Lloyd's Register Educational Trust

UNIVERSITY OF Southampton

Other Aspects of CCS

by

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The LRET Research Collegium
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“Other Aspects of CCS”

Magnus Melin
Lloyd’s Register

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What is relevant in addition to technology?

- **Challenges to overcome for large-scale deployment of CCS:**
  - Regulatory uncertainty
  - Cost
  - Significant financial risk from large investments and long return period
  - Public perception (safety)

- Technology not among key challenges but still important

- Multitude of aspects must be considered

FINANCIALS

Capture

- Two main costs: cost of equipment + reduced efficiency

Directly into air:

0-15 €/tonne CO_2

Current ETS price for CO_2 is €15/tonne CO_2

CO_2 capture:

≈ 25-90 €/tonne CO_2

The annual cost for a 800 MWe plant emitting 3.5 Mt CO_2/year will be > €100 million

Transportation by ship

- Cost is estimated to €10-25/tCO_2 depending on many factors
- Ship based transport give rise to additional costs at the injection site, e.g. pressurisation to 100-300 bar. These are not believed to be included in the estimates below.
- Overall, cost for transport is relatively small compared to cost for capture

Source of information	Comment	Cost (€/tCO_2)
MHI report “Ship transport of CO_2” from 2004	- Distance <1,000 km - Ship size 30,000-50,000 tonnes - Liquefaction from atmospheric pressure	13-15
Study by Panaware from 2010	- Distances 180 km, 750 km - Ship size 20,000-30,000 m^3 - “all in” scenario, including liquefaction	13-14
IPCC special report on CCS from 2005	- US$13/tCO2 for 1,000 km distance - 6 Mt CO^2 per year - Cost include storage facilities, harbour fees, fuel costs, loading, unloading activities and liquefaction	10

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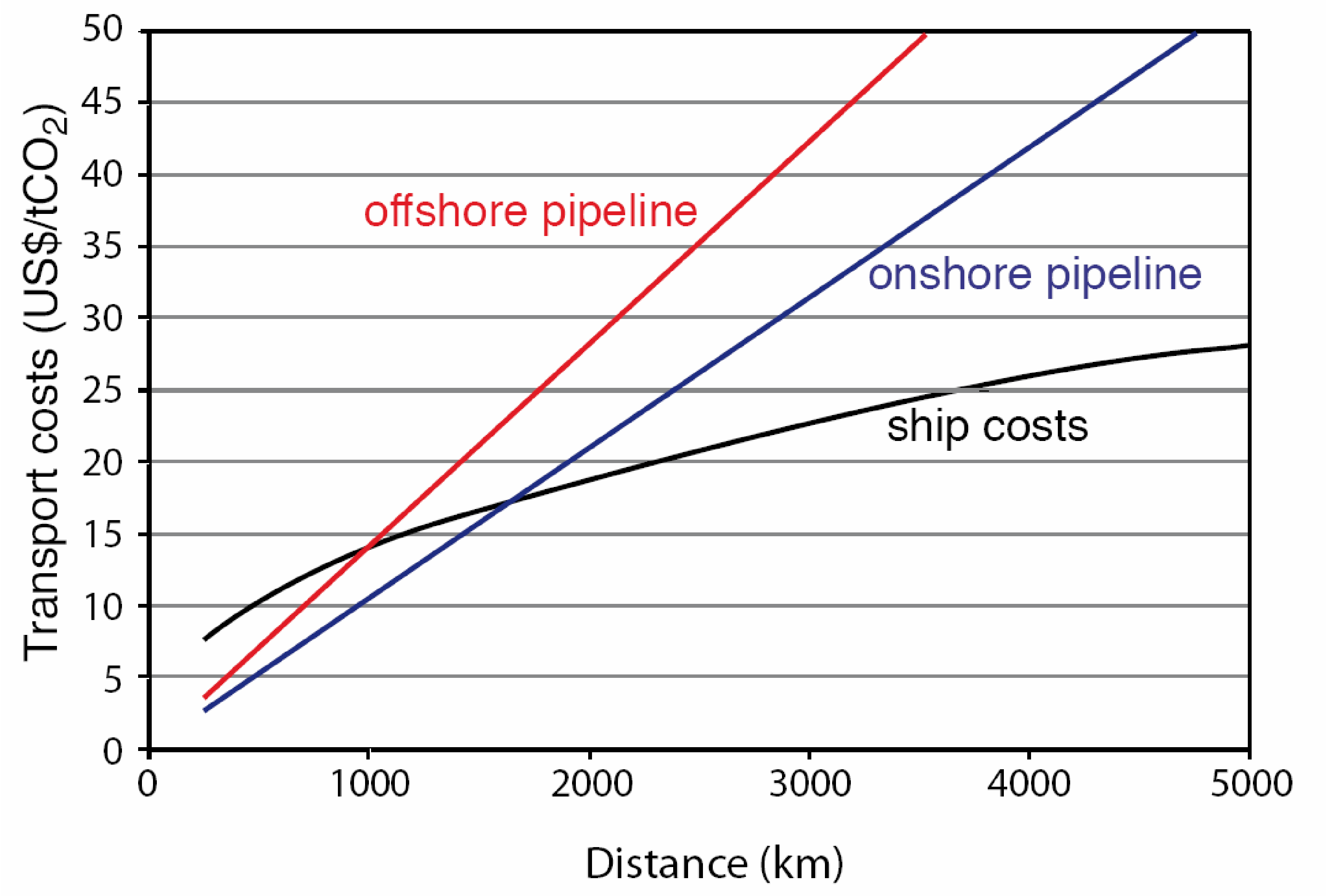
LIFE MATTERS

