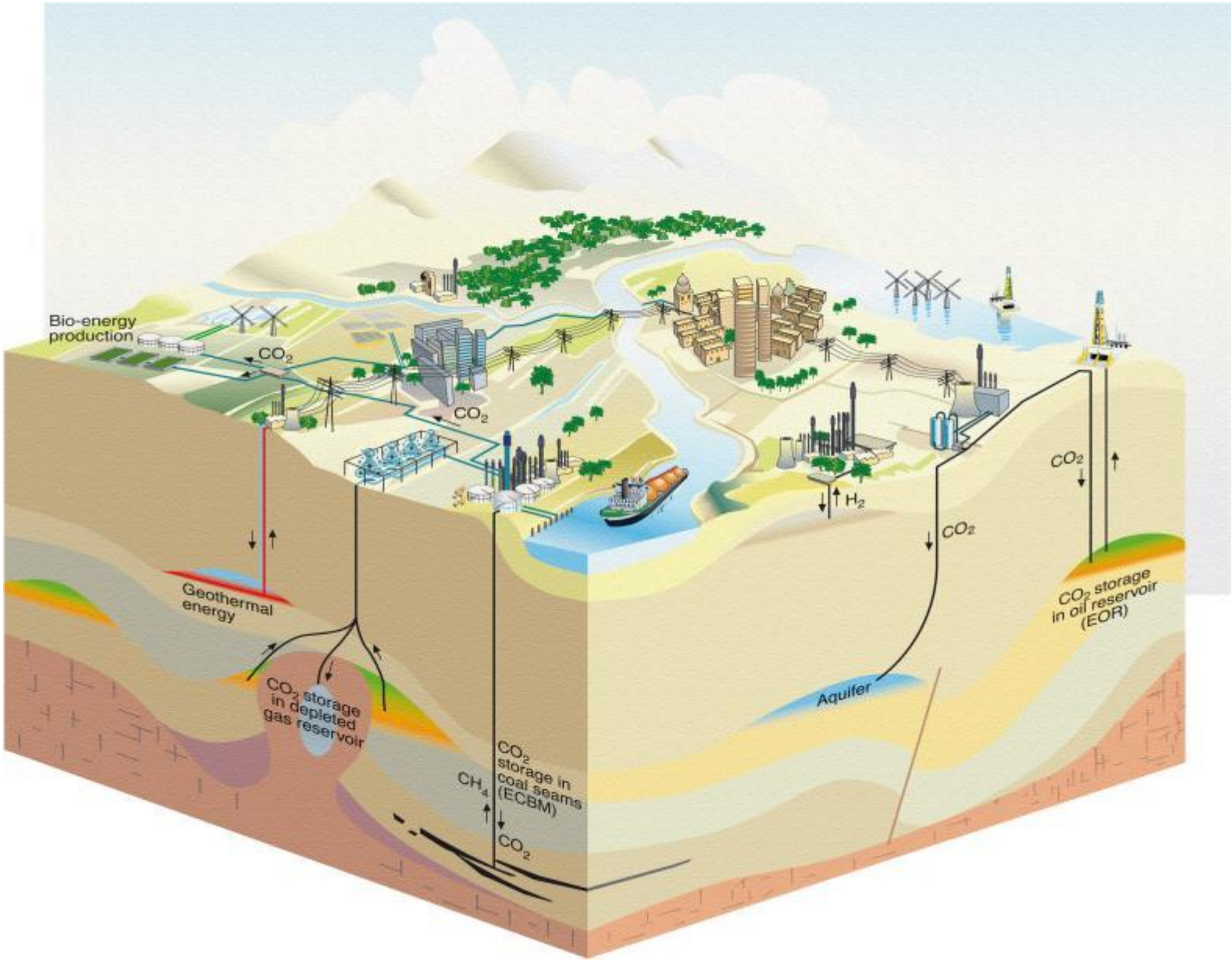
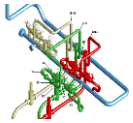
Carbon Capture, Transport, Storage & Utilization

TNO innovation for life





Contents

- General introduction TNO
- Status of CCS in Europe & Netherlands
- ROAD project (general)
- CATO; Dutch National R&D Program on CCS
- Air Liquide – Green Hydrogen project


TNO innovation for life

TNO: Netherlands Organization for Applied Scientific Research

- Founded in 1932 by act of parliament (*TNO law*)
- € 640 turn-over (1/3 direct government funding)
- 4.200 staff

- *Applied* R&D organization
  - technology development
  - contract R&D
  - non-routine consulting
  - special tasks (*Geological Survey of The Netherlands*)

- Independent, transparent, not-for-profit
- Focus on fundamental understanding & knowledge transfer
- *Comparable to IFP, SINTEF, CSIRO, KISR*

