Joint CO_2GeoNet – EERA Research Workshop
Regina, Saskatchewan, Canada, 17 June 2015

Rotterdam Opslag en Afvang Demonstratieproject (ROAD)

Lessons Learned from CCS Demonstration in EU

Hans Schoenmakers, Project Director ROAD

SUPPORTED BY
GLOBAL CCS INSTITUTE
Government of the Netherlands
Co-financed by the European Union
European Energy Programme for Recovery

Agenda

- Introduction to ROAD

- Project Siting: - Port and Industrial Area of Rotterdam
  - North Sea

- Lessons Learned:
  - Permitting Process
  - Capture Integration
  - Project Management and Funding

- ROAD: Stepping Stone for CO_2 Hub in Rotterdam and Europe

Co-operating Partners ROAD

- **Maasvlakte CCS Project C.V.** is a joint venture of:
  - E.ON Benelux
  - ENGIE (formerly GDF SUEZ)
- In **co-operation** with intended partners:
  - TAQA Energy
  - ENGIE E&P
- With **financial support** of:
  - European Commission (EU)
  - Government of the Netherlands
  - Global CCS Institute
  - Private partners (discussions pending)

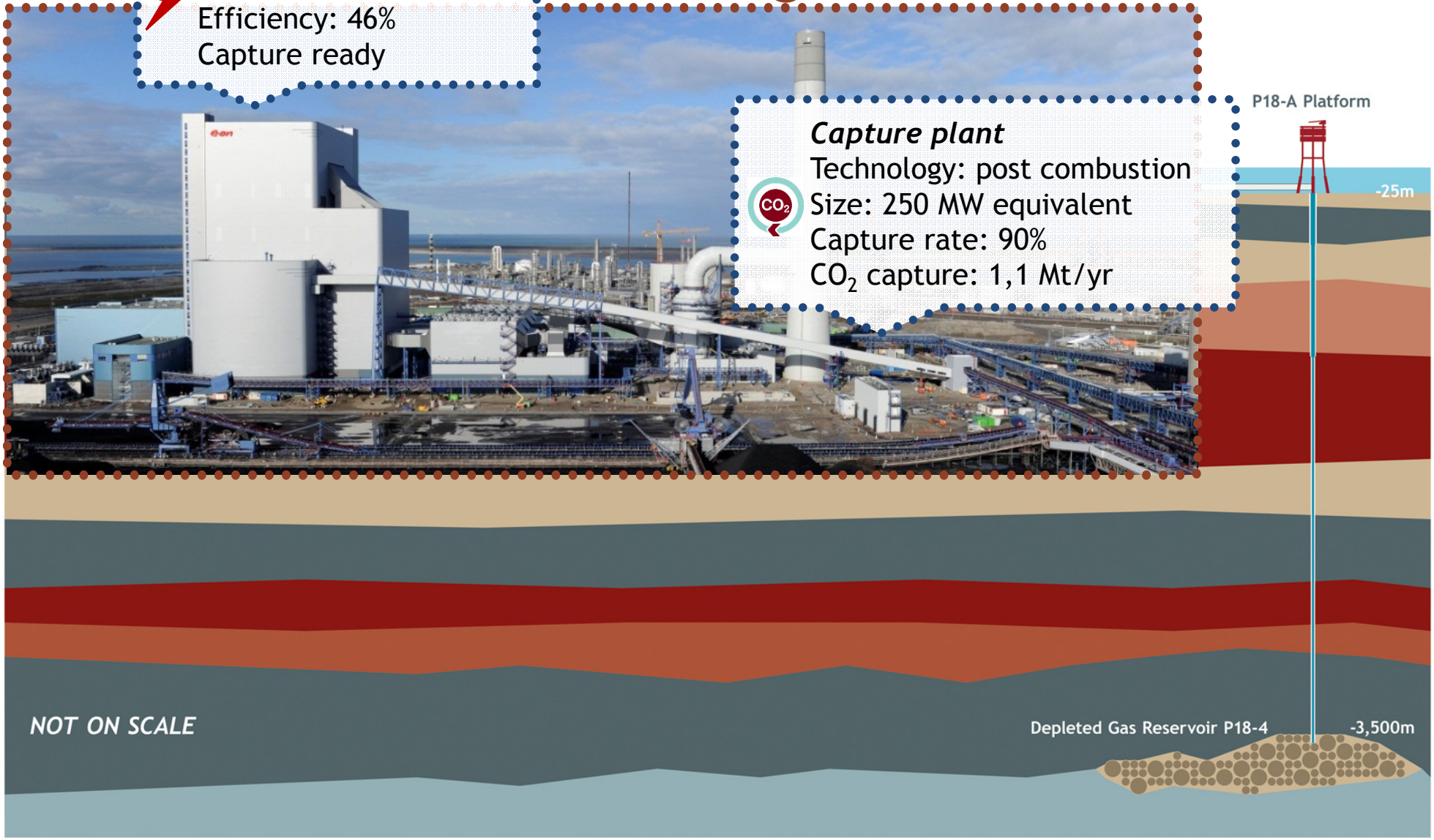
Co-financed by the European Union
European Energy Programme for Recovery

Government of the Netherlands

Integrated CCS Chain ROAD

Power plant
Output: 1 070 MWe
Efficiency: 46%
Capture ready

Capture plant
Technology: post combustion
Size: 250 MW equivalent
Capture rate: 90%
CO_2 capture: 1,1 Mt/yr

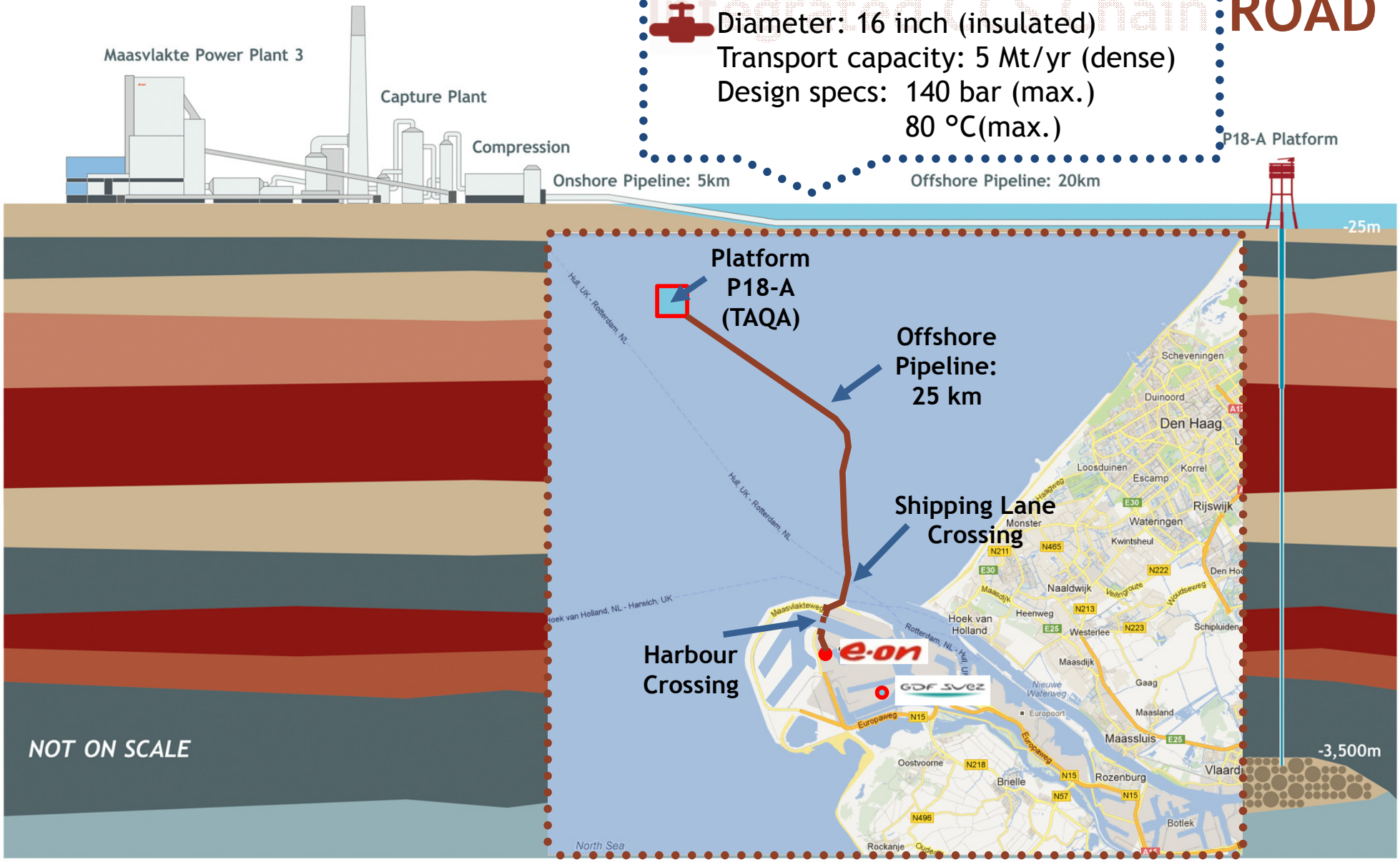


road CCS

Transport

Pipeline length: 5 km onshore
20 km offshore
Diameter: 16 inch (insulated)
Transport capacity: 5 Mt/yr (dense)
Design specs: 140 bar (max.)
80 °C(max.)

