EU GeoCapacity – Assessment of CO_2 Geological Storage Potential of Europe

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& the GeoCapacity project team

CO_2 Capture and Storage – Response to Climate Change, Vilnius, 13-14 April 2011

EU GeoCapacity – *in headlines*

- Started in January 2006
- Ended in December 2008
- Co-financed by EU – FP6
- 26 partners from 21 countries
- Geological storage assessment in 25 European countries and pioneer work in China

EU co-financed CO_2 storage capacity projects

- **Joule II** finalised 1993
  The joule II project: The underground disposal of carbon dioxide
  All Europe

- **GESTCO** finalised 2003
  Geological Storage of CO_2 from Combustion of Fossil Fuel
  Belgium, Denmark, France, Germany, Greece, Netherlands, Norway, UK

- **Castor** (WP 1.2) finalised 2006
  Bulgaria, Croatia, Czech Rep., Hungary, Poland, Romania, Slovakia, Slovenia

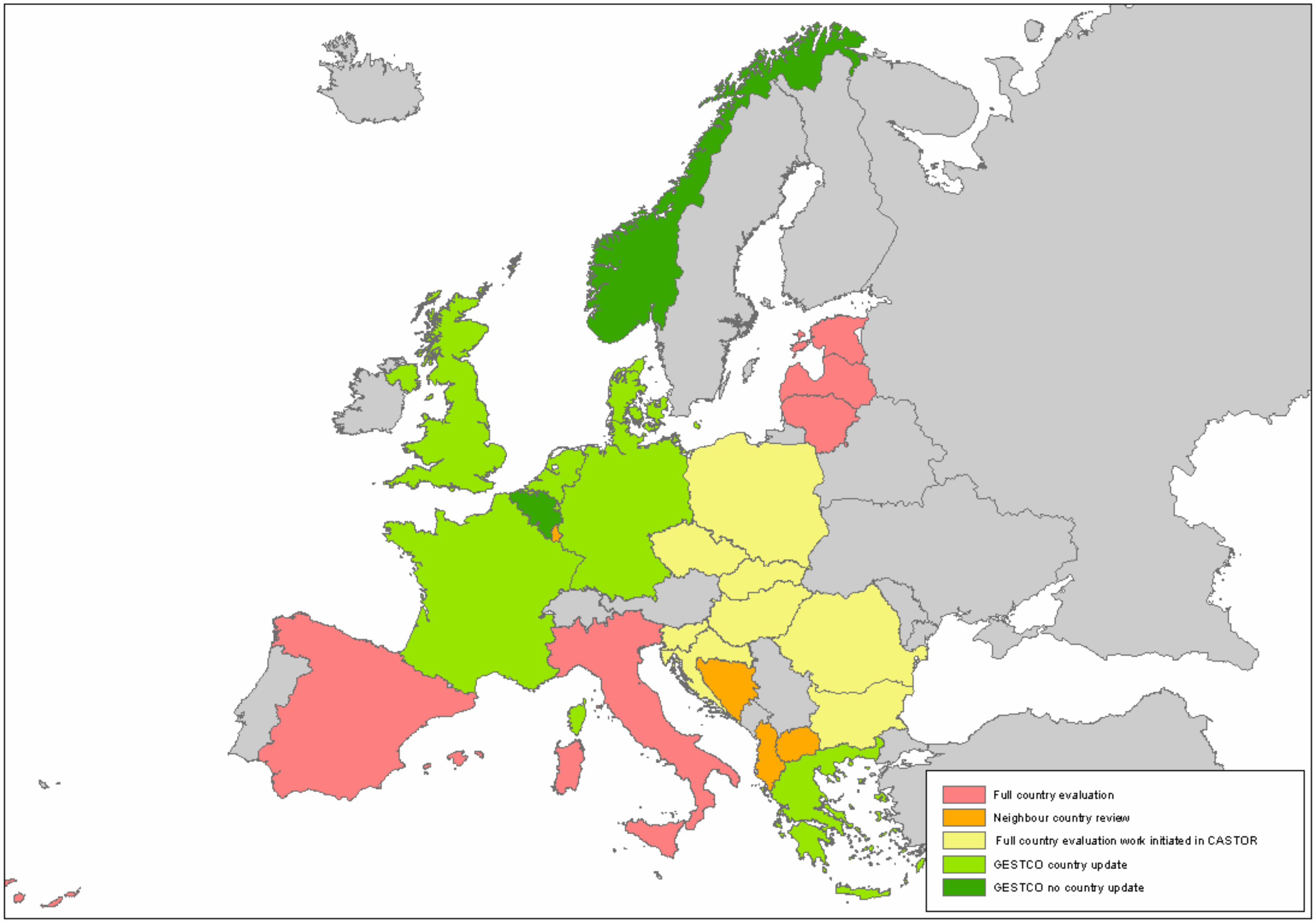
- **GeoCapacity** finalised 2008
  Assessing European Capacity for Geological Storage of Carbon Dioxide
  Bulgaria, Croatia, Czech Rep., Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, UK, Bosnia-Herzegovina, Albania, FYROM, Luxembourg, Belgium, Norway

