

The impacts of CO₂ capture technologies in power generation and industry on greenhouse gases and air pollutants in the Netherlands

Study for the Netherlands Environmental Assessment Agency within the Dutch Policy Research Programme on Air and Climate financed by the Dutch Ministry of Housing, Spatial Planning and Environment and Environment

TNO | Knowledge for business



EON Maasvlakte



Universiteit Utrecht

Toon van Harmelen

toon.vanharmelen@tno.nl

Toon van Harmelen (TNO)
Joris Koorneef (UU)
Arjan van Horsen (TNO)
Takeshi Kuramochi (UU)
Magdalena Jozwicka (TNO)
Andrea Ramírez Ramírez (UU)
René van Gijlswijk (TNO)
Erik Lysen (UCE)

Objective

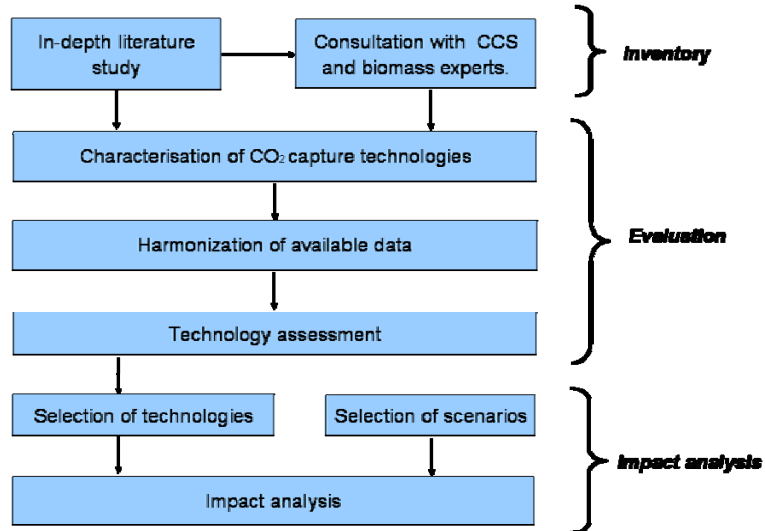
To generate a detailed impact analysis of different CO₂ capture technologies on transboundary air pollution in the Netherlands in 2020 and 2050

With specific attention for:

- different types of capture technologies
- data harmonization for a consistent assessment (not presented here)
- the Dutch power generation and industry
- additional mitigation measures and costs
- Life Cycle Analysis
- co-firing of biomass (not presented here)
- types of solvents (not presented here)



Approach



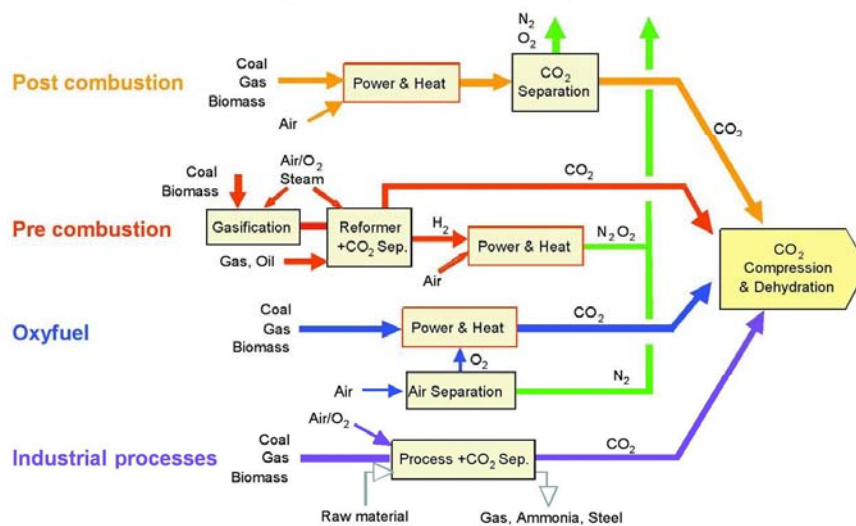
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3 types of CO₂ capture