ROAD



Storage

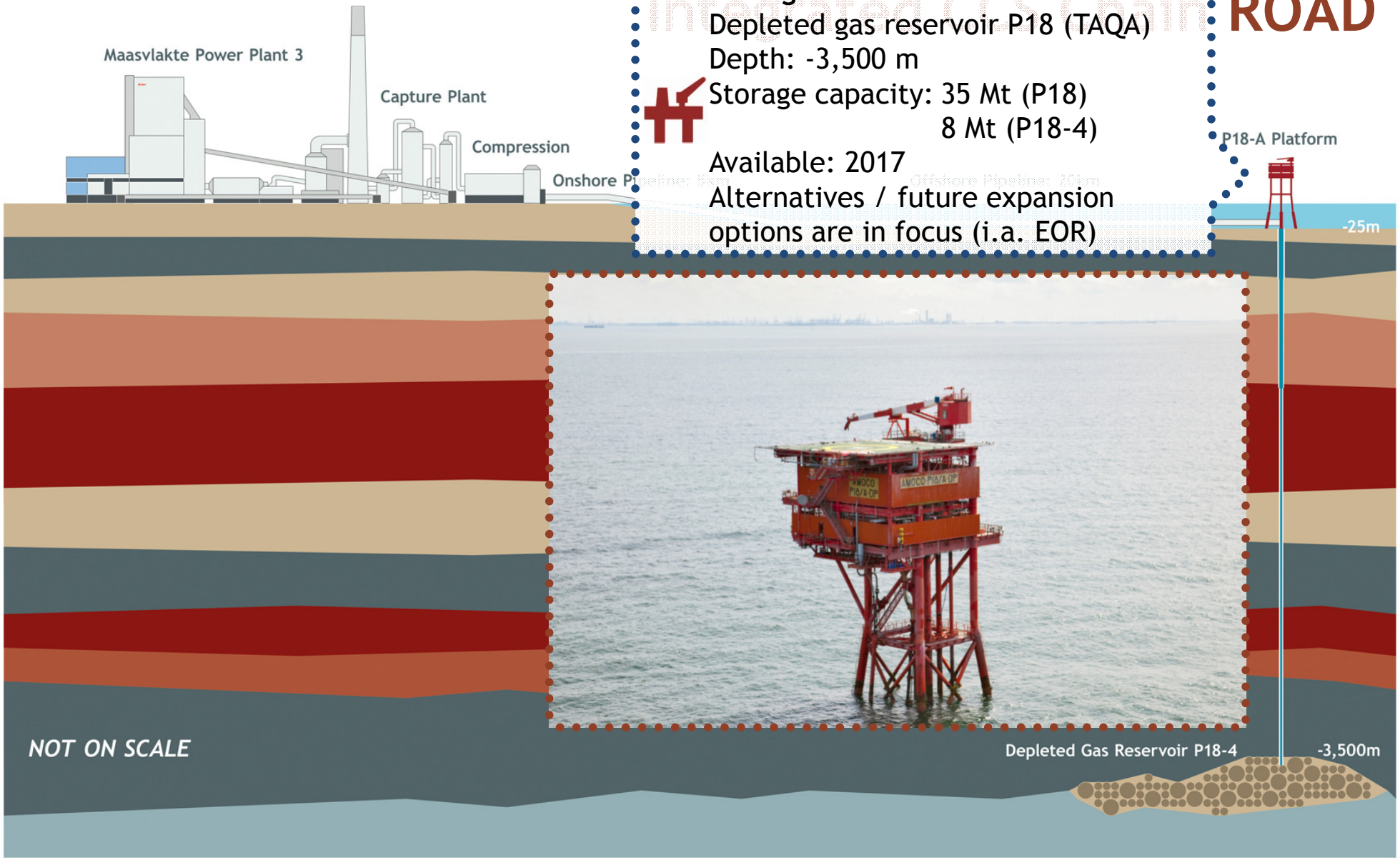
Depleted gas reservoir P18 (TAQA)

Depth: -3,500 m

Storage capacity: 35 Mt (P18)
8 Mt (P18-4)

Available: 2017

Alternatives / future expansion options are in focus (i.a. EOR)



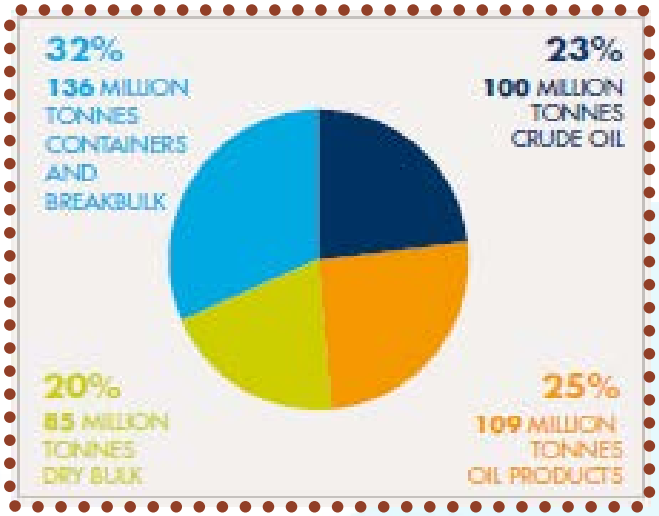
Agenda

- Introduction to ROAD
- Project siting: - Port and Industrial Area of Rotterdam
  - North Sea
- Lessons Learned:
  - Permitting Process
  - Capture Integration
  - Project Management and Funding
- ROAD: Stepping Stone for CO_2 Hub in Rotterdam and Europe

Rotterdam Port and Industrial Area

- Largest port of Europe (top 10 world ports)
- Direct added value € 15,5 billion
- Indirect added value € 6,5 billion
- Direct and indirect added value 3,3% of GNP
- Direct employment 90 000 people
- Indirect employment 55 000 people
- Annual average business invesment € 1,5 billion

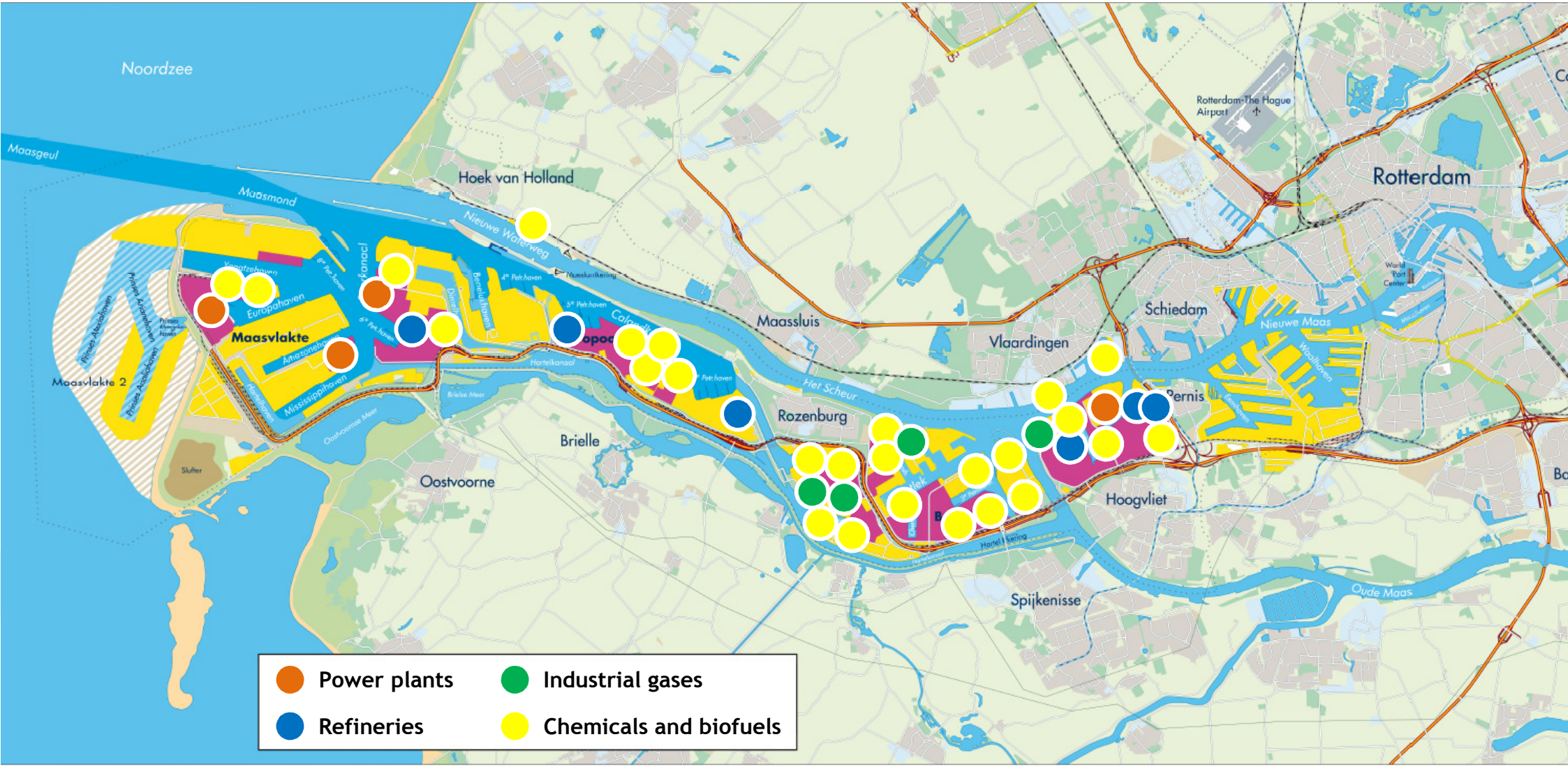
- ...and 17% (2013: 28 Mt) of total CO_2 emissions in the Netherlands (2013: 166 Mt)



