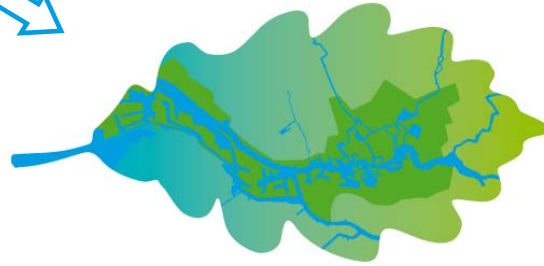


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# Partners



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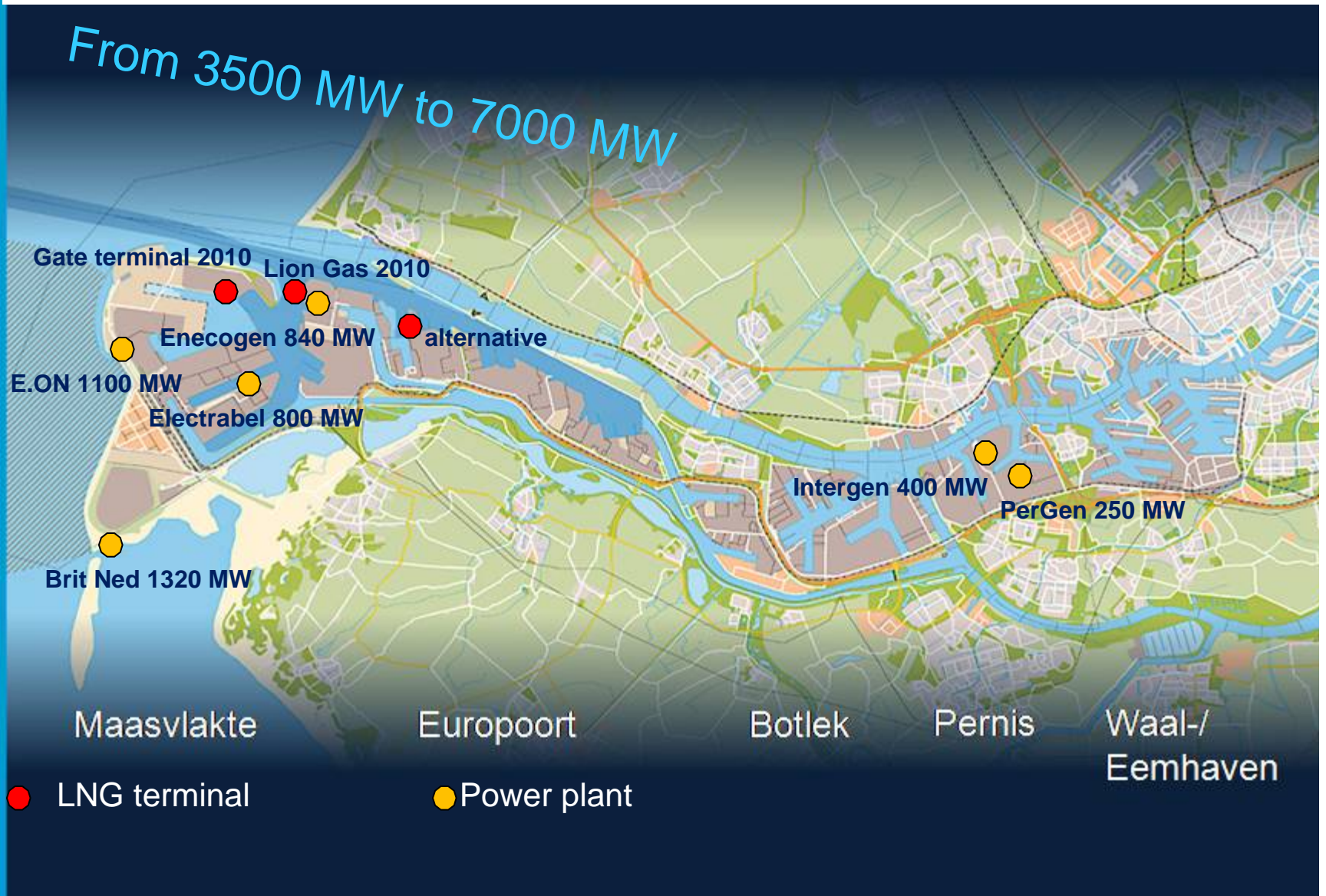
Gemeente Rotterdam