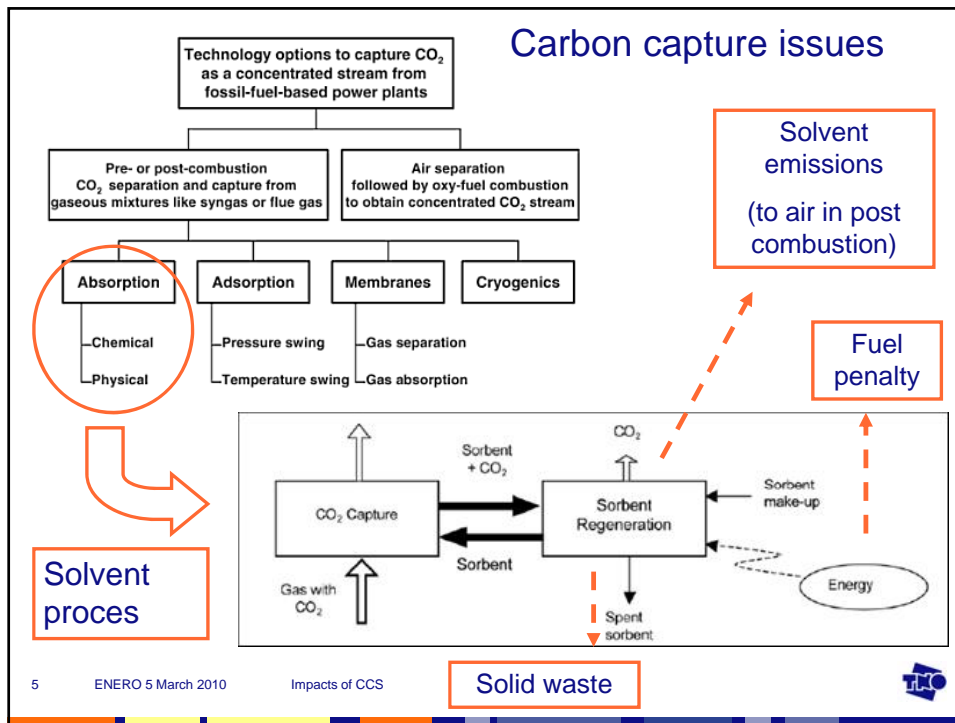


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Technology characterization


based upon >162 cases from >32 literature sources

Technology		Development phase	Applica-tion	Economic performance				Environmental performance						
				retrofit/robust/industry	electrical efficiency (%)	CoE (€ cts/kWh)	€ per tonne avoided	efficiency penalty (% pts)	CO ₂ (g/kWh)	NO _x (g/kWh)	SO _x (g/kWh)	PM ₁₀ (g/kWh)	NH ₃ (g/kWh)	Other impacts
No capture		PC	commercial	40%	5.4	-	0	795	0.37	0.25	0.042	0.0058		
		NGCC	commercial	57%	6.6	-	0	366	0.089	0	-	0.00037		
		IGCC	commercial	42%	5.4	-	0	762	0.23	0.036	0.030	0		
Post	Amine	PC	pre-commercial	yyy	31%	8.3	42	11	106	0.56	0.0072	0.048	0.19	Toxic waste
	Amine	NGCC	pre-commercial	yyy	49%	8.6	63	8	51	0.12	0	-	0.041	Toxic waste
	Chilled am	PC	pilot	yyy	39%	n.a.	16	n.a.	n.a. (~ Amine PC)				0.12	
	Membrane		lab scale	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Pre		GC	demonstration	nyy	49%	n.a.	n.a.	9	21	n.a. (~ Amine NGCC)				
		IGCC	demonstration	nyy	35%	6.9	24	7	100	0.24	0.010	0.035	0	
Oxy		PC	pilot	y?ny	33%	8.3	36	11	61	0.12	0.016	0.0059	-	
		GC	pilot	y?ny	53%	n.a.	n.a.	4	10	-	-	-	-	
		NGCC	pilot	y?ny	46%	9.5	89	11	6	0.00	0.00	-	-	

