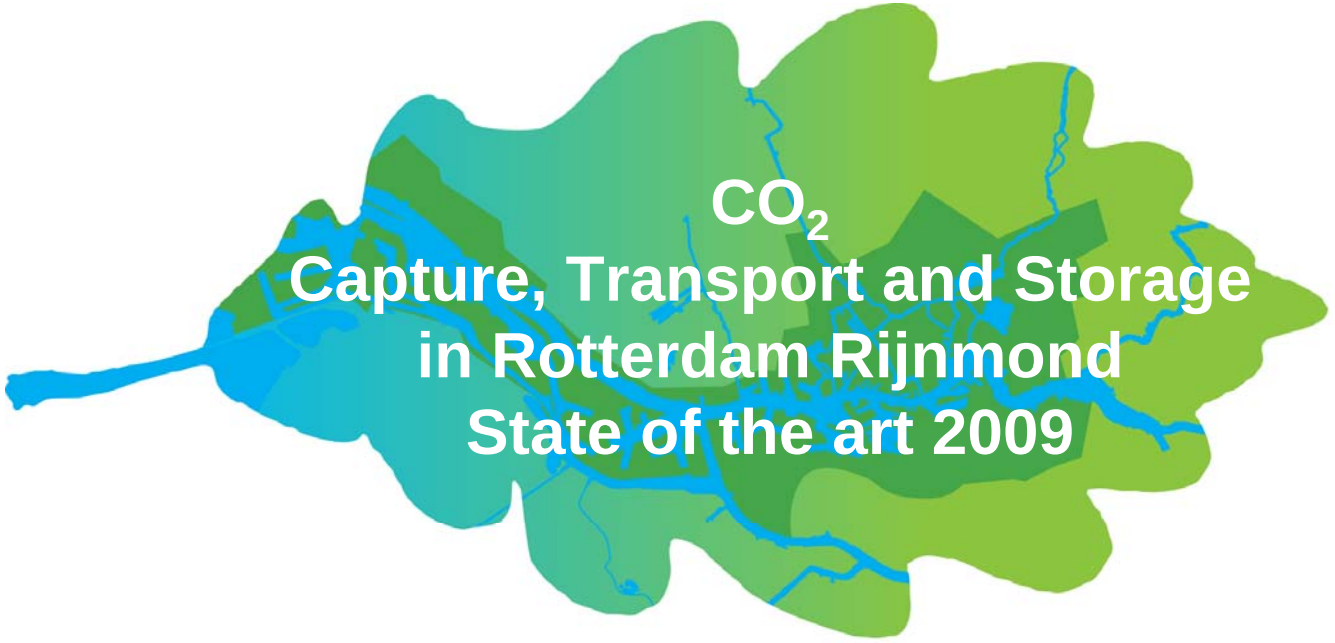

CO_2 Capture, Transport and Storage in Rotterdam Rijnmond State of the art 2009

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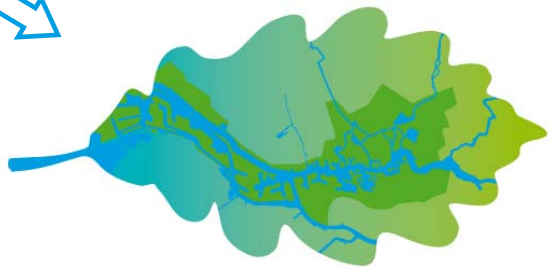
Partners