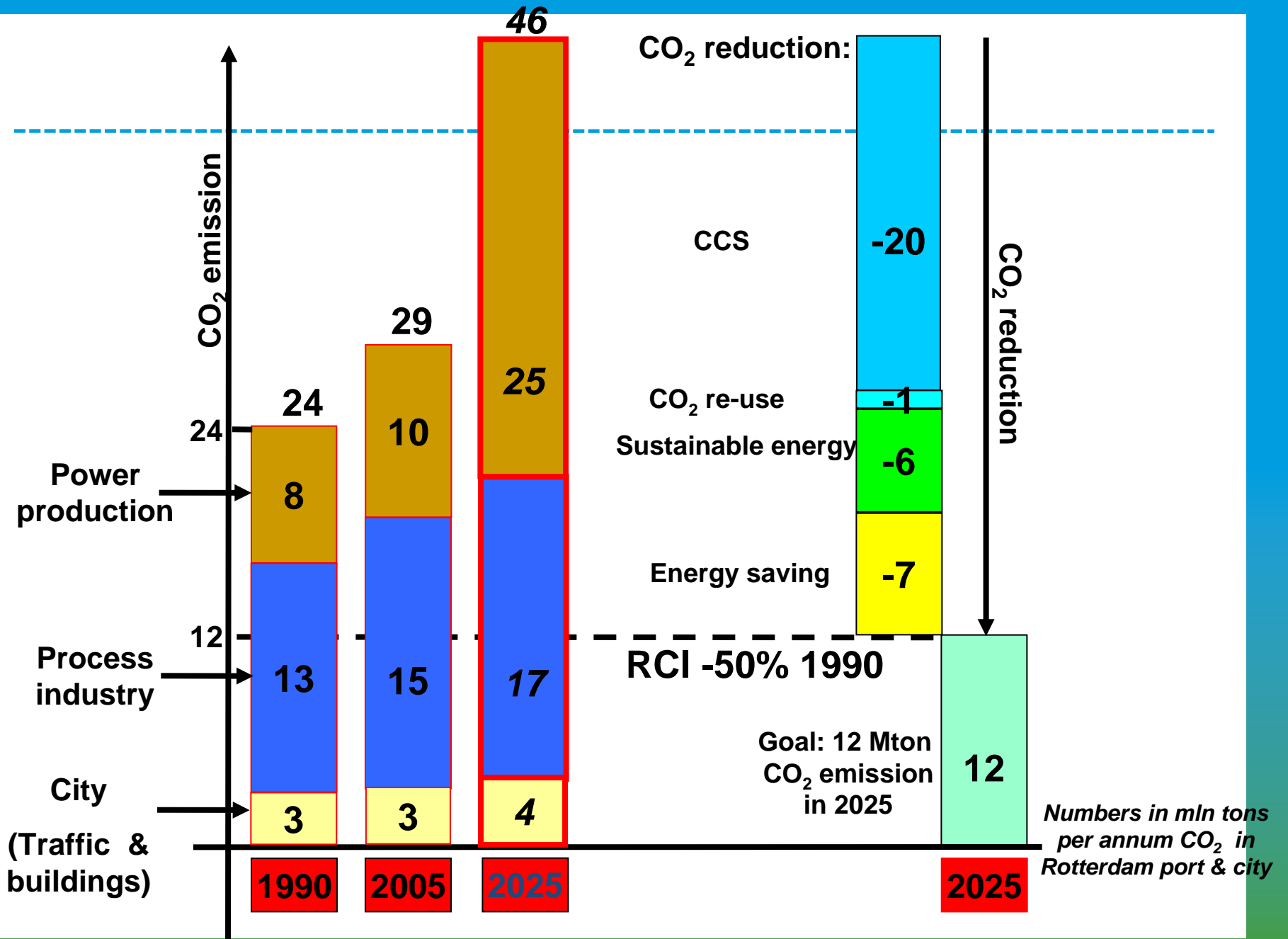


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# Rotterdam energy port

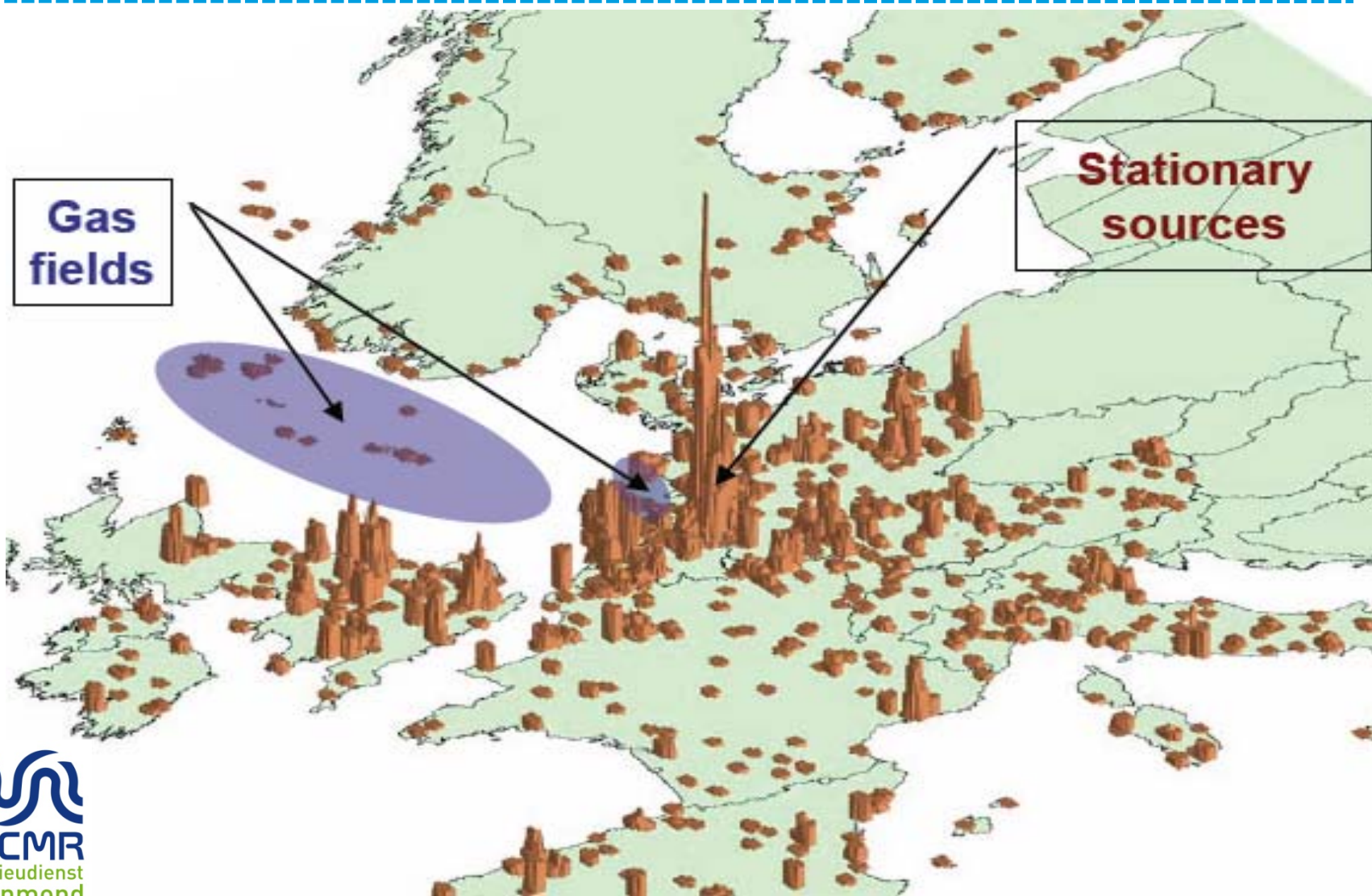
From 3500 MW to 7000 MW



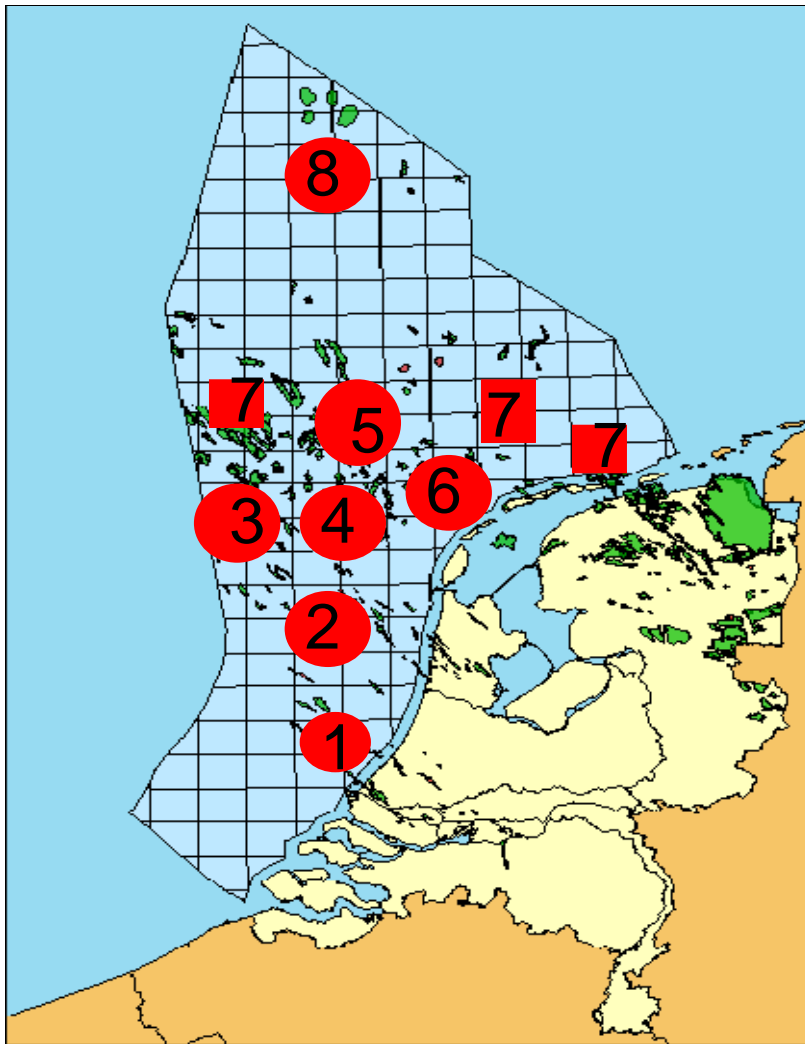




# CO<sub>2</sub> Sources in Europe



# Storage Capacity North Sea (NL)



Company	Storagecapacity
1: Taqa	60 Mton
2: Wintershall	100 Mton
3: Wintershall	100 Mton
4: Gaz de France	155 – 200 Mton
5: Total	150 Mton
6: Wintershall	70 Mton
7: NAM	150 Mton
8: Chevron	100 – 150 Mton
Total	900-1000 Mton



# Roadmap CCS in Rotterdam

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**2007**

Strategy for CCS, exploring the options:

- CO2 cluster approach: multiple sources/multiple sinks
- Leads to lower costs in chain of capture, transport and storage
- Policy and enabling framework needed
- Incentives from ETS and EOR/EGR