TNO organization

MARKETS


Healthy Living


Defence, Safety & Security


Transport & Mobility


Information Society


Industrial Innovation


Built Environment


Energy

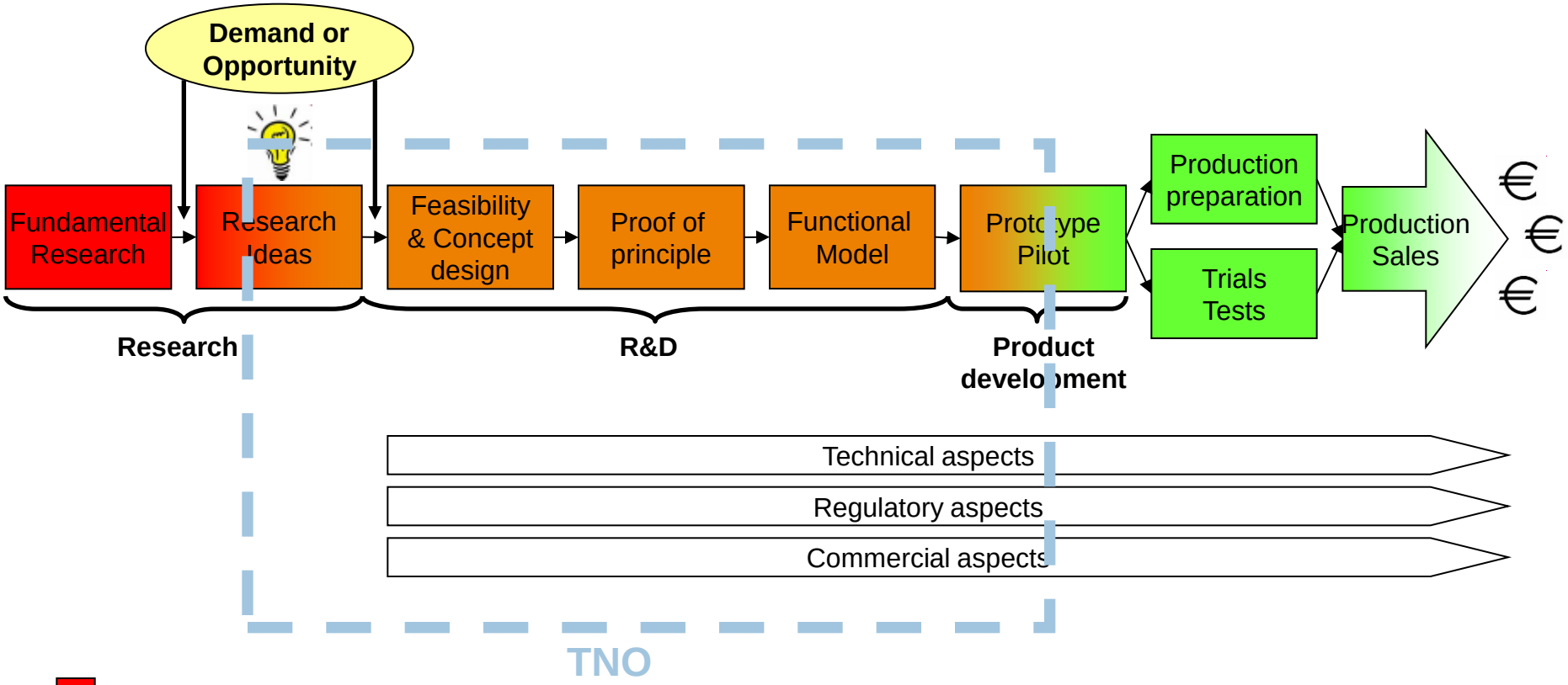
EXPERTISE

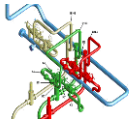
Technical Sciences

Behavioural & Societal sciences

Earth, Environmental & Life Sciences

Our position in innovation

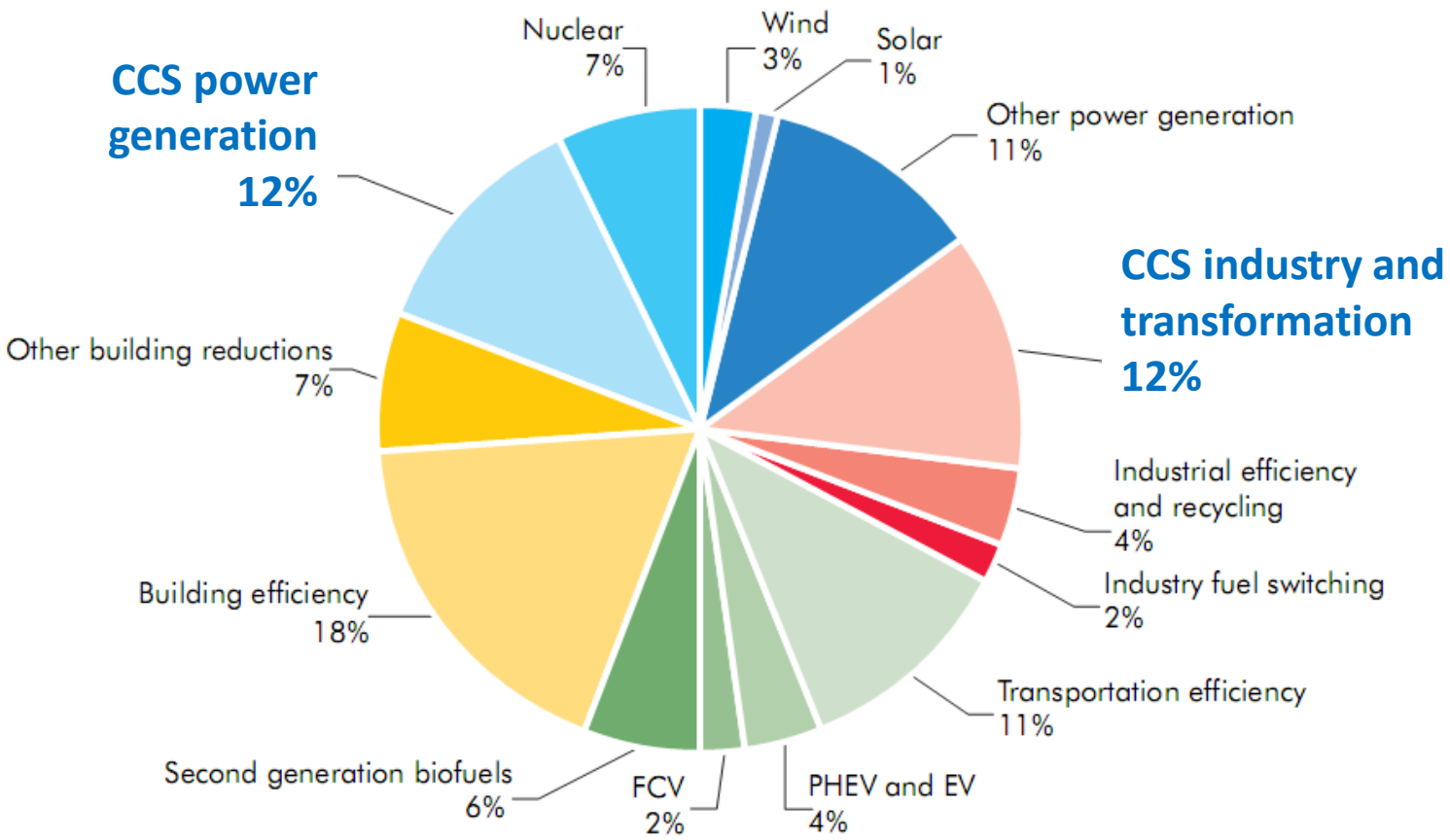