Transporting by ship versus pipeline



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LIFE MATTERS

Storage

- Large capex for modification of existing facilities and/or building new injection facilities

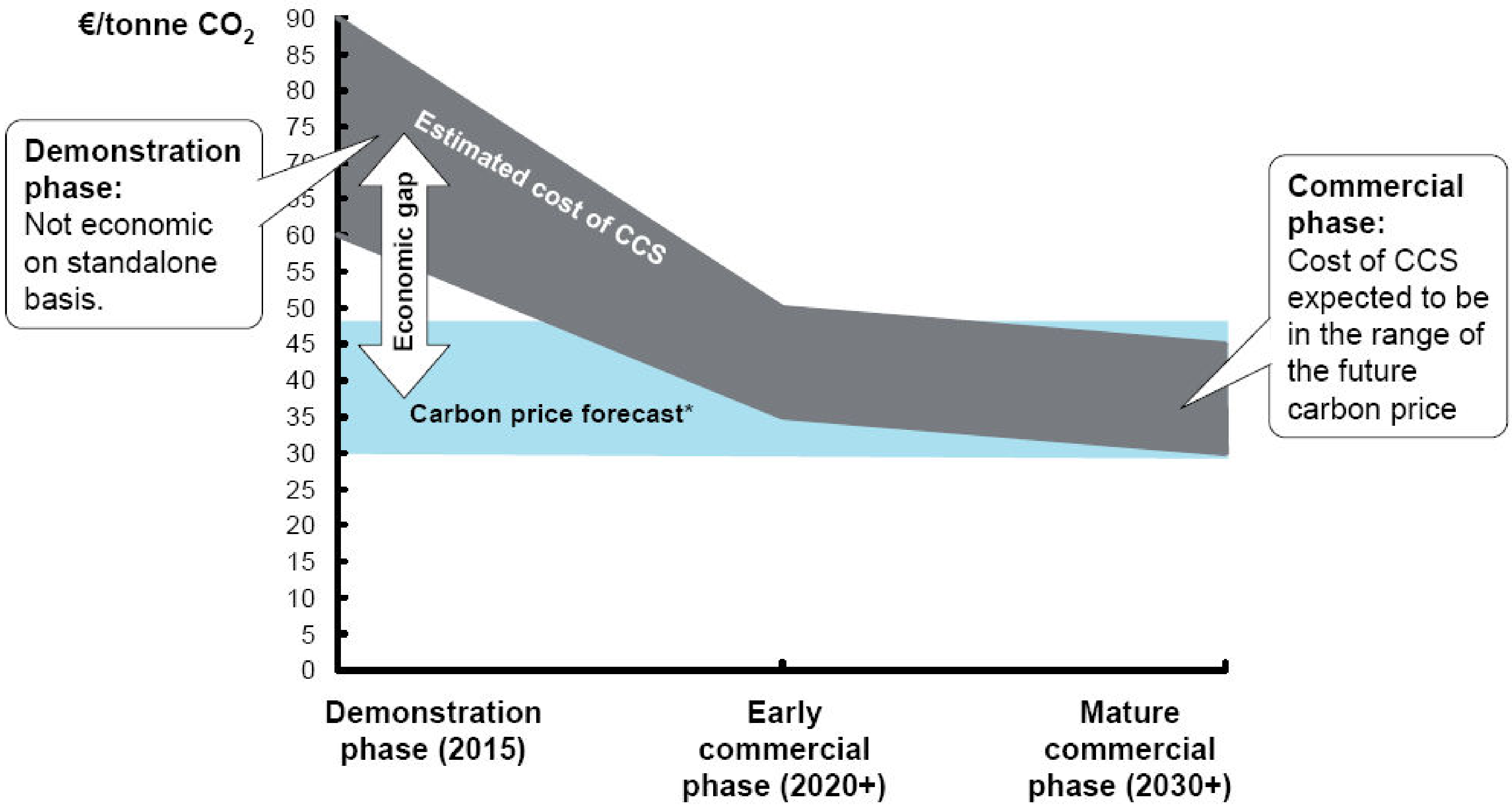
Source of information	Comment	Cost (€/tCO_2)
ElementEnergy, "Developing a CCS network in Tees Valley Region" 2010	Offshore storage in North Sea. Cost estimated to £12-14 per tonne CO_2 depending on scenario.	15
Pöyry, "Analysis of CCS cost-supply curves for UK. 2007.	Offshore storage in depleted oil & gas field. Storage in aquifers estimated to £1 per tonne CO_2.	1-20
McKinsey "CCS: Assessing the economics". 2008	Offshore storage. 80-90% of the cost is stated to be associated with capex.	11-12

LIFE MATTERS

Enhanced Oil Recovery (EOR)