26 Project partners from 21 countries

- Geological Survey of Denmark and Greenland
- Sofia University "St. Kliment Ohridski"
- University of Zagreb - Faculty of Mining, Geology and Petroleum Engineering
- Czech Geological Survey
- Institute of Geology at Tallinn University of Technology
- Bureau de Recherches Géologiques et Minières
- IFP
- Bundesanstalt für Geowissenschaften und Rohstoffe
- Institute of Geology and Mineral Exploration
- Eötvös Loránd Geophysical Institute of Hungary
- Instituto Nazionale di Oceanografia e di Geofisica Sperimentale
- Latvian Environment, Geology & Meteorology Agency
- Institute of Geology & Geography
- Geological Survey of the Netherlands
- Ecofys
- Mineral and Energy Economy Research Institute - Polish Academy of Sciences
- Geophysical Exploration Company
- National Institute of Marine Geology and Geo-ecology
- Dionýz Štúr State Geological Institute
- GEOINŽENIRING d.o.o.
- Instituto Geológico y Minero de Espana
- British Geological Survey
- EniTecnologie (Industry Partner)
- Endesa Generación (Industry Partner)
- Vattenfall AB (Industry Partner)
- Tsinghua University

The work in GeoCapacity comprised:

- Full assessment of countries not previously covered
- Update of GESTCO and CASTOR countries
- Inventory of major CO_2 emission point sources and infrastructure
- Assessment of regional and local potential for geological storage of CO_2:
- Technical site selection criteria and methodology for ranking
- Contribution to guidelines for assessment of geological storage capacity
- Analysis of source – transport – sink scenarios and economical evaluations
- Further development of mapping and analysis methodologies (GIS/DSS)
- Collaboration with China and other CSLF countries e.g. India and Russia


Full country evaluation
Neighbour country review
Full country evaluation work initiated in CASTOR
GESTCO country update
GESTCO no country update

Mapping of storage sites

- Initial screening for sedimentary formations
- 3 main types of storage considered
  - aquifers
  - hydrocarbon fields (incl. EOR/EGR)
  - unmineable coal seams (incl. ECBM)
- Application of site selection criteria
- Storage capacity estimation methodology
- Collection of data for GIS and project DSS

CO_2 storage options

Oil- and gas reservoirs

- Limited storage capacity, but well-known geology and proven capability to retain hydrocarbons
- Possibility to use CO_2 for enhanced oil/gas recovery (EOR/EGR)

Aquifers (saline)

- Large storage volumes, but relatively unknown geology and therefore uncertainties about reservoir integrity and properties

Coal fields

- Very limited storage capacity and injection rates, but possible to use CO_2 for production of methane

Basic site selection criteria

- Sufficient depth and storage capacity
  - supercritical CO_2 below 700-800 m
  - porosity may deteriorate below 2500-3000 m
  - trap type / areal extent / thickness
  - storage capacity
- Sufficient injectivity to be economically viable
  - permeability
  - reservoir lithology
  - heterogeneity of reservoir
- Integrity of seal
  - seal lithology and permeability
  - seal capillary pressure and pore entry pressure
  - faulting / tectonic activity / fracture pressure

Capacity calculations

Methodological resources:

- CSLF Task Force on CO_2 Storage Capacity Estimation
- Modeling work by TNO for aquifers
- US DOE methodology by the Geologic Working Group of the US Regional Carbon Sequestration Partnership Program
- Modeling by IFP for hydrocarbon fields
- Modeling work by PBG for coal beds

Top:

