Business from technology

Storage and transportation solutions for the Baltic Sea region

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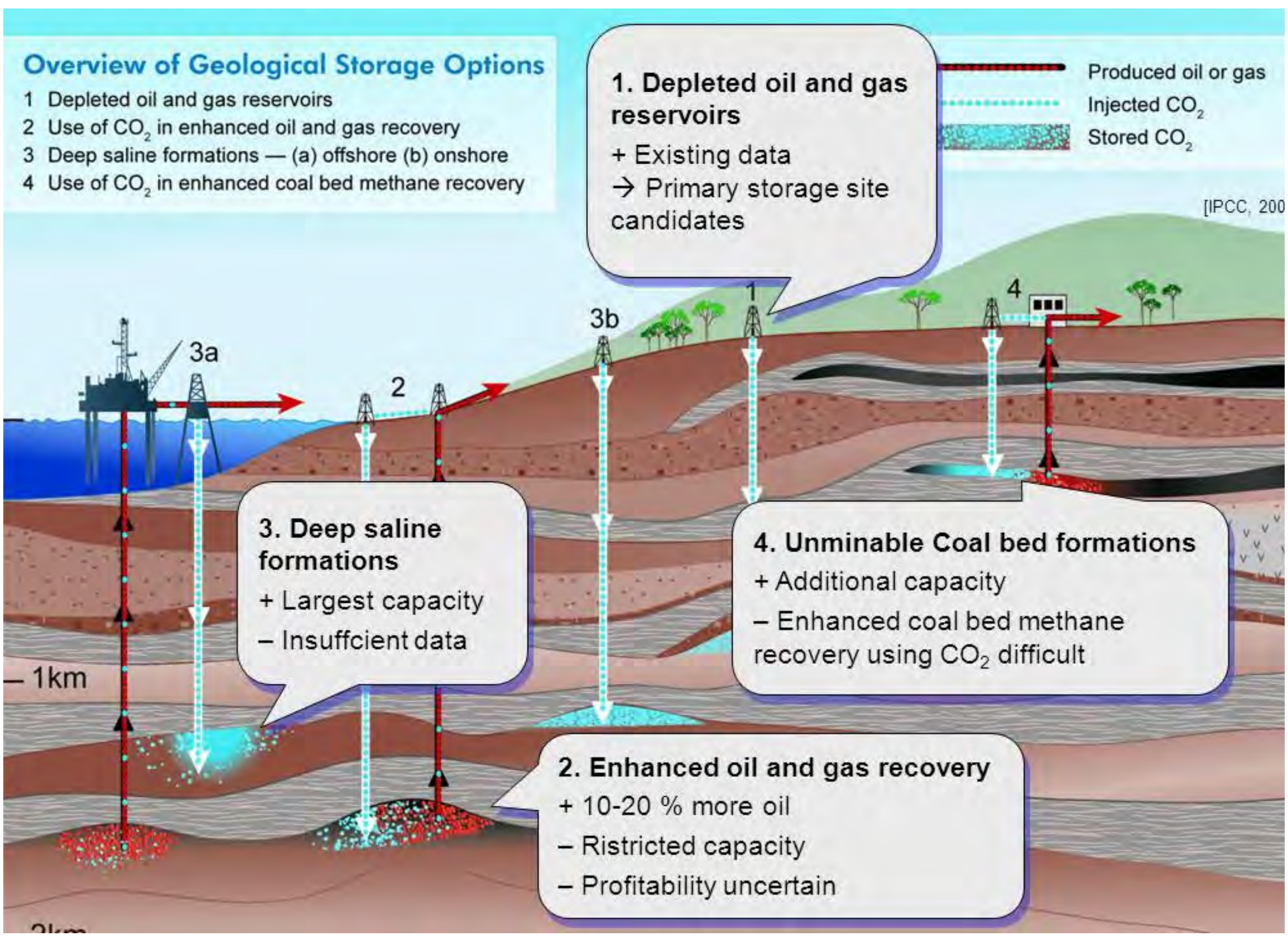
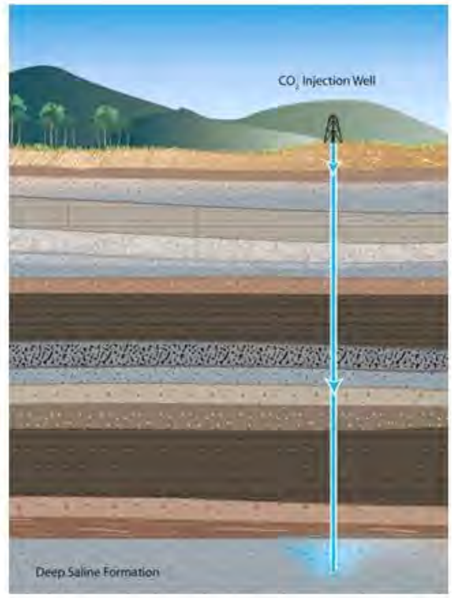
BASREC Conference on Carbon Transportation and Storage
Warsaw, March 6-7 2012