Rotterdam port and industrial complex is of great strategic value for (North-west) Europe

"Gateway to 350 million consumers"

Rotterdam Port and Industrial Area



40 km

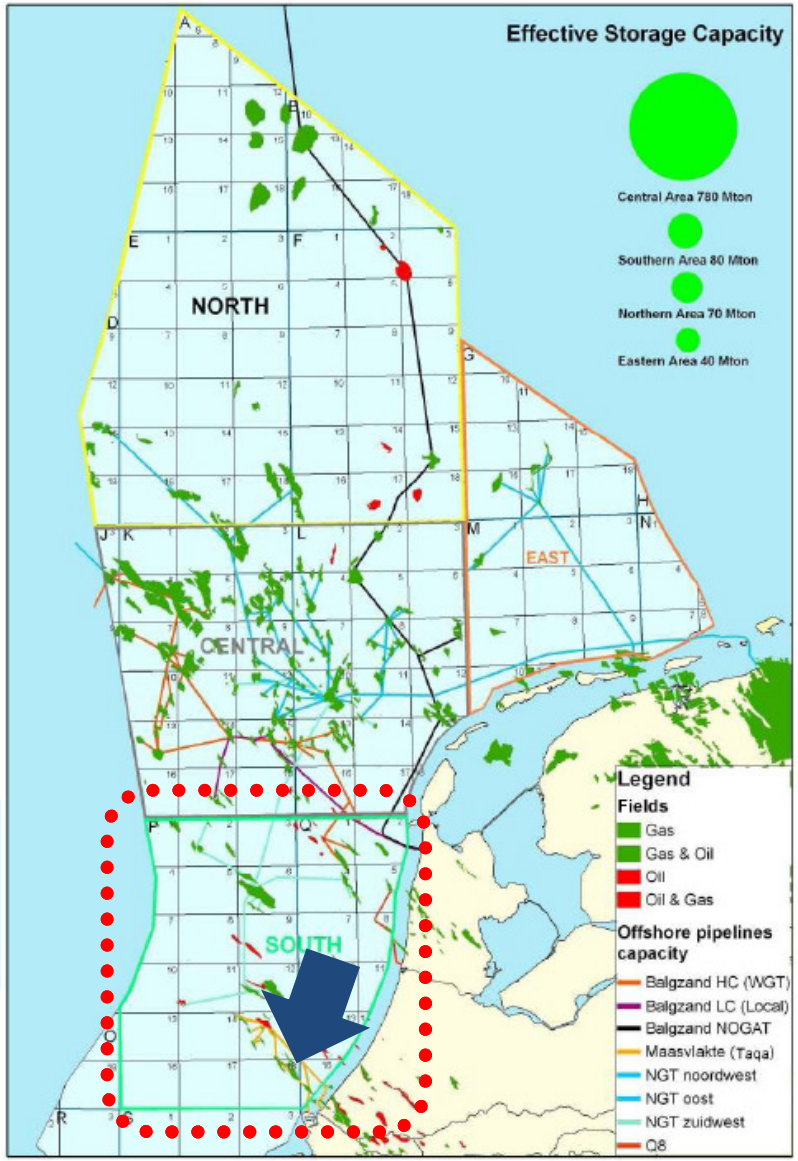
Why CCS Demonstration Project in The Netherlands?

- Several industrial areas with many large point sources
- New power stations under construction with potential deployment of CCS
- Depleted onshore and offshore gas reservoirs in years to come
- Gas reservoirs have right structure for permanent CO_2 storage
- Indepth knowledge of gas transport because of dense natural gas grid
- Vast experience with exploration and production of oil and gas, gas storage in gas reservoirs and aquifers

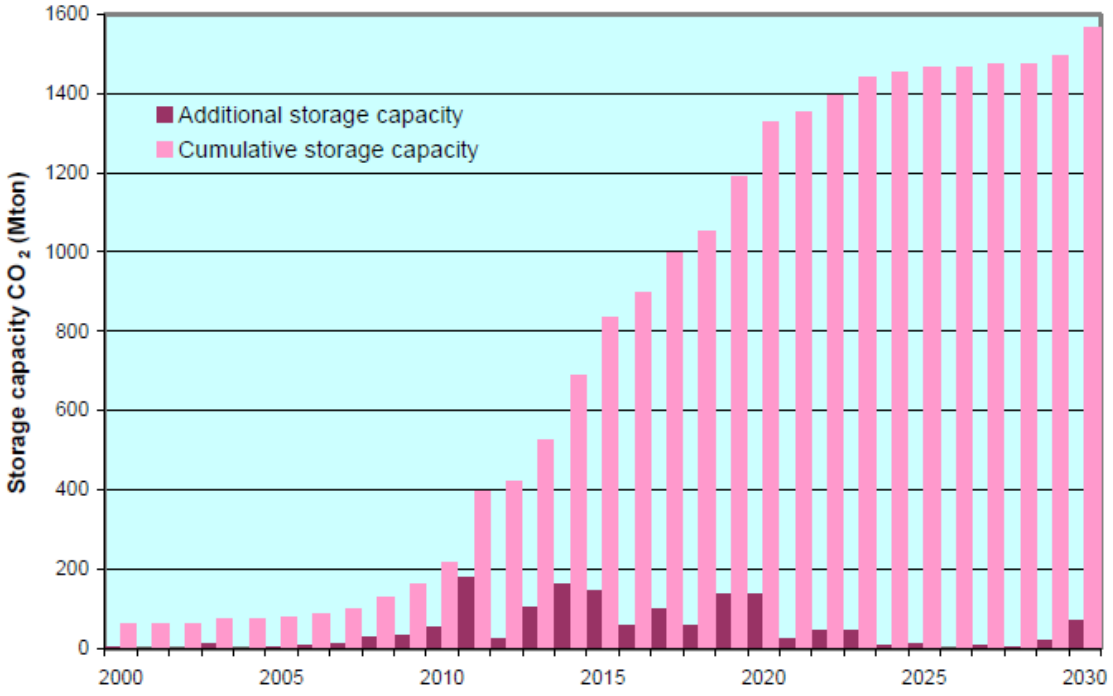
"God's greatest gift to Rotterdam is its location"

