Europe-wide CO_2 Infrastructures Feasibility Study

Dominic Ainger, Arup

Steve Argent, Arup

Prof. Stuart Haszeldine, SCCS/University of Edinburgh

Scope of the Study

- Commissioned by EC Directorate General Energy (DG-ENER)
- 8 months duration, February-October 2010
- Building on previous studies of storage capacity, e.g. Castor, GESTCO & GeoCapacity
- Databases of CO_2 sources and potential storage sites to be expanded to 36 countries; EU27 + Norway + Switzerland + Western Balkans
- Development of capture scenarios and blueprints for core transport infrastructure at 2030 and 2050

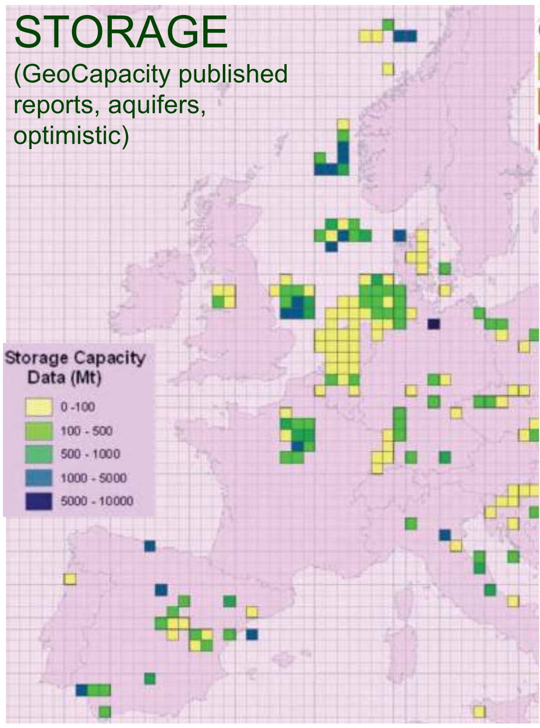
Project Drivers

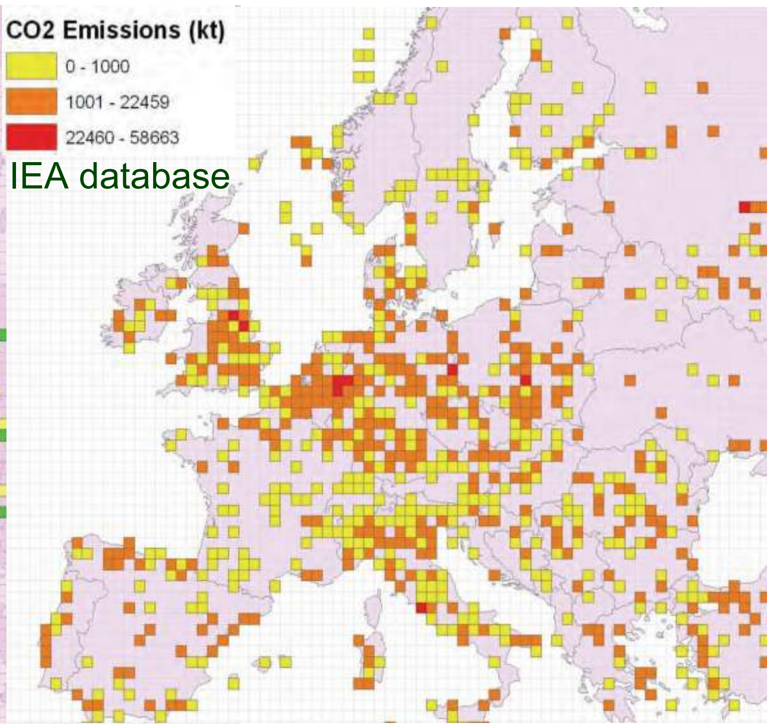
- Large infrastructure projects take a long time to plan and construct
- A vision for CO2 infrastructure aids strategic planning, with potential EC role if significant cross-border transport and pan-European network
- Possible outcome: inclusion of CO_2 infrastructure in the next revision of the Trans-European Networks Guidelines for Energy, due Summer 2011

WP 1 – Storage Evaluation

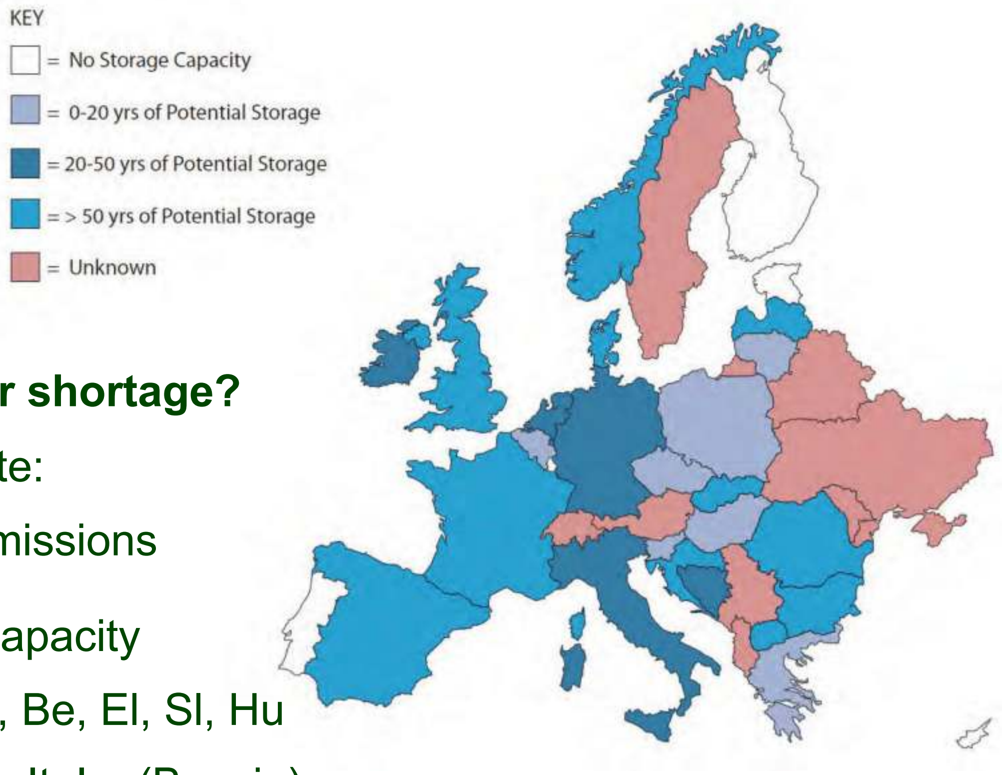
STORAGE Analyse results from previous projects, notably GeoCapacity

EMISSIONS plot large point sources - IEA database





WP 1 – Storage Evaluation



Abundance or shortage?