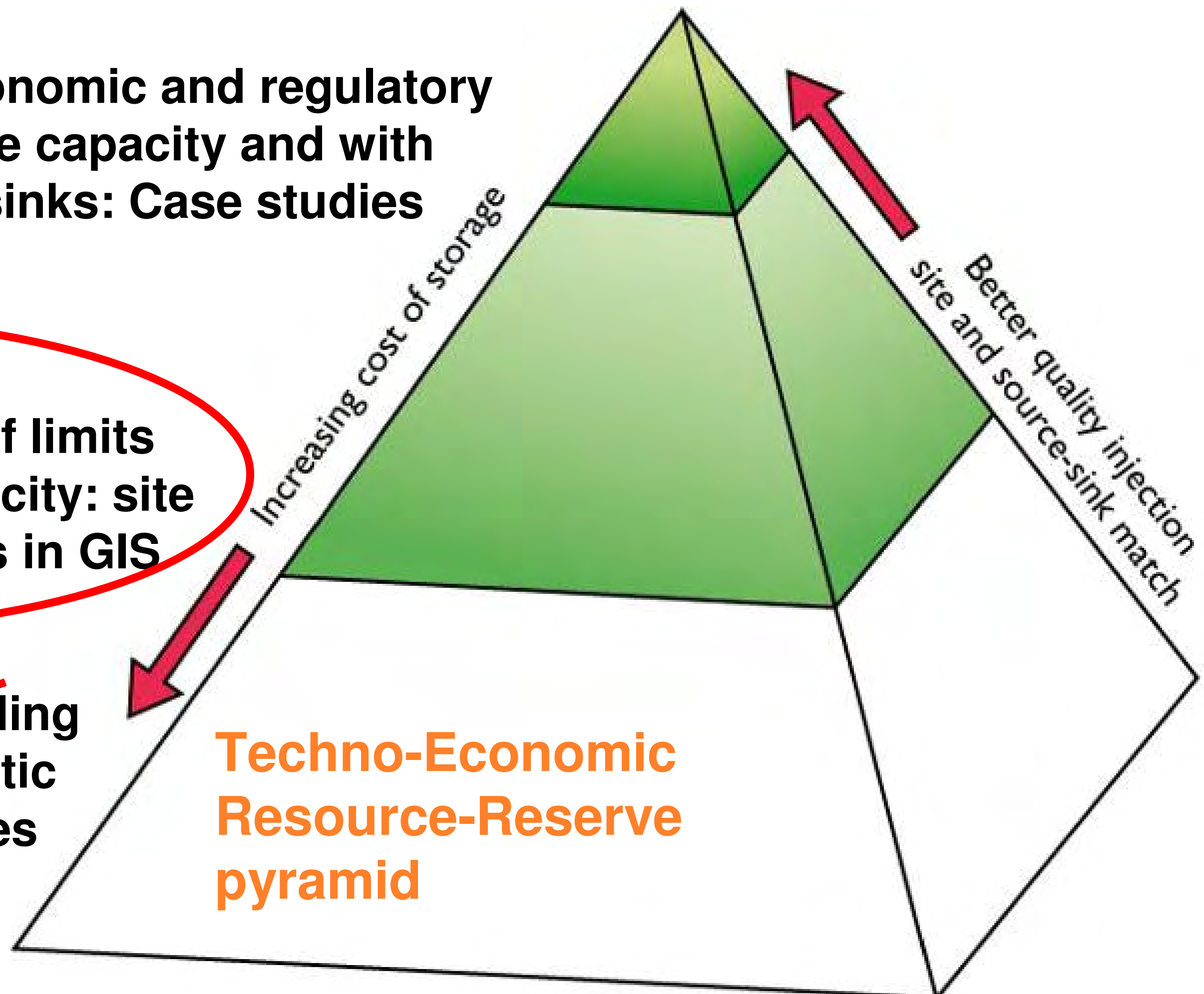
Practical capacity with economic and regulatory barriers applied to effective capacity and with matching of sources and sinks: Case studies

Middle:

Effective capacity with technical/geological cut-off limits applied to theoretical capacity: site specific/regional estimates in GIS

Bottom:

Theoretical capacity including large uneconomic/unrealistic volumes: regional estimates without storage efficiency



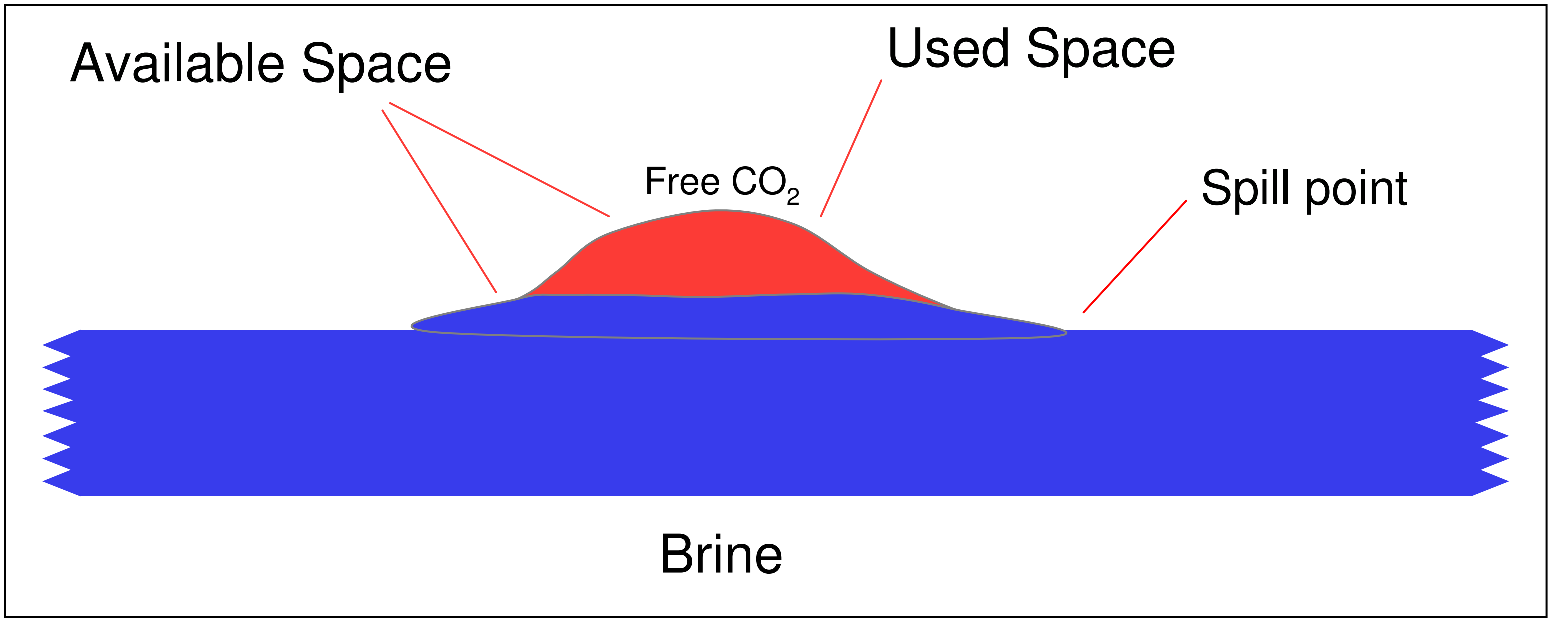
General considerations for saline aquifers