* New coal fired plants have a higher conversion efficiency

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Short technology characterization

	Main characteristic	Capture technology and application
Uncertainty 	Short-term & relatively cheap	Post combustion Amine PC
	Short-term & relatively clean	Post combustion Amine NGCC
	Mid-term & relatively clean coal	Pre combustion IGCC
	Long-term & clean	Oxyfuel Gas Cycle
	Long-term & cheapest	Chilled ammonia PC

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Three (coal based) **power generation scenarios** in the Netherlands in 2020

- 2020 without CCS: No CCS applied, based upon current plans
- 2020 with CCS -S1: CCS applied to 2 new coal power plants
 - ✓ IGCC – NUON (1200 MW Eemshaven) (pre combustion)
 - ✓ PC – EON (1100 MW Maasvlakte) (post combustion)
- 2020 with CCS -S2: CCS applied to all new coal power plants
 - ✓ IGCC – NUON (1200 MW Eemshaven) (pre combustion)
 - ✓ PC – EON (1100 MW Maasvlakte) (post combustion)
 - ✓ PC – Electrabel (800 MW Maasvlakte) (post combustion)
 - ✓ PC – RWE (1600 MW Eemshaven) (post combustion)

Assuming equal electricity production (for clear comparison)

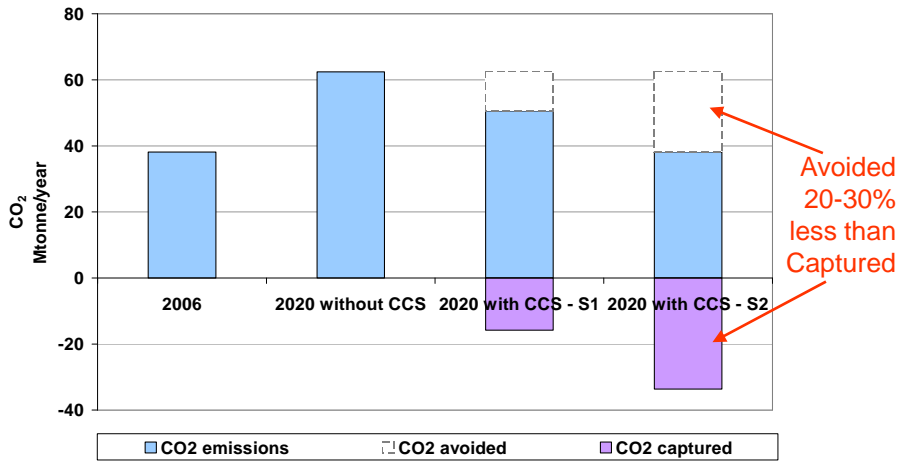
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CO₂ emissions in 2006 and three 2020 scenarios



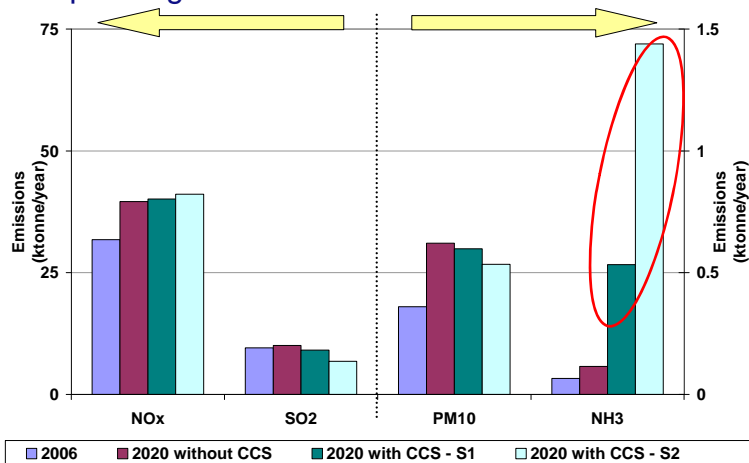
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Air pollutant emissions from power generation in 2020 in the Netherlands