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# Roadmap CCS in Rotterdam

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## 2008

Four phase model, preliminary cost calculations:

1. Start with pure CO<sub>2</sub> ('easy' sources) and use of CO<sub>2</sub> in greenhouses (2010)
2. Demonstration capture plants and building on existing infrastructure (2015)
3. Full scale CCS for power plants (2020)
4. Retrofitting existing industrial sources (2025)

Incentives from ETS: € 45 per tonne CO<sub>2</sub> needed





# Roadmap CCS in Rotterdam

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## 2009 (I)

Towards realisation:

- OCAP network growing: greenhouses and detailed study storage North Sea
- Eon/Electrabel proposal for EEPR: post-combustion (1,2 Mton), storage Taqa
- Shell refinery and storage in Barendrecht field
- Business case for T&S common carrier network (consortium lead by R'dam Port Authority)
- CO2 Liquid Logistics Shipping concept developed (consortium lead by Anthony Veder)
- Letter of Cooperation with 9 emitters: validated studies on capture projects
- Comprehensive financial analysis of CCS network in R'dam



# Letter of Cooperation RCI - emitters

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Company	Source (type)	CO2 emission (ton)
Confidential	Industrial CO2	900.000
AVR	Waste Heat Inc.	150.000
Air Liquide	Industrial CO2	500.000
Air Products	Industrial CO2	500.000
CGen	IGCC	2.500.000
Shell / Essent	IGCC	2.500.000
Eon	Post combustion	1,200.000
Electrabel	Post combustion	1.200.000
Confidential	IGCC	2.000.000
		11.450.000



# Reviewed installations

Plant type & size	Capture type & size	Target capture operational date
Ultra Supercritical Pulverised Coal Power Station with Biomass Co-Firing, 1080 MW	Post-combustion capture, 1.43 Mt CO <sub>2</sub> /yr	2015
Ultra Supercritical Pulverised Coal Power Station with Biomass Co-Firing, 800 MW		
Integrated Gasification Combined Cycle (IGCC) with potential biomass co-firing and hydrogen offtake, 900 MW	Pre-combustion capture, 5.07 Mt CO <sub>2</sub> /yr	2015
IGCC, 450 MW	Pre-combustion capture, 2.5 Mt CO <sub>2</sub> /yr	2015
IGCC, 350 MW	Pre-combustion capture, 2.0 Mt CO <sub>2</sub> /yr	2015
Hydrogen plant	Pre-combustion capture, 0.5 Mt CO <sub>2</sub> /yr	2015
Hydrogen plant	Pre-combustion capture, 0.5 Mt CO <sub>2</sub> /yr	2015
Furnaces in crude distillation unit	Post-combustion capture, 0.9 Mt CO <sub>2</sub> /yr	
Waste heat incinerator	Post-combustion capture, 0.15 Mt CO <sub>2</sub> /yr	



# Cost of capture

(real costs* – 2009 inflation basis, 2% annual rate)	Post-combustion plants		Pre-combustion plants
	PC Plant	Industrials	
<b>Using central case assumptions</b>			
In € per tonne captured	33	24 - 78	10 - 14
In € per tonne abated	48	24 -109	12 - 19
In €m per year	45	13 -70	20 - 66
<b>After sensitivity analysis on CAPEX, OPEX and commodity pricing</b>			
In € per tonne captured	24 - 42	17 - 90	6 -19

\*Note that the above numbers represent the additional support required over and above a prevailing long-term view of EUA price.