Simple estimate:

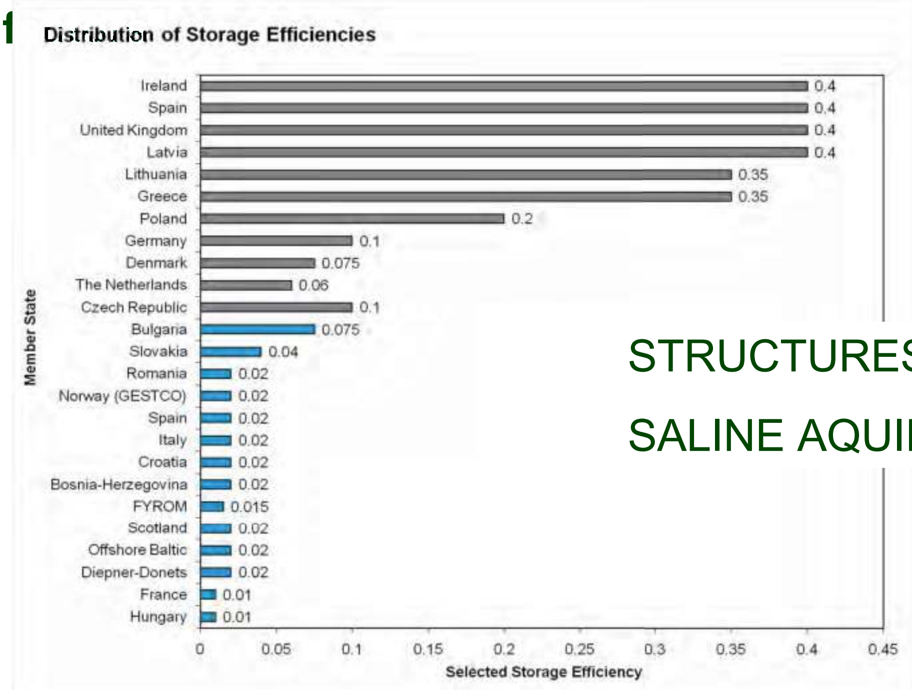
present day emissions
and
conservative capacity

< 20yr? Pl, Cz, Be, El, Sl, Hu

< 50yr? De, Nl, It, Ie, (Bosnia)

WP 1 – Storage Evaluation

DG Energy- review/establish coherent methodologies for assessing storage capacities ==> Efficiency



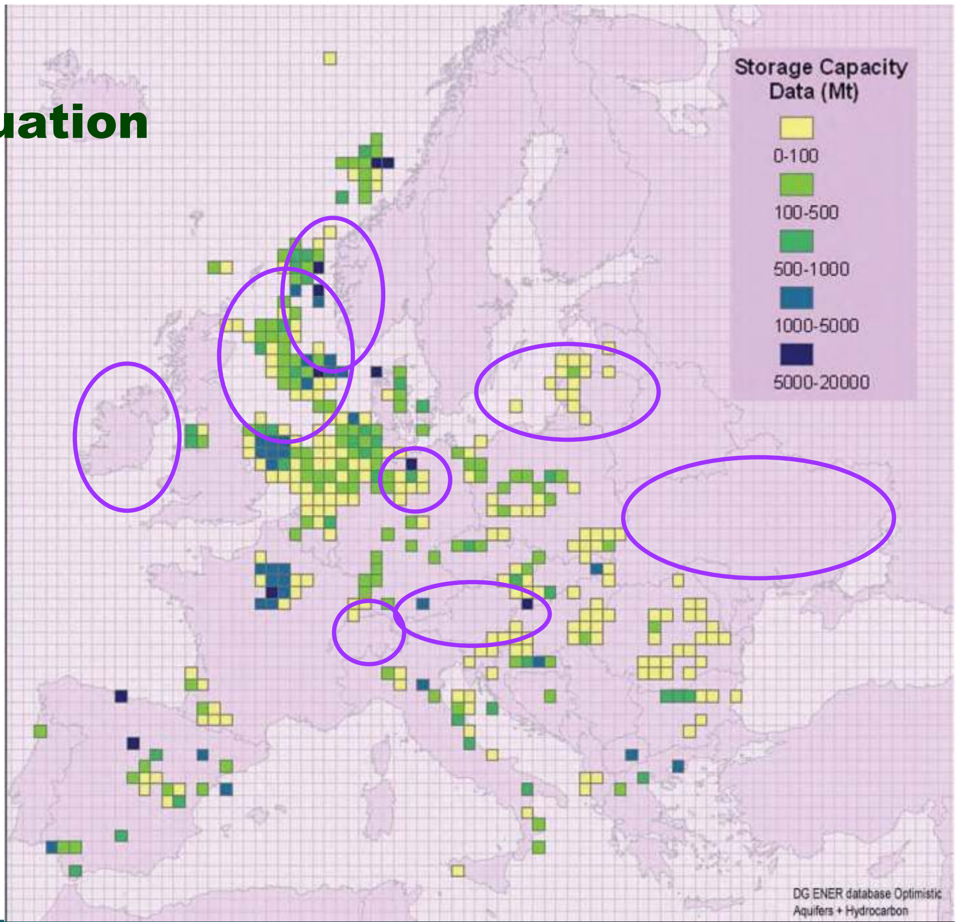
STRUCTURES = 40%

SALINE AQUIFERS = 2%

WP 1 – Storage Evaluation

DG ENER data Optimistic
Aquifer +hydrocarbon

- EU 50 x 50km grid
- States not assessed
- States updated
- Clustered display of central points
- Variable methods
- Data un-auditable