- Economy for offshore CO_2 EOR is challenging to estimate due to combination of complex technology, limited experience and dependence of incremental oil obtained (volume as well as future oil price uncertain)
- Example of additional costs include adaptation of existing platform, well upgrades, systems for monitoring reporting and verification of injected CO_2
- The incremental oil production is very difficult to estimate. Numbers in the order of 10% OOIP (Original Oil In Place) are generally found in publicly available information.
- Several studies (DTI, Senergy and others) indicate that **CO_2 needs to be supplied at neutral cost (no cost to obtain, no storage credit)** to the reservoir to make CO_2 EOR financially viable. If the reservoir is used as a long-term storage site, there will be a storage credit – e.g. NER300 and/or CDM – that could reduce the cost for CO_2 EOR

Overall cost



Source: McKinsey "CCS – Assessing the economics" (2008)

HEALTH & SAFETY

LIFE MATTERS

Is CO_2 dangerous?

- CO_2 is present in the air we breath (0.037%) and is not harmful at low concentration
- At high enough concentration, CO_2 causes asphyxiation (suffocation)
- CO_2 has been recognised as a workplace hazard for over a century.
- It is significantly heavier than air and many fatalities from asphyxiation have resulted from entry into pits, tanks, sumps or cellars where CO_2 has accumulated and displaced oxygen.
- Toxicity levels (from Wikipedia):

  - 1% can cause drowsiness with prolonged exposure.

  - 2% is mildly narcotic, causing increased pulse etc

  - 5% causes dizziness, confusion and difficulty in breathing

  - > 8% causes headache, sweating, dim vision, tremor and loss of consciousness after exposure for between five and ten minutes

Source: Health and Safety Executive, United Kingdom (www.hse.gov.uk) and Wikipedia

Example of CO_2 incidents

Industry

- Leak from fire suppressant system: 107 intoxicated, 19 hospitalised, no fatalities – Monchengladbach, Germany 2008
- CO_2 tank (30 Tonnes) BLEVE: 3 fatalities, 8 further injuries – Worms, Germany 1988
- Oil well release of 81% CO_2 (with H_2S): 2,500 people evacuated - Nagylengyel, Hungary 1998

Geological

- Lake Nyos, Cameroon, 1986 – 1,700 fatalities, 1,600 kT release

  fatal within 25 km radius
- Dieng volcano, Indonesia – 1979, 142 killed, 200 kT release

Risks along the CCS chain

- **Capture**

  - From a risk point of view with respect to human health and environment analysed as other type of process plants

  - Managed by well-established routines and regulations for chemical industry

- **Transportation**

  - Similar to transportation of other gases, for example LPG

  - Certain aspects needs to be addressed in more detail

- **Storage**

  - Biggest potential risk due to large volume of CO_2 and uncertainty associated with storage depth etc

  - Detailed and extensive risk studies needs to be performed together with long-term Monitoring Reporting and Verification (MRV) of the storage site

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LIFE MATTERS

Risk assessments of CO_2 storage sites

Quantative risk assessment methodology

Example on required input:

- Injection/production and storage concept
- Reservoir and cap rock studies including among others seismic studies, geological model, fault study, experimental studies of fracturing pressure, chemical reactions etc.
- Integrity studies of active and abandoned wells

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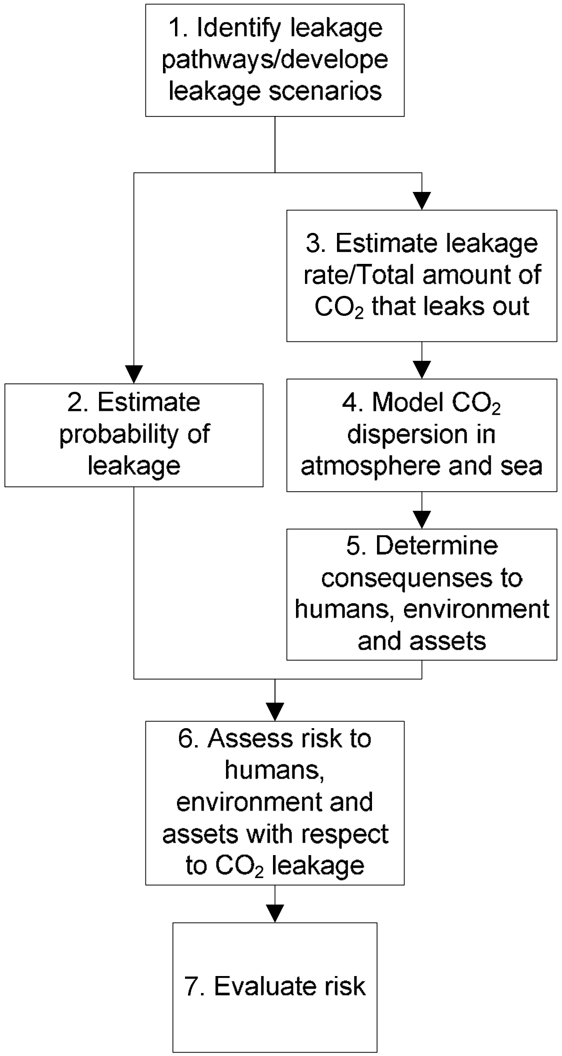


