INITIATING LARGE-SCALE STORAGE IN THE NETHERLANDS OFFSHORE

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CCS 'SITUATION' NETHERLANDS, 2017

- Government target: meet Paris agreement targets
  - 49% reduction in CO_2 emissions in 2030 (compared to 1990 levels)
  - Implying total additional reduction of 56 Mtpa
  - Of which 12 Mtpa by closing down coal fired power plants
  - Industry contribution: 22 Mtpa emission reduction
    - Process efficiency: 3 Mtpa
    - Recycling: 1 Mpta
    - CCS: 18 Mtpa
      - May 2018: ambition reduced to 7 Mtpa by 2030

  - M€ 300 /yr to be made available to develop policies, build expertise, run pilot projects (*not just CCS!*)

'No to CO_2'
(Barendrecht storage plans)

CURRENT CCS ACTIVITIES IN THE NETHERLANDS

- Rotterdam harbour: Porthos consortium
  - 20% of national emissions
  - Develop into ‘green port’
  - Continue economic activity under increasingly strict greenhouse gas emission regulations
  - Target ~5 Mtpa by 2030; to grow beyond 2030
- Steel plant (TATA Steel)
  - HIsarna process: pilot – demo – plant
  - CO_2 production 0.1 – 0.5 – 2-3 Mtpa
- Waste processing
  - Capture projects (CCU) starting or ongoing

Transport and storage of CO_2 in NL, 2017 ECN TNO innovation for life

TATA Steel, IJmuiden

AVR, Duiven

ROAD CCS PROJECT (CANCELLED 2017)

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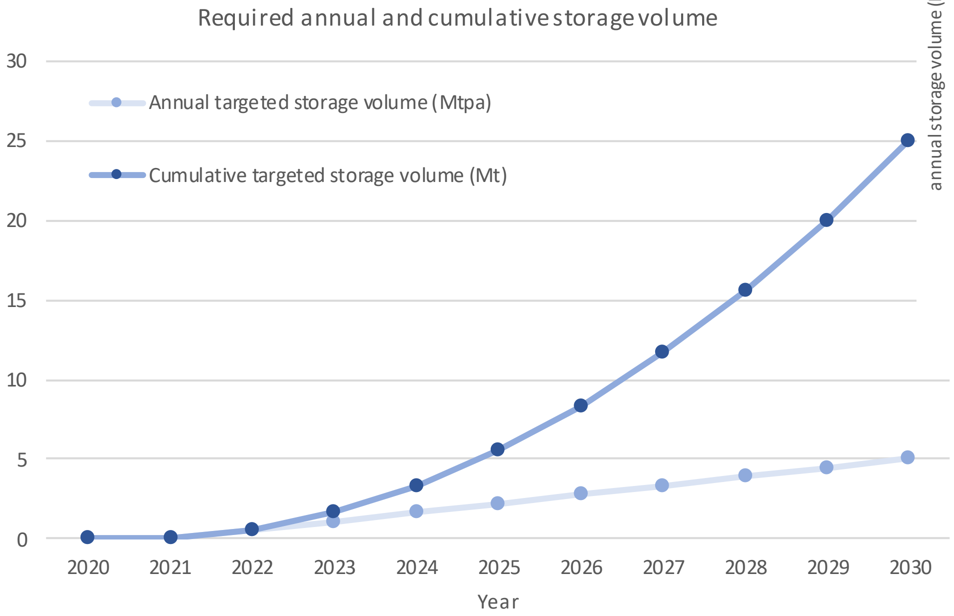
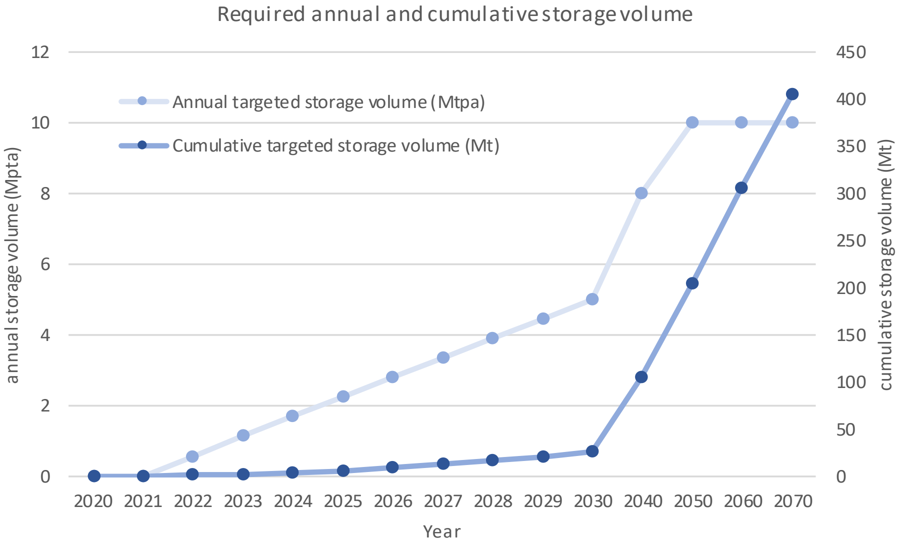
CO_2 storage licence!
~8 Mt