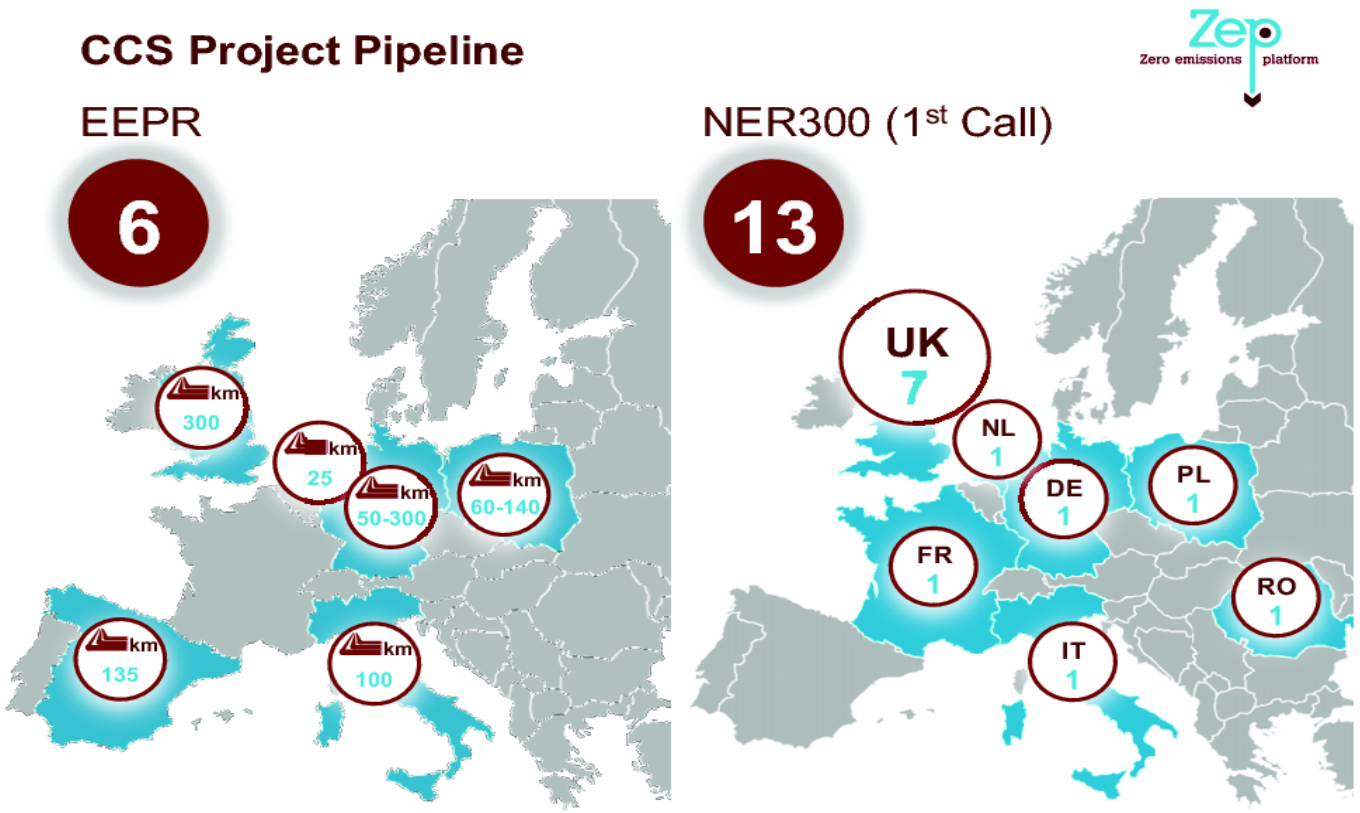
TNO innovation for life

Status of CCS in Europe & Netherlands

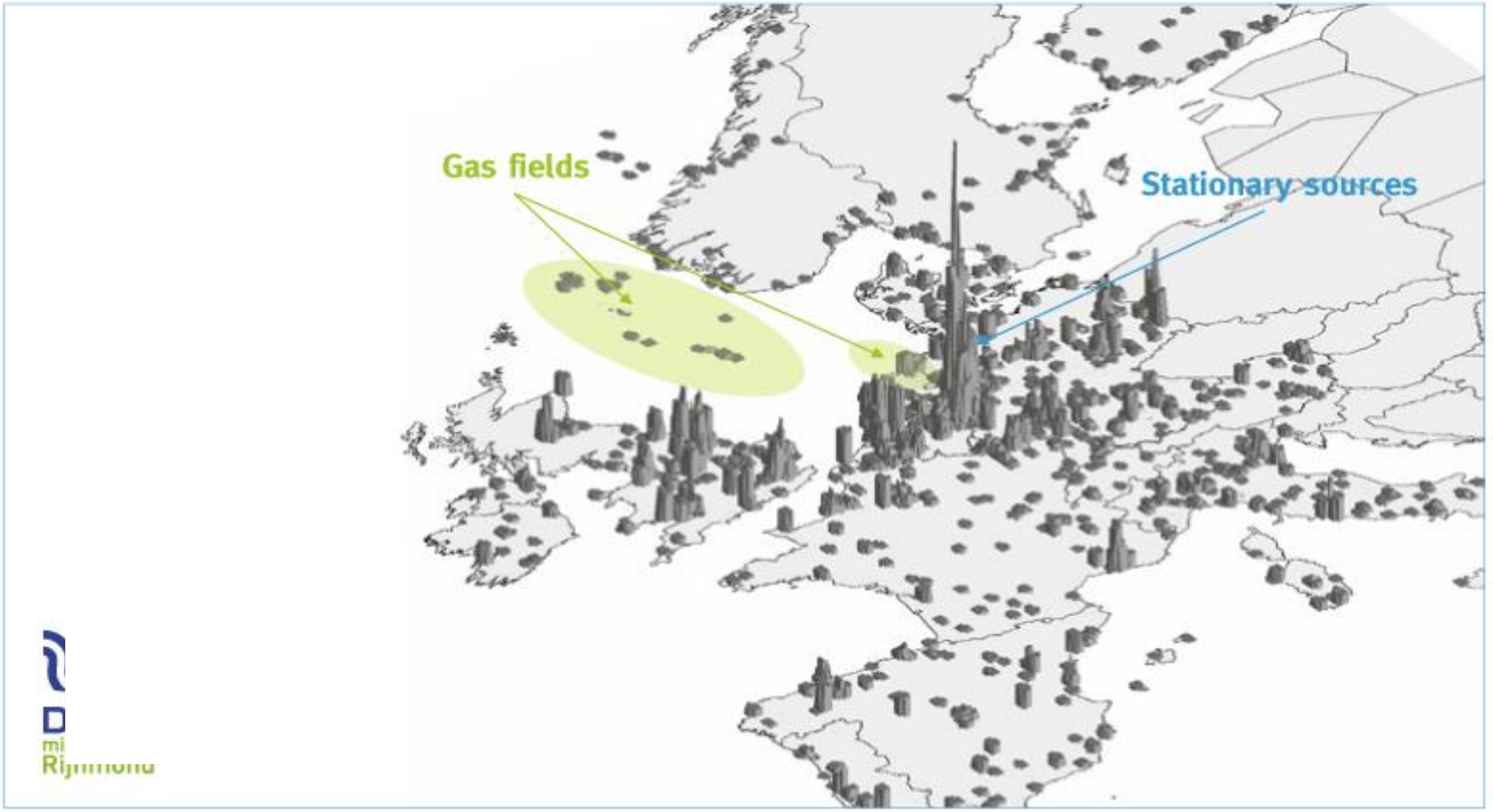
Within Europe CCS provides 24 per cent of the solution in power AND Industrial sector (source IEA).

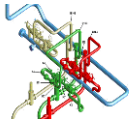


Overview large scale EU CCS demonstration projects



Netherlands; strategically located between CO2 emissions (peaks) and storage locations in North Sea

