

Forskning og teknologi innen CO₂ håndtering



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Klimakur Seminar, 20 Aug. 2009 - Stavanger

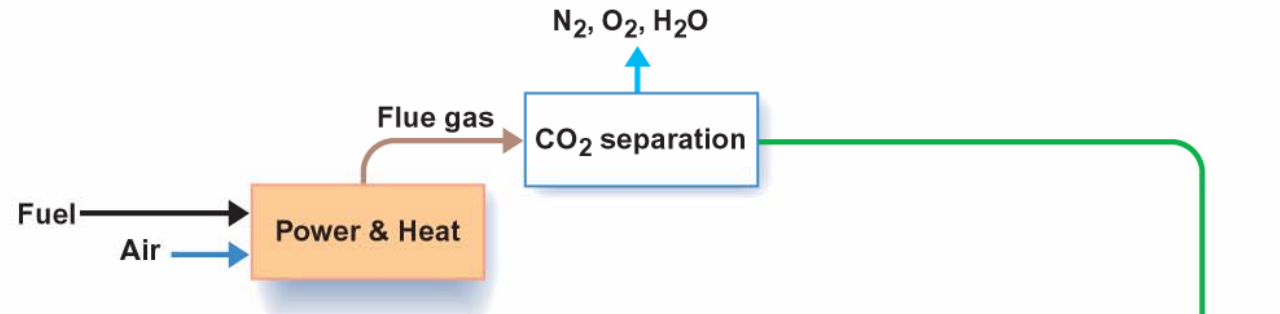
Tema

- Teknologier og ytelser
- Globale utviklingstrekk mhp prosjekter og teknologi
- Teknologiske utviklingstrekk- gap
- Oppsummering