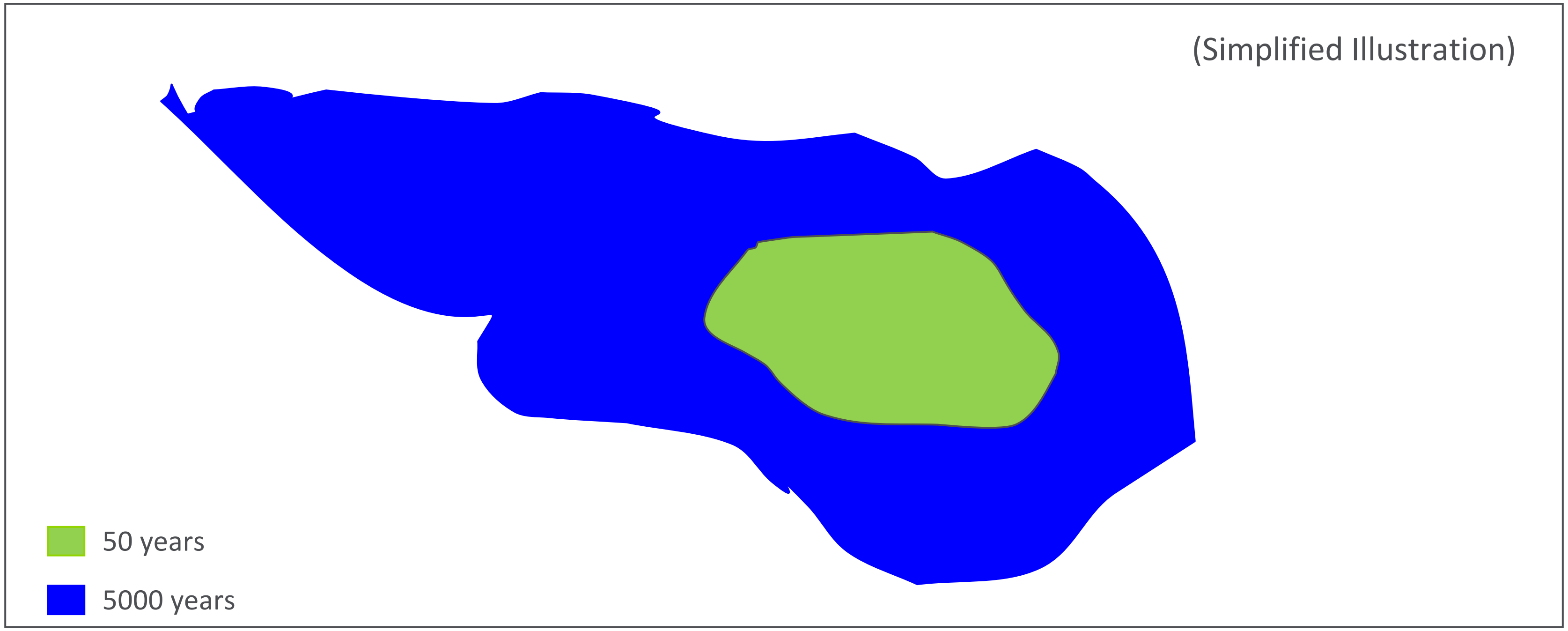
Risk assessments of CO_2 storage sites

Identification of possible leak ways from reservoir (HAZID)

- Faults
- Cracks
- Continuous sand formations/channels
- Other heterogeneities in cap rock (water/gas compaction structures)
- Capillary intrusion through cap rock
- Via injection wells
- Via old, abandoned wells
- Opening of cap rock due to earthquake
- Opening of cap rock due to chemical exposure/degradation

Risk assessments of CO_2 storage sites

Simulated plume extension after 50 years (end of injection period) and after 5,000 years



Basis should be 2D or 3D seismic surveys of the storage area

Risk assessments of CO_2 storage sites

Some challenges:

- Develop leakage scenarios through overburden and wells
- Estimate probability of leakage through geological formations
- Estimate leakage rate through geological formations (for various oil/CO_2/water mixtures)
- Assess effects on the local environment
- Assess possible subsidence effects on cap rock and wells
- …

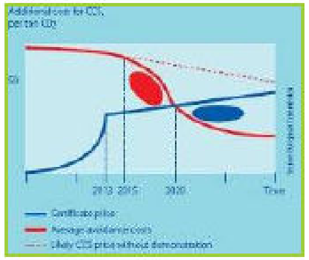
POLITICAL SUPPORT & REGULATIONS

European Union – the short story ...