- Distinguish between estimates for bulk volume of regional aquifers and estimates for individual structural or stratigraphic traps

- For estimates based on the bulk volume of regional aquifers we suggest a storage efficiency factor of 2 % based on work by US DOE

- For trap estimates the choice of storage efficiency factor depends on whether the aquifer system is open, semi-closed or closed

Conceptual model for open aquifers



- Storage space is generated by displacing existing fluids and distributing pressure increase in surrounding aquifer system
- Storage volume = A · height · N/G · ϕ · S_{eff}
- S_{eff} depends on connectivity to surrounding aquifer
- S_{eff} = Used space/Available space

• **From Filip Neele, TNO**

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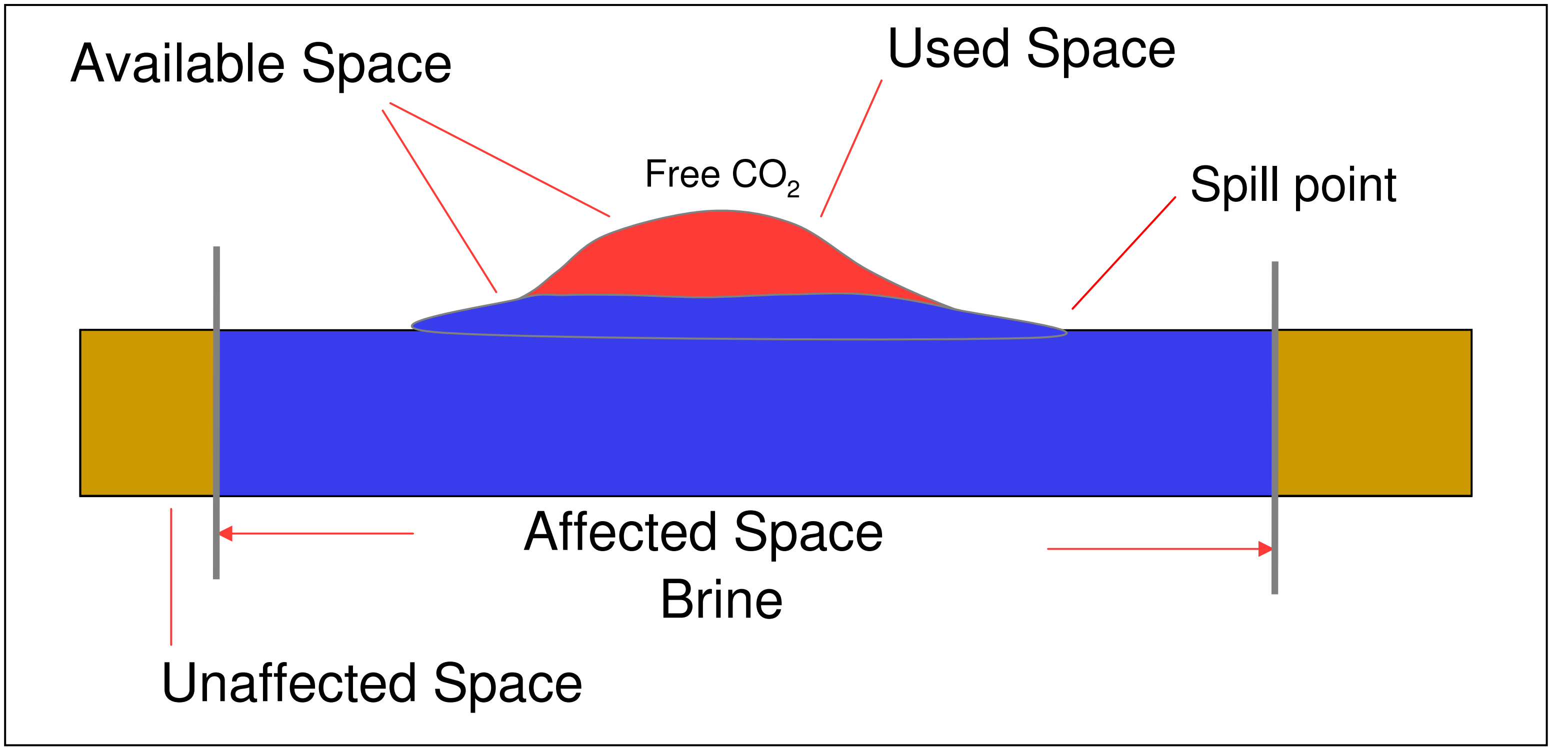
- For traps in open or semi-closed aquifer systems we suggest a rule-of-thumb approach with values for the storage efficiency factor in the range between 3 % and 40 % for semi-closed low quality and open high quality reservoirs, respectively