CO₂ capture – 3 main routes

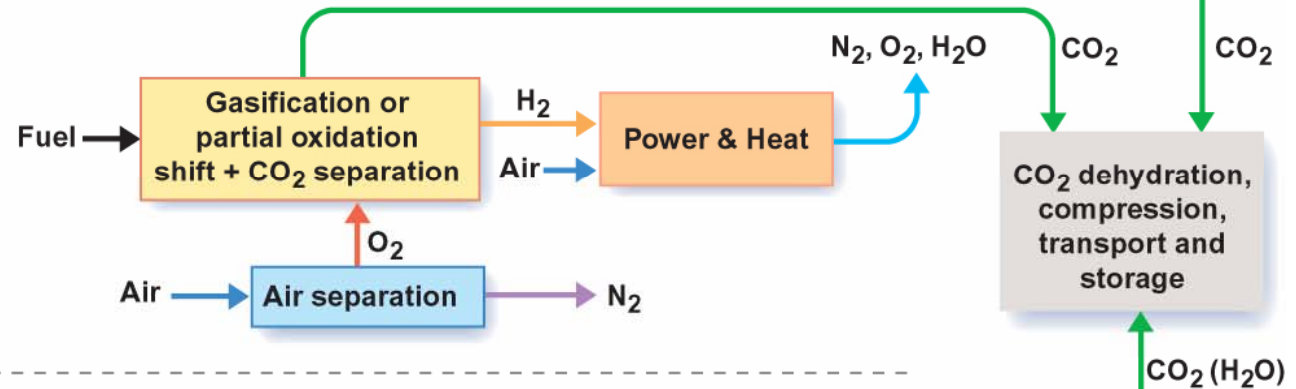
Post-combustion capture

Post-C



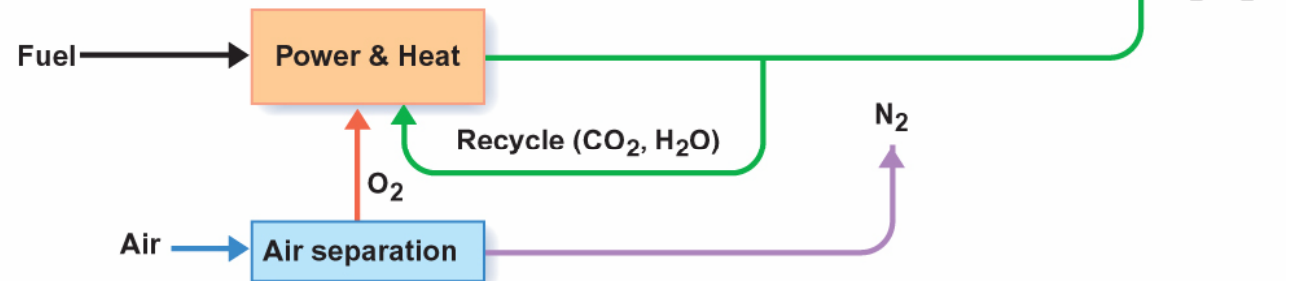
Pre-combustion capture

Pre-C