Alexander Rinnooy Kan, former chairman of
the Dutch Social Economic Council

North Sea CO_2 Storage Capacity

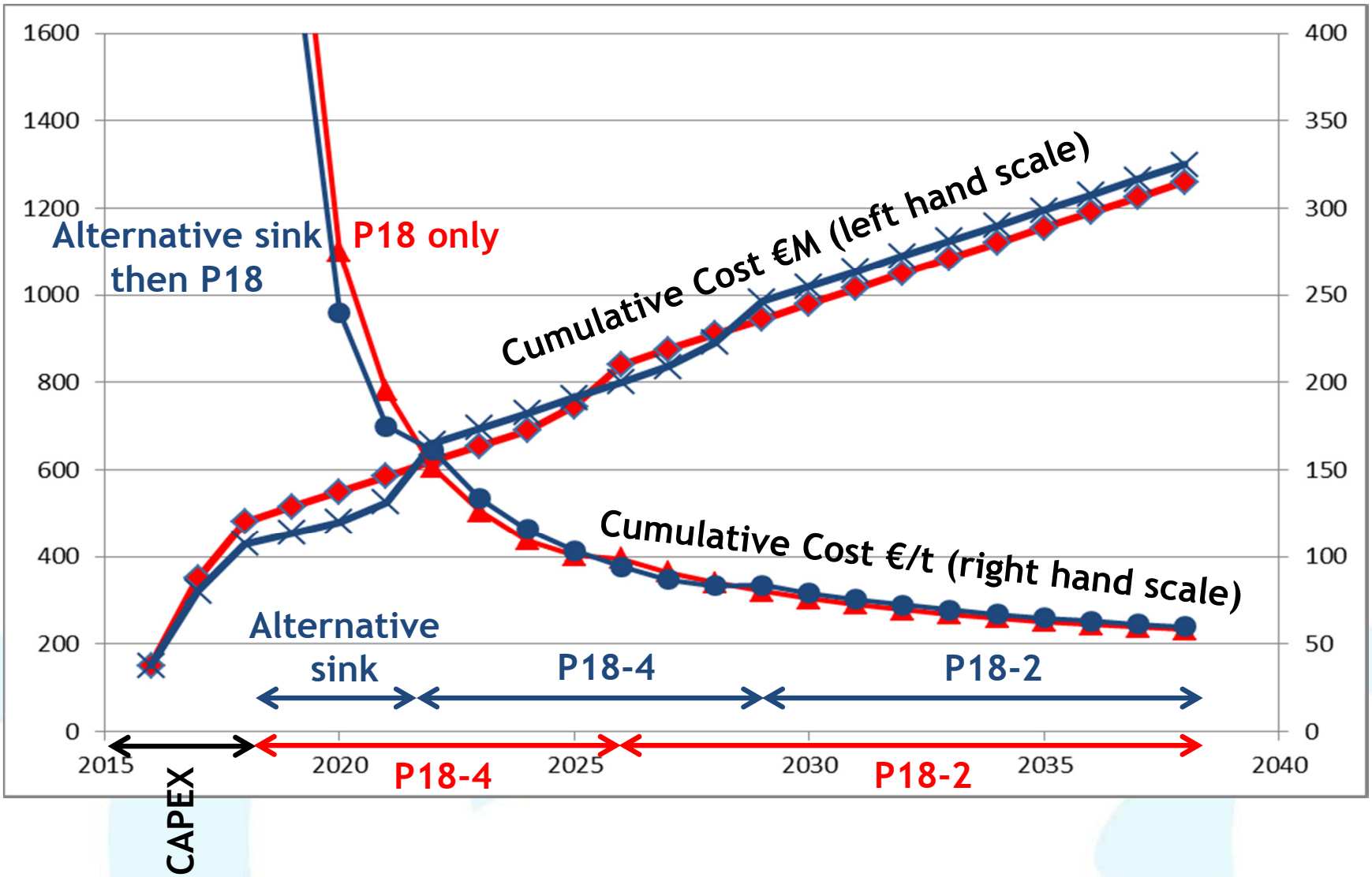


	Number of fields	Storage (Mton)
Theoretical Storage capacity	153	1566
Injectivity cut off	-74	-580
Storage cut off	-46	-61
Abandoned fields	-20	-98
Total storage below cut offs	98	-648
Effective Storage capacity	55	918



ROAD Location at Rotterdam Maasvlakte

Development of Total Cumulative Costs in Time



European CCS Project

ROAD is one of last six EEPR projects (due to its favorable location)

Don Valley (UK)
Pre combustion
Offshore
Gas reservoir

Rotterdam
Post combustion
Offshore
Gas reservoir

Bełchatów (Poland)
Post combustion
Onshore
Saline aquifers

Jänschwalde (Germany)
Oxy fuel post combustion
Onshore

Compostilla (Spain)
Oxyfuel CFB
Onshore
Saline aquifers

Porto Tolle (Italy)
Post-combustion
Offshore
Saline aquifers

Agenda

- Introduction to ROAD
- Project siting: - Port and Industrial Area of Rotterdam
  - North Sea
- Lessons Learned:
  - Permitting Process
  - Capture Integration
  - Project Management and Funding
- ROAD: Stepping Stone for CO_2 Hub in Rotterdam and Europe

Lesson Learned on Permitting Process ROAD

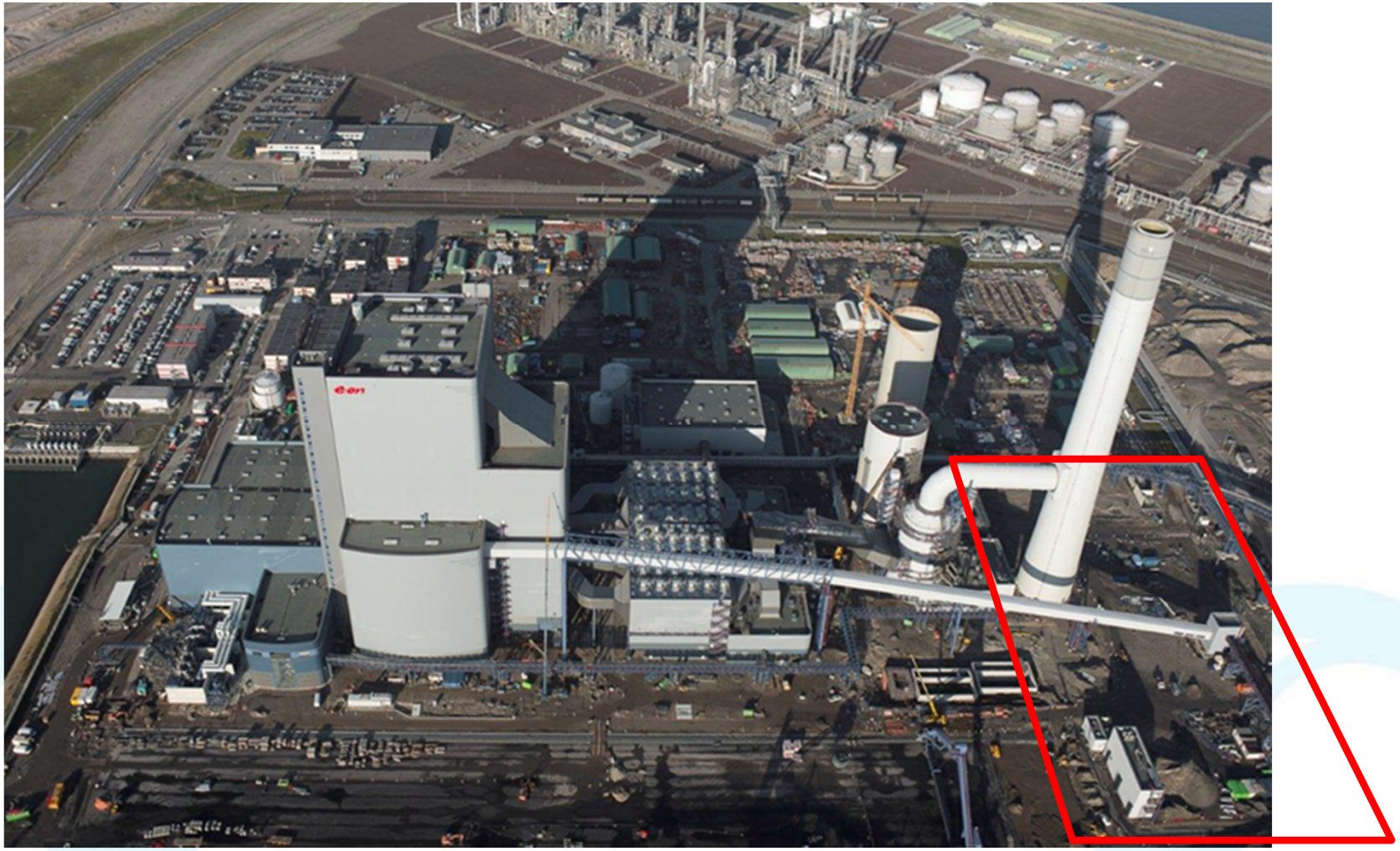
1. Alignment of permitting authorities: Dutch ministry of Economic Affairs was essential in coordinating permitting stakeholders and showing national relevance of project via State Coordination Scheme
2. Education and building trust of stakeholders: permitting authorities not only want to be informed on procedures, but also want to be educated on technical details of the project, as early as possible
3. Commitment of permitting authorities: contact persons at permitting authorities have to be well-connected and committed to project. Lack of sufficient resources (e.g. time, knowledge) can severely delay project