Conceptual model for closed aquifers



- Affected space is full! (rock and water for aquifers)
- More space only via **pressure increase** and **compressibility**
- Storage volume = $A \cdot \text{height} \cdot N/G \cdot \phi \cdot (C_w + C_p) \cdot \Delta p_{avg}$
- Δp_{avg} = allowed average pressure increase in affected area

• **From Filip Neele, TNO**

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- For traps in open or semi-closed aquifer systems we suggest a rule-of-thumb approach with values for the storage efficiency factor in the range between 3 % and 40 % for semi-closed low quality and open high quality reservoirs, respectively
- For traps in closed aquifer systems we suggest an approach based on trap to aquifer volume ratio, pore and water compressibility and allowable average pressure increase with typical values for the storage efficiency factor in the range between 1 % and 20 %
- Storage capacity estimates should always be accompanied with information on assumptions and approach for storage efficiency factor

Principal questions connected with CO_2 storage capacity in Europe:

- How critical is the availability of storage capacity?
- Are there countries where the urgency is higher?
- How much capacity do we actually need?
- When will it be required?
- Are there countries where a lack of storage capacity may hinder CCS?

What will happen after Kyoto?

- 2012: Kyoto/EU burden sharing: -8% on average

EU targets: 20-20-20 in 2020

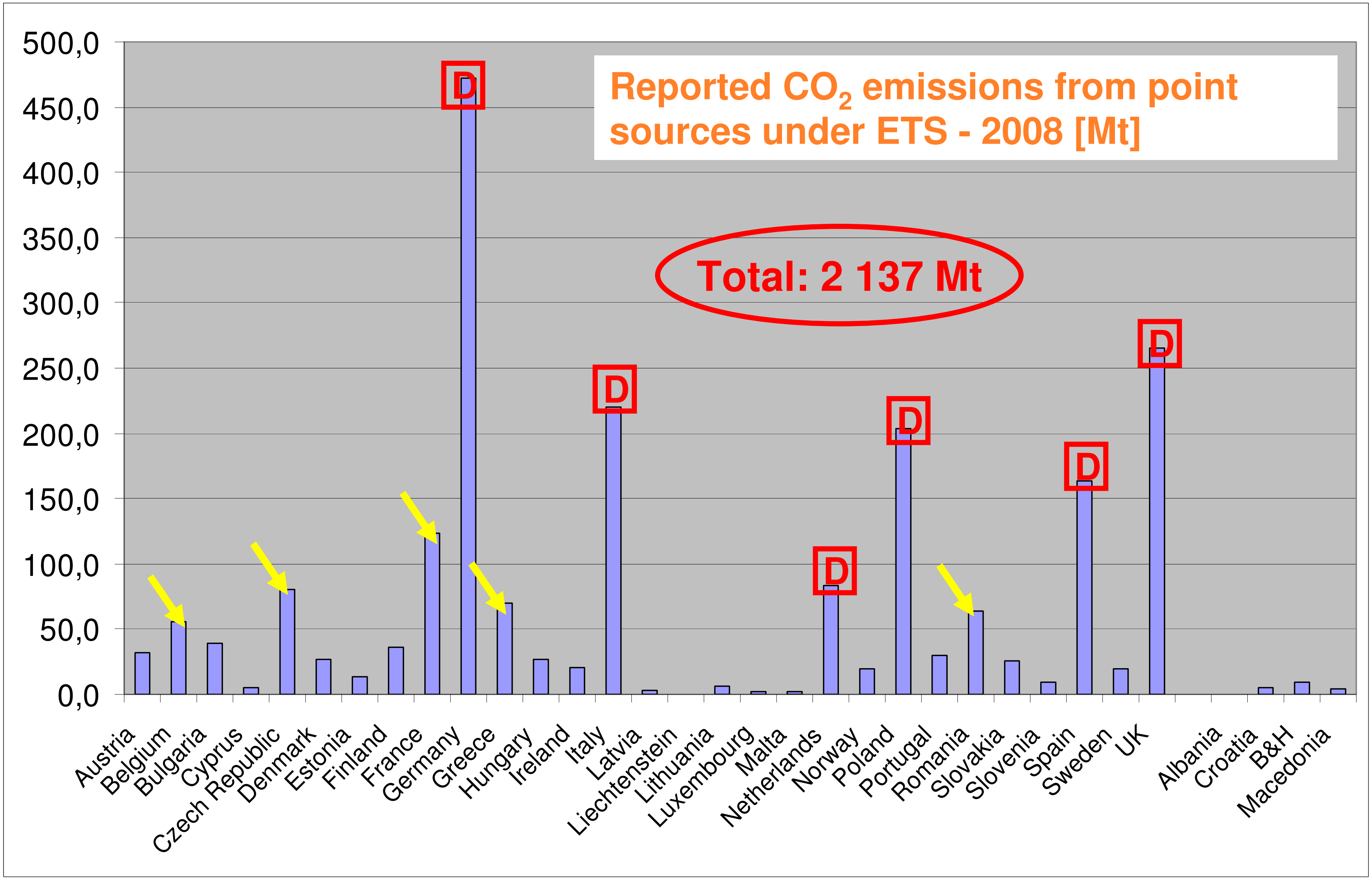
- 20 % reduction in CO_2 emissions compared to 1990
- 20 % of energy consumption from renewables
- 20 % improvement in energy efficiency