- Ambitious environmental targets for reduction of greenhouse gases
- Strong support for CCS as part of mix of mitigation measures
- Target: CCS commercially viable by 2020
- Challenging guidelines and regulations (still under development)
- Very significant public funding being released
  - EEPR €1 billion
  - NER300 €5-6 billion
- Early days with much work still to be done

European Union – the long story…

Addressing the challenges



- **Legislative hurdles**
  - EU - CCS Directive (2009/31/EC)
  - International: London Protocol (1/26) and OSPAR (4/7)
- **Non-legislative hurdles**
  - Economic viability
  - Technology and ongoing R&D
  - Public perception
  - Infrastructure needs
  - International engagement

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Source: Bolesta C: ” CCS Strategy of the European Commission - latest update” 2011

European Union – the long story…

Providing Regulatory Framework: CCS Directive

- **Enabling Framework**
  - Member States determine whether and where CCS will happen
  - To be transposed by **25 June 2011**
- **Key Elements**
  - Exploration and storage permit
  - CO2 stream composition
  - Monitoring and verification
  - Closure and post-closure obligations
  - Transfer of responsibility
  - Financial security and financial transfer
- **Implementation of the Directive**
  - Information Exchange Group
  - Establishment of Scientific Panel
  - Development of Guidance Documents

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Source: Bolesta C: ” CCS Strategy of the European Commission - latest update” 2011

European Union – the long story…

Guidance Documents

Climate Action

- GD1 - CO2 storage life-cycle approach to risk management
- GD2 - Specific approach to key stages of the CO2 storage life-cycle (Selection and monitoring of sites; composition of CO2 stream; corrective measures)
- GD3 - Transfer of responsibility
- **GD4 - Financial security (Art. 19) and financial transfer (Art. 20)**

- **Adoption**
  - » Stakeholders consultation held
  - » IEG consulted
  - » Publication – aim – Dec 2010

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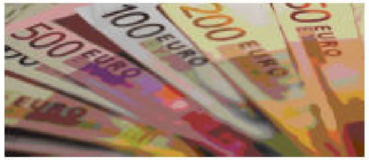
Source: Bolesta C: ” CCS Strategy of the European Commission - latest update” 2011

European Union – the long story...

Economic stimulus - EEPR

European Energy Programme for Recovery



- €1bn for large-scale CCS demos
  - Max. €180m per project for incremental CCS investment costs

Source: Powerfuel

- 6 projects have signed grant agreements in 2009/10
  - Jänschwalde, Hatfield, Porto Tolle, Rotterdam, Bełchatów, Compostilla

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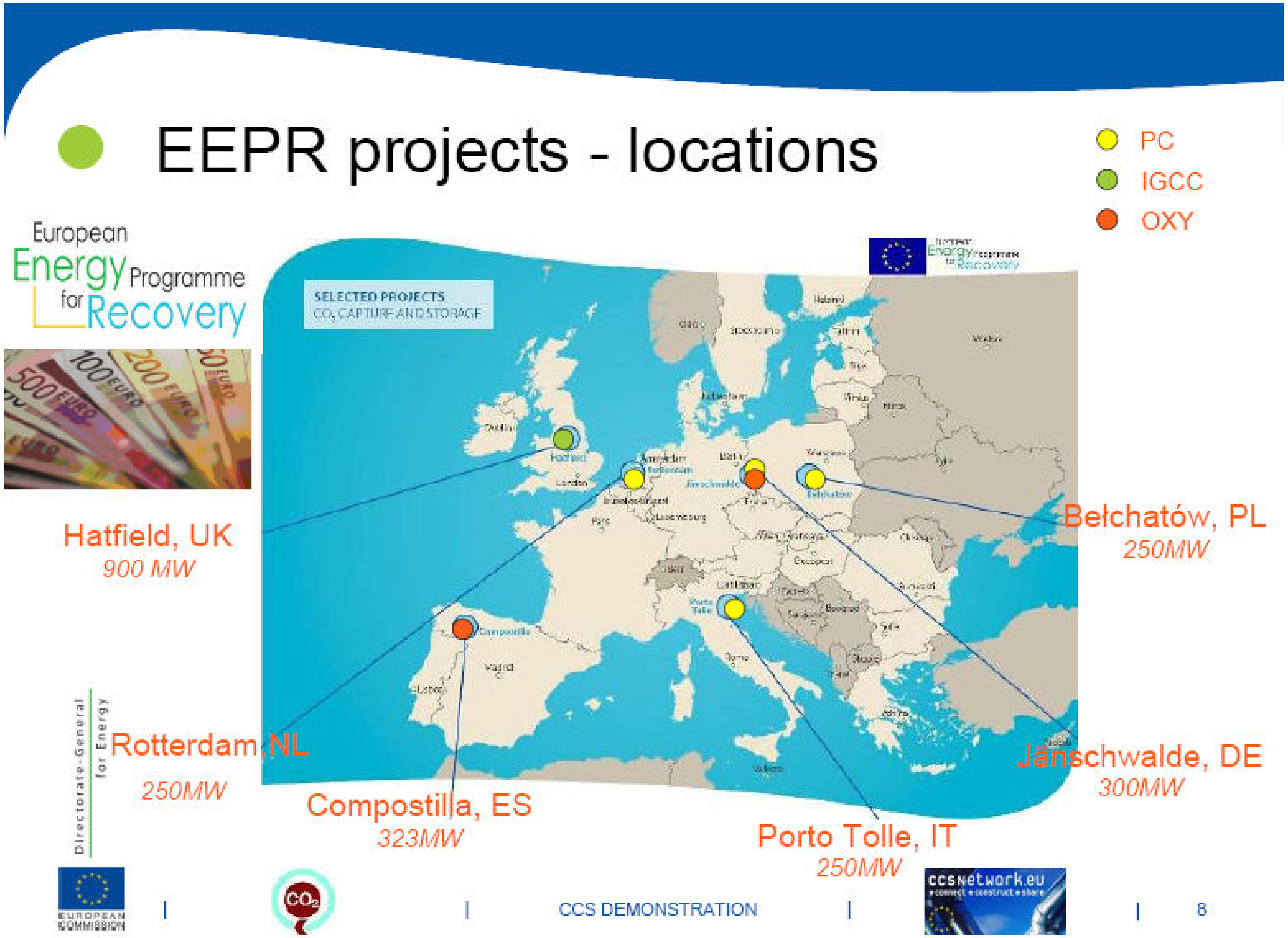
Source: Bolesta C: ” CCS Strategy of the European Commission - latest update” 2011

