Leading the development of Sustainable Power & Industrial clusters though CCS deployment: potential priority states

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Key questions national CCS preparedness:

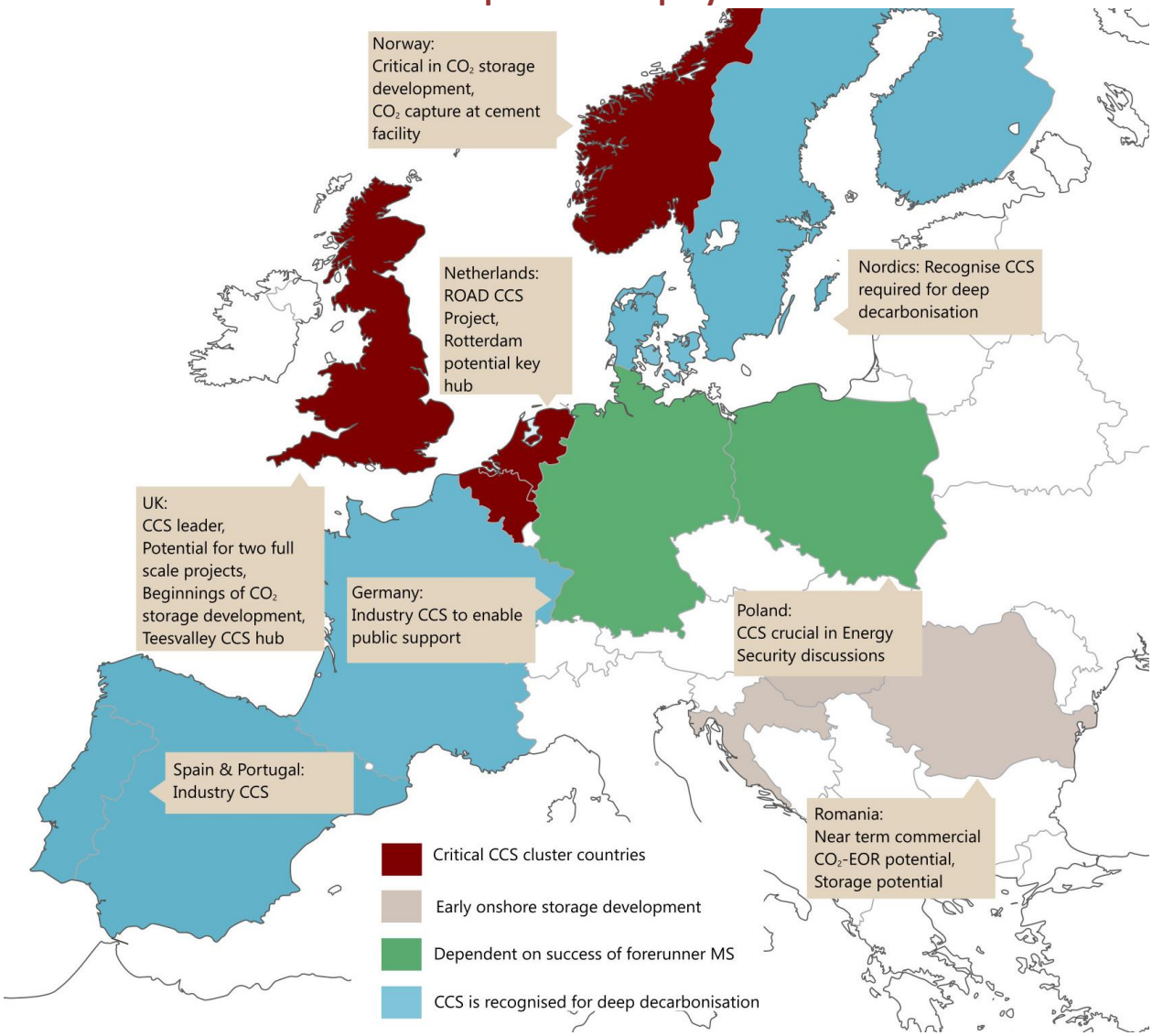
Political and Legislative

- To what extent have the MS quantified the CCS contribution to the 2030 and 2050 targets?
- Have MS developed a national plan/roadmap for CCS delivery?
- Have MS created the marginal abatement cost curve as part of the national plan? Where does CCS sit on this? Before or after the 2030 target? Do abatement strategies include core national industries, e.g. steel, cement, refineries, chemicals, pulp and paper?
- Do MS have support mechanism for clean power and clean industry to transition energy and industry systems to when carbon price is sufficiently high?
- Do MS have a section of government assigned to CCS – with deep understanding ranging from energy markets to storage capacity maturation?
- Do MS have a feel for public support and acceptance? Are they able to articulate the vision for sustainable cities and sustainable industry?