Agenda

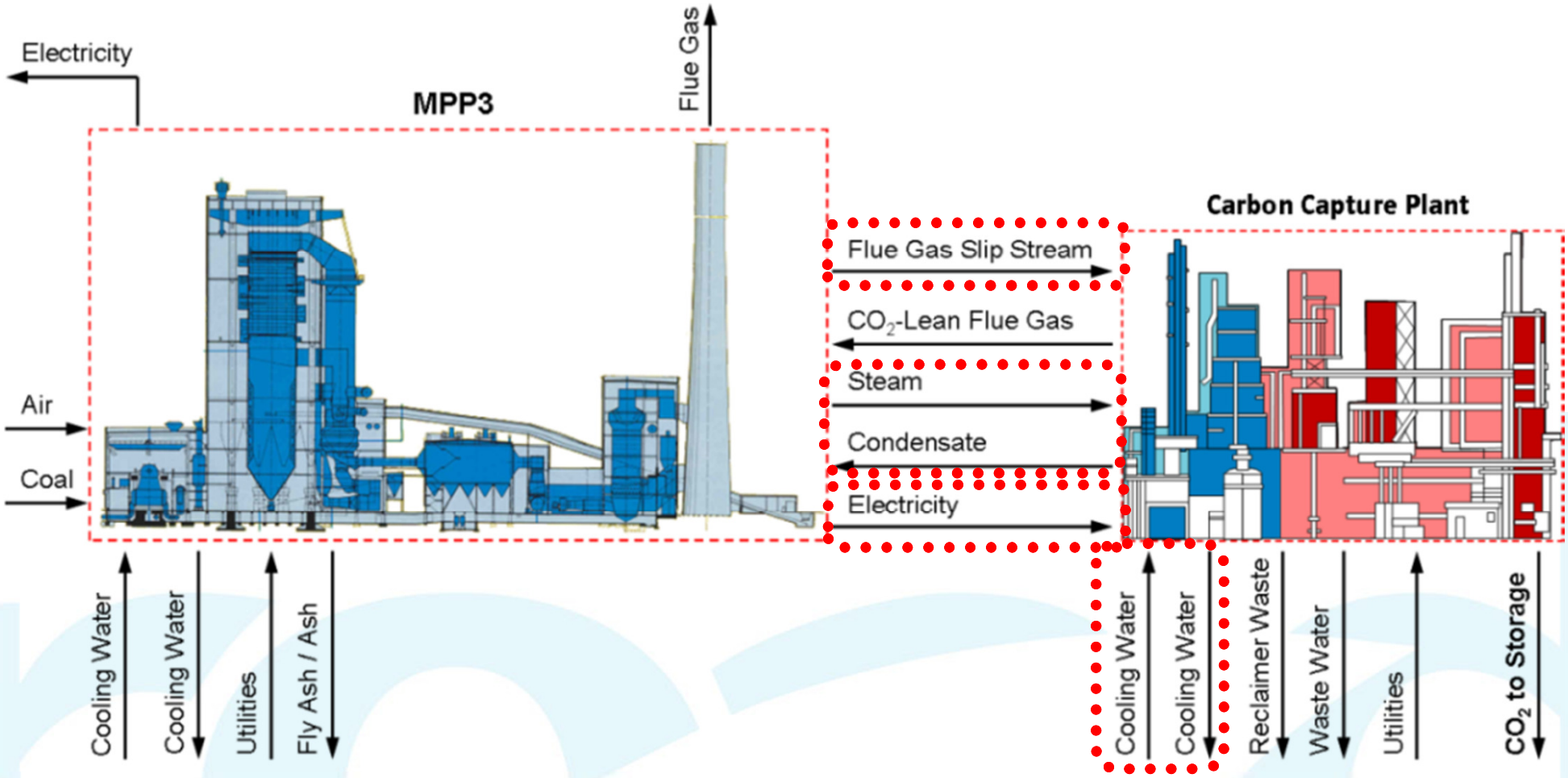
- Introduction to ROAD
- Project siting: - Port and Industrial Area of Rotterdam
  - North Sea
- Lessons Learned:
  - Permitting Process
  - Capture Integration
  - Project Management and Funding
- ROAD: Stepping Stone for CO_2 Hub in Rotterdam and Europe

Location of Capture Plant: Maasvlakte Power Plant 3

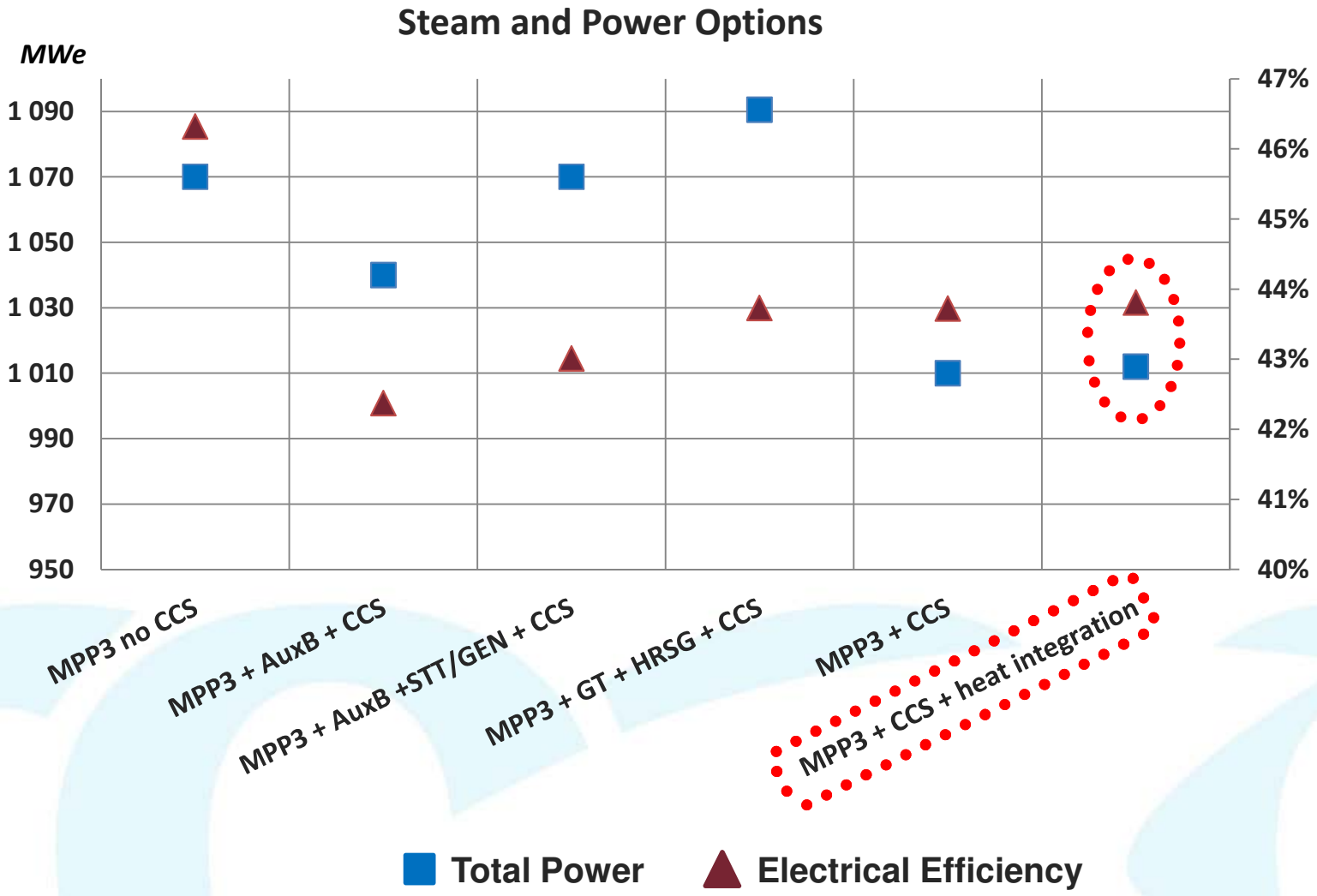
Retrofit on Existing Coal-Fired Power Plant (Capture Ready)



Interactions Between Power Plant and Capture Plant



Total Power Loss for Steam and Power Supply



Flexibility of Capture Plant and Control Philosophy

- In highly competitive power market controlled shut-down and return to service of capture plant on hourly basis is necessary

Operation modes of capture plant:

- Start-up capture plant with MPP3 already in operation at any load*
- Ramping up and down capture plant and MPP3 in parallel at the same ramp rate*
- Ramping up and down capture plant and MPP3 in parallel at different ramp rates
- Ramping up and down the capture plant leaving MPP3 in stable operation at any load
- Stable operation capture plant with MPP3 ramping up and down*

* *Expected to be used mostly. Capture plant shall be optimized for these modes, without restricting operation in other modes mentioned*

Lessons Learned on Capture Integration

1. Way ROAD project is funded, with substantial capital grants, but a low reward for operation, created a strong incentive to minimise capital costs, with a much lower focus on reliability
2. Focus on minimizing capital costs had a high impact on some major design choices. Capture plant is single train (including a single compressor). For interfaces with MPP3, capacity margins in MPP3 design are used for capture plant where possible
3. Because of relatively small capture plant size, capture plant could make use of MPP3's electric auxiliary system, MPP3's cooling water system, extraction of steam from existing steam cycle of MPP3
4. Engineering capture plant together with power plant would have led to other solutions with lower CAPEX, e.g. more optimal lay-out and combining utility system

Agenda

- Introduction to ROAD

- Project siting: - Port and Industrial Area of Rotterdam
  - North Sea

- Lessons Learned:
  - Permitting Process
  - Capture Integration
  - Project Management and Funding

- ROAD: Stepping Stone for CO_2 Hub in Rotterdam and Europe

Status ROAD

- Engineering

- Detail engineering of capture plant underway, FEED is complete
- Some long lead suppliers chosen and components engineered
- Pipeline route engineered and 'flow assurance' study completed
- 'Tie-ins' (i.e. flue gas, steam) with power plant installed
- Storage design complete, detail storage FEED ready to start

- Permits

- Permitting procedures finalized (beginning 2012)
- Capture permits are definitive and irrevocable
- Storage permits are definitive and irrevocable (TAQA) – Sept 2013
- Transport permits agreed, with publication ready

- Contracts

- Capture supplier selected and EPC contract was ready to be signed (on hold)
- Contracts with power plant (utilities etc) ready for signature
- Commercial contracts for transport (GDF Suez) and storage (TAQA) are agreed textually, and will be signed at FID
- But, price validity has expired - reconfirmation once funding gap is closed

- Finance

- Very low CO_2 prices have caused a financing gap compared to plan (>€100M)
- Delay in CCS role-out and loss of confidence in EU low carbon energy policy has also weakened the strategic case for the demo
- Currently, phased approach is being investigated by EC and several Member States in order to finance construction and initial operation

ROAD remains ready to start construction as soon as the funding gap has been closed

Current Timeline ROAD

Date	Milestone
April 2015	Agreement on “Governance Issues”
June	Heads of agreement on alternative storage location • Supported by robust range estimates for costs and benefits Plan new EC Roundtable
July	In principle agreement with funders Start of detailed technical and permitting work (ROAD project remobilisation)
Jan 2016	Firm costs available
February 2016	State aid clearance received Key (storage) permits modified
March 2016	Earliest credible date for “formal” FID