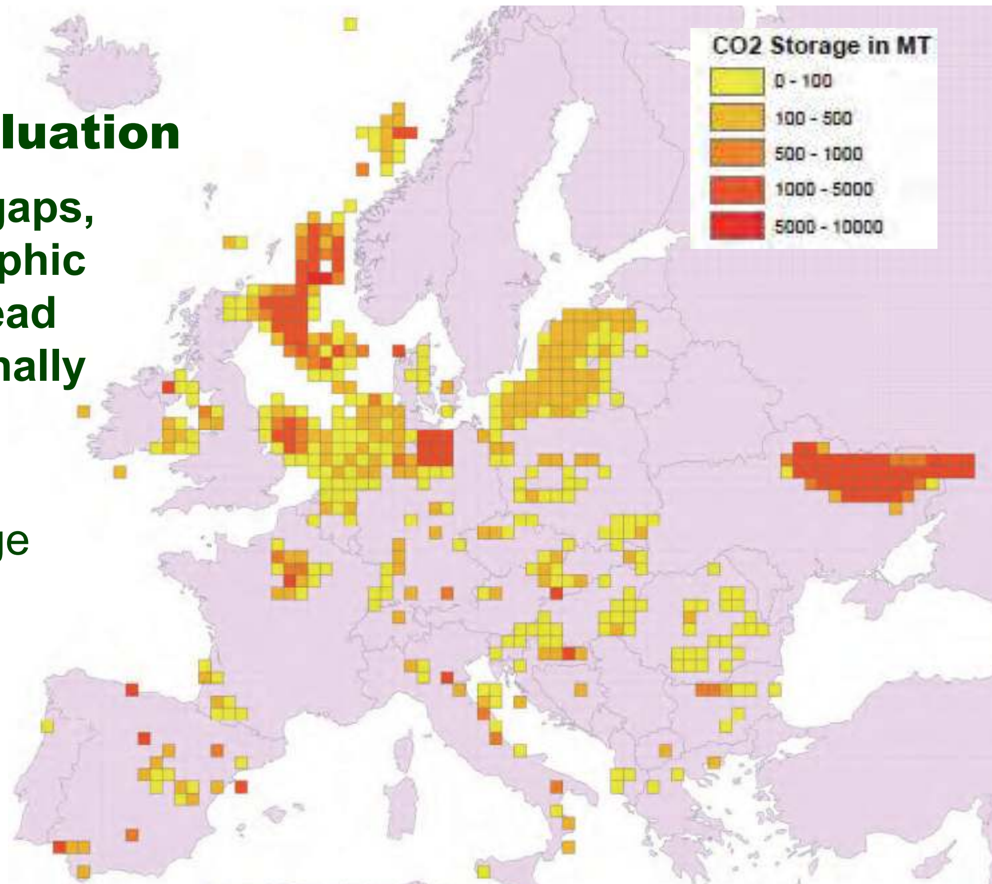
WP 1 – Storage Evaluation

Update, fill in gaps, extend geographic coverage, spread aquifers regionally

NEW:

North Sea - large
Ireland
Austria
Switzerland

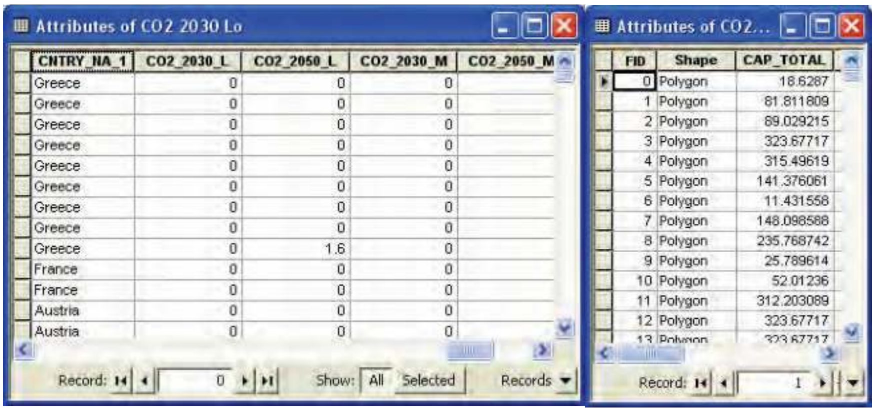
Baltic
Ukraine



Onshore well spread. North Sea very large - well known. Baltic, Ukraine large - not known

WP 2 – Development of a coherent and complete European database

- CO2 sources (2030 and 2050) and storage sites



Attributes of CO2 2030 Lo

CNTRY_NA_1	CO2_2030_L	CO2_2050_L	CO2_2030_M	CO2_2050_M
Greece	0	0	0	
Greece	0	0	0	
Greece	0	0	0	
Greece	0	0	0	
Greece	0	0	0	
Greece	0	0	0	
Greece	0	0	0	
Greece	0	0	0	
Greece	0	1.6	0	
France	0	0	0	
France	0	0	0	
Austria	0	0	0	
Austria	0	0	0	

Record: 0 Show: All Selected Records

Attributes of CO2...

FID	Shape	CAP_TOTAL
0	Polygon	18.6287
1	Polygon	81.811809
2	Polygon	89.029215
3	Polygon	323.67717
4	Polygon	315.49619
5	Polygon	141.376061
6	Polygon	11.431558
7	Polygon	148.098588
8	Polygon	235.768742
9	Polygon	25.789614
10	Polygon	52.01236
11	Polygon	312.203089
12	Polygon	323.67717
13	Polygon	323.67717

Record: 1

- Difficulties experienced in the lack of transparency and auditability of the GeoCapacity database
- Major gaps in data coverage have now been filled, although often at a very preliminary level of assessment.

WP 3 – Future CO2 Scenarios

Considering only sources >1Mt CO_2/year

Reviewed 9 existing scenarios from 4 sources:

- EU27: Baseline 2009 (Primes Ver. 4 Energy Model)
- DG-Clima EU27: "25+5" (Primes Model)
- UCL/SENCO Low Emission European Energy Scenarios
- Eurelectric "Role of Electricity" scenario
- Eurelectric "Power Choices" scenario
- European Climate Foundation Roadmap 2050 scenarios; 40% / 60% / 80% / 100% renewables

WP 3 – Future CO2 Scenarios

- Utilised existing scenarios as "foundations" for 3 Arup scenarios; Low, Medium and High CO2
- 2 design horizons; 2030 and 2050

Scenario	Primes BL	Primes -25	Rmap 80	Rmap 60	Rmap 40	Rmap BL	Eure P-Ch	Eure RoE
2030	272	495	47	121	235	0	-	587
2050	na	na	304	606	912	0	-	818