CO_2 SUPPLY PROFILES

Rotterdam (Rijnmond): 5 Mtpa by 2030

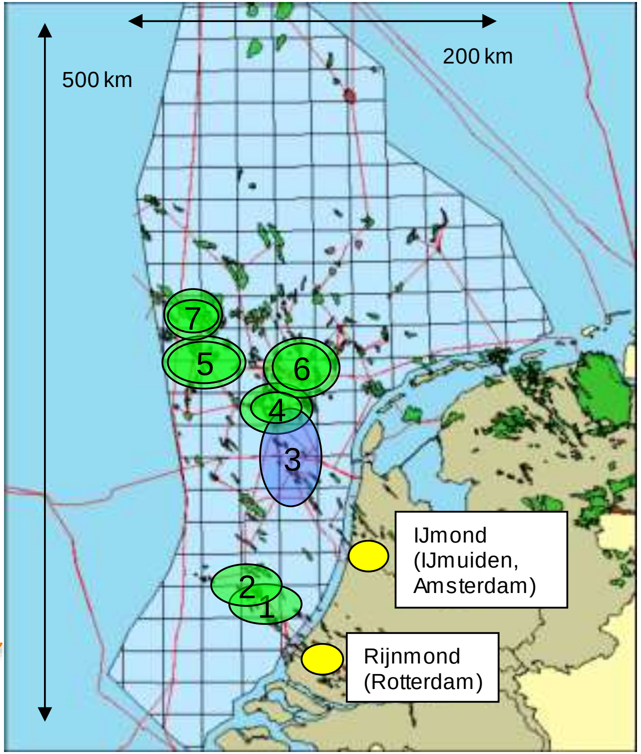




Amsterdam (IJmond)
5 Mtpa by 2030

STORAGE CAPACITY ASSESSMENT

#	Name	Capacity (Mt)	Type	Available (year)	Fields in cluster	Distance from Rotterdam (km)
1	P18	40	Gas fields	2020	2	25
2	P15	35	Gas fields	2025	3	40
3	Q1	135-235	Saline fm gas field	2020	1	100
4	K15	165	Gas fields	2020	6	150
5	K08	195	Gas fields	2020	6	180
6	L10	175	Gas fields	2022	3	170
7	K05	150	Gas fields	2028	9	200
Total capacity		960 Mt				