Technical and Practical

- Do MS have a specific transport and storage plan for CO2?
- Are CO_2 sources and CO_2 sinks mapped? Do the MS know the longevity of sources and the mix of industry and power?
- Have MS got CCS and CO_2 storage regulations in place? To what extent are the different business model elements present for CO_2 storage development?
- Have MS established a long term liability management mechanism for stored CO_2?

Core countries for near-term European CCS deployment



Critical CCS Cluster Countries / Enablers of EU CCS to enable post 2030 decarbonisation: The development of core infrastructure

- **The Netherlands'** ROAD project could if progressed return Rotterdam and the Netherlands to the centre of European CCS discussion and move the North Sea forward as a CCS hub. But the ROAD project still needs a positive FID and pressure to progress this.
    - The development of Rotterdam, with its location at the mouth of the Rhine, as a CO_2 cluster to access North Sea storage is critical to the timely and effective decarbonisation of Western Europe (including the core industrial areas of the Rhine and Ruhr).[1] [2] [3]

[1] CO_2 capture and storage in Rotterdam A Network Approach, *Rotterdam Climate Initiative,* 2011
[2] Towards a transport infrastructure for large-scale CCS in Europe, *CO2Europipe*, 2009

- Commercial potential for Netherlands in the development of CO_2 transport and storage hub through Rotterdam. CO_2 export, handling and storage services creating skilled employment and leveraging analogous experience in offshore industries.[4]
- Significant local and national CCS expertise need support to be grown to the next level, or risk dissolving.
- Already existing CO2 pipeline infrastructure around ROAD, taking low-cost capture CO2, from hydrogen and bioethanol production (potential for negative emissions) to feed Dutch greenhouses during parts of the year.[5]

- **Belgium** and the port of Antwerp are well placed to complement a growing CO_2 transport and export nexus. Many relevant industries (chemicals, refineries, steel…) in vicinity. The Port of Antwerp consortium has outspoken interest in a possible North Sea PCI for CO_2 transport with ROAD and/or UK industry. [6]
- **UK's** two projects, White Rose and Peterhead, are still on track for a positive FID in late 2015/early 2016. The UK is the only European country to put in place operational support measure for CCS in the form of a Feed-in Tariff with contract for difference (CfD). The UK is also the only European country to have an EPS and a ban on new unabated coal capacity. Thanks to the two Competition projects, the Don Valley project (recently bought by Sargas Power and in receipt of EEPR funding), a Summit Power project at Grangemouth and an industrial CCS cluster project in the Teesside region, the UK is advanced on commercial CO_2 storage development. In addition the UK has provided funding for CO_2 storage characterisation at the next five key strategic storage sites. Continued engagement from the EU will be required to see ensure both competition projects cross the finish line.
  - National long term decarbonisation goal (2050) has led the UK to develop incentives for CCS and a commercialisation program to enable long term deep decarbonisation. [7]
  - Large CO_2 storage capacity, analogous offshore industry and potential for CO_2 use in EOR. [8]
  - Emerging CO_2 storage sector, leveraging offshore skills and supply industry. [9]
  - Emerging CO_2 capture and storage cluster in the Humber, Teeside and Aberdeenshire regions. [10]
- **Norway** has yet to lay out a path following the cancelation of the full-scale CCS project previously planned at gas power plant and a refinery at Mongstad. Norway, while not a MS, is well placed to become a large exporter of offshore CO_2 storage services to Europe. CO_2 storage must be communicated as a commercial opportunity that could replace declining activity in the hydrocarbon sector.

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[3] A roadmap towards a European CO2 transport infrastructure, *Neele et al*, GHGT-11, 2013
[4] Rotterdam Business cases, *cato₂*, 2015
[5] Strategic Position Paper - Development CO_2 Hub In Rotterdam, *Rotterdam Climate Initiative,* 2012
[6] Towards a Low Carbon Emission Industry in the Port of Antwerp: the role of Carbon Capture, Utilization and Storage, *Karen Callebaut, Port of Antwerp*, 2015
[7] CCS Cost Reduction Taskforce, CCS Cost Reduction Taskforce, DECC, 2013
[8] Economic impacts of CO_2 enhanced oil recovery for Scotland, Final report, *elementenergy*, 2013
[9] CCS Sector Development Scenarios in the UK, Final report, *energy technologies institute,* 2015
[10] Building A CO_2 Storage Hub In The Central North Sea - Sco2tland's Blueprint For A Carbon-Proofed Economy, *Scottish Enterprise*, 2013

- Emerging renewed CO_2 capture and storage strategy focuses on CO_2 capture from industrial sites, with strong industry interest and involvement (cement, waste incineration) and the development of strategic CO_2 stores.[11]
- Emerging potential CO_2 storage service sector, leveraging offshore skills and supply industry. [12]

Additional CCS storage clusters and early onshore storage development

Romania has significant potential for commercial EOR (Enhanced Oil Recovery) operations onshore, creating a potential early business case which the current EUA price cannot, hence reducing need for opex subsidies. Cooperation between local industry as CO_2 providers and the hydrocarbon CO_2 transport and storage infrastructure will need to be furthered.