# Technical validation summary

Item	Unit of measurement	Pre-combustion IGCC	Pre-combustion H <sub>2</sub> plant	Post-combustion
Units affected by the CO <sub>2</sub> capture process in the plant	-	Whole plant	CO <sub>2</sub> capture & compression, Utilities	CO <sub>2</sub> capture & compression, Utilities
Power demand of the CO <sub>2</sub> capture & compression units <sup>(2)</sup>	kWh/t of CO <sub>2</sub> <sup>(1)</sup>	60 – 100 <sup>(4)</sup>	100 – 115	110 – 135
Overall additional power demand of the whole plant (electrical parasitic losses)	kWh/t of CO <sub>2</sub> <sup>(1)</sup>	130 – 160 <sup>(4)</sup>	105 – 125	120 – 145
Steam demand of the CO <sub>2</sub> capture unit	MJ/kg of CO <sub>2</sub> <sup>(1)</sup>	-0.02 – -0.04	0.5 – 1.0	3 – 5
Efficiency of plant without CO <sub>2</sub> capture	%	38 – 45	Not applicable	43 – 46
Efficiency penalty for case with CO <sub>2</sub> capture	Percentage points	6 – 10 <sup>(4)</sup>	Not Applicable	9 – 12 <sup>(3)</sup>





# Economic validation

Item	Unit of measurement	Pre-combustion		Post-combustion	
		IGCC	H <sub>2</sub> plant	USC-PC	Others
Specific investment cost of the CO <sub>2</sub> capture & compression units <sup>(2)</sup>	$\frac{\text{€}}{\text{(kg / h)}}^{(1)}$	140 <sup>(3)</sup> – 220	950 – 1100	680 – 760	1700 – 1900
Specific investment cost of the whole CO <sub>2</sub> capture plant (TIC)*	$\frac{\text{€}}{\text{(kg / h)}}^{(1)}$	480 – 680 <sup>(3)</sup>	1000 – 1200	850 – 950	2000 – 2200
Operating & Maintenance costs	€/t of abated CO <sub>2</sub>	5 – 10 <sup>(3)</sup>	10 – 12	4 – 5	75 – 85
CO <sub>2</sub> abated cost	€/t	35 – 50 <sup>(3)</sup>	35 – 45	40 – 60	110 – 130



# Cost of transport

(real costs – 2009 inflation basis, 2% annual rate)	Early Phases / low volumes		Later Phases (post-2020, volumes over 17 Mton per year)
	Volumes up to c. 5-6 Mton per year (up to 2015)	Volumes of between c. 5-6 Mton per year and c. 10 Mton per year (2015 to 2020)	
In € per tonne stored	20 – 29	13 -21	13 - 38
In €m per year	23 – 135	60 -156	229 - 482

(Note: the costs reported above include compression, transport and storage)