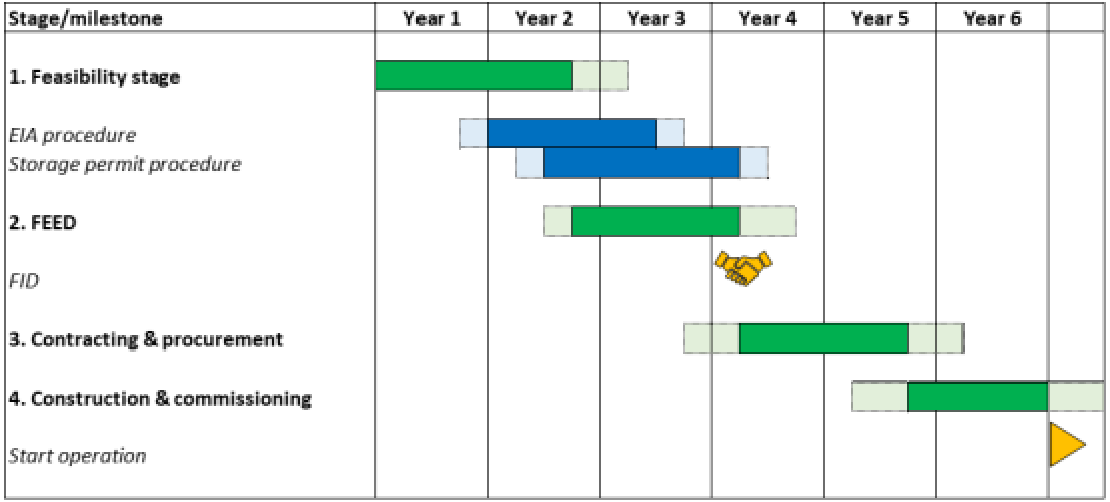


Nr 3: depleted aquifer connected to four small oil fields

STORAGE DEVELOPMENT LEAD TIMES

- Re-using platforms, wells
- New build pipelines

- Developing a depleted gas field into a CO_2 storage site takes at least 6 years



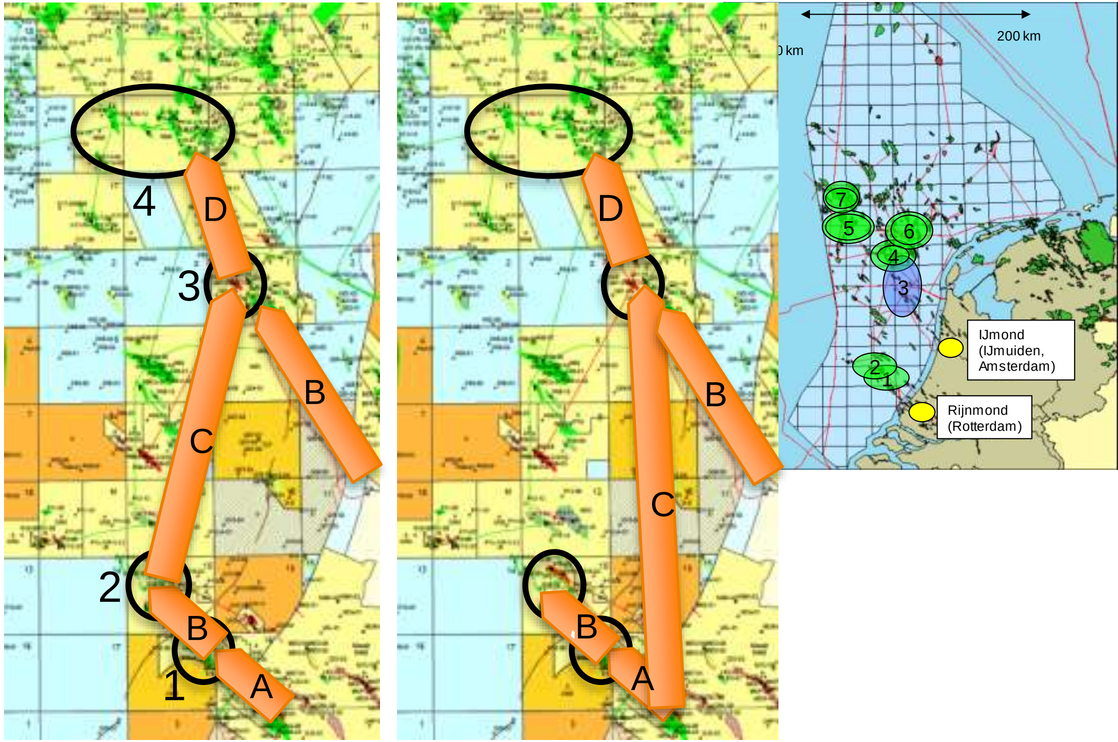
NETWORK DEVELOPMENT

- ‘Boundary conditions’
  - Depleted field injection management
    - Warm injection – near shore cluster, CO_2 through insulated pipeline
    - Cold injection – from offshore hubs, CO_2 arrives at hub at sea water temperature
  - Offshore clusters choice and workover
    - Availability
    - Cluster fields size
    - Fields risk level assessment
    - Unit storage cost estimates

POTENTIAL NETWORK DEVELOPMENT SCENARIOS

- CO_2 supply from Rotterdam & Amsterdam regions
- First element (‘A’) currently being designed
- Design element ‘A’ depends on choices made for later elements

- Selecting network development options:
  - Unit cost of storage and transport
  - Risk assessment of clusters and fields
  - Availability of fields, platforms & wells
  - Storage capacity & injection rates