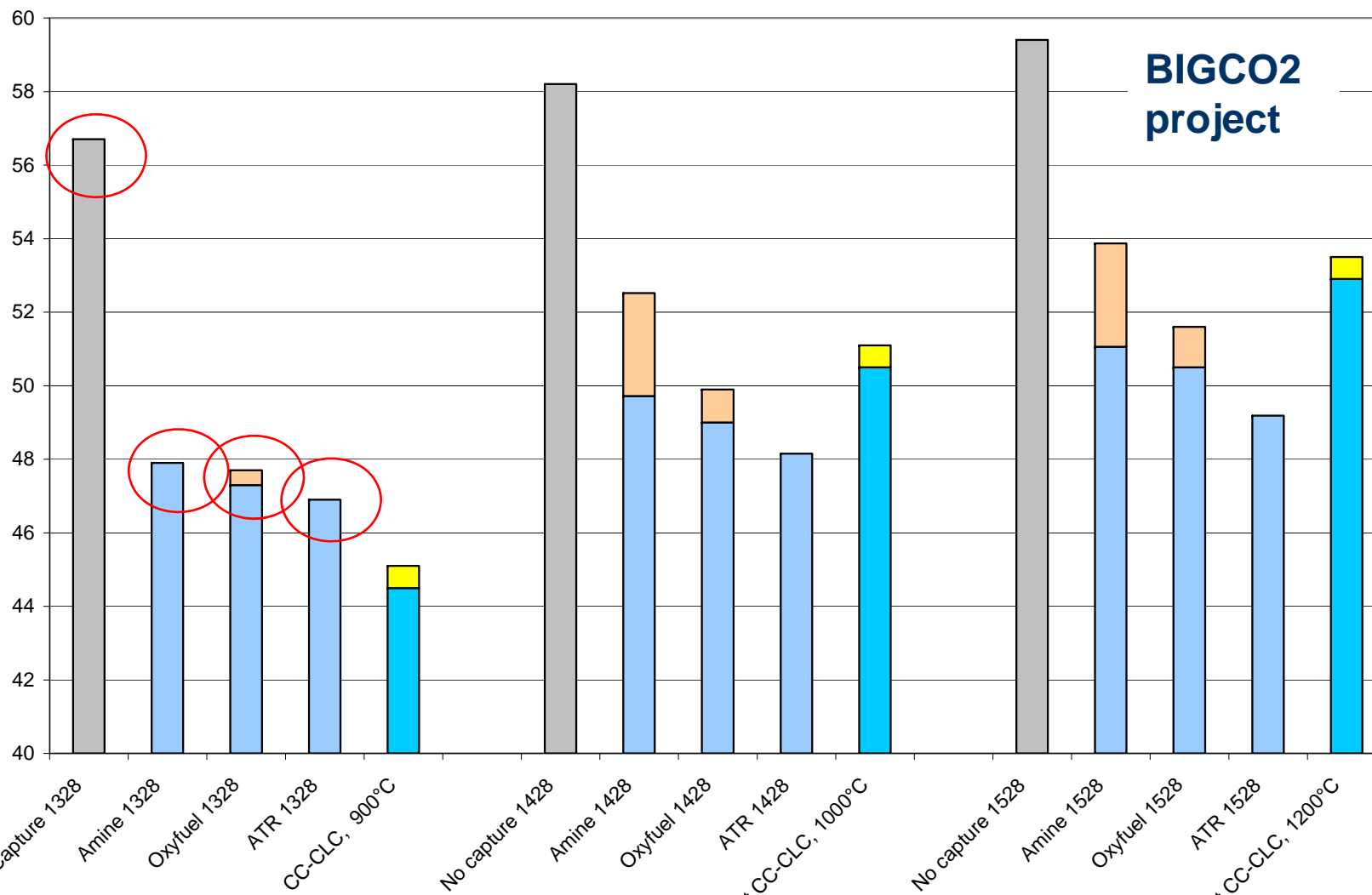


O₂/CO₂ recycle (oxyfuel) combustion capture

Oxy-fuel



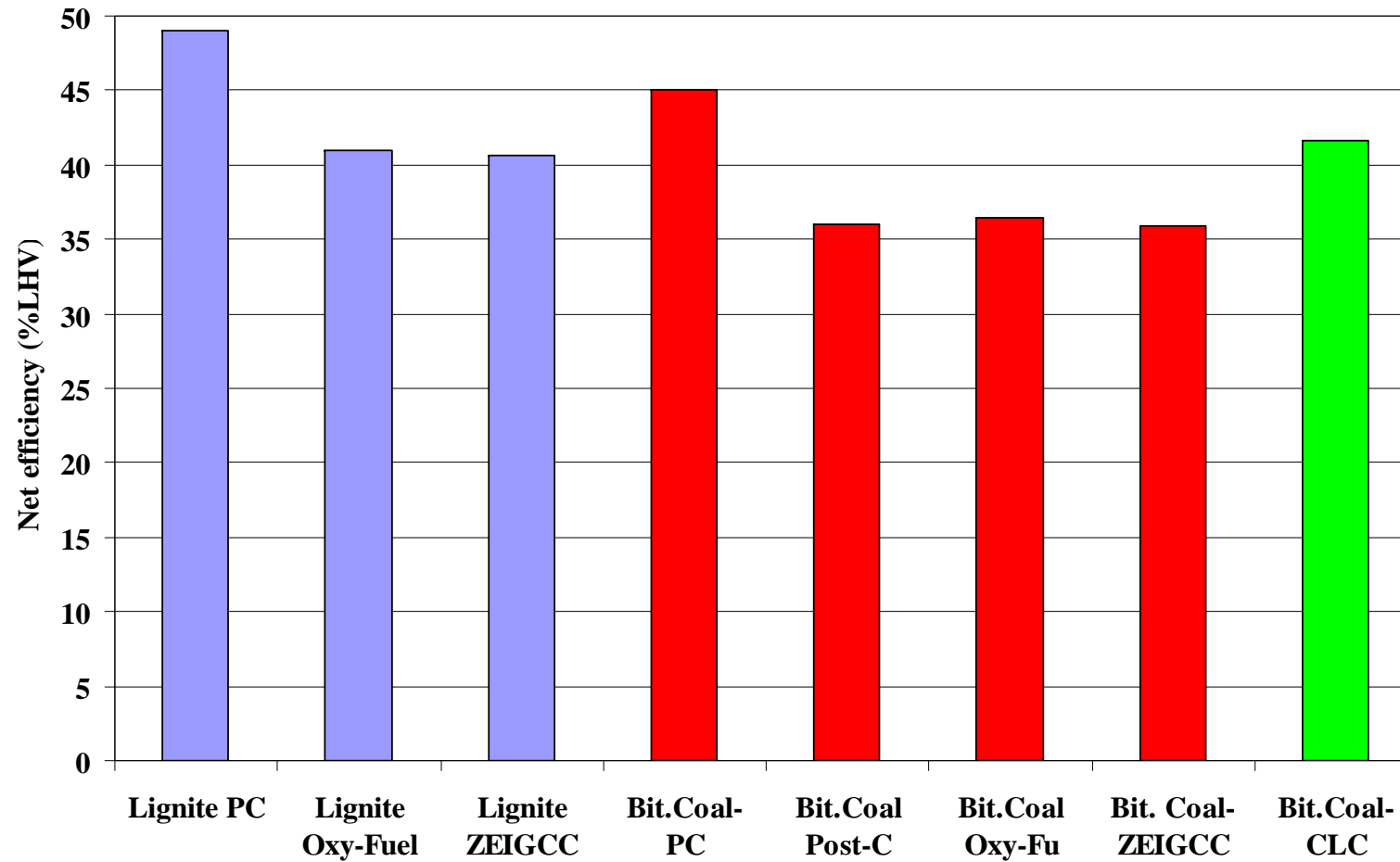
Net plant efficiencies of the natural gas-fired cycles