DCMR milieudienst Rijnmond

Port of Rotterdam



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Deltalinqs

Gemeente Rotterdam

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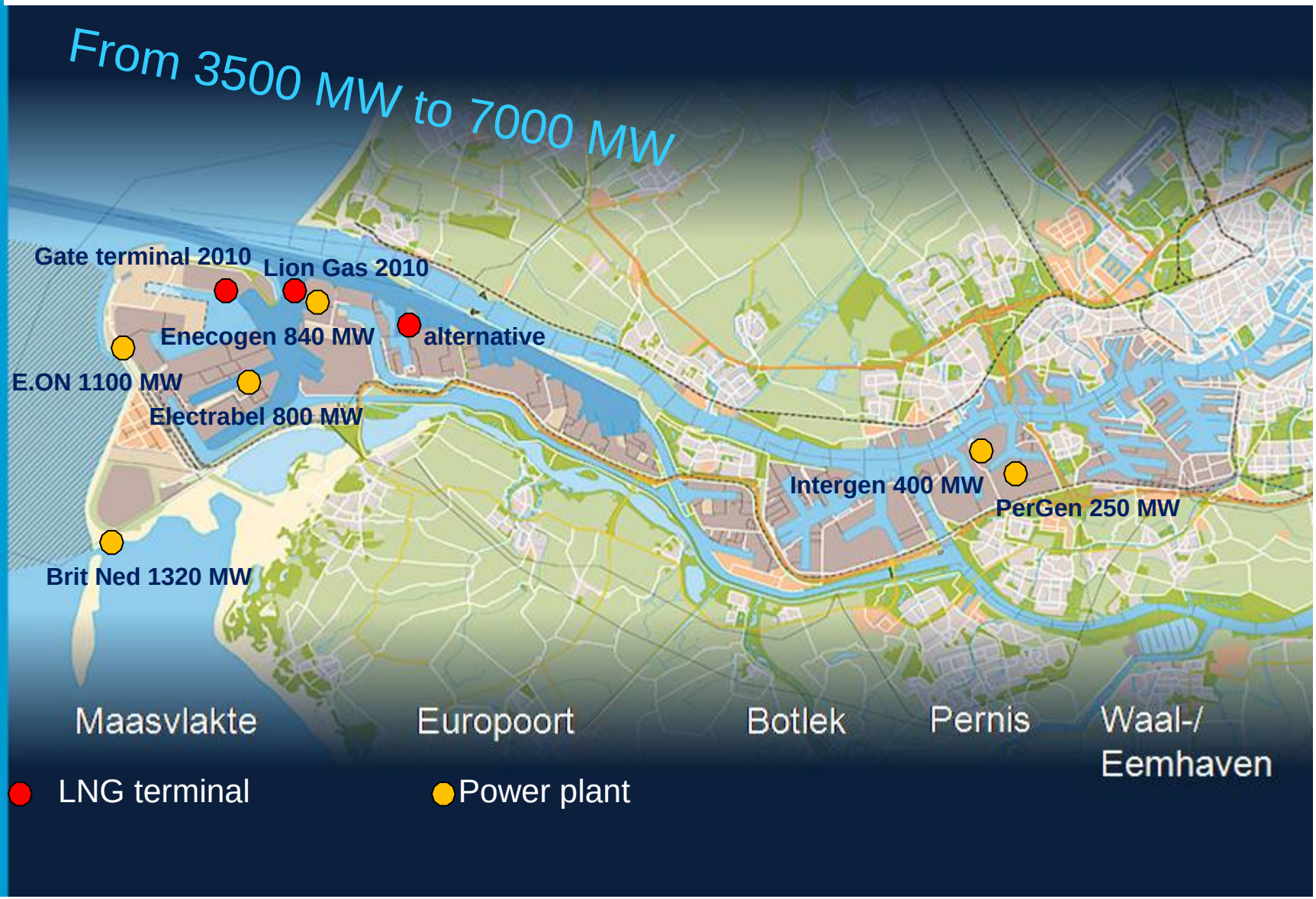