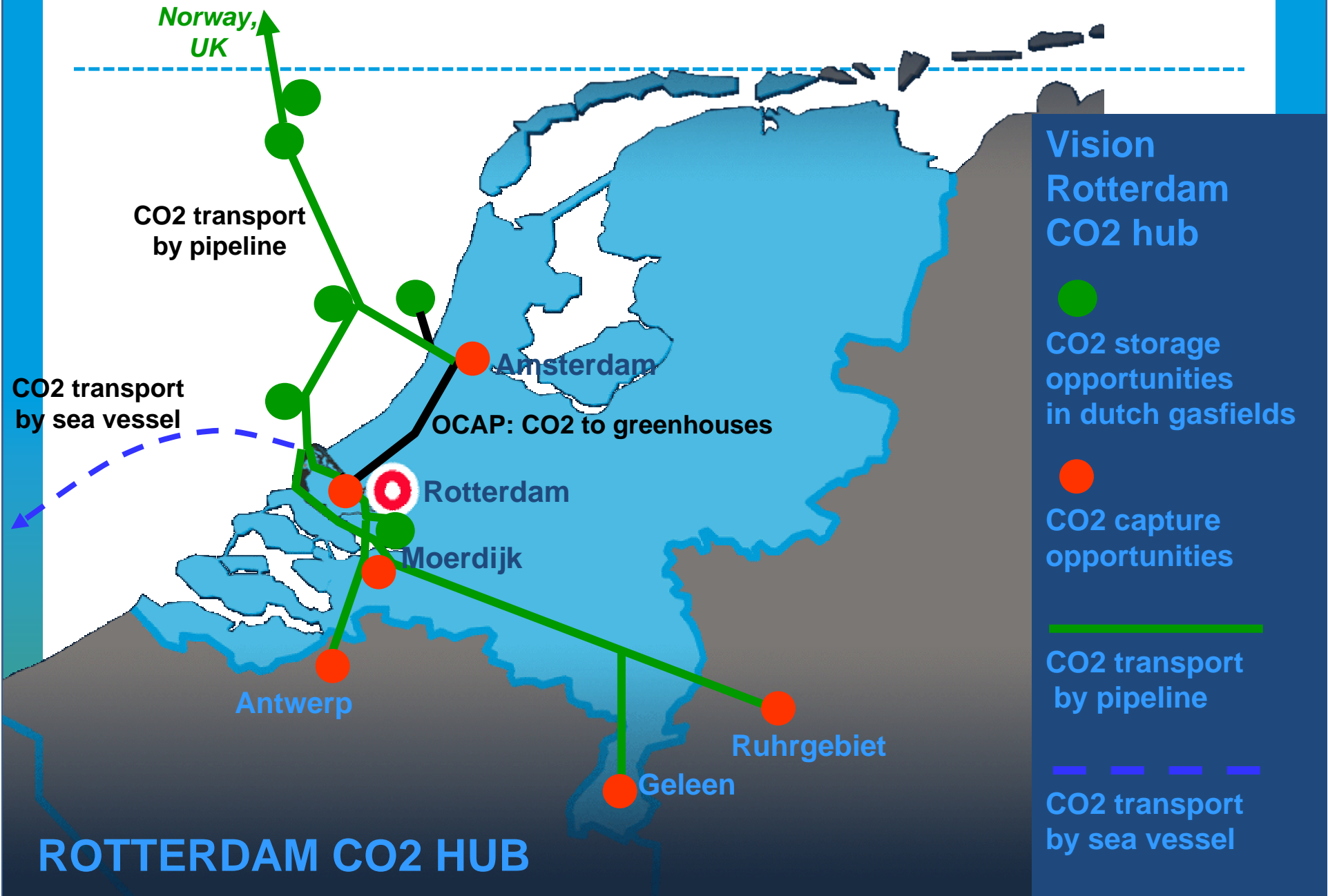


# Roadmap for CCS in Rotterdam

	Volume	Sources (cumulative)	Usage + proposed storage locations	CCS costs €/ton *	Total capex (cum) €m
2010	1 Mton	Refinery and other pure CO <sub>2</sub> sources	Greenhouses (re-use) Barendrecht or North Sea fields(storage)	€24	
2015	5 Mton	Post combustion PC plant + pre combustion IGCC	North sea fields (storage)	€42	€920m
2020	15 Mton	2 additional hydrogen plants, full scale capture 2 PC plants + additional IGCC		€35	€1,690m
2025	20 Mton	Additional 5Mton IGCC + retrofit existing industrial		€31	€2,550m



\* Additional to ETS benefits



**Vision**  
**Rotterdam**  
**CO2 hub**

- CO2 storage opportunities in dutch gasfields
- CO2 capture opportunities
- CO2 transport by pipeline
- - - CO2 transport by sea vessel

**ROTTERDAM CO2 HUB**

# Roadmap CCS in Rotterdam

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## 2009 (II)

Funding large scale demonstration:

- 2 programmes EU: EEPR and NER/ETS
- NL co-financing: government via infrastructure
- Investments by companies

Ensuring full scale CCS:

- In addition to ETS and funds for demos
- Complementary measures for CCS in 2020 (for power plants in NW-Europe)

Need for public awareness



ROTTERDAM CLIMATE INITIATIVE



## Next steps

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- Joint approach for demonstration projects under NER
- Cooperation with other regions, Groningen and IJmond
- A 1.5 billion Euros demonstration programme is the challenge.
- RCI aims to develop the first and best European demonstration programme

