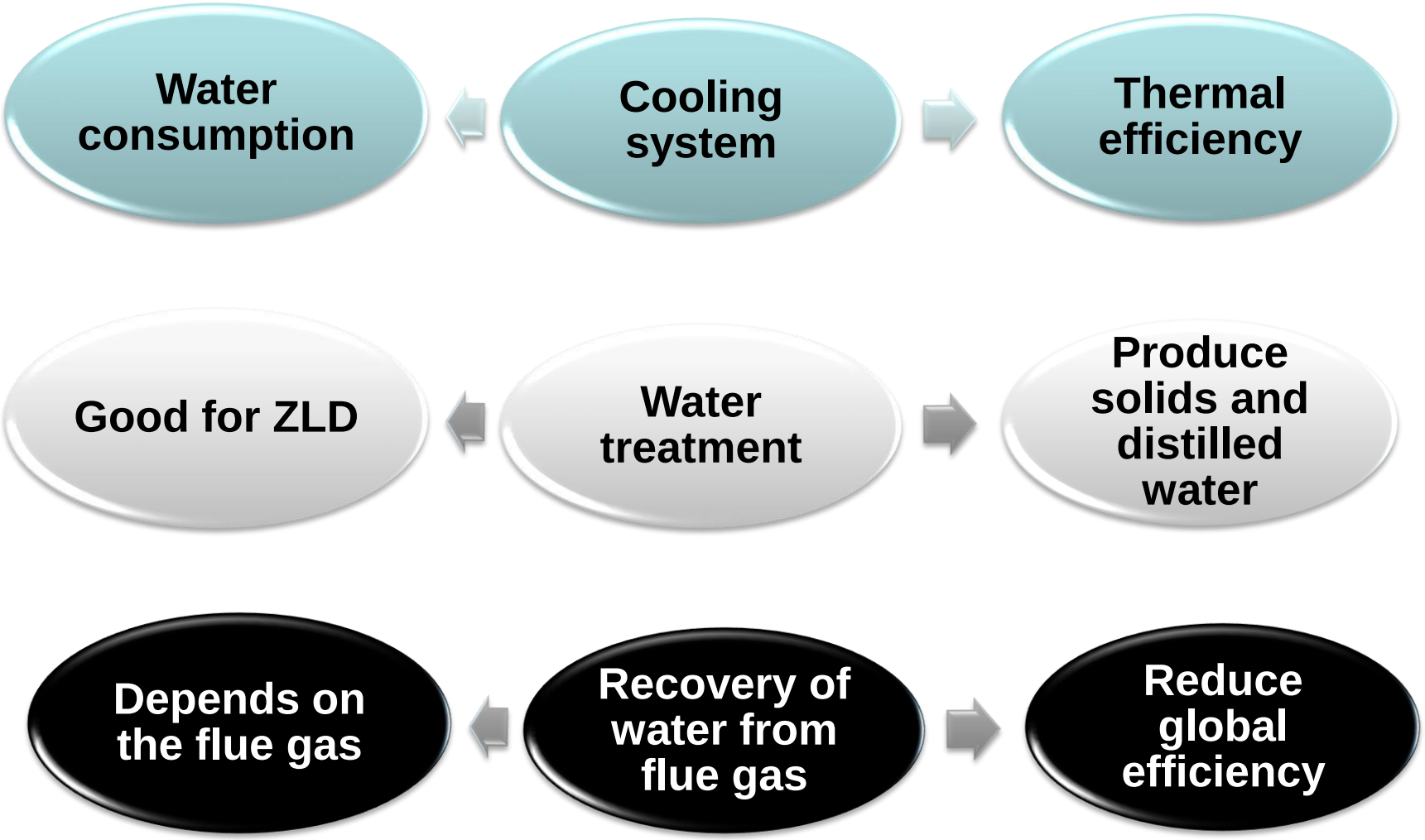
Extracting formation water from CO_2 storage

- **Scope**
  - Deep saline formations, good potential for CO_2 injection
  - Pressure management by water extraction
  - Use/disposal of water extracted
  - Identify research priorities
- **Findings**
  - Depends on storage site characteristics
  - Generally water extraction increases storage capacity
  - Use of extracted water is unlikely to be financially beneficial
    - **Locations:** offshore or coastal areas
    - **Conditions:** combination of energy costs, water availability, quality of extracted water, other parameters

Evaluating analysis of water use of power plants with CO_2 capture

- **Scope**
  - Review techniques to reduce water consumption in power plants
  - Compare water usage with and w/o CO_2 capture
  - Evaluate the costs with and w/o CO_2 capture, with and w/o water reduction techniques
- **Evaluation**
  - Air cooling
  - Wastewater treatment
  - Water recovery from flue gas

Evaluating analysis of water use of power plants with CO_2 capture (2)



Evaluating analysis of water use of power plants with CO_2 capture (3)

- **Effects of plant location on CCS cost**
  - **Plants:** Supercritical pulverised coal (SC PC) boiler and natural gas combined cycle (NGCC) power plants, with and without CO2 capture (solvent scrubbing)
  - **Locations:** Netherlands, Poland (USA, dry and wet), Canada, South Africa (inland, coastal), Australia, India, China, Japan, Indonesia, Chile, Brazil, Egypt
- **Findings**
  - Costs of CO_2 capture is highly dependent on location
  - Cooling systems, ambient conditions, fuel quality and price, water availability, are of great importance
  - Local economic parameters impact on the plant cost

Evaluating analysis of water use of power plants with CO_2 capture (4)

- **Incentives to optimize the nexus**
- **Regulations**
  - **Best available technology:** closed-loop cooling systems, dry cooling (air-cooled condensers)
    - Not always meeting regulations! E.g. FGD
  - **Legislation, permitting:** Site specific
  - **Zero-liquid discharge (ZLD):** No need to meet discharge limits - revenue from secondary products (e.g. China)

Source: IEA Clean Coal Centre TCP (2018), *Wastewater regulations and issues for coal-fired power plants.*

Collaborative project with CSIRO

- **Objectives**
  - Techno-economic evaluation of water usage along the whole CCS chain
    - Develop a methodology (applied to the Netherlands)
    - Study the whole range of locations
  - Understand the potentials and challenges
    - Using extracted water in CCS and power plants
  - Inventory of best-case integration strategies

Summary

- **Power plants require substantial quantities of water**
  - The overall use can be mitigated through CO2 capture and re-use of extraction water
- **Costs and efficiencies of the energy-water-CCS nexus is highly dependent on site characteristics and economic conditions**
  - The GHG TCP/CSIRO project will provide additional conclusions on the reuse of extracted water in the power plant

For more information

Research areas

- Water usage in CCS
- CCS in industry (update soon!)
- Emerging CO2 capture technologies
- Fuel cells
- Cost of CCS
- Environmental impact of CCS (emissions) and risks

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Get in touch!