Scenario	Arup Low	Arup Mid	Arup High
2030	50	120	350
2050	280	600	800

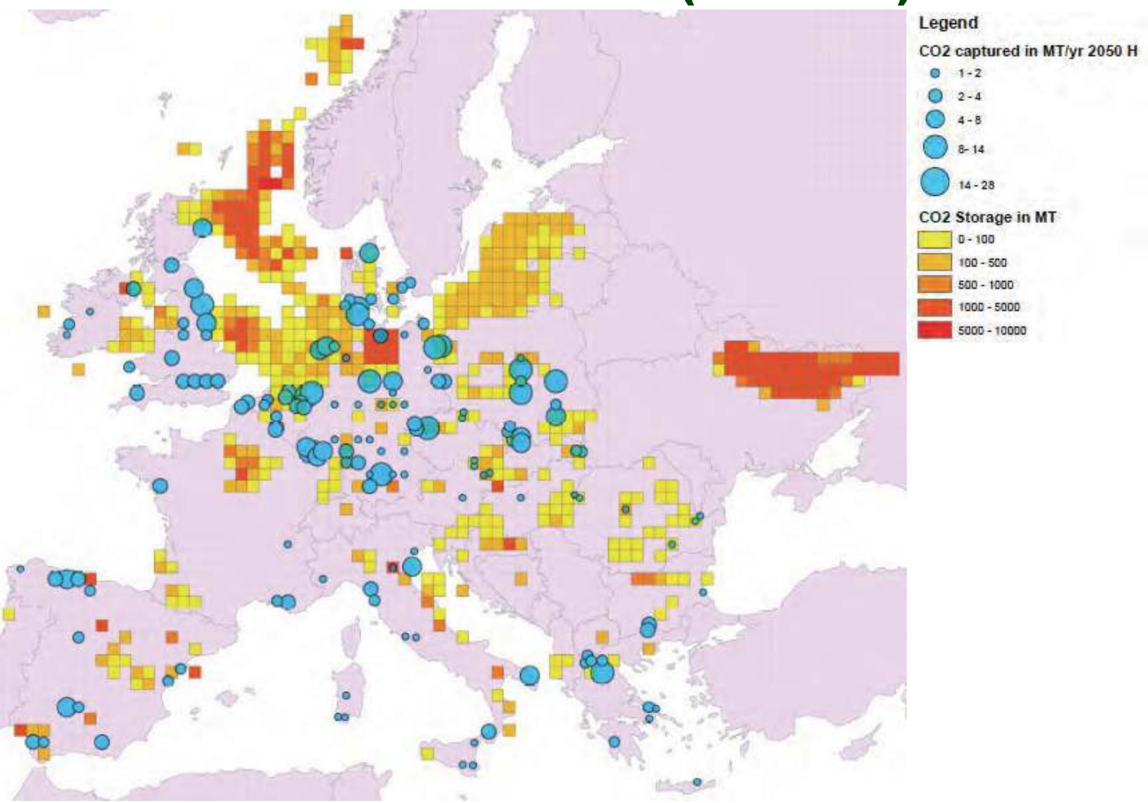
Capture quantities (MtCO2/yr)

s.haszeldine@ed.ac.uk

Berlin Forum on Sustainable Fossil Fuels, 18-19 October 2010

ARUP

WP 3 – Future CO2 Scenarios (2050 Hi)



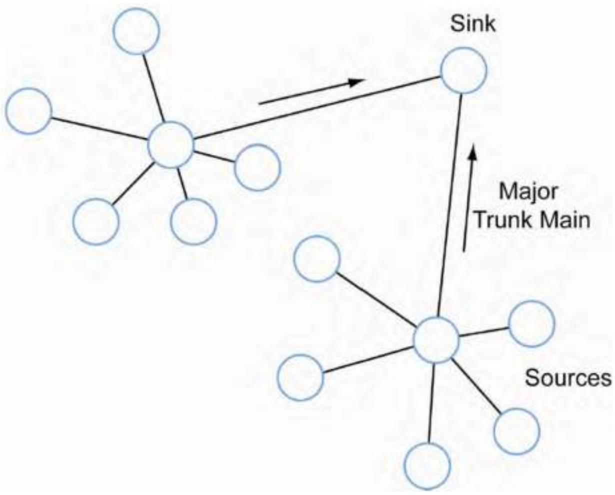
s.haszeldine@ed.ac.uk

Berlin Forum on Sustainable Fossil Fuels, 18-19 October 2010

ARUP

WP 4 – CO2 Transport Infrastructures

- Identifying a "blueprint" for transport infrastructure at 2030 and 2050, for each H/M/L capture scenario
- Matching sources to sinks, using optimisation routines in hydraulic models, considering
  - Throughput/volume
  - Design velocity
  - Economic cost model
- Storage site dataset from WP1 simplified
- Source dataset from WP3

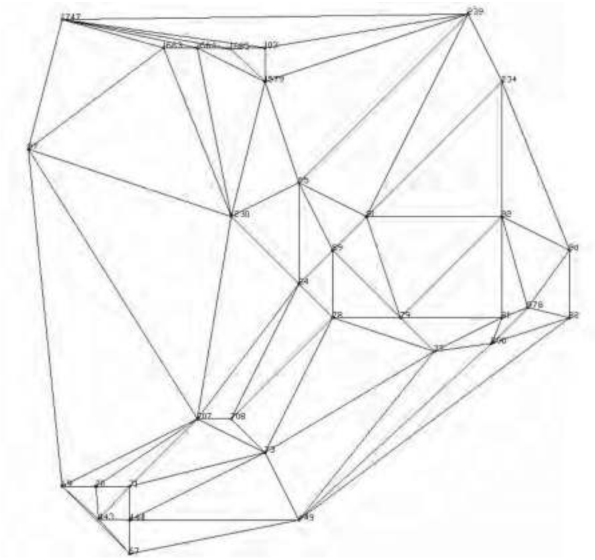


WP 4 – Modelling Methodology

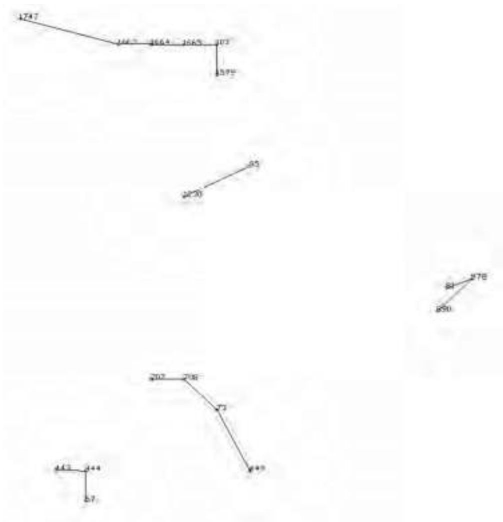
- Fully functioning hydraulic model
- Assumed dense-phase (supercritical) CO2
- Assumed design velocity of 2m/s
- Tested different network types/shapes; cost premium for ring mains, so one route deemed adequate
- Ant Colony Optimisation Algorithm
- Sole optimisation criterion is cost (capital)
- Cost model derived from IEA/IPCC CO2 pipeline data