=> Relatively minor increases (NOx) and decreases (SO2, PM) except for NH3

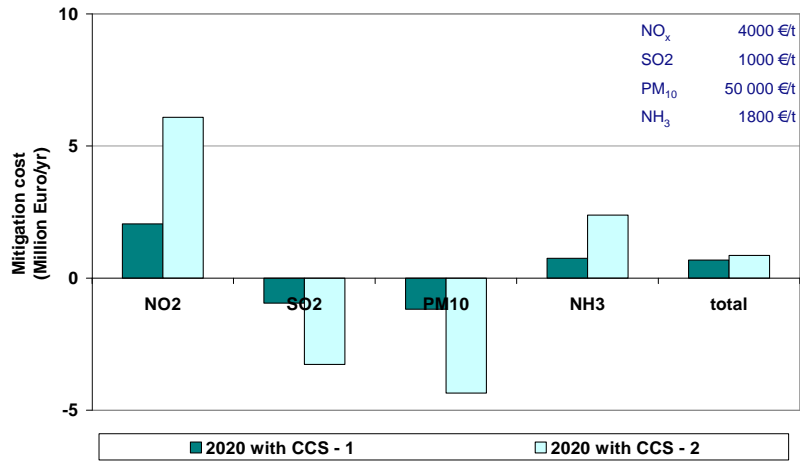
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Air pollution Costs and Benefits due to CCS



=> Relatively minor (net) costs and benefits

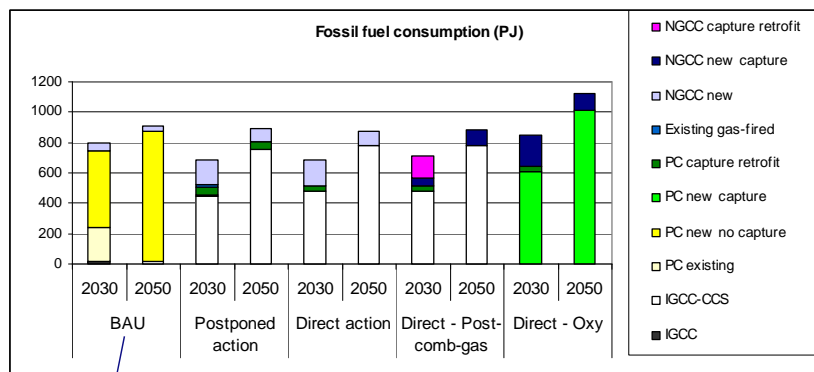
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Scenarios for power generation in 2030 / 50 in the Netherlands