Geological storage of CO_2 doable, but challenging

- Most of the technology existing in the oil and gas industry
- Physical criteria for a storage site
  - Capacity: tens of Mt CO_2
  - Permanence >1000 years
  - Reliability
  - Safety
  - Environmental impact
  - Costs: 1-20 € (ZEP, 2011)
- Legal and social criteria
  - Location (EEA)
  - Acceptability



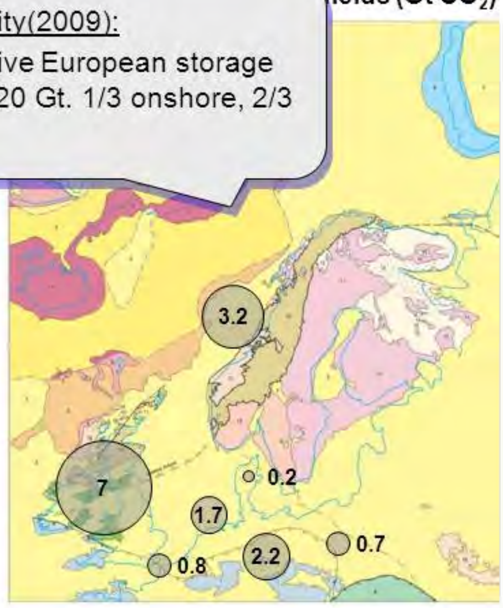
(Image: CO2CRC)

Current knowledge on geological storage capacity

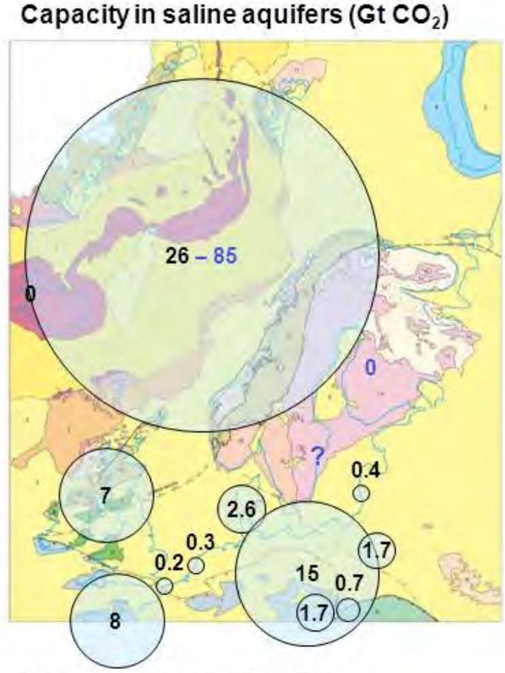
Geocapacity(2009):

Conservative European storage capacity 120 Gt. 1/3 onshore, 2/3 offshore.

fields (Gt CO_2)



Capacity in saline aquifers (Gt CO_2)



(Data: GeoCapacity 2009; VTT 2010 – Russia and not included in study)