WP 4 – Modelling Methodology

- Network creation & optimisation



Over-specified network



Optimised network

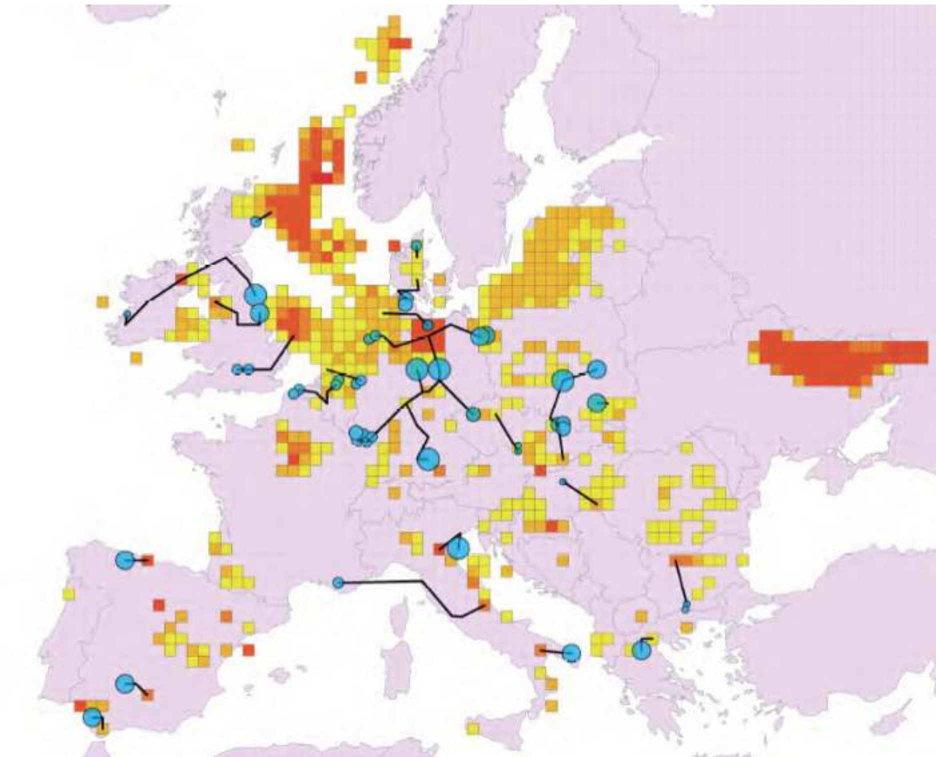
WP 4 – CO2 Transport Infrastructures; Results

- **Model simulations run and optimised for 2 storage scenarios, 3 CO2 scenarios, and 2 design horizons to create 12 network maps…**

- **All storage available**
  - 2030 Low CO2
  - 2030 Mid CO2
  - 2030 High CO2
  - 2050 Low CO2
  - 2050 Mid CO2
  - 2050 High CO2

- **Offshore storage only**
  - 2030 Low CO2
  - 2030 Mid CO2
  - 2030 High CO2
  - 2050 Low CO2
  - 2050 Mid CO2
  - 2050 High CO2

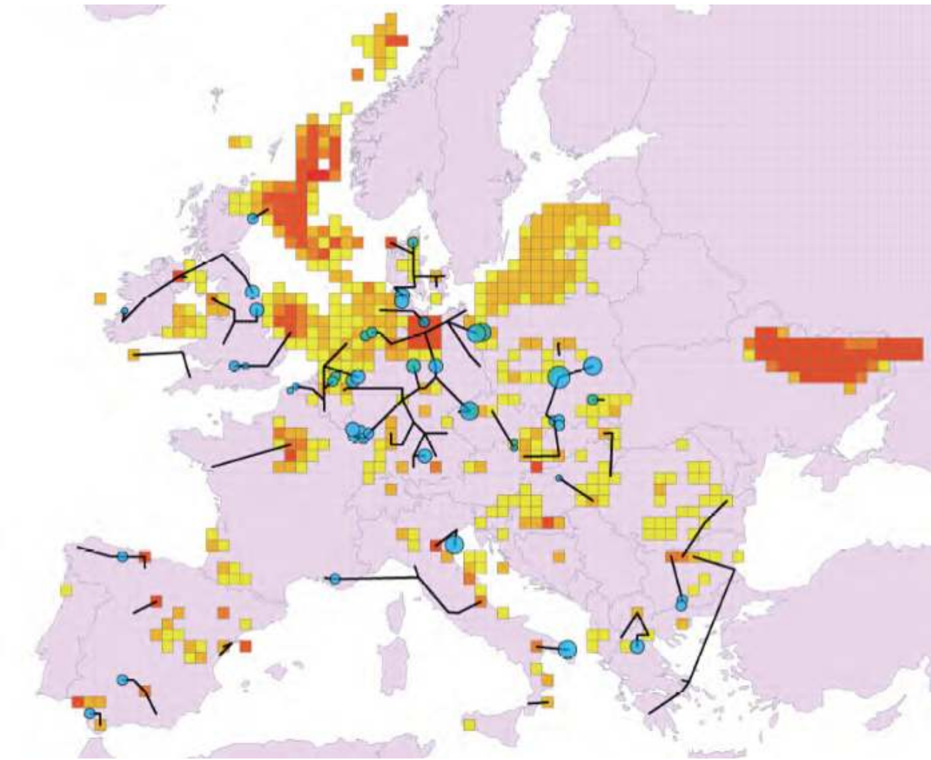
WP 4 – 2030 Low; All Storage Available



Simulation does not consider technical ability to develop CO2 storage.

s.haszeldine@ed.ac.uk Berlin Forum on Sustainable Fossil Fuels, 18-19 October 2010 ARUP