Funding and Commercial Issues

- CAPEX cost estimate has risen because of:
  - Inflation, as construction is delayed at least 3 years
  - Some design modifications add cost (principally provision for a wet ESP for emissions control and a tie-in for future CO_2 network in Rotterdam)
  - Cost of demobilization and remobilization
  - Cost of maintaining project team during “slow mode”
- OPEX cost estimate has reduced because:
  - Forecast electricity prices are lower. ROAD uses about 1 MWh of electricity for every 3 tonnes of carbon captured, making electricity costs of order half total OPEX
  - Minimum amount of CO_2 stored has been reduced to 4 Mt, with possibilities under discussion to lower it further. Intent is that a later separate funding scheme will pay for longer term operation. It is not intent to build plant and then decommission it after 4 years operation
- Forecast carbon prices have reduced substantially

ROAD: not a typical CCS project…

	ROAD	Typical CCS Project
Minimum Injection Period	3-5 years	>15 years
Total CO_2 injected	3-8 Mt	>50 Mt
Storage field life (from FID to full decommissioning)	≈10 years	>50 years
Storage risk	Single well into deep depressurised gas field	Large connected reservoir, multiple wells
Financial Risk	CAPEX largely grant funded, OPEX loss-making, therefore it can stop without major financial impact	Major financial impact for whole chain if unable to operate

… ROAD is funded as true demonstration project

Agenda

- Introduction to ROAD

- Project siting: - Port and Industrial Area of Rotterdam
  - North Sea

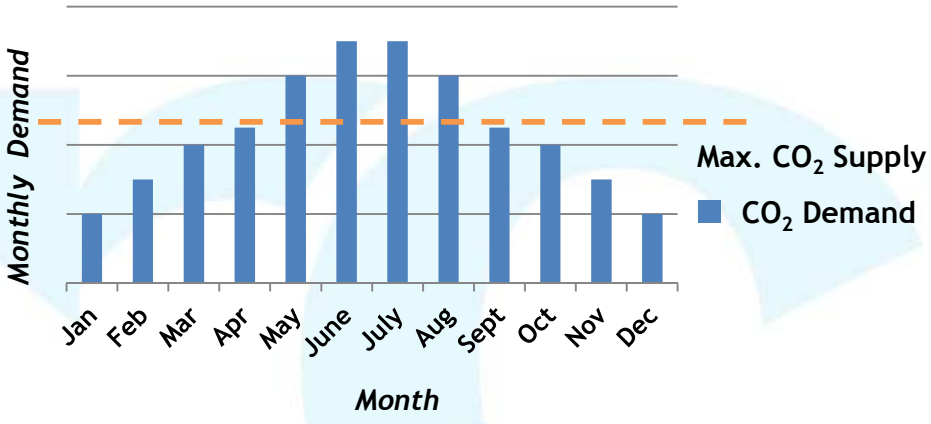
- Lessons Learned:
  - Permitting Process
  - Capture Integration
  - Project Management and Funding

- ROAD: Stepping Stone for CO_2 Hub in Rotterdam and Europe

Rotterdam CO_2 Hub - Existing OCAP* System

OCAP System:

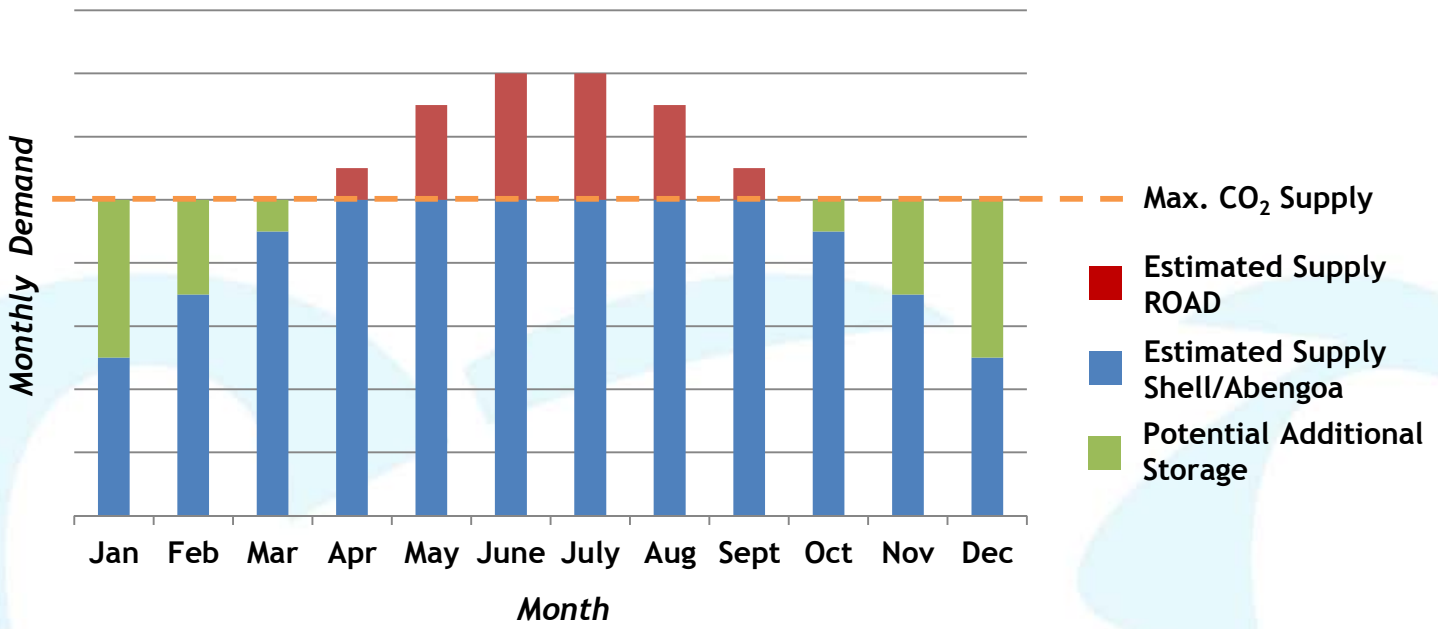
- Supplies 400 kt CO_2 to ≈600 greenhouses
- Shell Pernis CO_2 is from natural gas-based hydrogen production facility
- Abengoa is a first generation bio-ethanol plant
- OCAP claims CO_2 emission reduction of ≈200 kt/year through avoidance of natural gas use in the greenhouses
- There is additional CO_2 demand OCAP can't meet



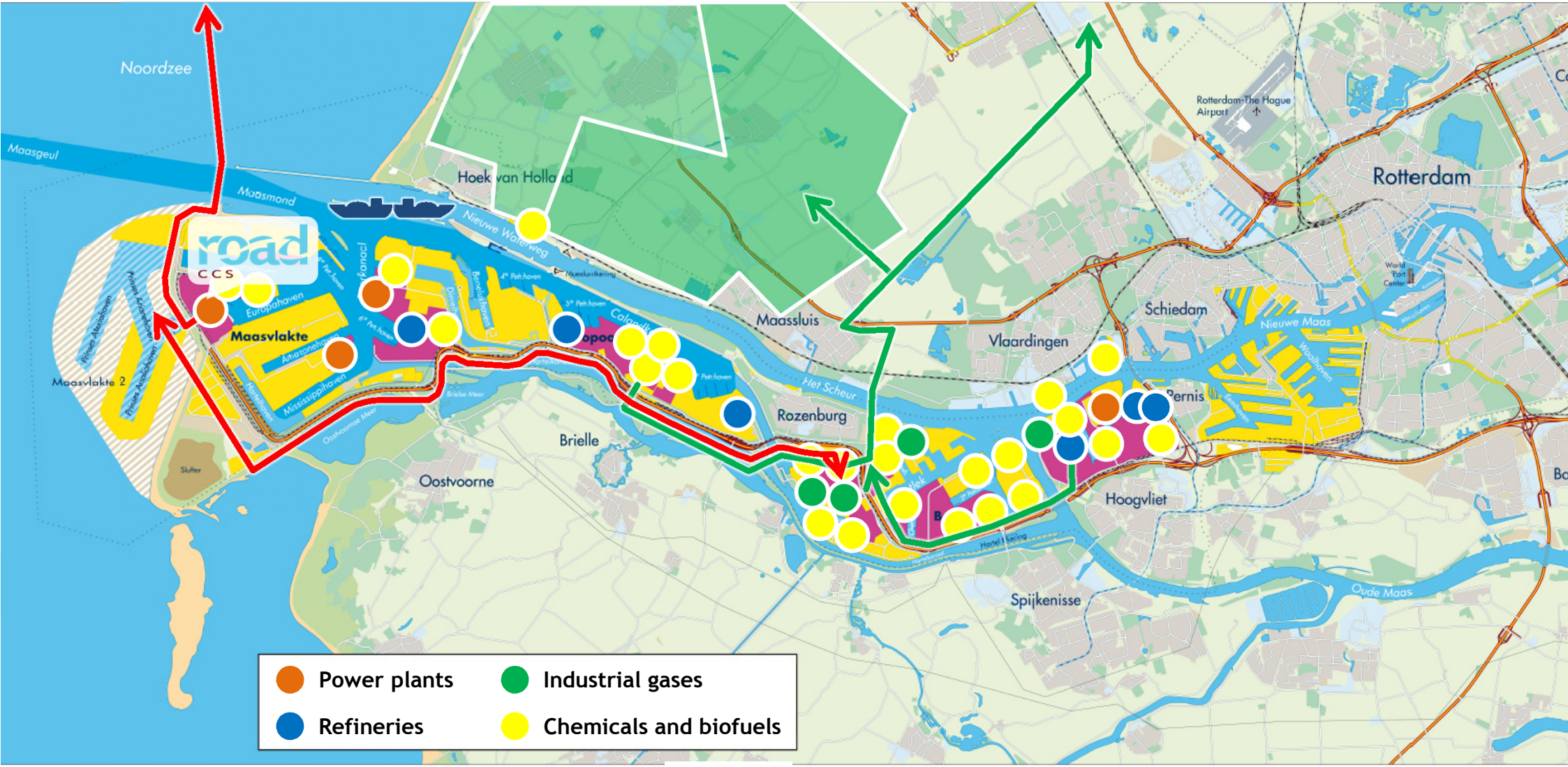
* *OCAP: Organic CO_2 for Assimilation by Plants*