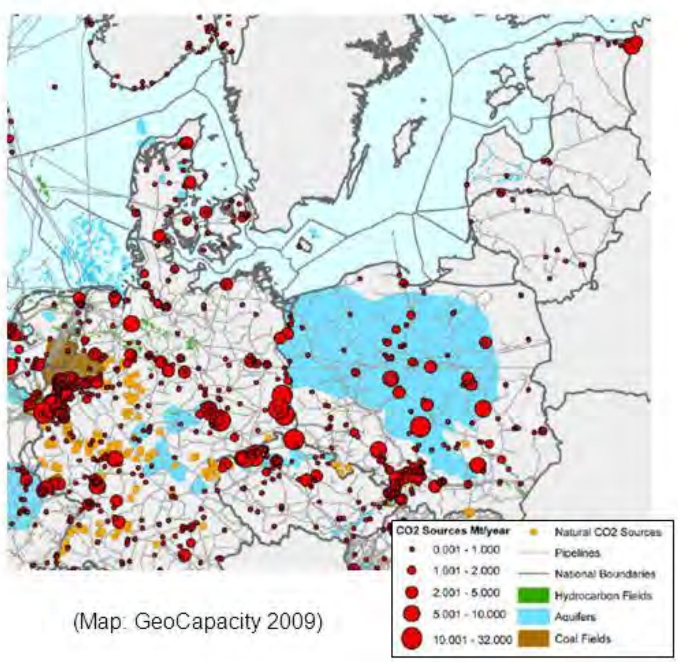
CO_2 capacity for Baltic Sea countries

Country	Annual CO_2 emissions from large point sources (Mt)	CO_2 storage capacity in deep saline aquifers (Mt)	CO_2 storage capacity in hydrocarbon fields (Mt)	CO_2 storage capacity in coal fields (Mt)
Estonia	12	-	-	-
Latvia	2	404	-	-
Lithuania	6	30	7	-
Poland	188	1761	764	415
Germany	465	14900	2180	-
Denmark	28	2553	203	-
Sweden	19	?	?	-
Finland	40	-	-	-
Russia	?	?	?	?
	760	**19648**	**3154**	**415**

(Data: GeoCapacity 2009; VTT 2010 – Russia and not included in study)

CO_2 capacity for Baltic Sea countries

- Mostly onshore capacity
  - What about public acceptance?
  - Onshore vs. offshore → Large impact for CO_2 transportation costs
- Need for data
  - Formations in the Baltic Sea currently being assessed (BASTOR)
  - Russia's capacity largely unknown

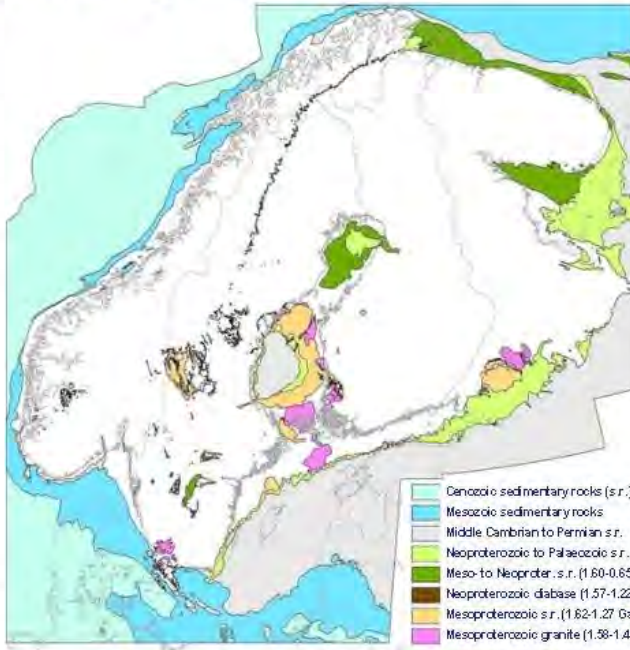


(Map: GeoCapacity 2009)

Case Finland: No formations for long-term underground storage of CO_2

- Finnish bedrock belongs to the Fennoscandian shield area
  - No hydrocarbon reservoirs
  - Sedimentary rocks are very compact
  - Occurence of saline aquifers unlikely
  - Bedrock may be suitable for intermediate storage of CO_2
- High availability of rocks suitable for mineral carbonation with CO_2
  - Carbonation technology not (yet) feasible for storage

→ **Captured CO_2 has to be transported abroad for storage**



GTK

CCS Finland (2008-2011)