Supported by documents like:

- Strategic Energy Technology plan (SET)
- Amended ETS directive to include CCS
- CCS directive enabling regulatory framework
- European CCS Demonstration Plan

Means of funding:

- NER: New Entrant Reserve, 300 mill. CO_2 allowances, 4-5 billion € for CCS demo
- EEPR: European Energy Programme for Recovery, 1 billion € for CCS demo


Reported CO_2 emissions from point sources under ETS - 2008 [Mt]
Total: 2 137 Mt
500,0
450,0
400,0
350,0
300,0
250,0
200,0
150,0
100,0
50,0
0,0
D
Austria
Belgium
Bulgaria
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Liechtenstein
Lithuania
Luxembourg
Malta
Netherlands
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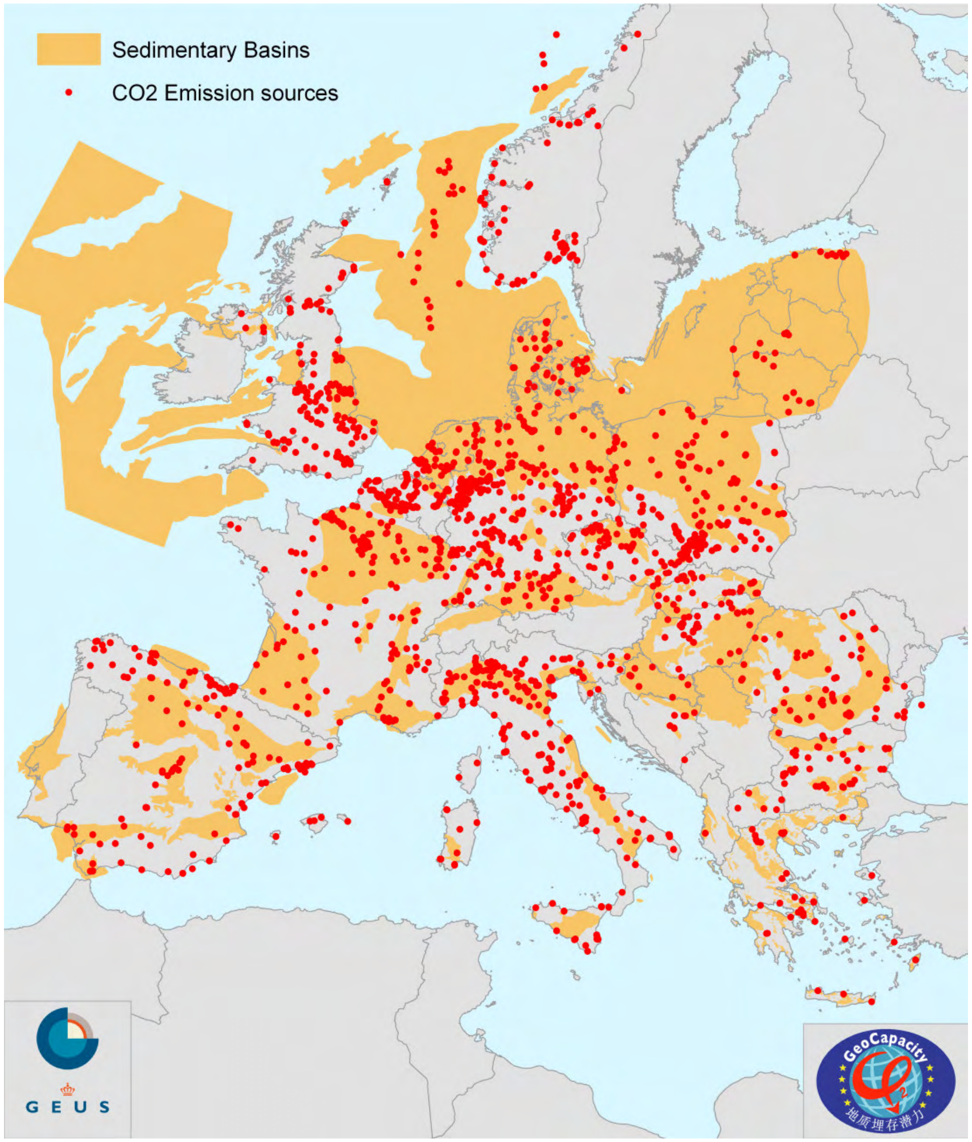
Croatia
B&H
Macedonia