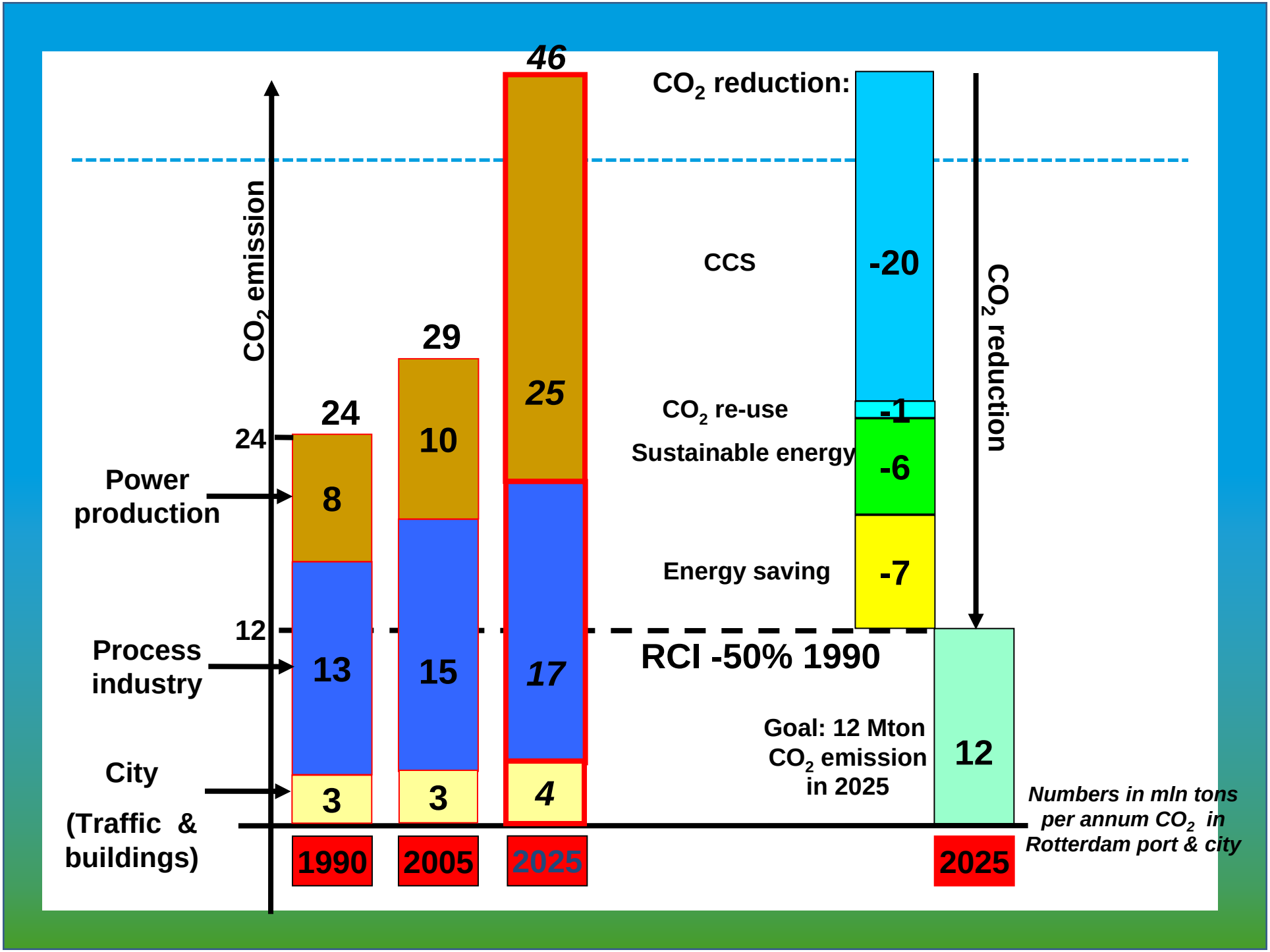
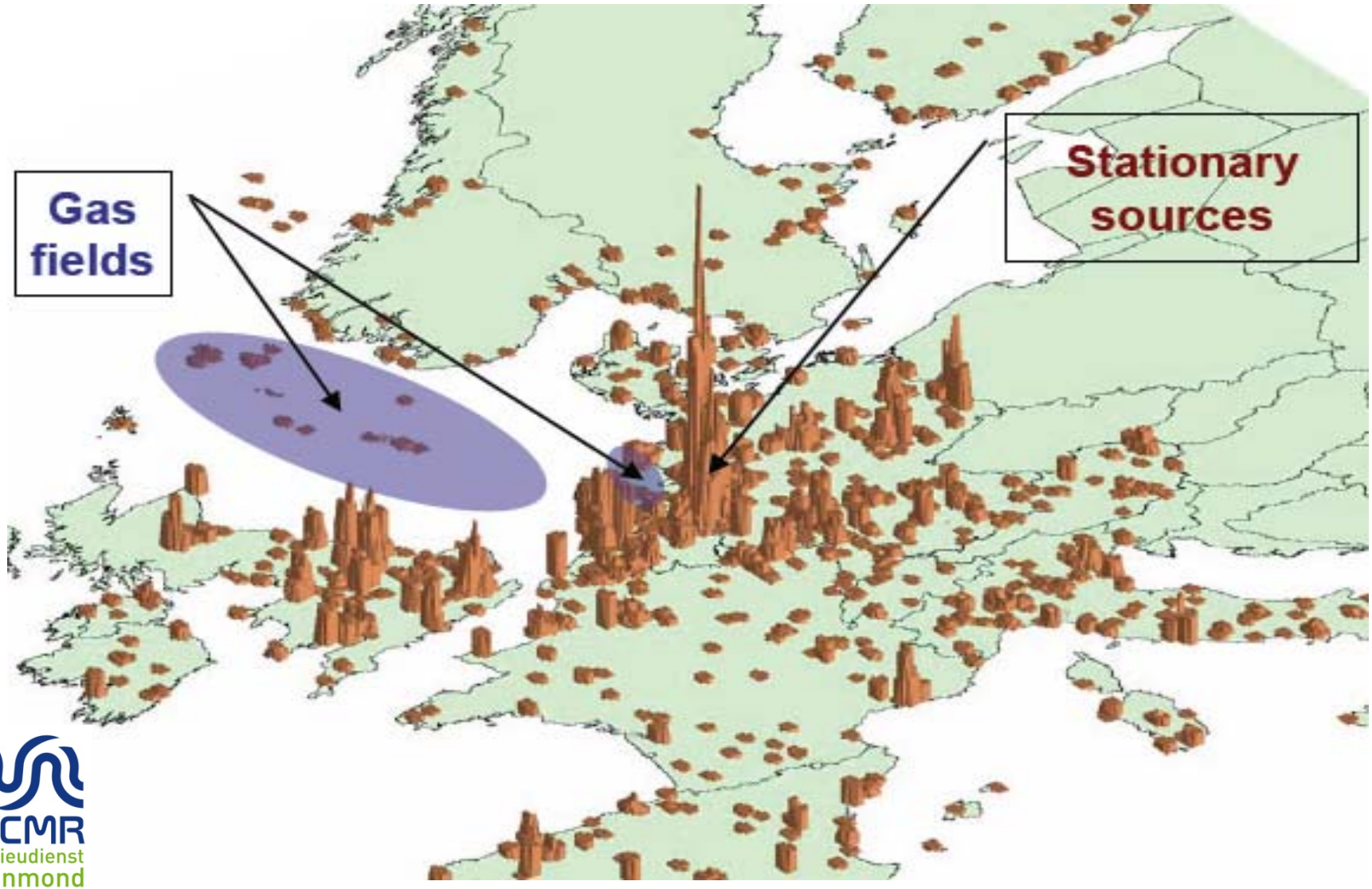
Rotterdam energy port