Cost-effective;
coal based,
no GHG policy

CCS PC exist
IGCC new

CCS PC exist
IGCC new
+ gas exist &
new

Oxy coal
& gas

MARKAL: CO₂ reduction 15% in 2020; 50% in 2050; start in 2020 or 2010

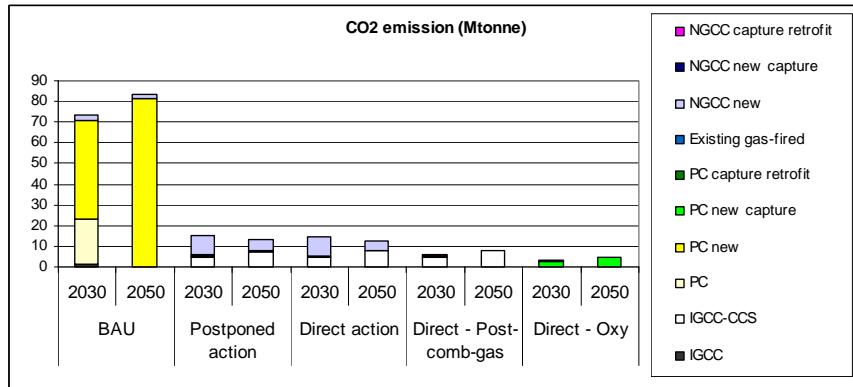
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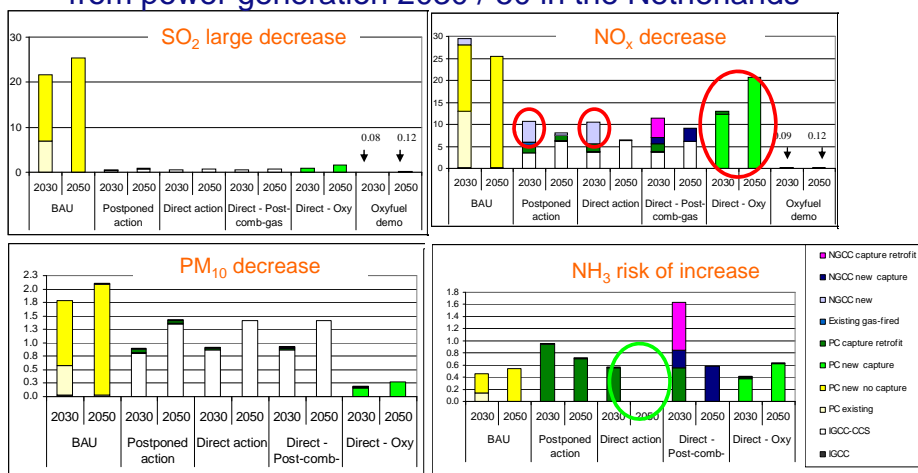
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CO₂ emissions from power generation in 2030 / 50 in the Netherlands



Air pollutant emissions from power generation 2030 / 50 in the Netherlands



The worldwide CO₂ emission contribution of large industrial sources (> 0.1 MtCO₂ per year) (IPCC, 2005)

Process	Number of sources	Emissions (MtCO ₂ , yr ⁻¹)
Fossil fuels		
Power	4,942	10,539
Cement production	1,175	932
Refineries	638	798
Iron and steel industry	269	646
Petrochemical industry	470	379
Oil and gas processing	Not available	50
Other sources	90	33
Biomass		
Bioethanol and bioenergy	303	91
Total	7,887	13,466

=> CO₂ capture potential is significant, but majority in power generation

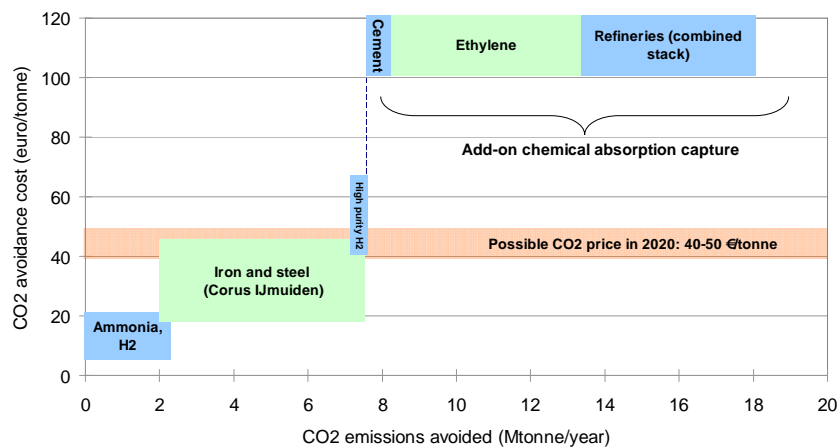
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CO₂ avoidance costs curve of CO₂ capture in the Dutch industry in 2020