DEVELOPMENT OF CO_2 STORAGE SITE PORTFOLIO

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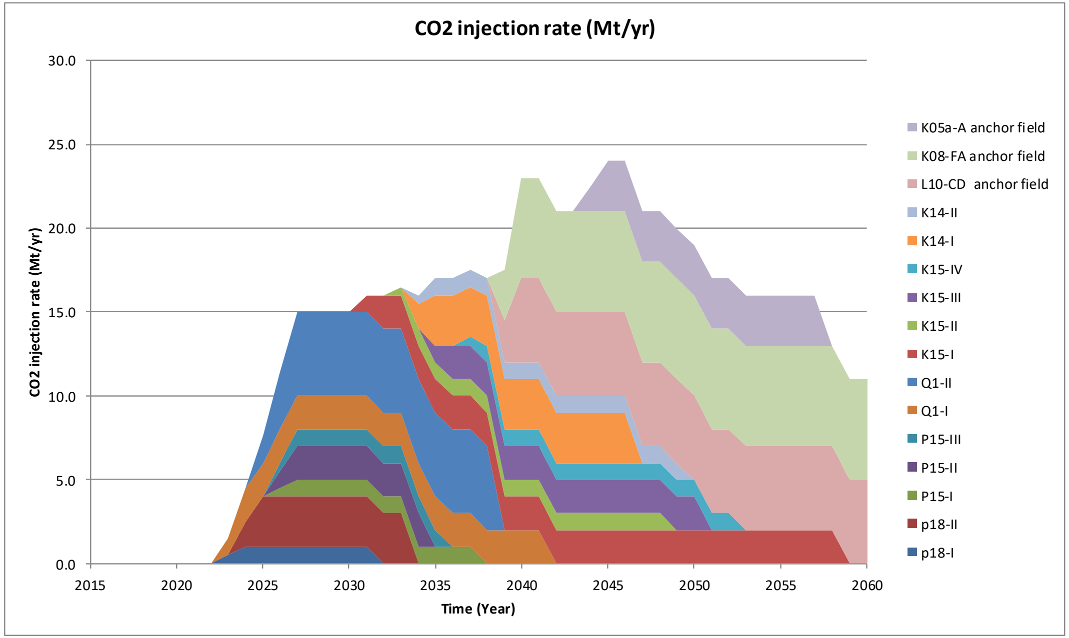
Depleted gas fields

- Gas fields: typical capacity 15-50 $MtCO_2$
- Developing field clusters
  - Connect several fields to central hub
- Storage capacities 15-20 Mtpa reached by stacking *many* fields
  - Up to10 fields online in parallel
- High rate of development
  - Fields brought online on yearly basis



COST ESTIMATES

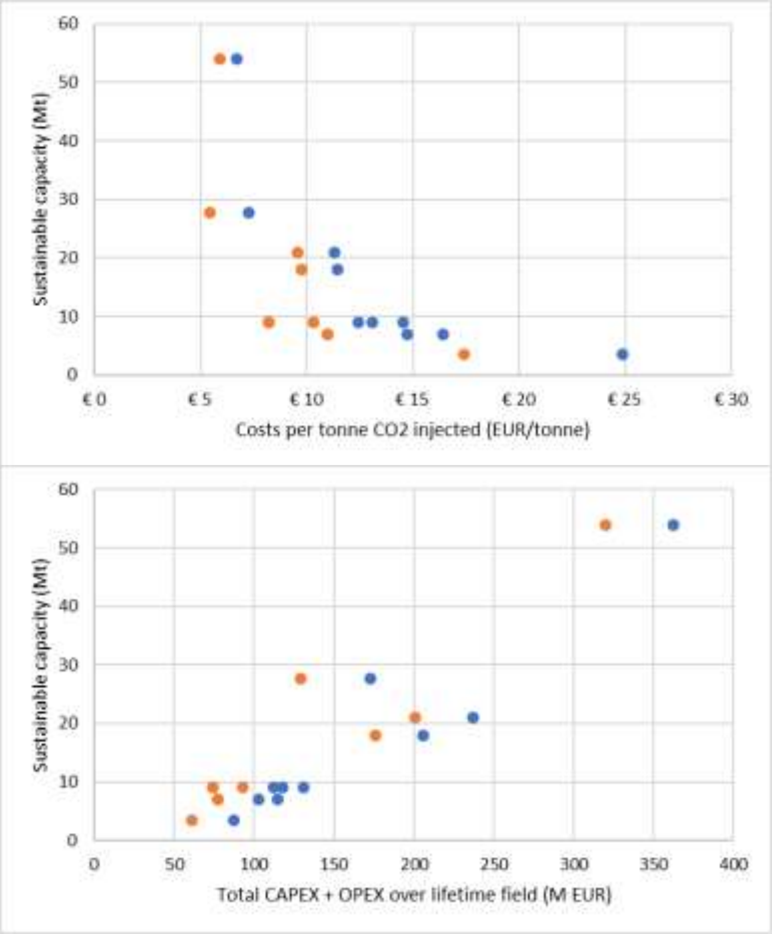
- Re-use *vs* new build
  - Platforms
  - Wells