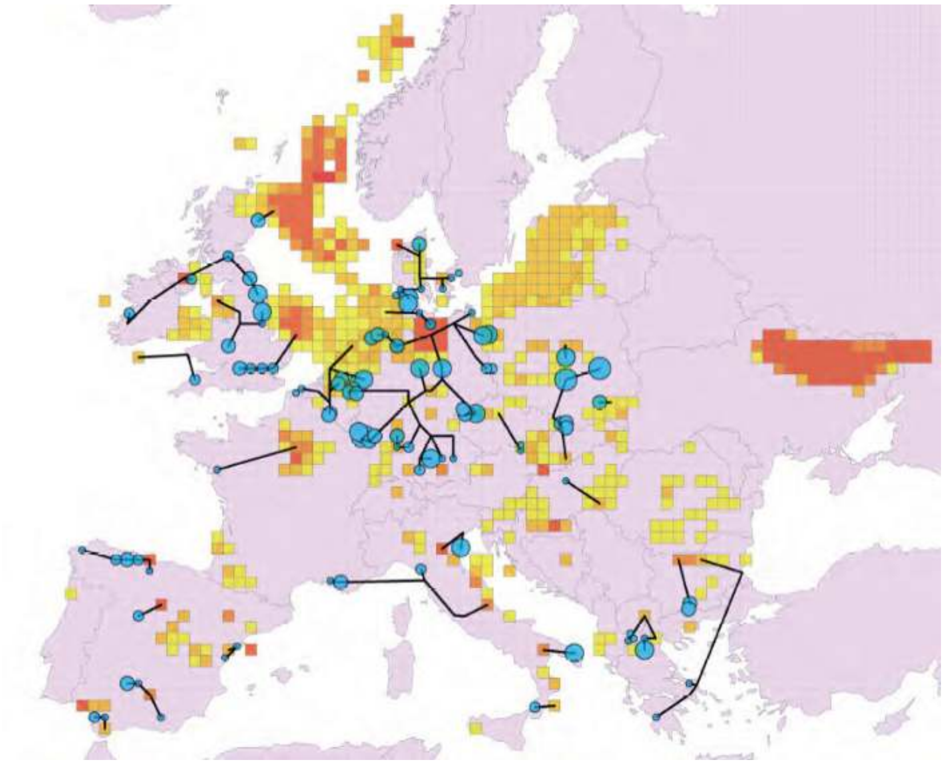
WP 4 – 2030 High; All Storage Available



Simulation does not consider technical ability to develop CO2 storage.

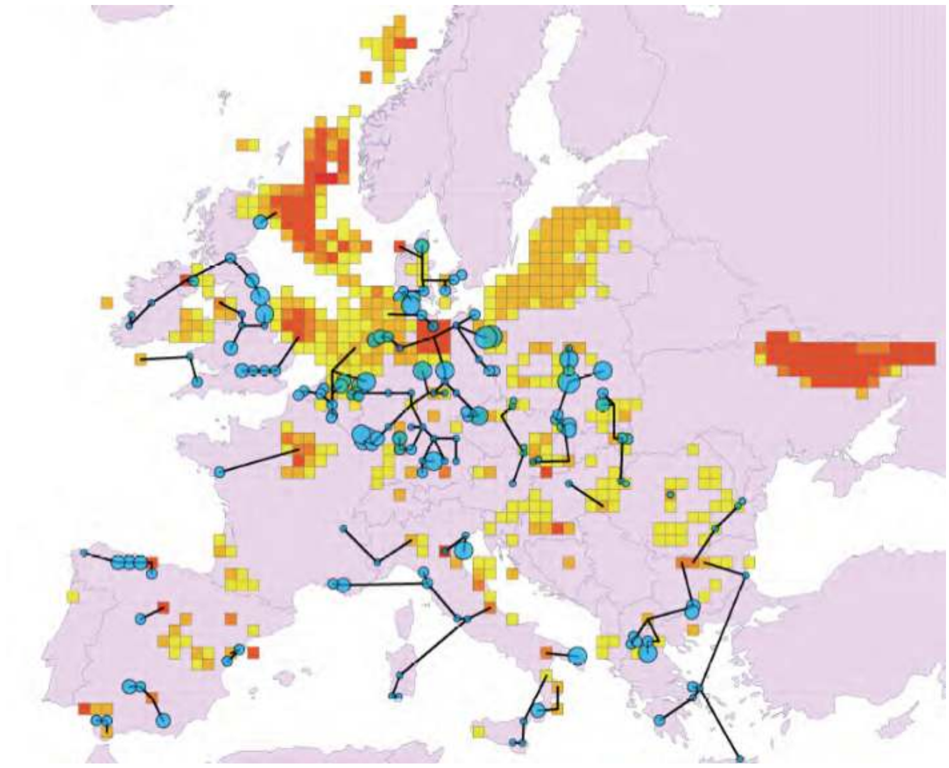
s.haszeldine@ed.ac.uk Berlin Forum on Sustainable Fossil Fuels, 18-19 October 2010 ARUP

WP 4 – 2050 Low; All Storage Available



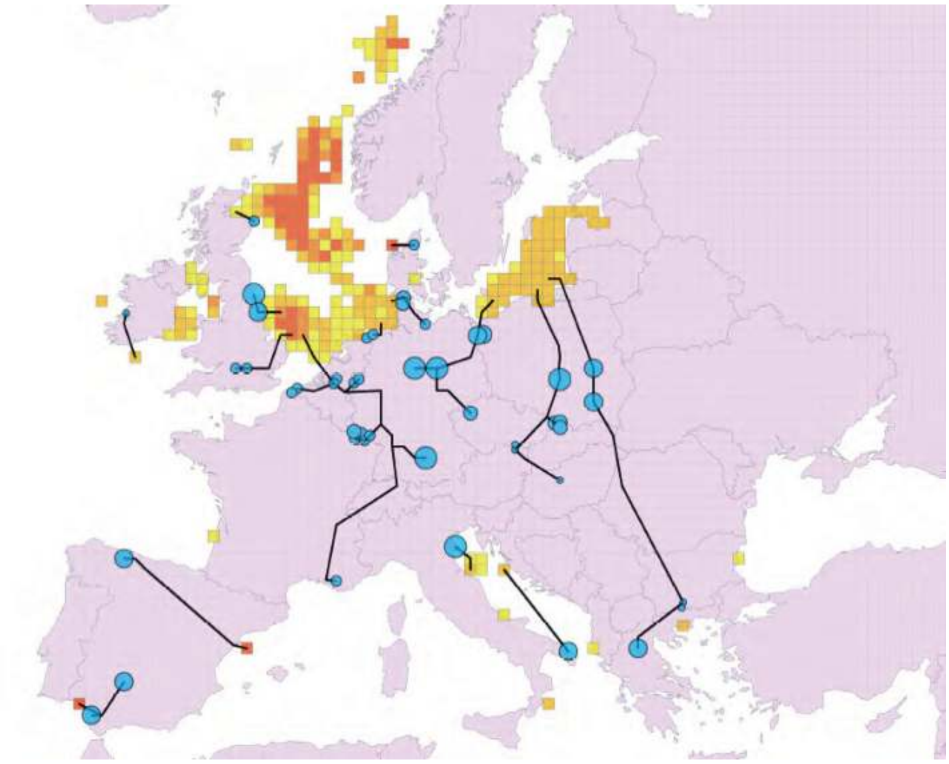
Simulation does not consider technical ability to develop CO2 storage.