European Union – the long story…



Source: Bolesta C: ” CCS Strategy of the European Commission - latest update” 2011

European Union – the long story…

New Entrants Reserve (NER 300)

Climate Action

- Revised ETS Directive (2009/29/EC)
  - 300 million CO_2 allowances (EUAs) - €4.3bn
  - Available until 31 December 2015
  - CCS & innovative renewables
- Decision on modalities
  - A range of CCS technologies
  - 8 large-scale projects
  - 1-3 with same capture t; min 3 for storage option
  - Main award criterion requested funds/CO_2 stored

- Timetable - 1st call (200m EUAs)
  - Call published – 9 November 2010
  - Info day – held on 19 November
  - 3 months to submit to Member State (9 Feb)
  - 3 months for MS to submit to EIB
  - 9 months for EIB to assess

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Source: Bolesta C: ” CCS Strategy of the European Commission - latest update” 2011

European Union – the long story…

- Why CO_2 should be part of future European Energy Infrastructure?

- Cross-border CO_2 transport needed
- Co-operation to avoid different standards
- Regional clusters will kick-start the network
- Verification of storage potential essential for optimising network plan but also for CCS dev in general

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- Analysing whether CO_2 infrastructure should be addressed at EU level: ARUP and JRC studies

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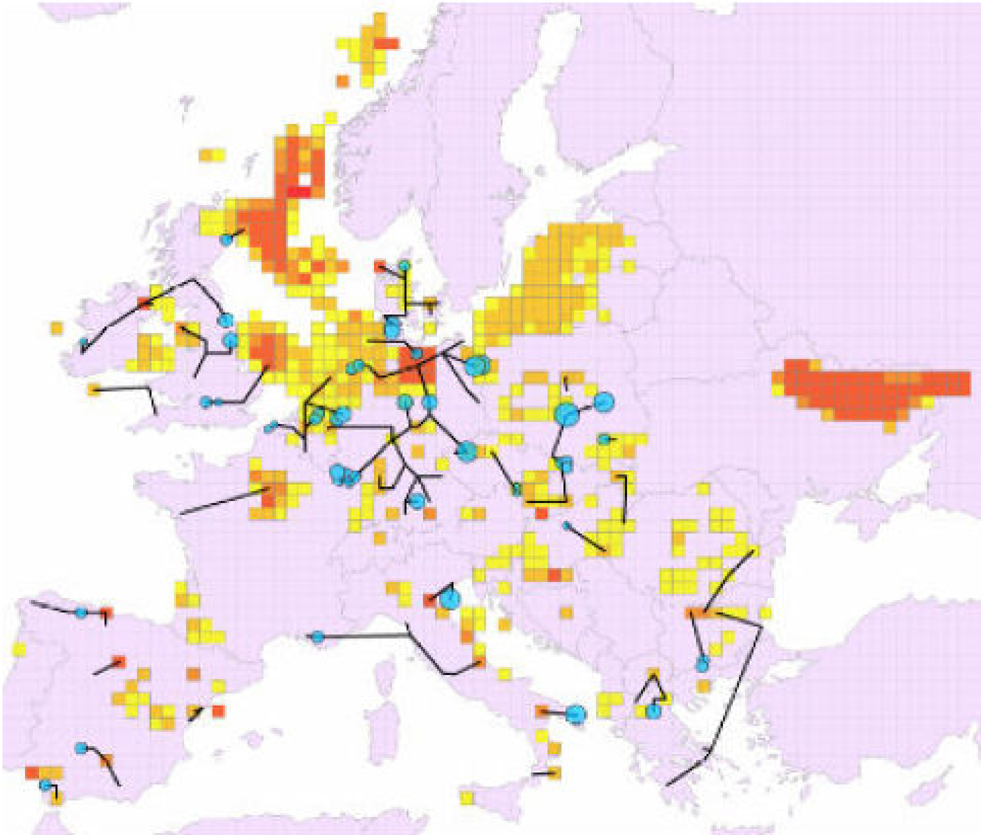
Source: Bolesta C: " CCS Strategy of the European Commission - latest update" 2011

European Union – the long story…

Potential pipeline network based on available CO_2 sources and sinks



Source: Bolesta C: ” CCS Strategy of the European Commission - latest update” 2011