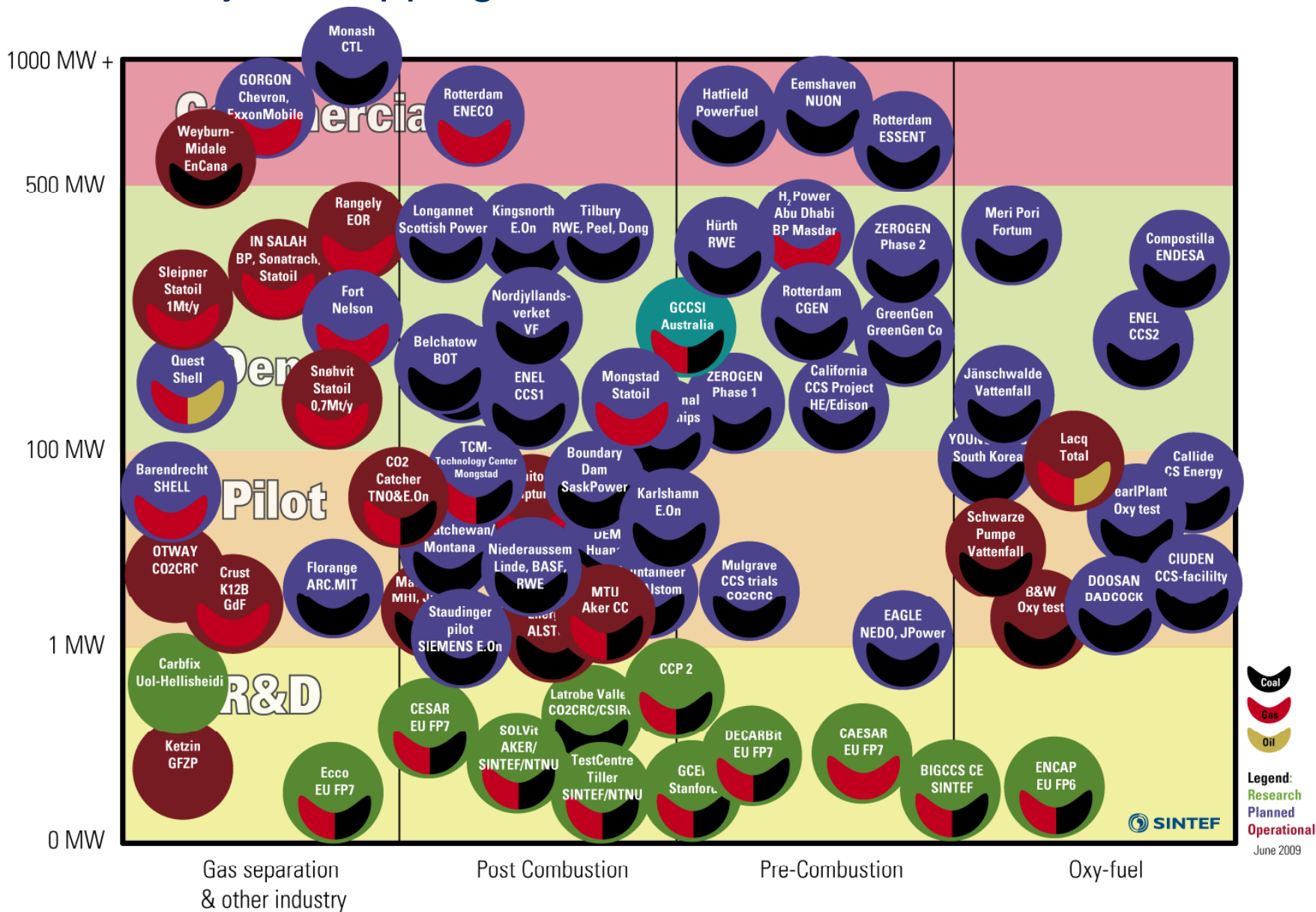
Post-C får med seg alle kraftverksforbedringene som vil bli utviklet