Sedimentary Basins
CO2 Emission sources
GEUS

Pan-European storage capacity estimates in database

- Emissions from large point sources in database is 1.9 Gt CO_2/year

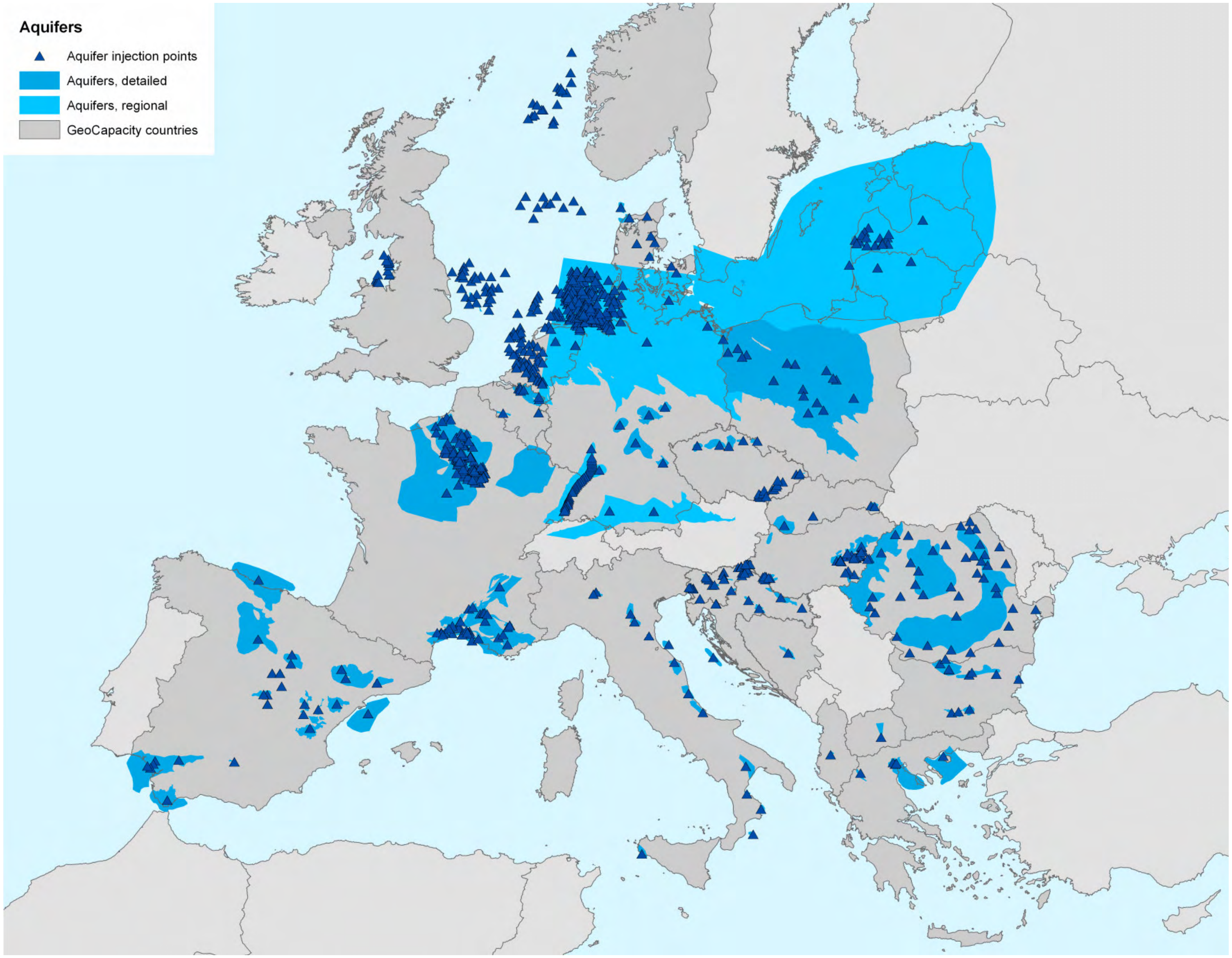
- Total European storage capacity in GeoCapacity database is 360 Gt CO_2
    - 326 Gt in deep saline aquifers
    - 32 Gt in hydrocarbon fields
    - 2 Gt in unmineable coal beds