WP 4 – 2050 High; All Storage Available



Simulation does not consider technical ability to develop CO2 storage.

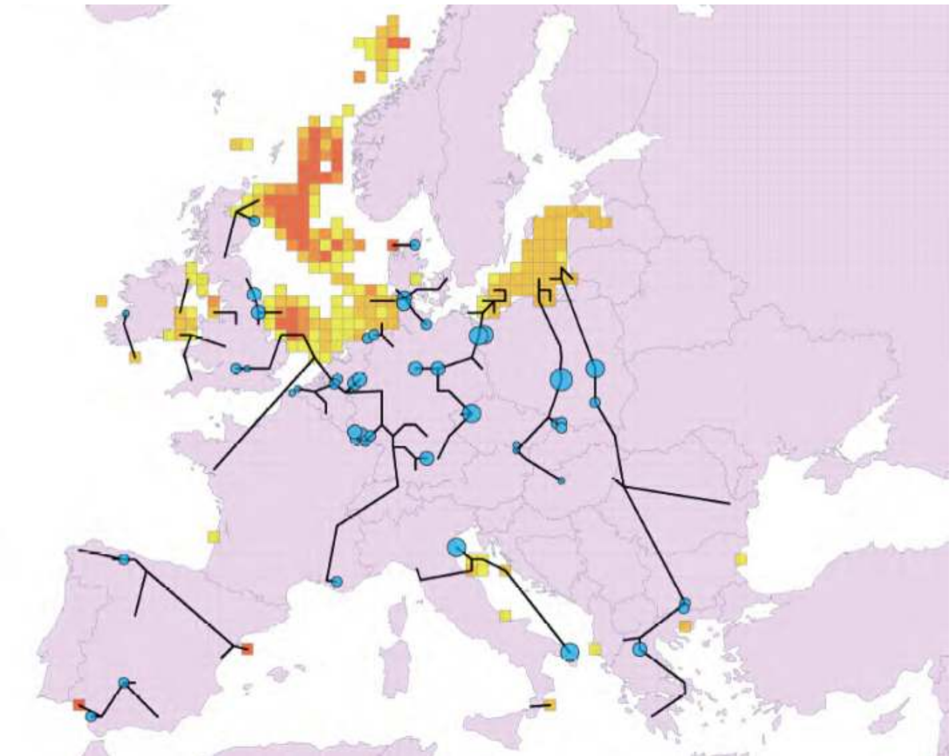
WP 4 – 2030 Low; Offshore Only



Simulation does not consider technical ability to develop CO2 storage.

North Sea much more advanced than Baltic, and likely to develop first.

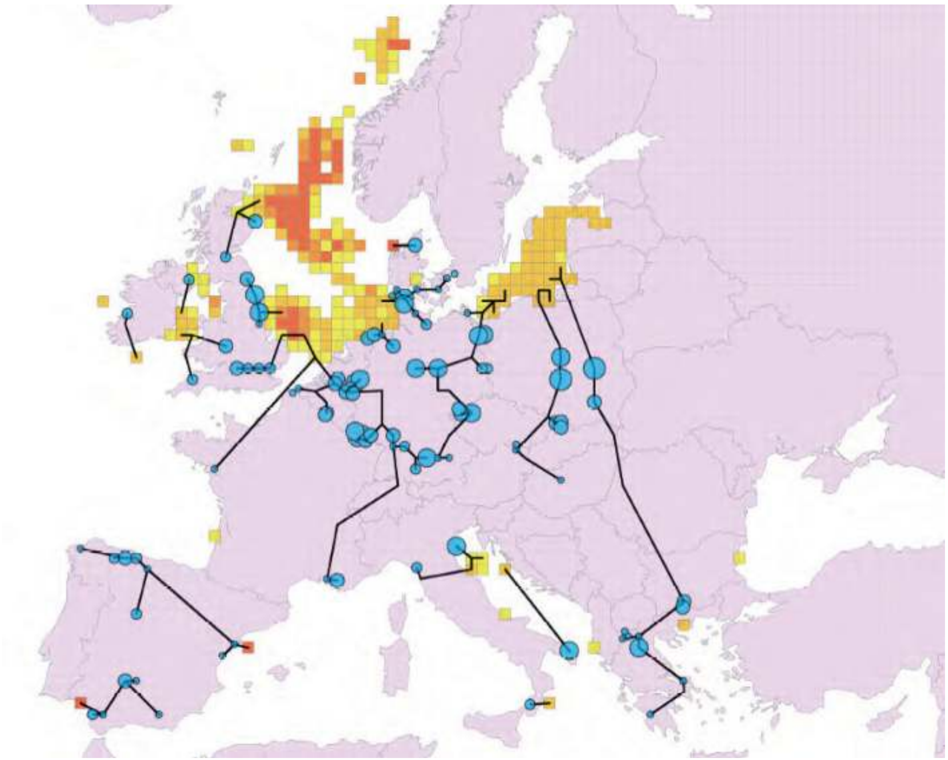
WP 4 – 2030 High; Offshore Only



Simulation does not consider technical ability to develop CO2 storage.

North Sea much more advanced than Baltic, and likely to develop first.