PUBLIC SUPPORT / CONCERNS

Public support / concerns

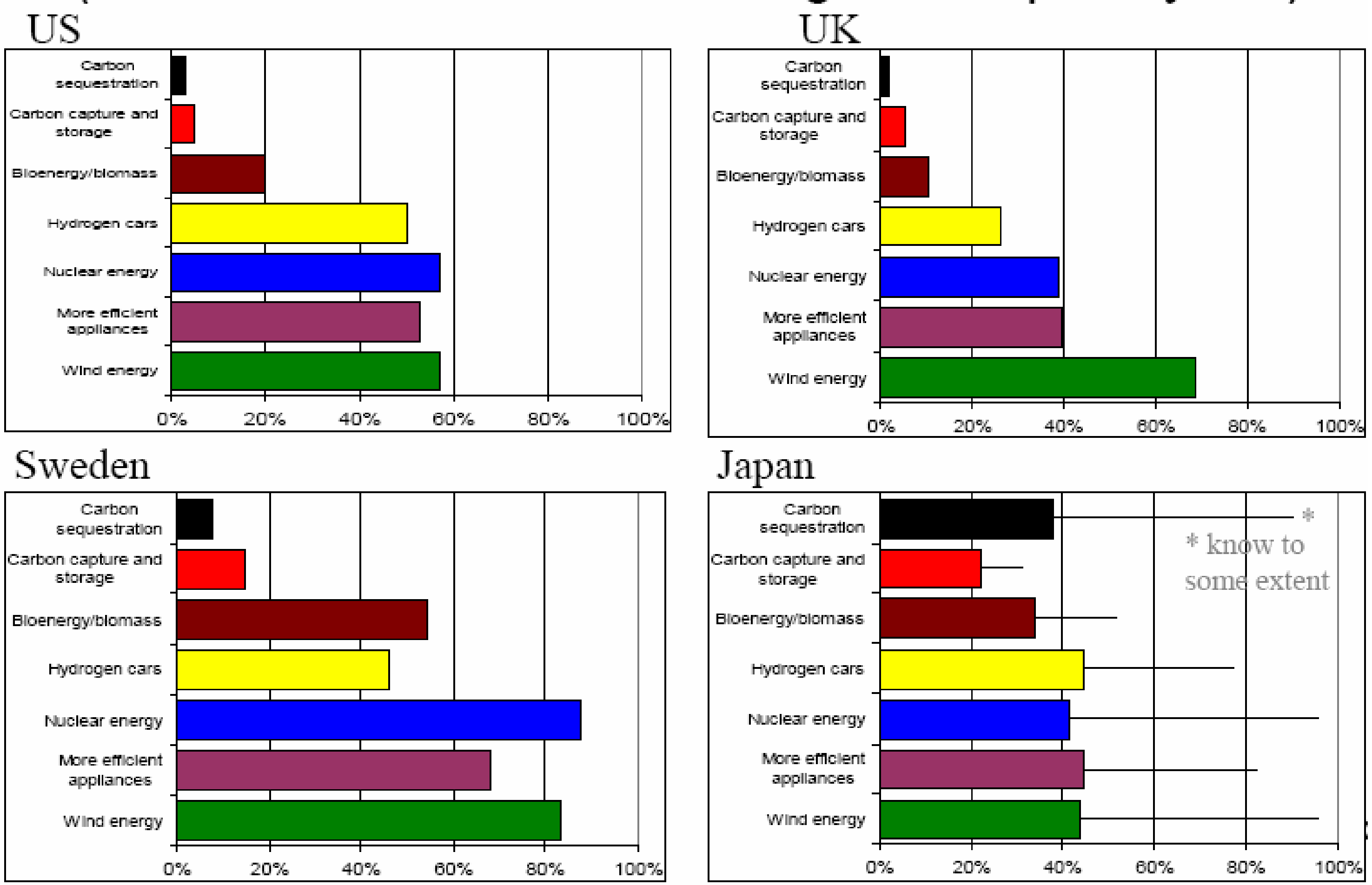
- Experience so far shows that while CCS projects seem to be accepted in some regions/countries, strong opposition is seen in other regions/countries
- Barendrecht project (onshore storage in Netherlands) stopped due to public concerns. Dutch government later banned onshore CO2 storage.
- Considerable public concerns in Germany about CCS projects (Beeskow)
- In contrast, community seem to support Longannet project in Scotland