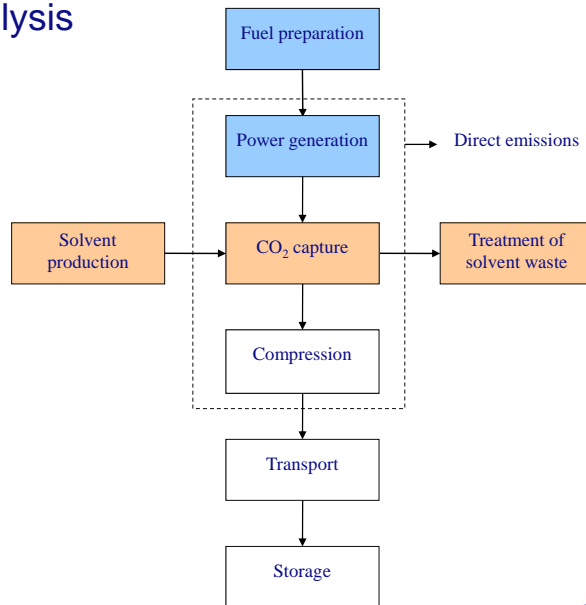
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Life cycle analysis



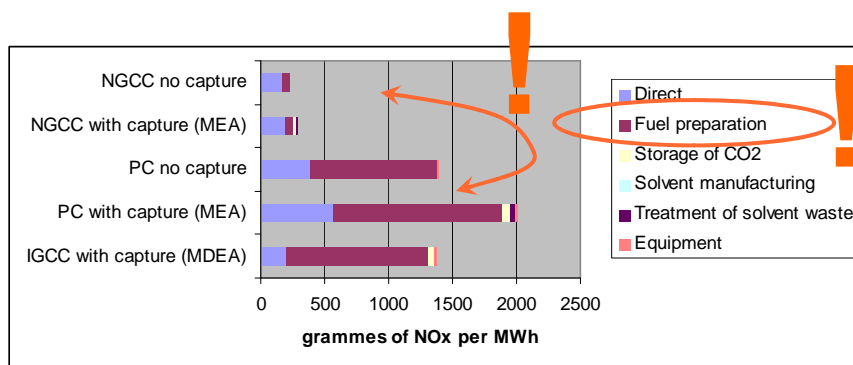
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Direct and indirect NO_x emissions



Indirect emissions are larger than the direct emissions...

...but are emitted outside EU

Uncertainties are large

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Main conclusions

- At the moment, there is no clear “best” capture technology; Different types of capture technologies have different pro's and con's (economically, CO₂ avoidance costs, fuel use, emissions, waste)
- CO₂ reduction potentials are significant in industrial processes, but the largest part of CCS potentials is found in power generation
- In general transboundary air pollutant emissions tend to decrease or increase only slightly; mitigation measures can be applied using current available technology without significantly changing the economic feasibility of the options
- The introduction of coal fired plants has much more negative impact on transboundary air pollutants, also due to indirect emissions outside the EU
- Risk for NH₃ emissions and waste from post-combustion, addressed by research on solvent degradation



Thank you!

Interviewed experts:

- Kay Damen (NUON, expert pre combustion / system analysis)
- Paul Feron (CSIRO Energy Technology, lead expert CCS)
- Peter Geerdink (TNO, expert oxyfuel combustion)
- Frank Geuzebroek (SHELL, expert pre & post combustion)
- Jan Hopman (TNO, expert post combustion)
- Daan Jansen (ECN, expert pre combustion)
- Geert Versteeg (Procedé, expert post combustion)
- Jean Pierre Birat (Arcelor Mittal)
- Arjen Boersma (ECN, Unit Biomass, Coal and Environmental Research)
- Earl Goetheer (TNO, Post Combustion/Solvents expert)
- Gerard Jägers (Corus Steel)
- Ton Pereboom (ENCI)
- Pierre Ploumen (KEMA, Plant configuration expert)
- Jiri van Straelen (Shell)
- Noim Uddin (Lead Climate Change Verifier, Det Norske Veritas Australia and New Zealand)
- Kenneth Möllersten (Swedish Energy Agency)
- James S. Rhodes (Carnegie Mellon University, Department of Engineering and Public Policy)