TCCS4:Jordal

Net plant efficiencies of coal fired cycles

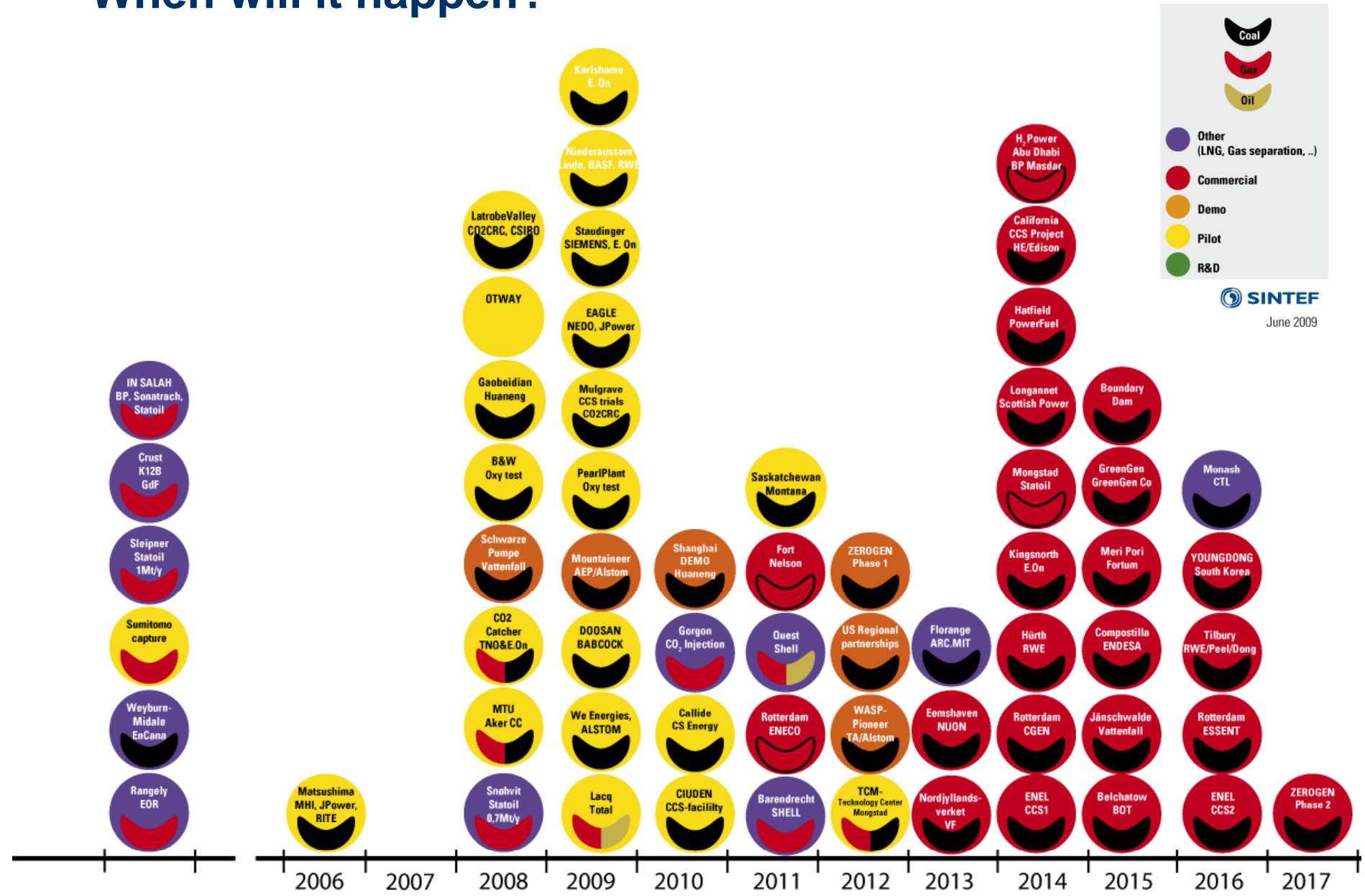


Project mapping- tech's vs size – Global view



Legend:
 Research (Green)
 Planned (Yellow)
 Operational (Red)
 June 2009

When will it happen?



- Coal
- Gas
- Oil
- Other (LNG, Gas separation, ..)
- Commercial
- Demo
- Pilot
- R&D

SINTEF
June 2009

Observations

- No technology winner
 - (ZE)IGCC - coals
 - (ZE)IRCC - gas
 - Post-C- coals and gas
 - Oxy-fuel – coals
 - No oxy-fuel gas pilot/demo announced
- Crowded in the Post-C pilot/demo combination
- No such thing as pilot for Pre-C- GT's come in discrete sizes
- Europe and N.America have a slight preference for Post-C plants although oxy-fuel is gaining momentum

- 12 Pre-C projects whereof 10 are 100MW+
- 12 Oxy-fuel projects whereof 4 are 100 MW+
- 25 Post-C projects whereof 12 are 100 MW+



Utsyn – teknologiutvikling 2020 og mot 2050

- Fase I : til 2020: For det meste teknologier slik vi kjenner dem i dag
 - Utfordringen ligger i å ta de i bruk, optimalisere og kommersialisere dem
- Fase II: 2020- 2030: Videreutviklinger av teknologier som er tatt i bruk innen 2020 og kommersialisering av dette samt utforskning/pilotering av helt nye teknologier som er på forskningsstadiet i Fase I
- Fase III: 2030-2050. Teknologier som blir brakt til kommersialisering i denne perioden er basert på optimisering og raffinering av teknologiene i fase I og II. Demonstrasjon av teknologier fra forskningsstadiet i fase II, teknologier som forutsetter bygging av helt nye anlegg.
- EU's teknologiplattform for CCS – ZEP har under utarbeidelse en Long Term R&D plan beyond 2020
- Ser på FoU behov og implisitt hvor det bør satses