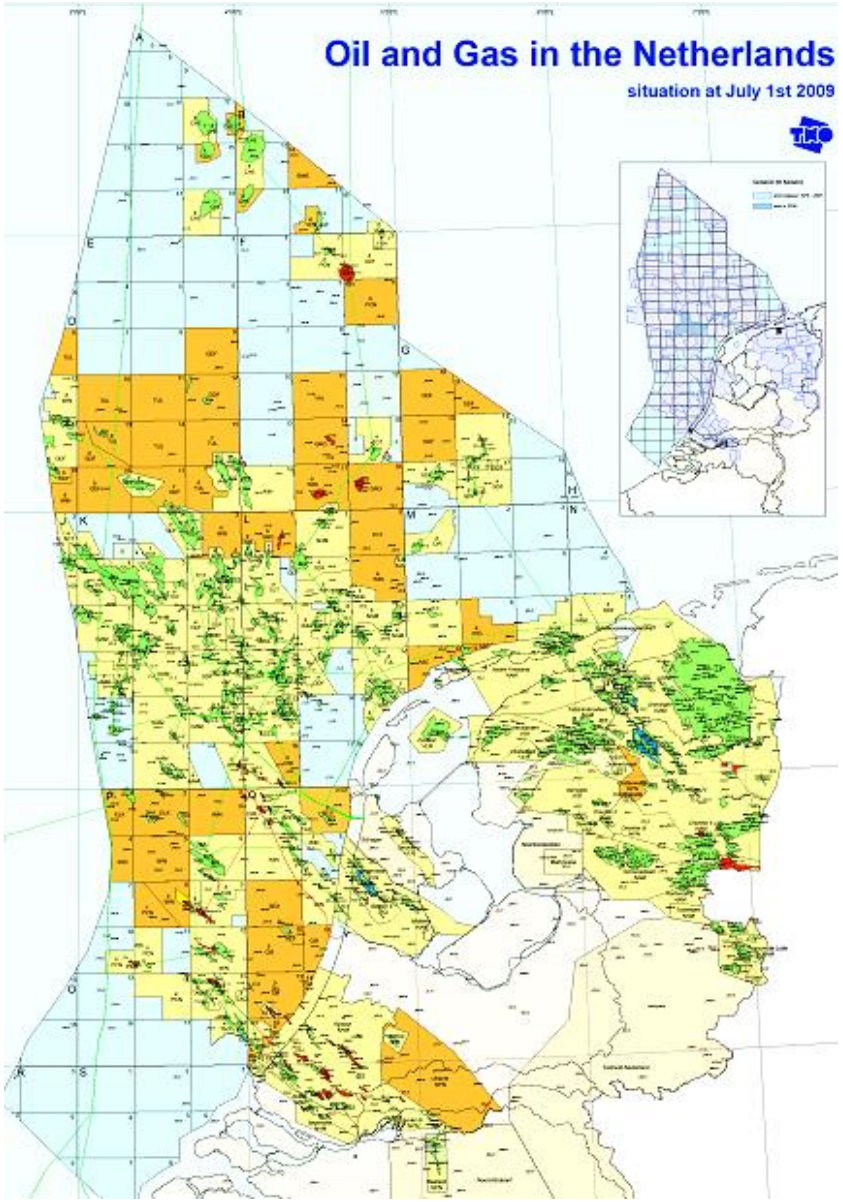




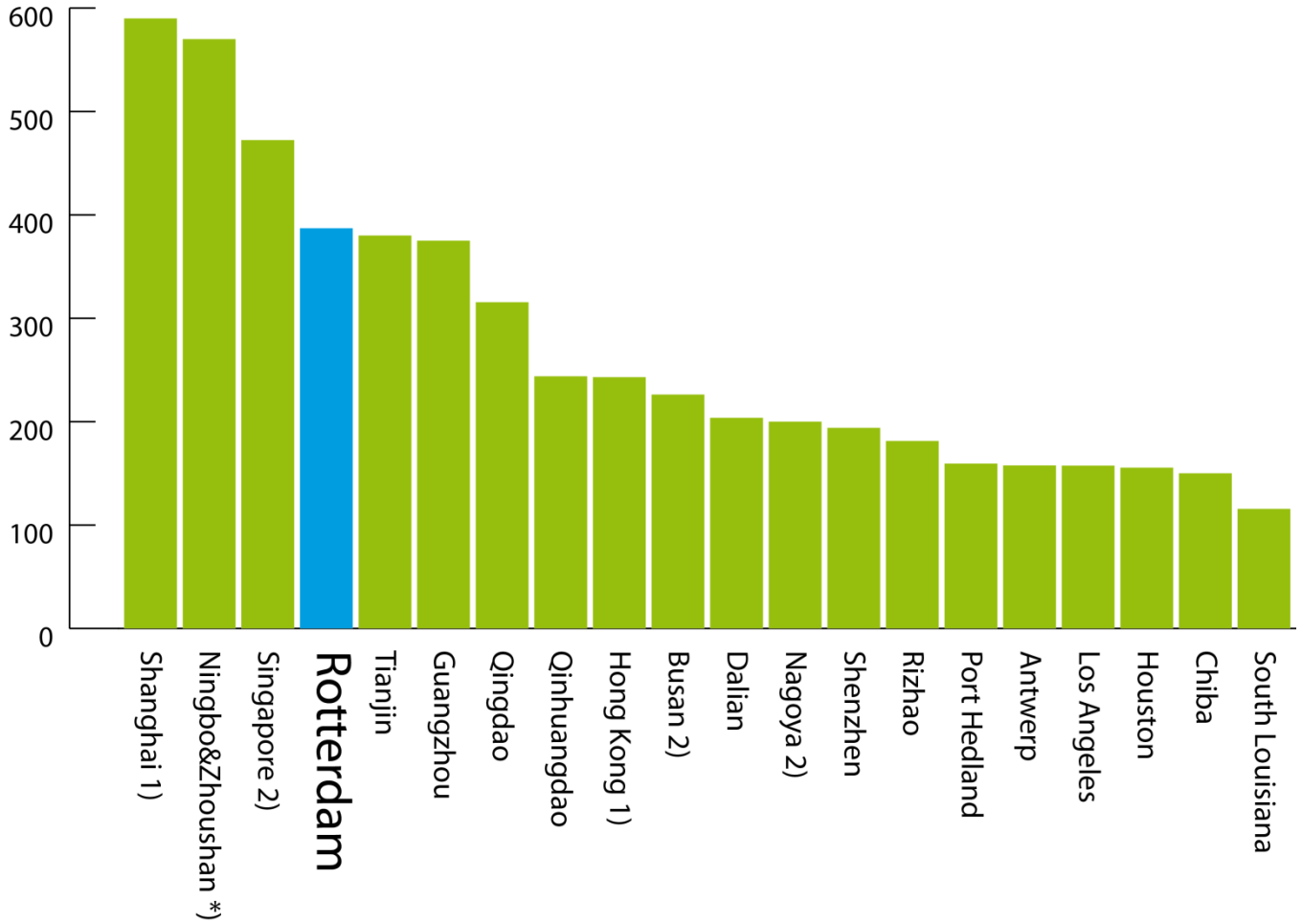
TNO innovation for life

Why CCS and the Netherlands:

- Availability (clustered) large CO_2 point sources
- Large storage capacity; > 3 Gton
- Relatively short transport distances
- Extensive knowledge of oil & gas and CCS
- CATO R&D program since 2004
- Serious business interests and commitment of relevant parties
- Substantial government funding
- 2 large scale demo’s



Rotterdam: 4th largest port in the world



Port of Rotterdam yesterday…


Today...

… and in 2030:

Maasvlakte 2: 1000 hectares new land

CO_2 sources

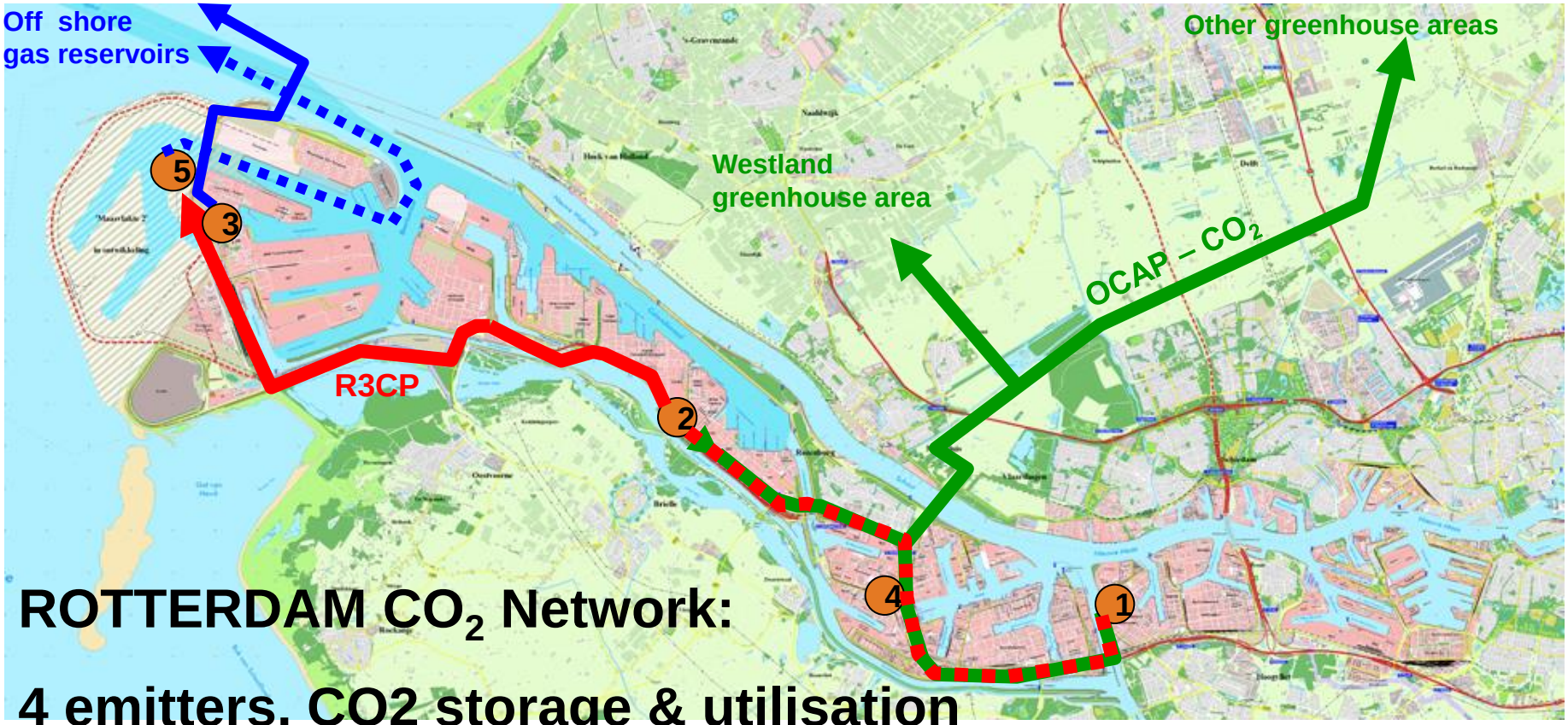
1. Shell (since 2005)
2. Abengoa (since 2011)
3. ROAD (2016 / 2017)
4. Air Liquide (2016 / 2017)