Transportation of CO_2

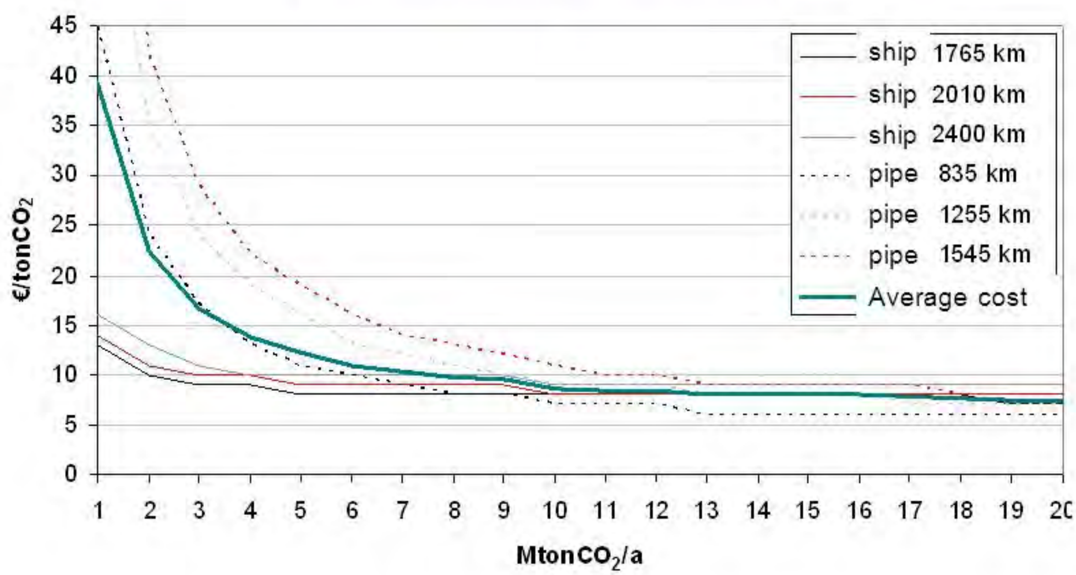
- Pipelines commercially established technology
  - High investment costs
  - Cheaper CO_2-unit costs for larger volumes
  - Costs relatively linear to transportation distance
- Tankers commercially available technology, but less experience from large volumes
  - Cheaper for long distances (>1000 km) and smaller CO_2 volumes

Case Finland: Cost analysis for transportation

- Comprehensive cost analysis of transportation costs performed
  - Ship and/or pipeline transportation
- Transportation routes to current storage activities in the North Sea
- Ship transportation best alternative for Finland
  - Costs for transportation 10-20 €/t CO_2
- Pipeline transportation competitive >10 Mt/a
  - Largest single source in Finland Raahe steel plant (~4 Mt/a)

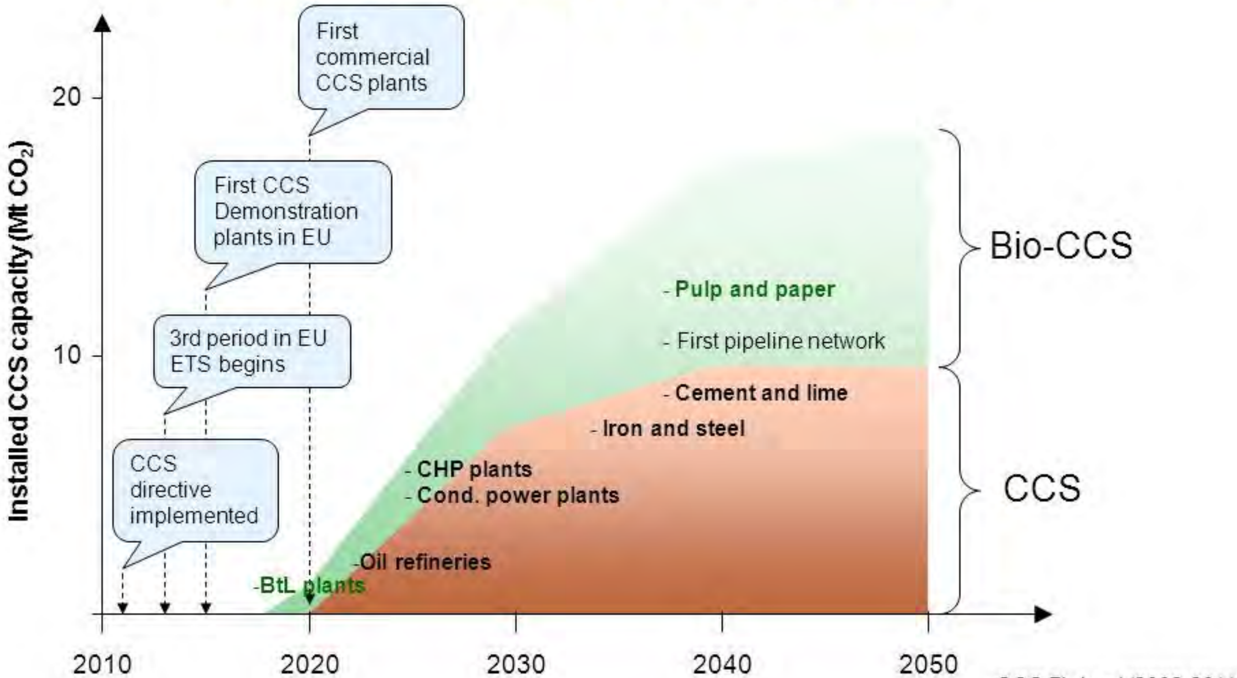
CCS Finland (2008-2011)