Hovedtrekk- Post Combustion

- Lavere energibehov pga bedre kjemikalier/prosess
 - Fase I: 3 GJ/ton
 - Fase II: 2 GJ/ton
 - Fase III: 1.5 GJ/ton
- Røykgassresirkulering og oxygen anrikning for økt konsentrasjon av CO₂ i gassturbiner
 - Kommersielt i Fase II-III
- Membraner
 - Kommersielle i Fase II-III
- Utfrysing
 - Kommersielt i Fase II-III
- Adsorbenter
 - Kommersielt i Fase III

Hovedtrekk- Pre Combustion (gassrelatert)

- Forbedret oksygen produksjon for reformering/gasifisering (kommerisell)
 - Kryogen (Fase I)
 - Membraner (Fase II-III)
 - Adsorbenter (Fase III)
- Integrerte prosesser med membraner/adsorbenter – Fase III
- Bedre kjemikalier for CO₂ fangst ved høyt trykk og temperatur – Fase II
- Optimaliserte gass turbiner for hydrogen forbrenning (Fase II)

Hovedtrekk Oxy-fuel teknologier (gass relatert)

Pt ingen leverandører

Viktige områder:

- Oxy-fuel forbrenning – fundamentalt
- Oxy-fuel: mixing med røykgass og tilførsel (fase II)
- Oxy-fuel gass turbin (Fase II- demo)
- CLC (Chemical Looping Combustion) (Fase II-III)
 - Materialer
 - Pilot og demo
 - Reaktorer
 - Integrasjon

Other factors – sensitivity analysis- early commercial plant

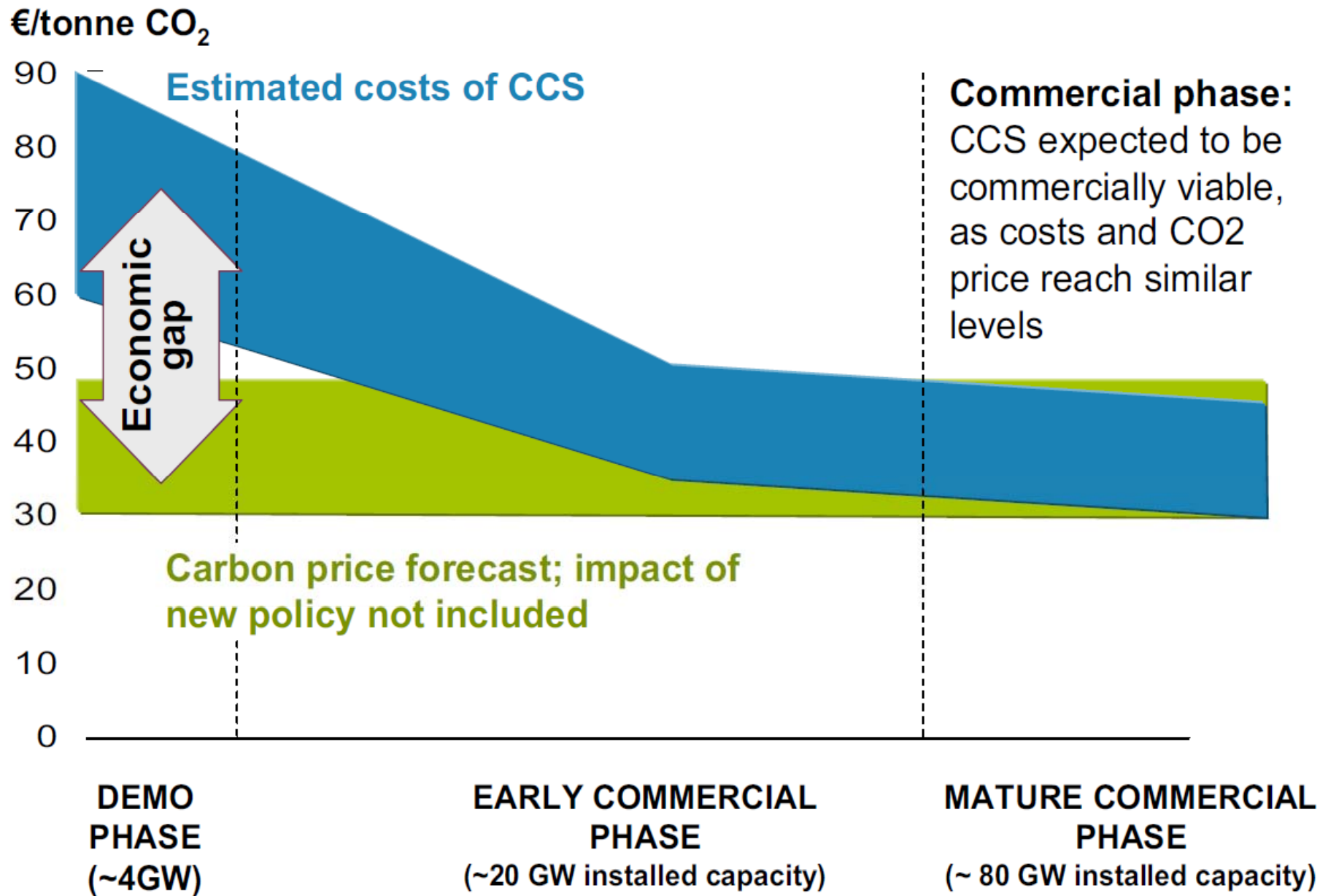
Parameter	Reference case value	Sensitivity value	Rationale for change	Impact on total cost of change €/tonne CO ₂ abated, 2020**
CCS – Capex €/kW	1,000	750	• 25% reduction of additional Capex vs. non-CCS plant because of breakthrough technology	-6
Fixed Opex Percentage of Capex	2.5	4.0	• Opex above industry norm initially before learning CCS operations	3
Efficiency penalty Percent	7.0	3.5	• Breakthrough technology reduces efficiency loss vs. non-CCS	-2
Utilization Percent	86	81	• Market conditions reduce utilization by 5% points	4
Learning rate Percent*, 2020-2030	12	6	• Most conservative expert group estimate	3