Public support / concerns

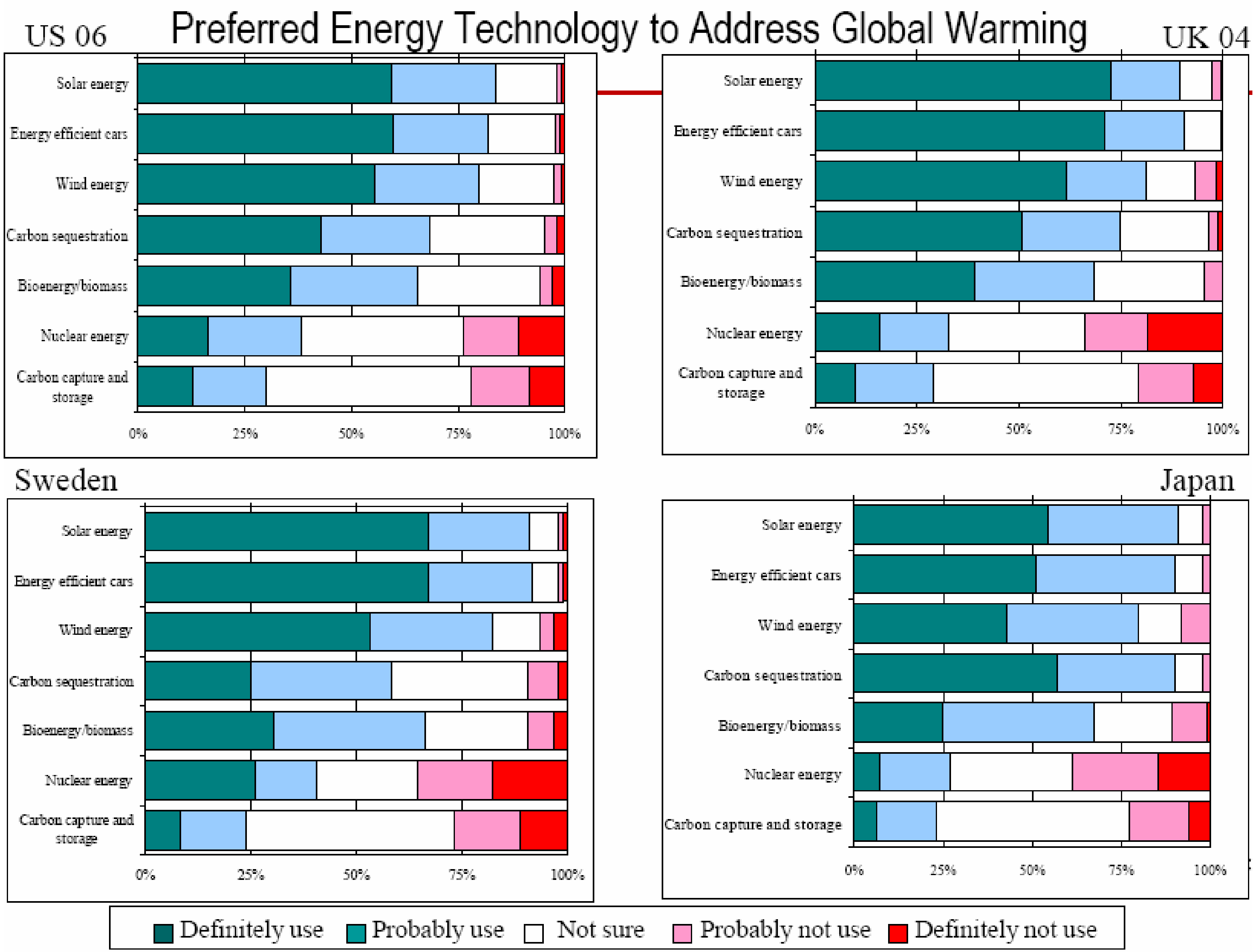
Source: Reiner D. "Understanding Why the Public Chooses to Support or Oppose CCS Projects". 2011.

Public Awareness

(heard/read of the following in the past year)



Source: Reiner D. "Understanding Why the Public Chooses to Support or Oppose CCS Projects". 2011.



Source: Reiner D. "Understanding Why the Public Chooses to Support or Oppose CCS Projects". 2011.

Findings

- *National-level differences are usually more important than within-nation differences*
- *Initial attitudes towards CCS correlates with support for specific CCS proposals.*
- *Need to examine both risks and benefits.*
- *Concerns over personal risks (and benefits) are slightly more important than social risks (or benefits) in regions*
- *Onshore storage (and onshore transport) proposals raise most serious concerns.*

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Source: Reiner D. "Understanding Why the Public Chooses to Support or Oppose CCS Projects". 2011.

PUBLIC ENGAGEMENT

Key Principles in CCS Community Engagement and Roles for Each Party in the Process

	Understand Local Community Context	Exchange Information about the Project	Identify Appropriate Level of Engagement	Discuss Risks and Benefits of Project	Continue Engagement through Time
REGULATORS	Learn community concerns. Determine, meet, and possibly improve public participation requirements.	Educate, respond to, and provide information to the public.	Establish a multistakeholder engagement process.	Require communication and contingency measures and regular updates during life cycle. Evaluate environmental and other impacts.	Require public participation at key stages and increase engagement in the process.
LOCAL DECISIONMAKERS	Understand community interests, identify leaders, and establish a dialogue early.	Contact developers early. Ask questions. Identify, seek, and publicize pertinent information about the project.	Determine engagement level and establish a transparent process.	Ask questions. Identify and communicate concerns and clarify follow-up process. Insist on full disclosure.	Establish institutional memory, possibly a taskforce. Consider participating in monitoring and reporting. Regularly update the community.
PROJECT DEVELOPERS	Assess community dynamics and your historical presence. Weigh participatory engagement.	Engage early and develop a relationship with the community. Answer questions. Seek input, and provide information openly and transparently.	Foster two-way engagement; consult and negotiate with communities. Address concerns. Convey feasible level of engagement.	Answer questions. Discuss with community risks, benefits, uncertainties, and mitigation and contingency plans. Consider benefit sharing.	Engage community at each step of project schedule. Consider informal, long-term relationship to ease stewardship transition.

Source: World Resources Institute. Report "Guidelines for Community Engagement in Carbon Dioxide Capture, Transport, and Storage Projects". 2010

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