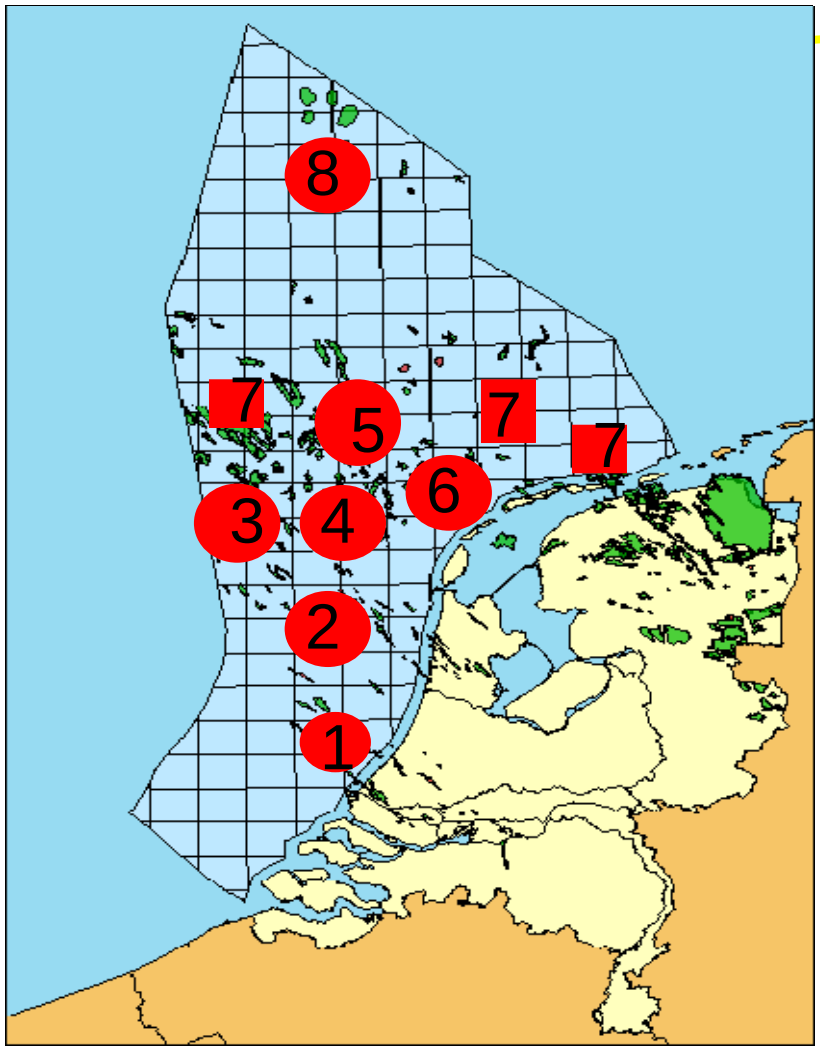

46
CO2 reduction:
CO2 emission
CCS
-20
CO2 reduction
29
25
24
CO2 re-use
-1
24
10
Sustainable energy
-6
Power production
8
Energy saving
-7
12
Process industry
13
15
17
RCI -50% 1990
Goal: 12 Mton CO2 emission in 2025
12
City
3
3
4
(Traffic & buildings)
Numbers in mln tons per annum CO2 in Rotterdam port & city
1990
2005
2025
2025

CO_2 Sources in Europe



DCMR milieudienst Rijnmond

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

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Roadmap CCS in Rotterdam

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

2008

Four phase model, preliminary cost calculations:

1. Start with pure CO2 (‘easy’ sources) and use of CO2 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 CO2 needed

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Roadmap CCS in Rotterdam

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

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Letter of Cooperation RCI - emitters

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

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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_2/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_2/yr	2015
IGCC, 450 MW	Pre-combustion capture, 2.5 Mt CO_2/yr	2015
IGCC, 350 MW	Pre-combustion capture, 2.0 Mt CO_2/yr	2015
Hydrogen plant	Pre-combustion capture, 0.5 Mt CO_2/yr	2015
Hydrogen plant	Pre-combustion capture, 0.5 Mt CO_2/yr	2015
Furnaces in crude distillation unit	Post-combustion capture, 0.9 Mt CO_2/yr	
Waste heat incinerator	Post-combustion capture, 0.15 Mt CO_2/yr	

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Cost of capture

(real costs* – 2009 inflation basis, 2% annual rate)	Post-combustion plants		Pre-combustion plants
	PC Plant	Industrials	
Using central case assumptions			
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
After sensitivity analysis on CAPEX, OPEX and commodity pricing			
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.

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Technical validation summary

Item	Unit of measurement	Pre-combustion IGCC	Pre-combustion H_2 plant	Post-combustion
Units affected by the CO_2 capture process in the plant	-	Whole plant	CO_2 capture & compression, Utilities	CO_2 capture & compression, Utilities
Power demand of the CO_2 capture & compression units[2]	kWh/t of CO_2 [1]	60 – 100[4]	100 – 115	110 – 135
Overall additional power demand of the whole plant (electrical parasitic losses)	kWh/t of CO_2 [1]	130 – 160[4]	105 – 125	120 – 145
Steam demand of the CO_2 capture unit	MJ/kg of CO_2 [1]	-0.02 – -0.04	0.5 – 1.0	3 – 5
Efficiency of plant without CO_2 capture	%	38 – 45	Not applicable	43 – 46
Efficiency penalty for case with CO_2 capture	Percentage points	6 – 10[4]	Not Applicable	9 – 12[3]

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Economic validation

Item	Unit of measurement	Pre-combustion		Post-combustion	
		IGCC	H2 plant	USC-PC	Others
Specific investment cost of the CO_2 capture & compression units[2]	€ / (kg / h) [1]	140[3] – 220	950 – 1100	680 – 760	1700 – 1900
Specific investment cost of the whole CO_2 capture plant (TIC)*	€ / (kg / h) [1]	480 – 680[3]	1000 – 1200	850 – 950	2000 – 2200
Operating & Maintenance costs	€ /t of abated CO_2	5 – 10[3]	10 – 12	4 – 5	75 – 85
CO_2 abated cost	€/t	35 – 50[3]	35 – 45	40 – 60	110 – 130

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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)

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Roadmap for CCS in Rotterdam

	Volume	Sources (cumulative)	Usage + pro-posed storage locations	CCS costs €/ton *	Total capex (cum) €m
2010	1 Mton	Refinery and other pure CO_2 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