Note: Sensitivities performed for following examples: early commercial hard coal reference plant (capture), offshore network for single early commercial plant (transport), offshore depleted oil gas field (storage)

* Per doubling of installed plant capacity for EU rollout (increase from 22.5 to 81 GW)

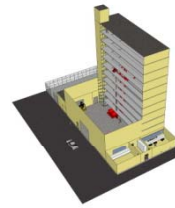
** 2030 for learning rate sensitivity

McKinsey: CCS-Assessing the economics (2008)



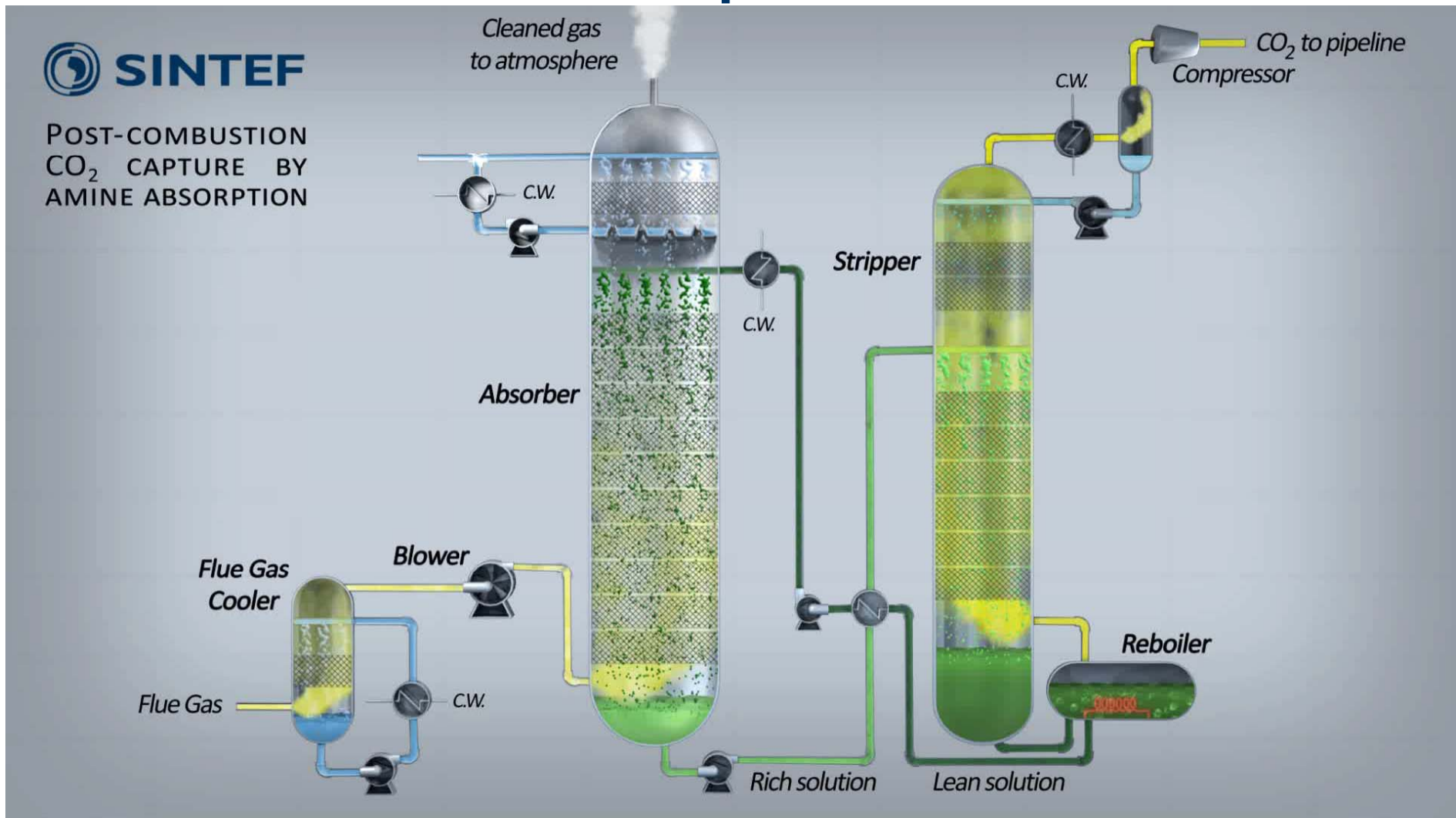
ZEP 2009

Summary

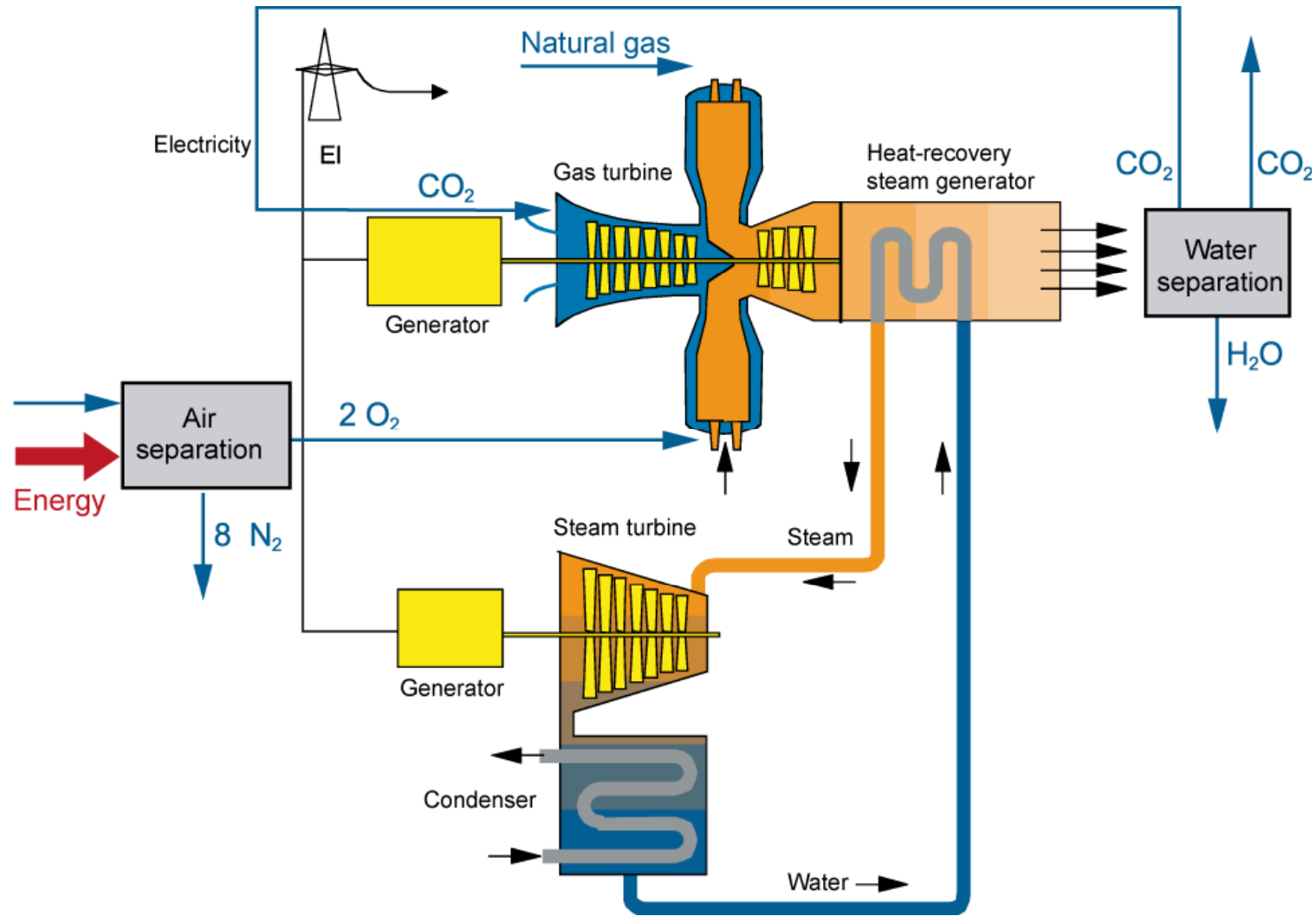


- CCS R&D, pilot, demo and full scale projects are underway and pilots are booming for the time being
- All technology routes are being followed at present in industrial led initiatives – we will see a portfolio of capture technologies
- CCS demo and large scale are being facilitated in many economies to promote the first real plants with a view to become a commercial solution around 2020
- Post-combustion and Pre-combustion seems closer to commercial operation than Oxy-fuel - consistent with ZEP technology block assessment
- Emission standards may shift relative importance of gas versus coal- CCS will be required for gas, also needed for large cuts.
- Outlook today is that there are few really new technologies with groundbreaking better performance – thermodynamics is still the king!