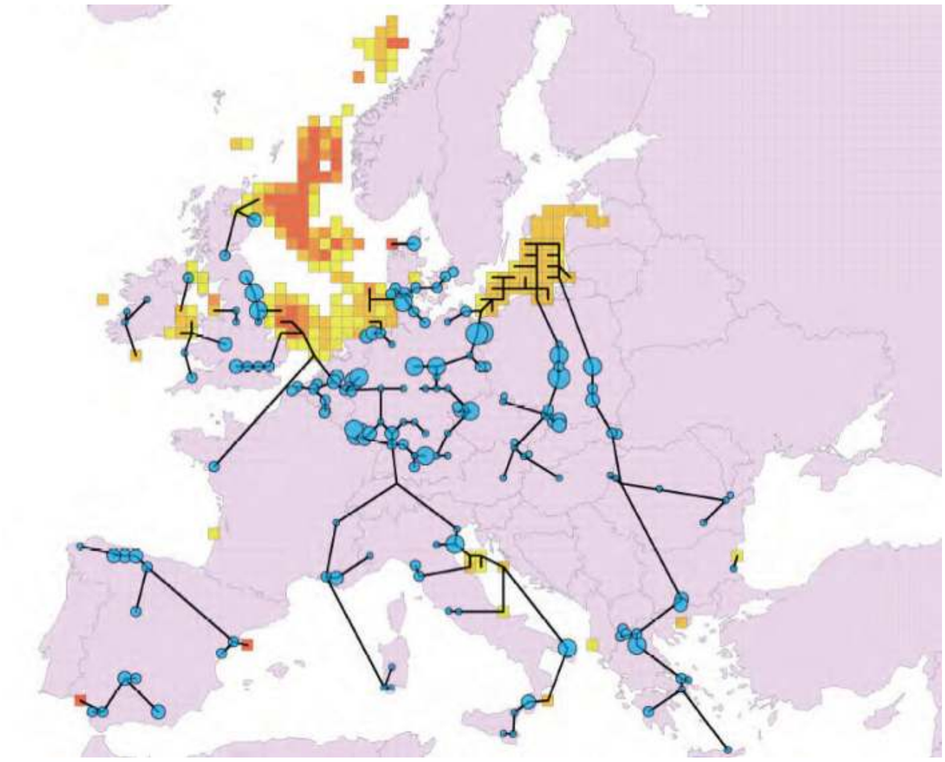
WP 4 – 2050 Low; Offshore Only



Simulation does not consider technical ability to develop CO_2 storage.

North Sea much more advanced than Baltic, and likely to develop first.

WP 4 – 2050 High; Offshore Only



Simulation does not consider technical ability to develop CO_2 storage.

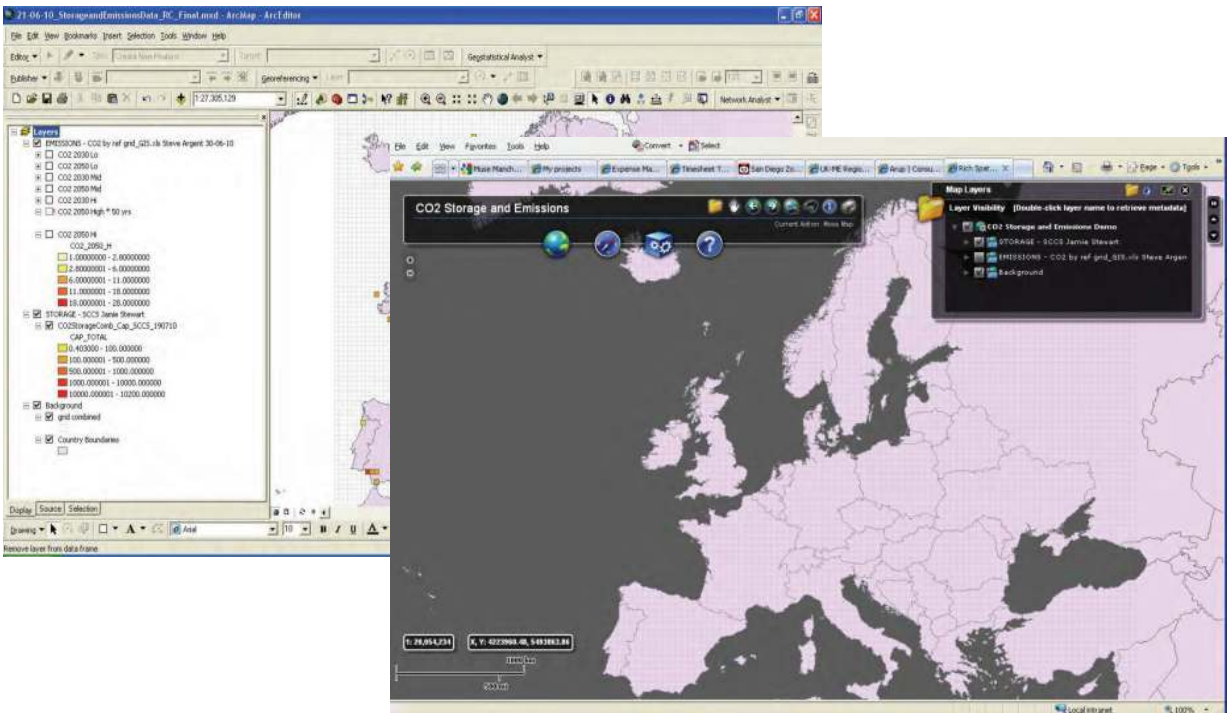
North Sea much more advanced than Baltic, and likely to develop first.

WP4 – Summary

- Range in total length / cost of CO_2 pipeline networks reflects range in CO_2 source predictions,
  from 6879km / €2,074 million (2030 Low CO_2),
  to 15013km / €12,667 million (2050 High CO_2)
  or 20041km / €19,782 million (2050 High CO_2; offshore only)
- No regretted pipeline routes at 2030
- Network shape and extent of cross-border transportation is highly dependent on the availability/acceptability of onshore storage
- Costs are indicative, but significant value in promoting/gaining acceptance of onshore storage

WP 5 – Data accessibility

Communication options for a single European database...



s.haszeldine@ed.ac.uk
Berlin Forum on Sustainable Fossil Fuels, 18-19 October 2010
ARUP

Conclusions, Oct 2010

STORAGE

- Total storage abundant. Some States limited nationally
- Previous work on storage capacity not transparent
- Availability and acceptability of onshore storage is a critical judgment
- Dominant secure storage tonnage is offshore North Sea
- Baltic and Ukraine large potential - (very) poorly known
- EC actions: desk study to upgrade method, quality & reliability of assessment, and easy access to data.
- EC Injection tests essential to validate saline formations

Conclusions, Oct 2010

SOURCES

- Wide variation in future scenarios of CO_2 sources, from 0 to 800 $MtCO_2$/yr
- These differences in CO_2 quantities captured though CCS have a significant impact on the extent of CO_2 transportation networks

Conclusions, Oct 2010

TRANSPORTATION INFRASTRUCTURE

- **Hydraulic models with optimisation algorithms can be used to identify key strategic planning issues**
- **Significant cost premium for security of supply**
- **Several options within 10-15% of optimal cost solution - suggests flexibility**
- **Progression from 2030 to 2050 – further analysis required. Magnitude of flow increases and economic factors make ‘future-proofing’ unattractive**
- **Gaps in current cost models, e.g. sink development**
- **Importance of clusters, pipeline dynamics and common entry specifications**

Thank you

Dominic Ainger, Arup

Steve Argent, Arup

Prof. Stuart Haszeldine, SCCS/University of Edinburgh

Berlin Forum on Sustainable Fossil Fuels, 18-19 October 2010
s.haszeldine@ed.ac.uk
ARUP