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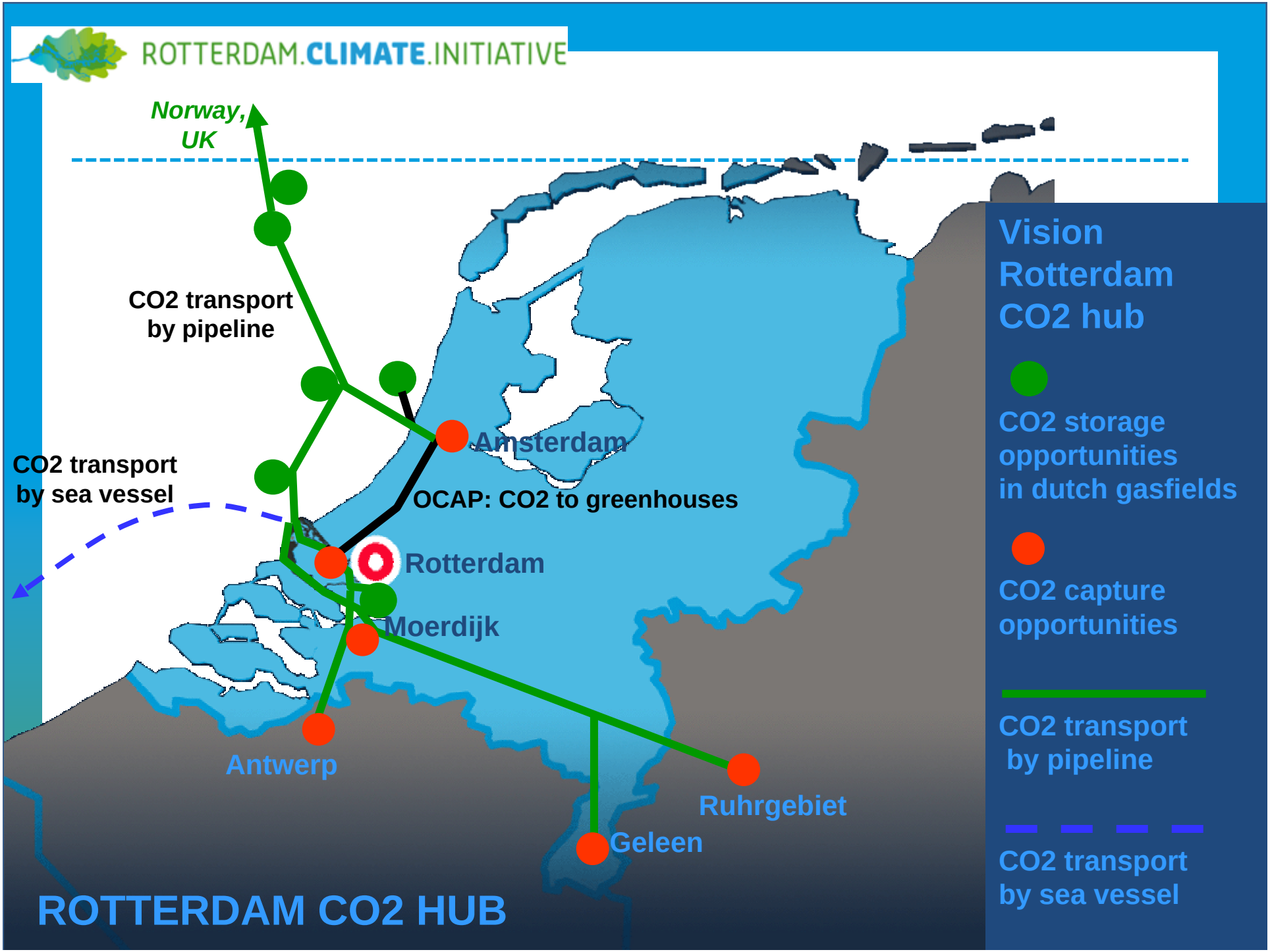
* Additional to ETS benefits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Norway,
UK
CO2 transport
by pipeline
CO2 transport
by sea vessel
Amsterdam
OCAP: CO2 to greenhouses
Rotterdam
Moerdijk
Antwerp
Ruhrgebiet
Geleen
ROTTERDAM CO2 HUB
Vision
Rotterdam
CO2 hub
CO2 storage
opportunities
in dutch gasfields
CO2 capture
opportunities
CO2 transport
by pipeline
CO2 transport
by sea vessel

Roadmap CCS in Rotterdam

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

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Next steps

- 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 porgramme

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