CO_2 logistics

- OCAP
- R3CP: common carrier collection pipeline)
- Offshore pipeline to
- 5 CO_2 Terminal

CO_2 destinations

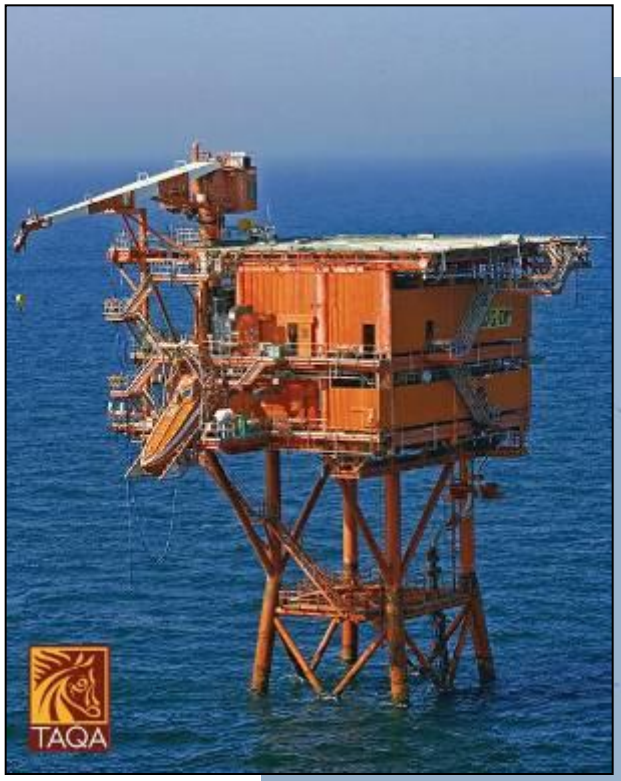
- greenhouses for enhanced crop growing
- Taqa P18 Gasfield
- EOR North Sea



ROTTERDAM CO_2 Network:

4 emitters, CO2 storage & utilisation

ROAD CCS DEMO (250 MW PC); FEED study P18 storage location executed by TNO



General Overview

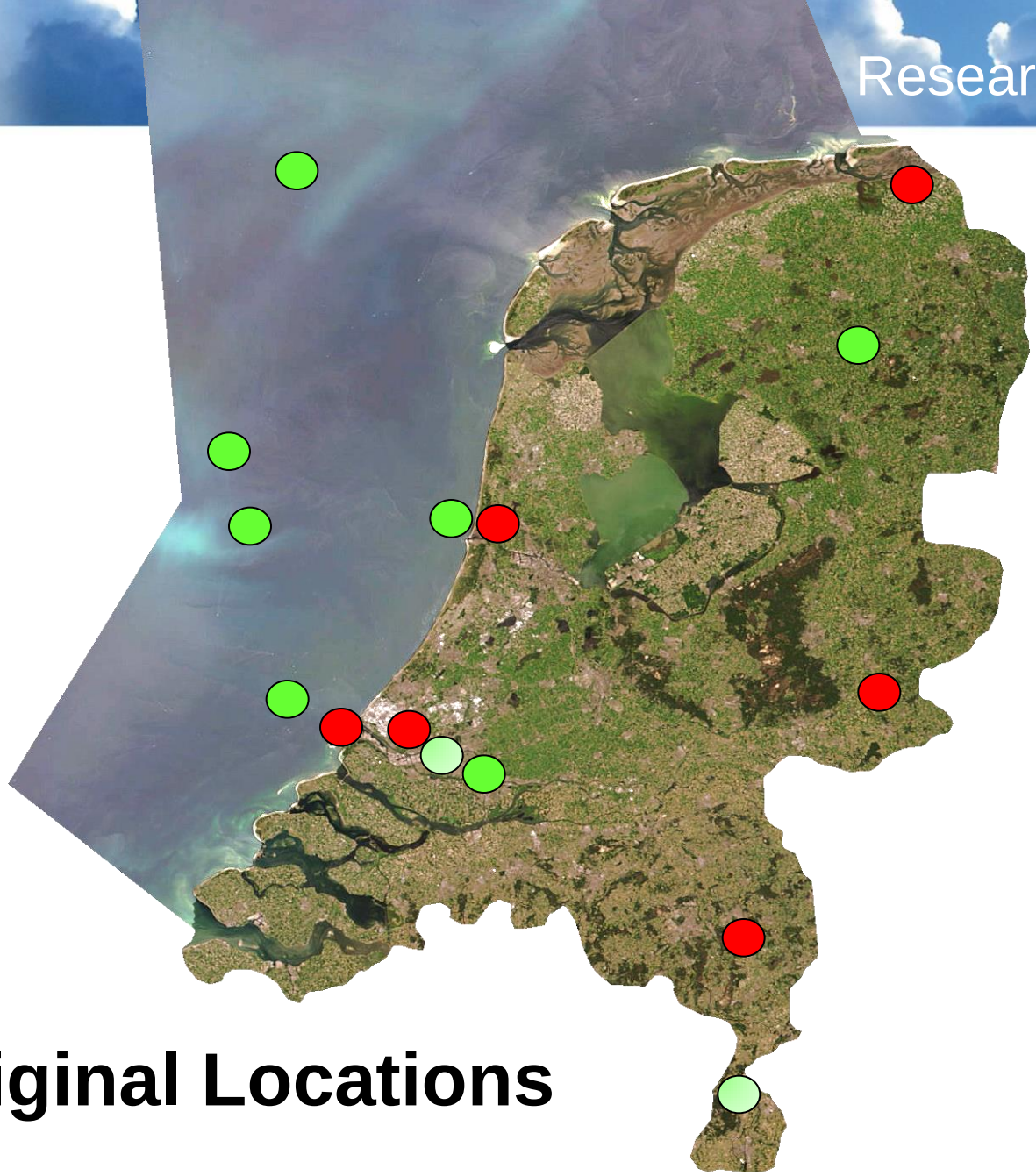
CATO in a glance

- Applied and scientific research
- Complete CCS Chain
- Demand driven & flexible program
- 86 M€ (50% government)
- 200 researchers & 45 PHD students
- Coordination: TNO
- 2004-2013
- Partners from industry, SME, university, NGO

CATO-2 Parties



	SP	Sub-Programs
	0	Coordination, dissemination, cooperation
	1	Capture
	2	Transport and chain integration
	3	Storage & monitoring
	4	Regulation and safety
	5	Public perception



Original Locations

SP-1: Capture	
Post Combustion	- Applied: Scale-up of first generation capture technology to demo scale - Fundamental: Develop second generation capture technology
Pre Combustion	
Oxy Fuel	
Evaluation & Benchmarking	
CCS in Northern Netherlands	
Toxicology and Ecotoxicology of Carbon Dioxide and CCS by-products	
CO2 Re-use	