Proposed Link between ROAD and OCAP

- OCAP cannot expand due to lack of CO_2 in summer peak (usually a few days only)
- ROAD could supply OCAP with summer peak CO_2
- Expansion is desirable to reduce CO_2 emissions by greenhouses
  - Estimate of greater than 200kt/yr further reduction achievable (with heat pipe - to be confirmed)
- In winter CO_2 from Shell and Abengoa (bio-CCS) could be sent for geological storage by ROAD



Rotterdam CO_2 Hub: First Steps



40 km

Summary of Lessons Learned

- A superb location is crucial for success of early development
- If lower invesments cost can make the difference to get a demonstration project accross the line, even though the characteristics are less favorable (e.g. much smaller sink size), it is worthwhile considering
- Engineering capture plant together with power plant would have led to other solutions with lower CAPEX
- Position of Dutch ministry of Economic Affairs was essential in co-ordinating many permitting authorities
- When CO_2 has no (economic) value and price of carbon credits (EU ETS) is too low, projects with an obligation for permanent storage are extremely hard to realize: find a business case

ROAD | Maasvlakte CCS Project C.V.

Visit

Parallelweg 1
3112 NA Schiedam
The Netherlands

Post

P.O. Box 133
3100 AC Schiedam
The Netherlands

Contact

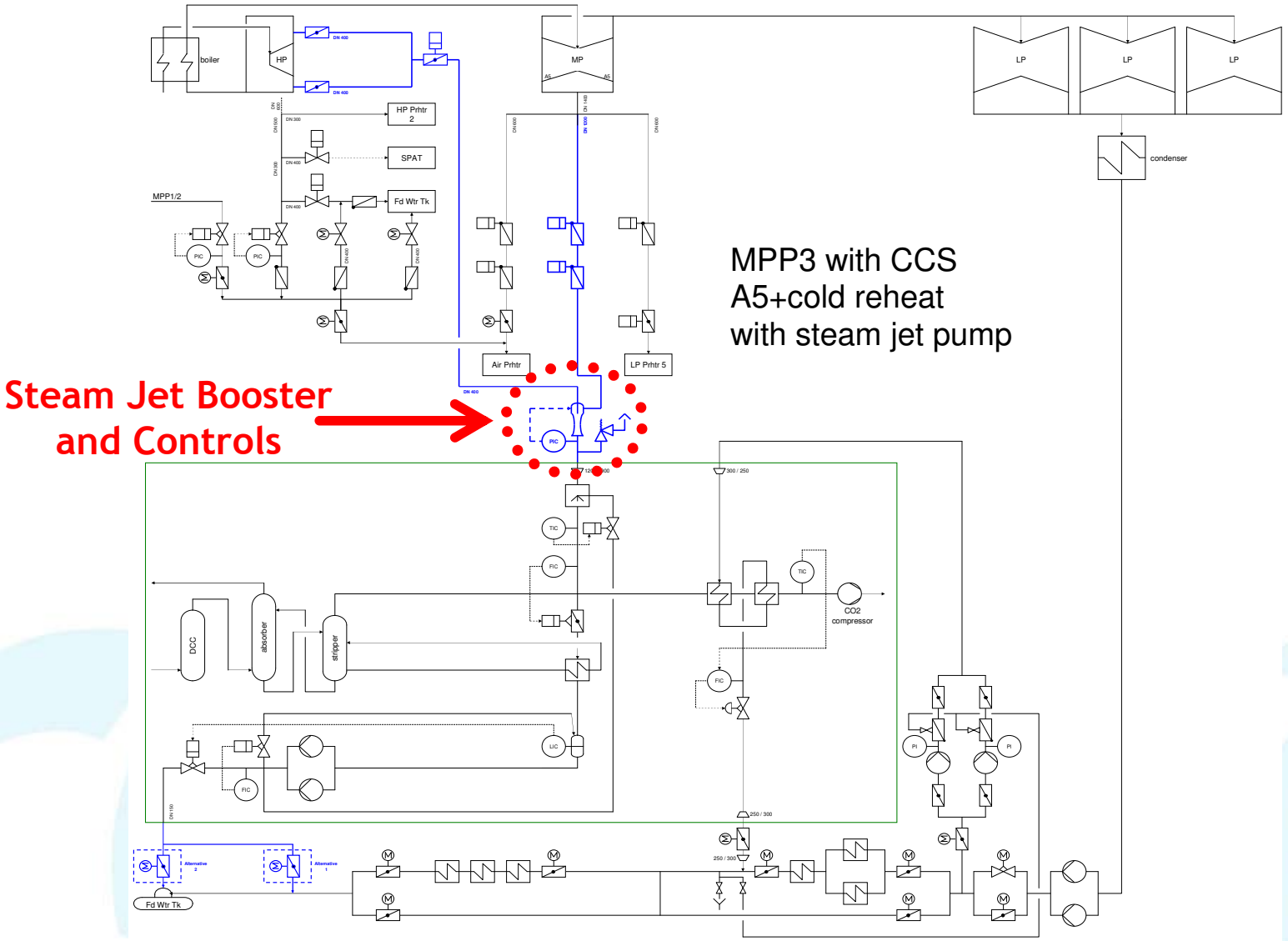
T: +31 (0)10 75 34 000
F: +31 (0)10 75 34 040
E: info@road2020.nl
W: www.road2020.nl

Government of the Netherlands

Co-financed by the European Union
European Energy Programme for Recovery

Back-Up Slides

Reboiler Steam: Option 6

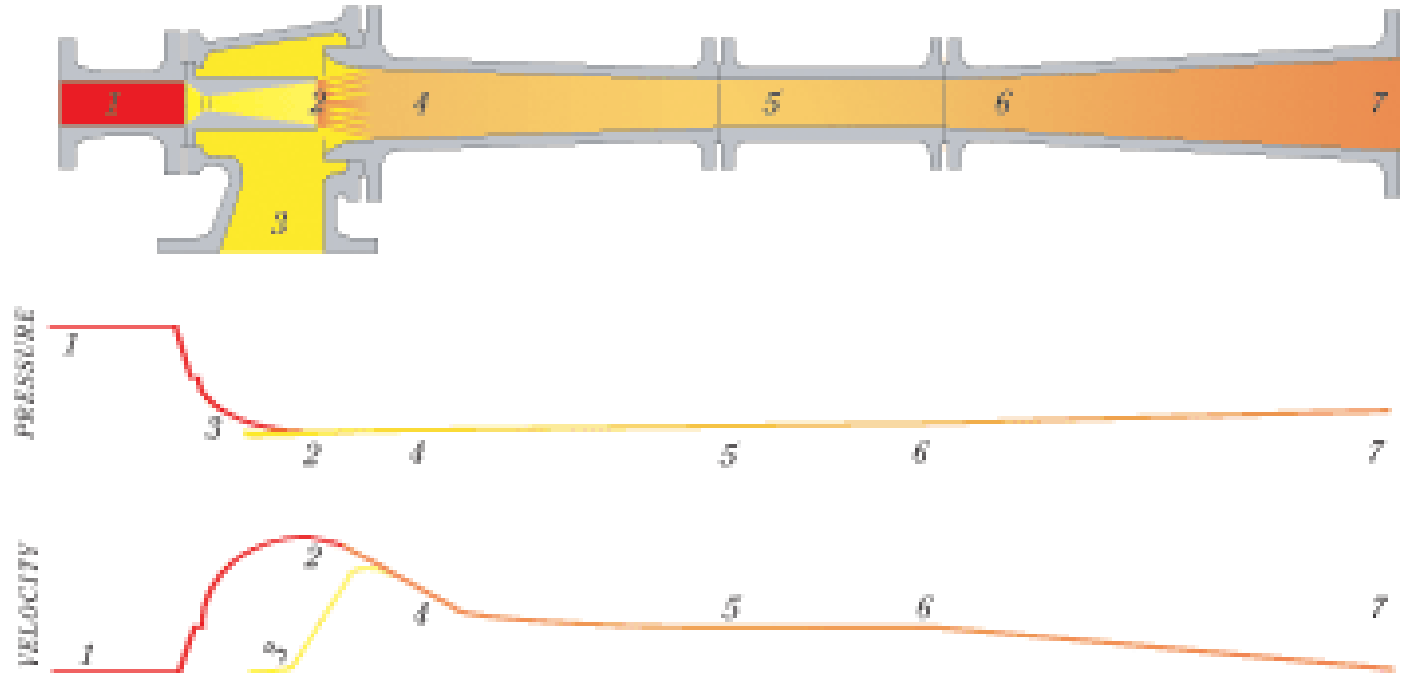


Reboiler Steam: Tie-ins

MPP3 w
A5+cold reheat
with steam jet pump

Reboiler Steam: Option 6 (Steam Jet Booster)