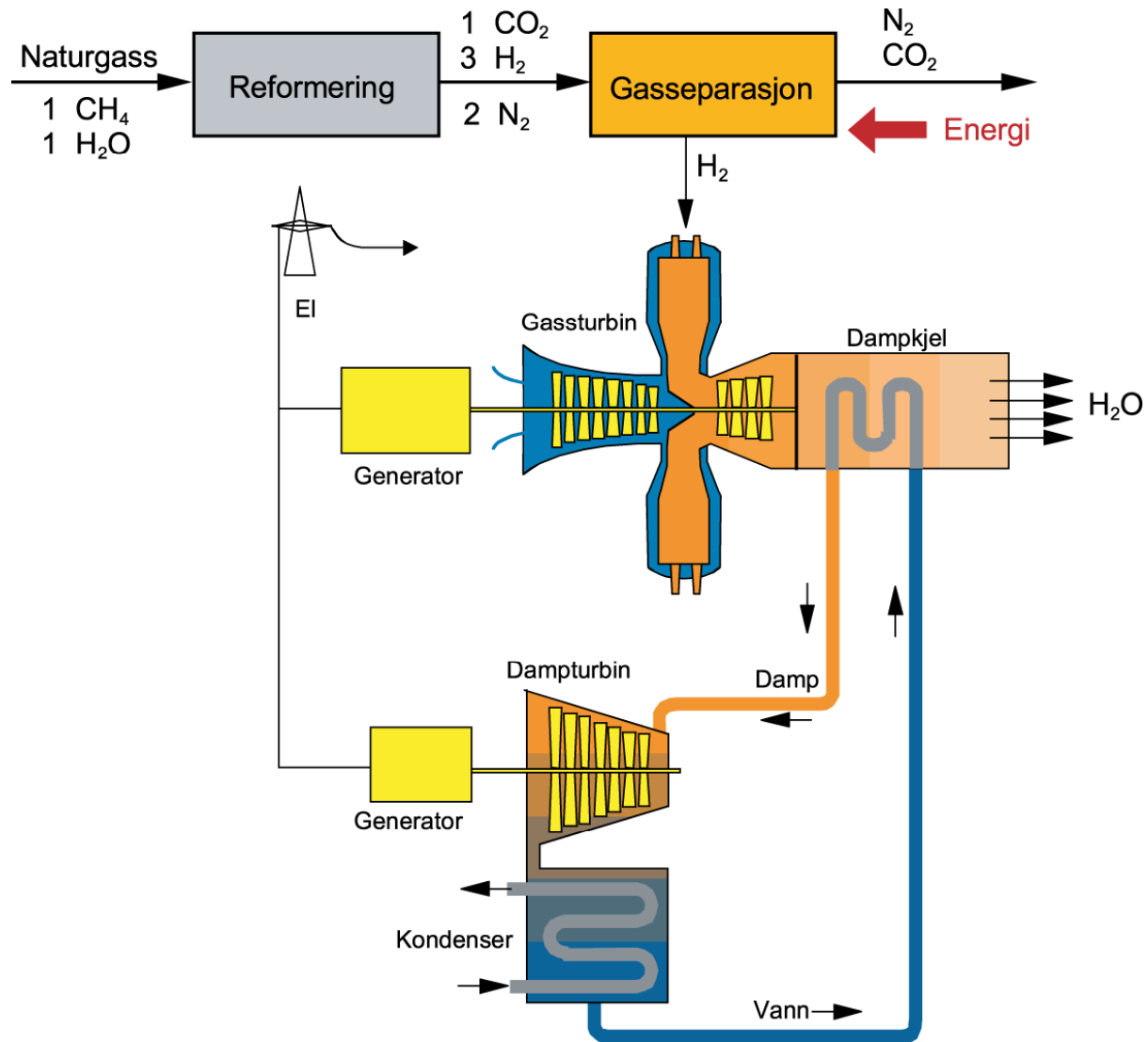
Post – combustion capture



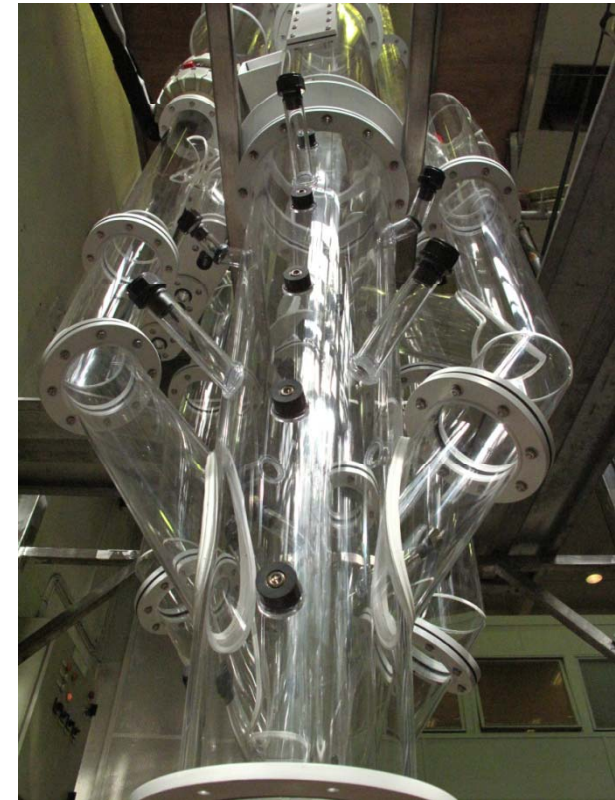
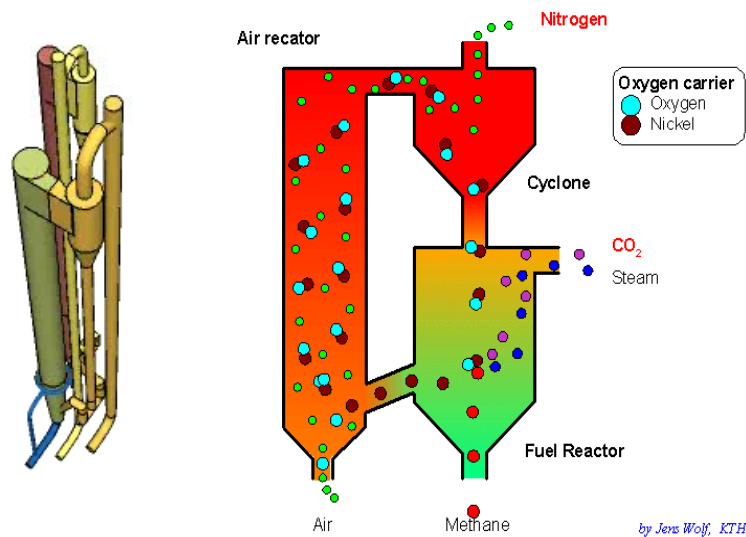
Oxy-fuel – Natural Gas fired Power Cycle



Pre-Combustion- production of H₂ for use in a Gas Turbine



Chemical Looping Combustion



BIGCLC reactor, 150kW_{th}