CATO2 SP1 Capture

Overview And Highlights

Work packages:

WP 1.1A1 User Requirement Specification WP 1.1A2 DEMO Preliminary Design WP 1.1A3 Solvents WP 1.1A4 Absorber WP 1.1A5 STRIPPER WP 1.1A6 Process development WP 1.1A7 Environmental Aspects WP 1.1A9 CO2 capture at Municipal Solid Waste Combustion (MSWC) plants WP 1.1F1 Phase Change Solvents WP 1.1F3 Thermodynamic Models WP 1.1F5 Adsorptive Systems WP 1.1F6 Hybrid system for gas fired power plants WP 1.1F7 Multiple Phases Absorption Liquids WP 1.1F8 Multiple Phases Pilot	1.1 ‘post’
WP 1.2A1 CO2-CATCHUP: Plant operation and optimization WP 1.2A2 Water gas shift catalysis WP 1.2A3 CO2-CATCHUP: CO2 absorption section WP 1.2A4 Sorption-Enhanced Water Gas Shift (SEWGS) WP 1.2A5 Industrial CCS at Tata Steel WP 1.2F1 Hydrogen Membrane Technologies WP 1.2F2 Nano-structured sorbents for CO2 capture WP 1.2F3 Novel materials for H2 - CO2 separation WP 1.2F6 High pressure and temperature selective solvents	1.2 ‘pre’
WP 1.3F2 Chemical Looping Combustion WP 1.3F3 Oxy combustion of solid fuels	1.3 ‘oxy’
WP 1.4 Techno-economic evaluation & Benchmarking WP 1.5 CCS in Northern Netherlands (RWE) WP 1.6 Toxicology and Ecotoxicology of Carbon Dioxide and CCS by-products WP 1.7 CO2 Re-use	

Post Combustion Capture

CATO Pilot (2008) at E.ON Maasvlakte

Flue gas details:

- 1250 m^3/hr flue gas, 250 kg/hr CO_2 captured
- Flue gas gas from pulverized coal power plant
- 90% of CO_2 captured from flue gas side-stream

Pre-Combustion Capture

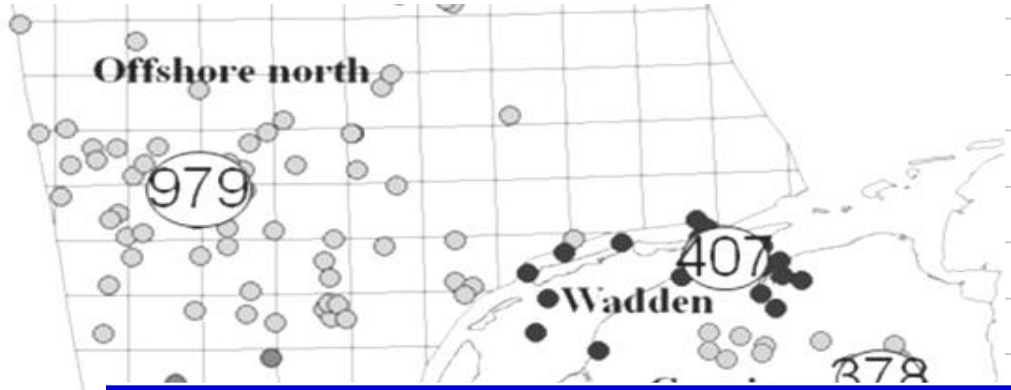
Pd/alloy membranes

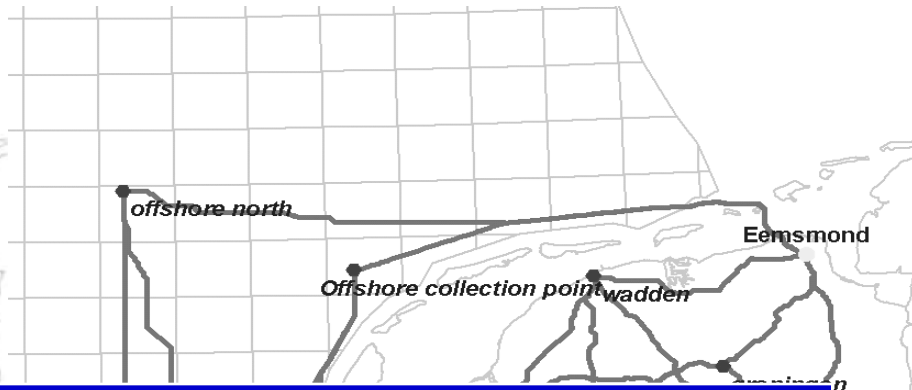
Sorption Enhanced Water Gas Shift

Buggenum pilot plant

WP1.3 Oxyfuel

- Fundamental research
  - Fixed bed chemical looping combustion (PhD)
  - Oxy combustion of solid fuels