Figure 1
Basic structure & flow model of steam Jel Ejector

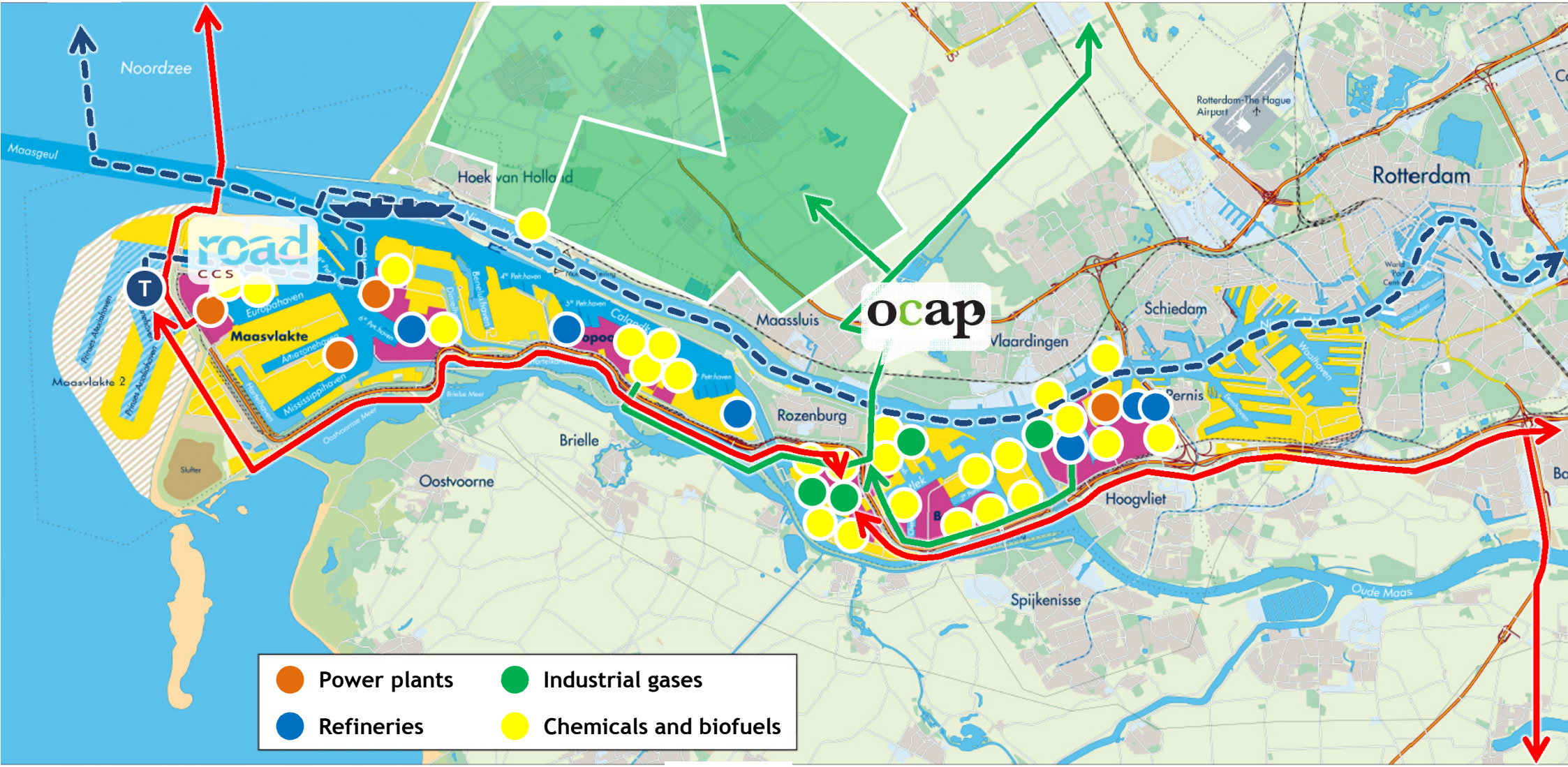


ROAD as Stepping Stone for CCS in Europe

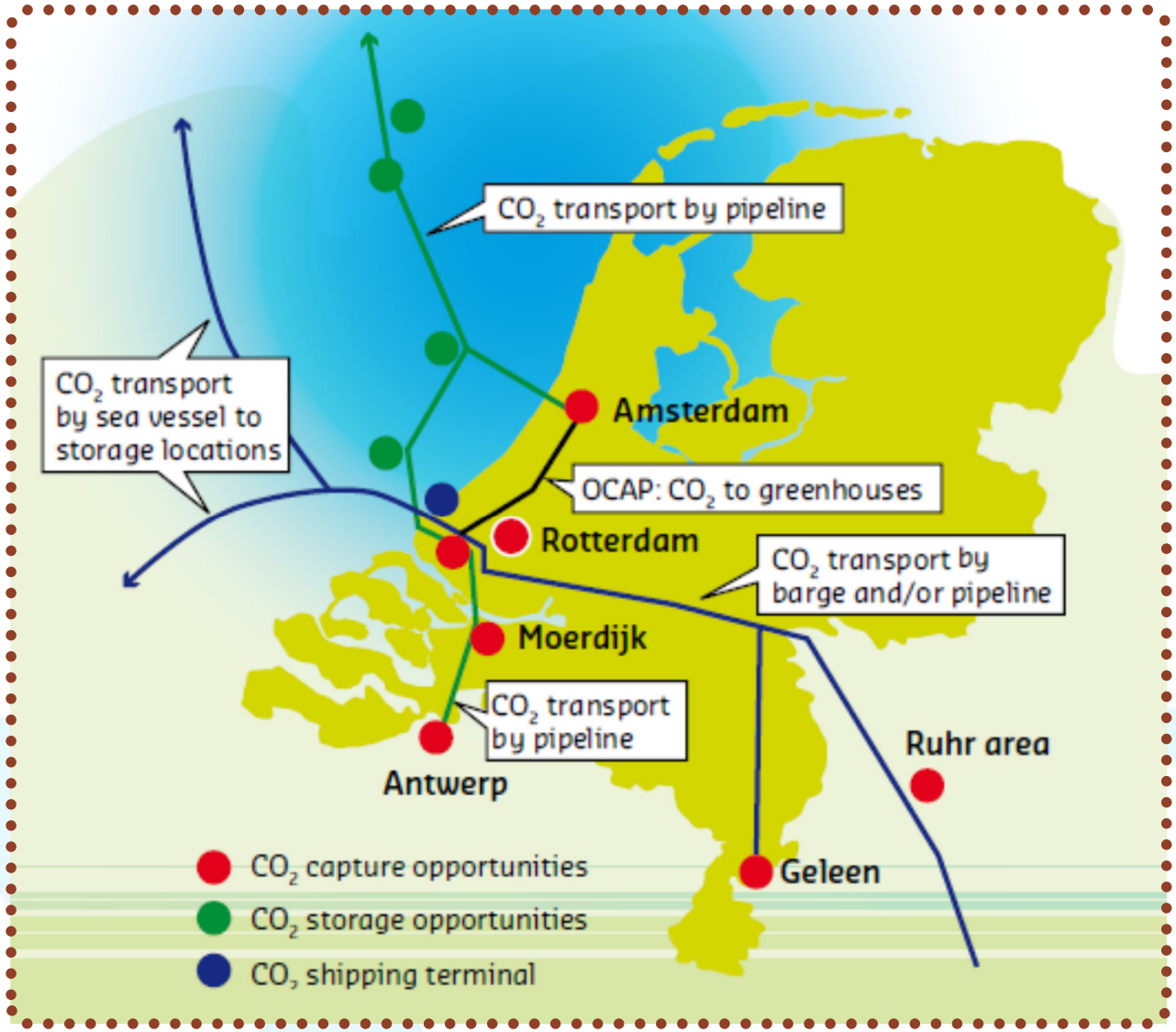
ROAD is one of best positioned CCS demonstration project in EU ready to be implemented:

- Efficient, new generation power plant (capture ready)
- Port and industrial area of Rotterdam (local support)
- Proximity of source to sink (25 km)
- Offshore storage (available storage capacity)
- National regulation and required permits completed
- Start of integrated CO_2 network in Rotterdam and NW Europe

Rotterdam CO_2 Hub: Vision 2030



Rotterdam Vision: CO_2 Hub of Northwest Europe



- Europe will need CCS to meet climate targets
  - Not only in power, but essential in industry
- CO_2 hubs will strengthen sustainable economic growth at lower costs
- Rotterdam is ideal place in North-west Europe: "Gateway to 350 mln. customers"
- ROAD is the next step