Case Finland: Cost analysis for transportation (from coastal locations)



CCS Finland (2008-2011)

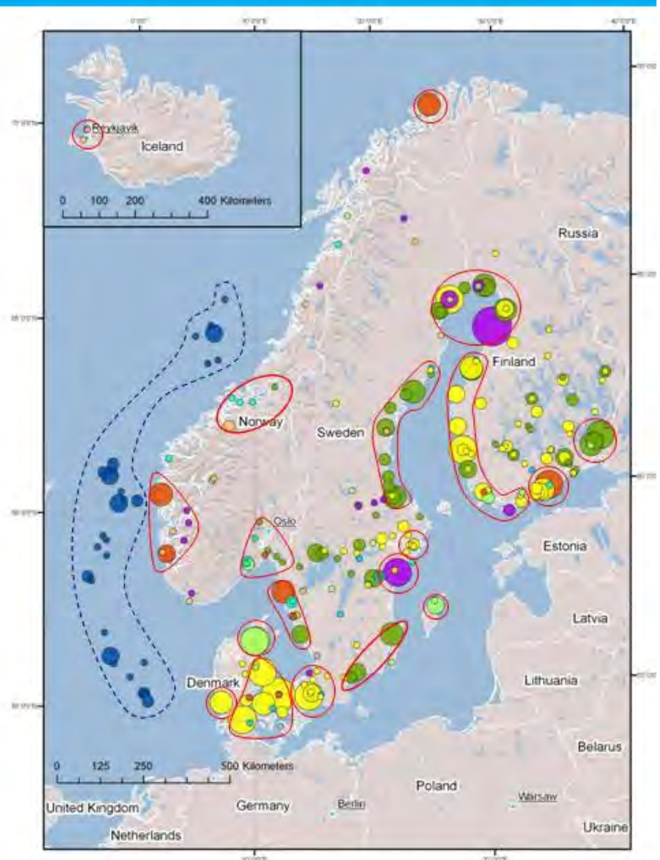
About 10-30% of current Finnish CO_2 emissions could be abated by 2050 using CCS



CCS Finland (2008-2011)

CCS Nordic (prestudy)

- Results from scenario calculations: 30-50 Mt/a by 2050
  - Nordic Countries 220 Mt in 2007
- Most large emission sources on the coast line → facilitates ship transport
- Significant mature capacity for storage in underground storage formations in the North Sea
- Bio-CCS of interest for Finland and Sweden
  - Lack incentive



Status of CO_2 technology development for transportation and storage

- Pipeline transportation already established technology, no technical hurdles for ship transportation either
  - Pipeline transportation requires a large initial investment in the infrastructure
  - Ship transportation better option for remote demonstration plants located on the coast line
- Geological storage demonstrated and mature for use
- Proper care must be taken in selection of sites
- Development ongoing in monitoring and verification techniques

[Statoilhydro]

CCS Directive & ETS – some hurdles to overcome

- Ship transportation not included by default in ETS
  - Can be ”opted-in”
- Storage and transportation only allowed on the European Economic Area (EEA)
  - EEA = EU + Iceland, Norway and Liechtenstein

Alternative approaches to CO_2 storage

- Fixation of CO_2 as solid carbonate minerals
  - Theoretically a high storage potential, but minerals not reactive enough for an economically feasible process
  - Fixation using solid alkaline industrial residues being piloted
    - Global potential ~ 100 Mt C/a, but local potential <<100 kt C/a
- CO_2 as a chemical product or feedstock
  - Global potential ~ 100 Mt C/a
  - Permanence ranging from days to years

Upcoming CCS report by European Academies Science Advisory Council

Alternative approaches to CO_2 storage

- CO_2 from flue gases for algae cultivation
  - High energy requirements for mixing, harvesting and drying
  - Large land usage – a 600 MW power plant would require a farm of 100 km^2
- Storage of biochar from pyrolysis of biomass
  - Large potential: 1.8 Gt C/a
  - Bioenergy has greater mitigation impact in regions that have both high soil fertility and good prospects for offsetting coal emissions (Woolf, 2010)

Upcoming CCS report by European Academies Science Advisory Council

Conclusions & recommendations

- CCS is needed to help achieve the radical CO_2 reductions needed in the next 40 years
- A storage atlas of the Baltic Sea area (with offshore and onshore capacity specified) is needed
- Ship transportation needs to be included into EU regulations and ETS
- Incentives for bio-CCS needed
- ”Alternative” methods not really an alternative to CCS
    - Lacks the capacity of CCS and/or not ready for deployment for decades ahead

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