- Romania has large geological potential for CO_2 storage and EOR. [13]
- Romania could pave way for onshore CO_2 injection at scale for CO_2 EOR, leading to familiarity and greater support for onshore CO_2 storage

- **Hungary / Croatia** have experience of CO_2 of onshore EOR. [14] [15]

Critically dependent on success of CCS forerunner MS for post 2030 decarbonisation:

- **Germany** is pivotal in the formation of EU wide polices and re-engaging the German environmental movement on its CCS position is of critical importance. Communicating the need for CCS in tackling industrial emissions could provide a way forward in facilitating NGOs, local industry and local government to develop CCS strategies. German dialogue on CCS should focus on the reduction of CO_2 emissions from industries like steel, cement and chemicals; this will be a core requirement in meeting post 2020 CO_2 reductions.
  - The Rhine valley/Ruhr industrial area will require CCS as a solution to its emissions. In the absence of local/permissible CO_2 storage, the transport of CO_2 on the Rhine will be needed via barge to Rotterdam to access North Sea storage. CO_2 transport infrastructure to evolve over time to include high capacity pipelines.[16]
  - Critical that Rotterdam develops as CO_2 storage hub to allow decarbonisation of Europe's largest industrial area. Steps need to be taken to keep link the option open to link to Rotterdam
  - Potential utilization of CO_2 popular in Germany, however CO_2 storage is the only feasible way to achieve any significant reduction of CO_2 emissions from industrial base. Potential for smaller demos of CO_2 use in enhanced geothermal heat recovery
  - Mapping study of German industrial cluster(s)

[11] Samandrag av Gassnovas utgreiing av moglege fullskala CO2-handteringsprosjekt i Noreg, *Gassnova*, 2015
[12] CO_2 Storage Atlas Norwegian North Sea, *NPD*, 2012
[13] Our Future Is Carbon Negative A Ccs Roadmap For Romania, *Bellona*, 2012
[14] Enhanced Oil Recovery through CO2 Injection in Hungary, *Geo Energy*, 2004
[15] Ivanić CO2 EOR Project in Croatia, *D. Domitrović, Second EAGE CO2 Geological Storage Workshop*, 2010
[16] CO_2 Transport Infrastructure In Germany – Necessity And Boundary Conditions Up To 2050, *DNV.GL*, 2014

- **Poland's** energy supply security has grown to dominate much of Poland's energy strategy discourse. With Poland already deriving approx. 90 % of its electricity from coal, CCS will be required to for policy makers to square climate considerations and the use of indigenous fossil fuels.
    - Post 2030 climate targets for a Poland that has reinvested in coal will be impossible to reach in the absence of CCS transport and storage infrastructure.[17]
    - Offshore CO_2 storage capacity and infrastructure in the Baltic Sea region will be a prerequisite to the decarbonisation of continued coal use. [18]
    - Without CCS as a viable option, Poland will continue to oppose/undermine long-term EU climate ambition. EU-backed CCS infrastructure could help break this deadlock.

MS where CCS is recognised for deep decarbonisation

- **Nordics – Denmark, Sweden and Finland** have many options to decarbonise energy through various renewables deployment and storage technologies. However decarbonisation strategies have shown the requirement of CCS, and there is moreover an awareness of the potential of Bio-CCS (bioenergy and –fuels production with CCS) to attain negative CO2 emissions, effectively removing CO2 from the atmosphere. [19]
- **Iberian Peninsula – Spain and Portugal** have extensive hydropower and/or other renewable potential (notably solar power). However a large cement industry will require the development of national CCS schemes to achieve deep decarbonisation. The Portugese government (and in past the Spanish, until the CIUDEN Compostilla project was put on ice due to insufficient funding[20]) has shown a relatively strong interest, but given the ongoing financial difficulties, positive signals on support from the EU are necessary. [21]
- **France**
    - Shipping of CO_2 from Le Havre industrial area to the North Sea storage hubs would enable the first steps in decarbonisation of a significant proportion of French industry.
    - Rotterdam and Antwerp would be well place for CO_2 emissions from eastern industrial areas, potentially in coordination with a future German infrastructure

[17] Energy Policy of Poland until 2030, *Ministry of Economy*, 2009
[18] BASREC pre-study on transportation and storage solutions for CO2 in the Baltic Sea region, *BASREC*, 2012
[19] NORDICCS CCS Roadmap, *7th Trondheim CCS Conference, TCCS-7*, 2013
[20] http://www.globalccsinstitute.com/project/oxycfb-300-compostilla-project
[21] CCS in Portugal: A bridge to a low carbon economy, *Seixas et al*, 2015