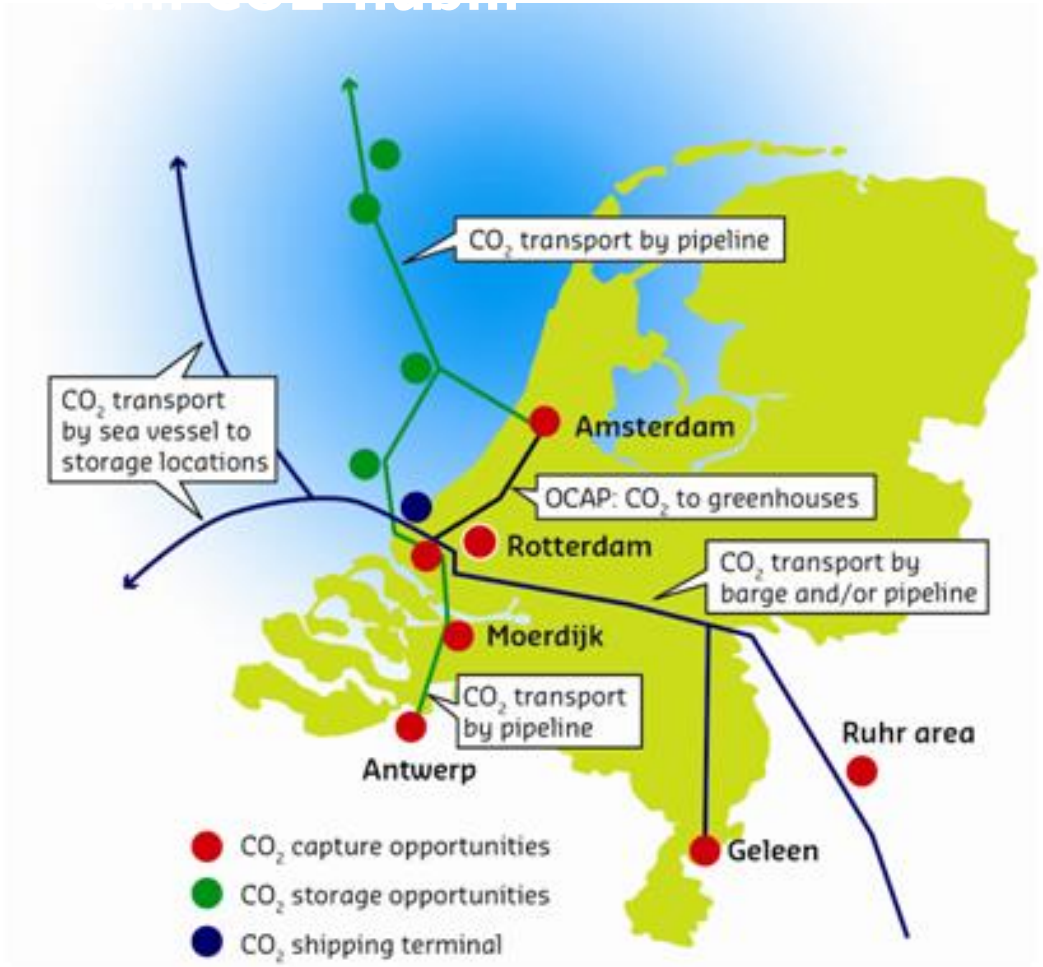


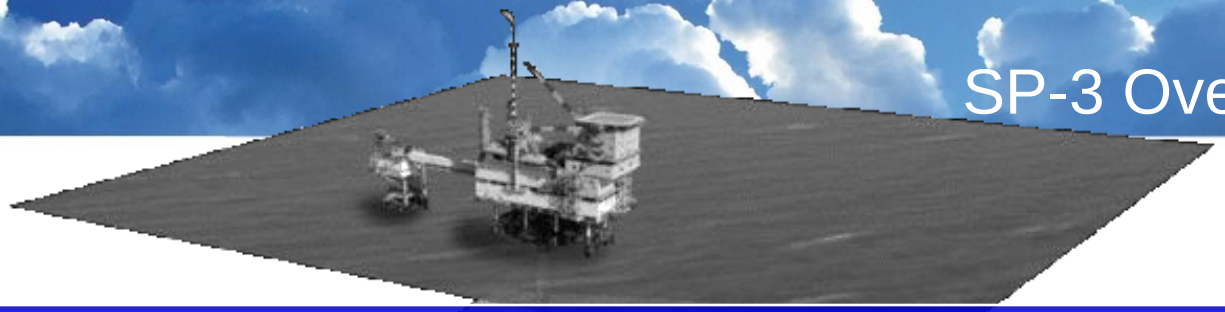


SP-2: CO2 transport and chain integration

- Technical aspects of CO2 transport infrastructure
- Techno-economic chain analysis
- International CCS policy
- Chain integration and CCS implementation plan
- Technical assessment of the ROAD CCS chain in non-steady conditions

CCS Roadmap for the Netherlands

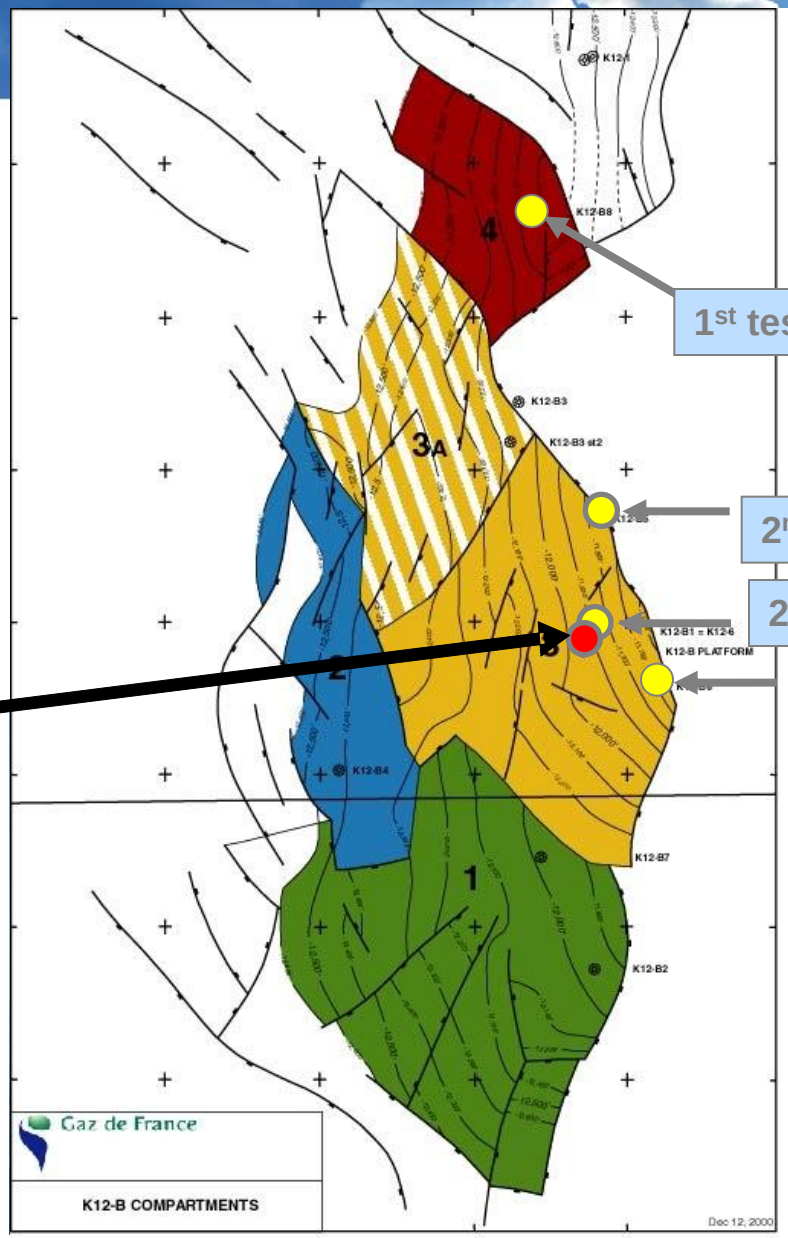




SP-3: Underground storage, monitoring, verification
Geological models
Reservoir behaviour
Cap rock & fault integrity
Well integrity
Additional benefits of CO2 injection (EOR & temporal buffering)
Shallow (sub-) surface monitoring
Permanent geophysical monitoring
Lab exp. geophysical monitoring
Site-specific monitoring