	Existing export platform	New export platform	Existing satellite platform	New satellite platform
Modification or new build cost (M€)	21	60	13	60
Operational costs (M€/yr)	16	6	6	6
Decommissioning (M€)	31	20	20	20

	Cost level (M€)
Workover for transfer to injector	8
Newly drilled and completed	21
Operational costs (MEURpa)	2
Plug and abandon	6

UNIT STORAGE COST

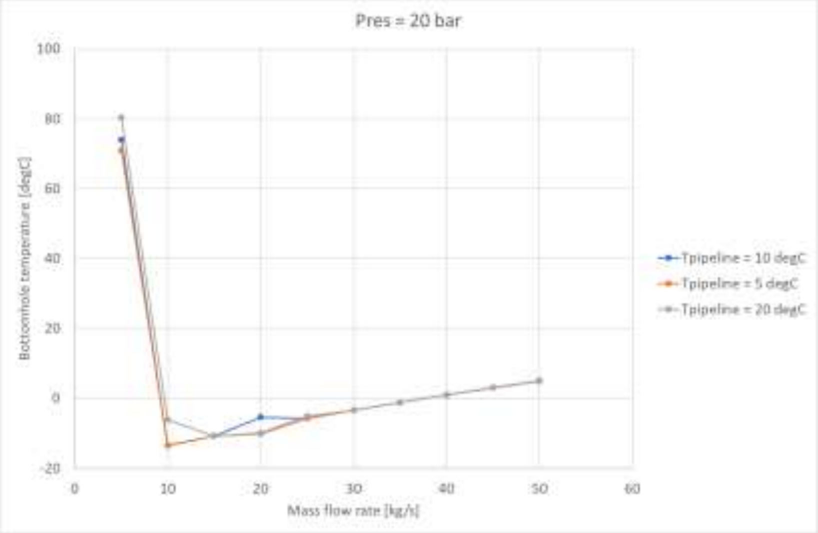
- Cost elements
  - Platform
    - Satellite or large central platform (both M€ 60)
    - Re-use (modified) or new (M€ 13 or 21)
    - Opex (6 or 16 M€ /yr)
  - Wells
    - Workover (8 M€ /well)
    - Opex (2 M€ /yr/well)
    - Abandonment
- Abandonment cost in case of re-use (platform & wells)
  - Included in CO_2 storage cost (●)
  - Not included, is part of gas field production cost(●)



DEVELOPING T&S INFRASTRUCTURE

Low-pressure wells

- Issue: (very) low depletion pressures cause issues when injecting CO_2
  - Injection to start at low rates to avoid low temperatures:
    - In the well (freezing of well bore)
    - At bottom hole (freezing of near well area, hydrate formation)
  - Direct injection from backbone pipeline (~ 100 bar) possible only once reservoir pressure above about 60 bar
  - At lower pressures: shut-in & start-up to be handled carefully
- Solving these issues will affect the design of the T&S infrastructure



Example showing bottom hole temperature in a low-pressure well for various flow rates (50 kg/s = 1.6 Mtpa)

ONGOING WORK

- Hot vs cold CO_2 injection
  - How to manage safe injection when reservoir pressure is (*very*) low?
  - What are feasible rates when CO_2 is at 80 bar, 10 °C at offshore hub?

- Network development choices
  - Design and lay-out first elements impact on options in later phases of network development
  - Later phase must be clear at start network development

- Network flexibility and robustness
  - Assurance of storage capacity supply
  - Managing (absorbing) operational upsets

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THANK YOU FOR YOUR ATTENTION

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