GDF-Suez K-12B

Offshore Enhanced Gas Recovery, CO2 gas treatment

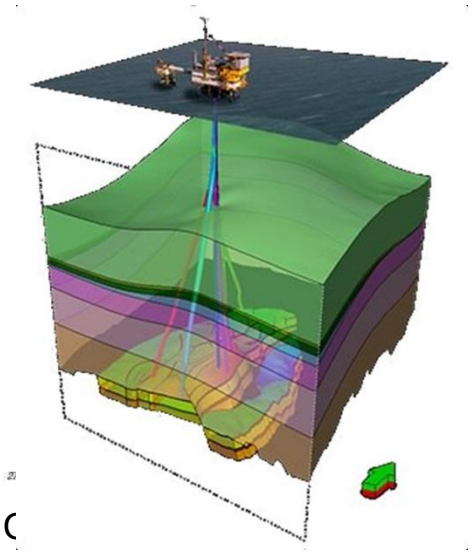


1st test: K12-B8 - Injector

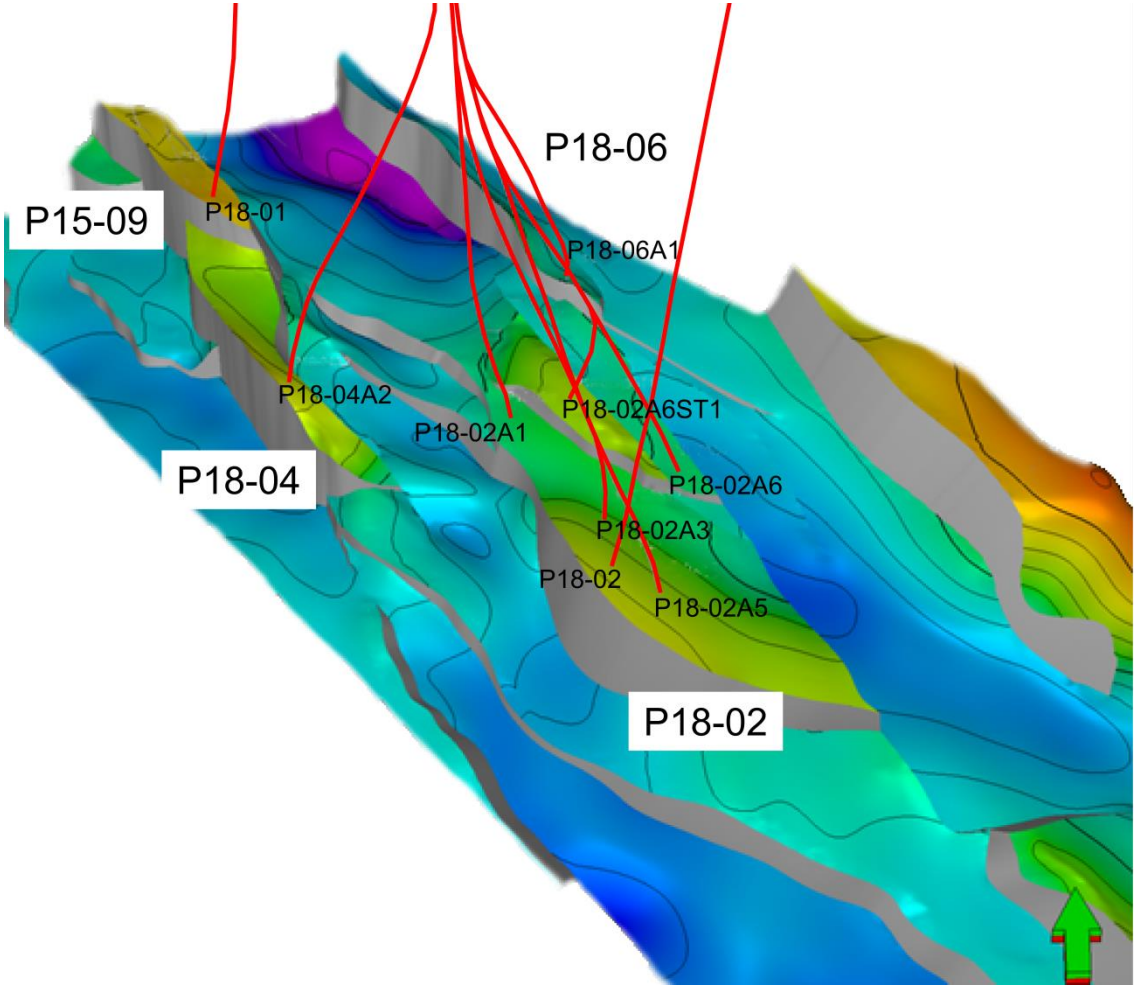
2nd test: K12-B5 - Producer

2nd test: K12-B1 - Producer

2nd test: K12-B6 - Injector



ROAD Storage location; The P18-4 gas field



SP-4: Regulation and safety

- Legislative framework & guidance
- Permitting & best practice
- Environmental performance
- Risks CO2 transport
- Risks geological storage of CO2

Ministry of Housing, Spatial Planning and the Environment

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Results announced of additional study on CO2 storage in Barendrecht

29-10-2009

Today the results were announced of the three supplementary

de Volkskrant

Nieuws Opinie Cultuur Opmerkelijk Video Service Webwinkel

Binnenland Buitenland Economie Sport Kunst Wetenschap Internet

Barendrecht gaat in verzet tegen CO2-opslag

ANP op 18 november '09, 17:25, bijgewerkt 19 november '09, 11:46

Barendrecht protesteert tegen CO2-opslag (RTV Rijnmond)

vk.nl/groen **BARENDRECHT - De gemeente Barendrecht legt zich er niet bij neer dat in de gemeente een proef komt met de opslag van het broeikasgas CO2.**

- Barendrecht krijgt CO2-opslag

DOSSIER

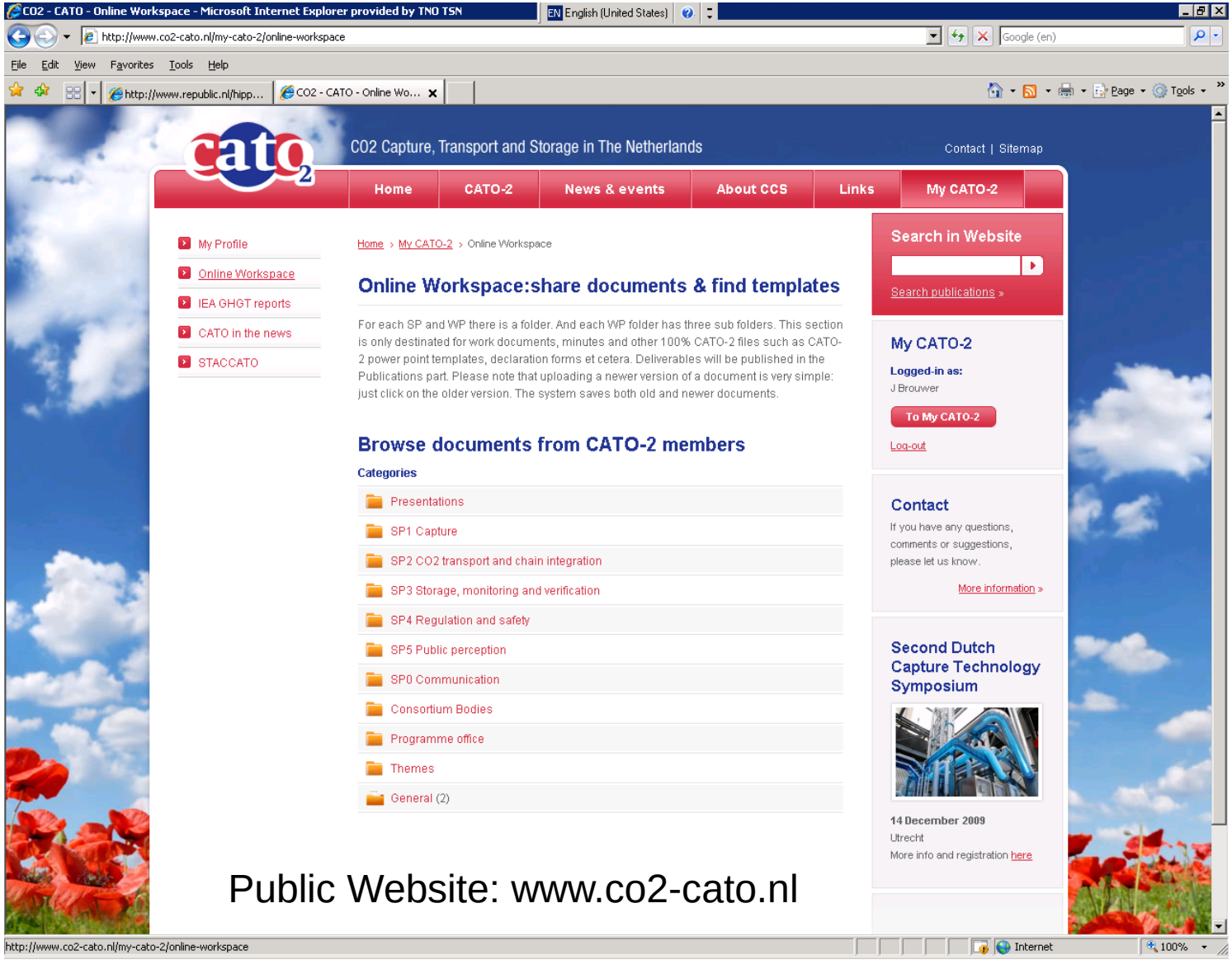
BEKIJK

Nog geen besluit over CO2-opslag

SP-5: Public perception

- Local communication near CCS
- Framing effects in CCS communication
- Trends in public opinion about CCS
- Resistance of valid beliefs about CCS against low quality information

Public Website: www.co2-cato.nl



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