- Onshore storage capacity is 116 Gt CO_2

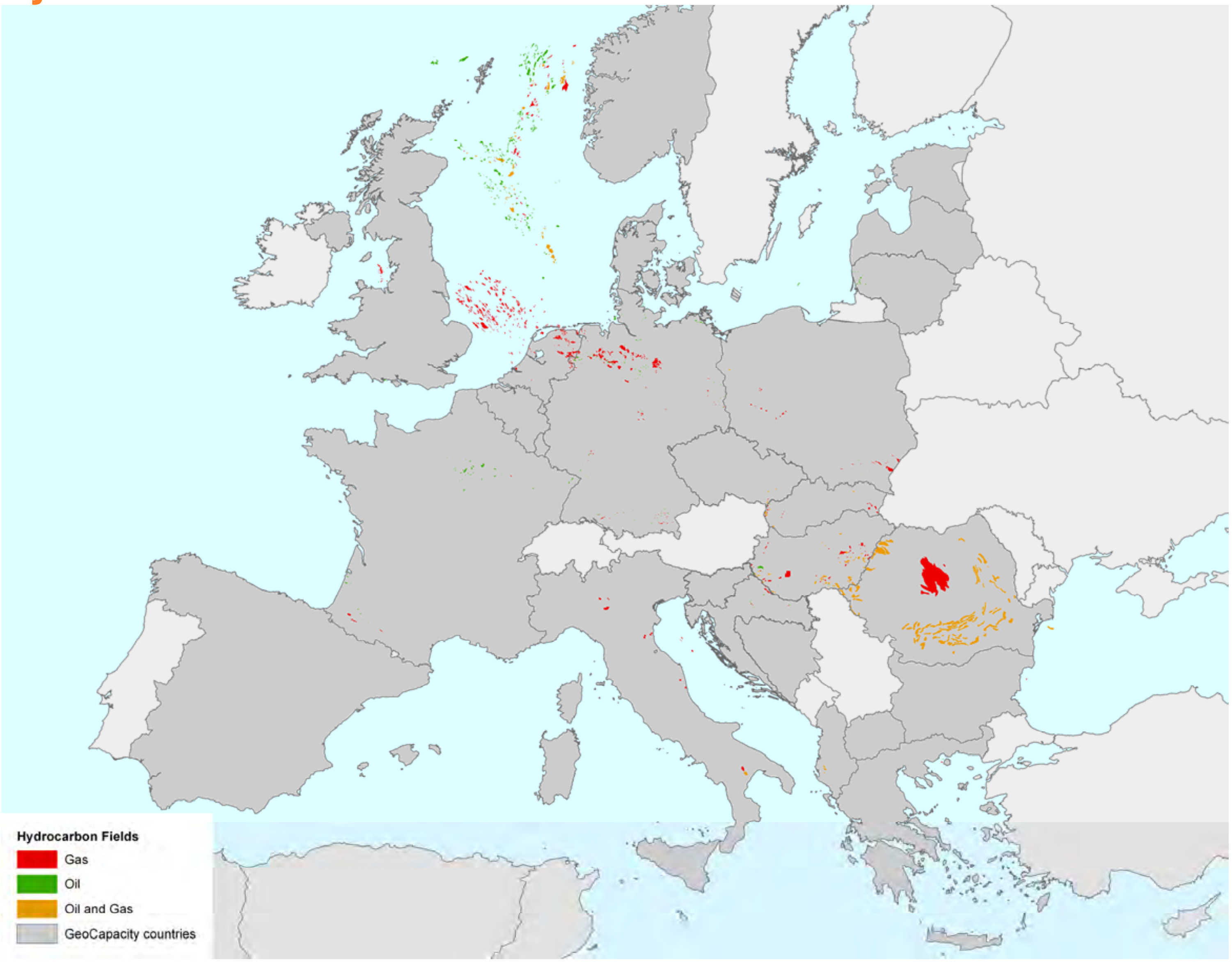
- Offshore storage capacity is 244 Gt CO_2

- Almost 200 Gt of this is optimistic capacity offshore Norway

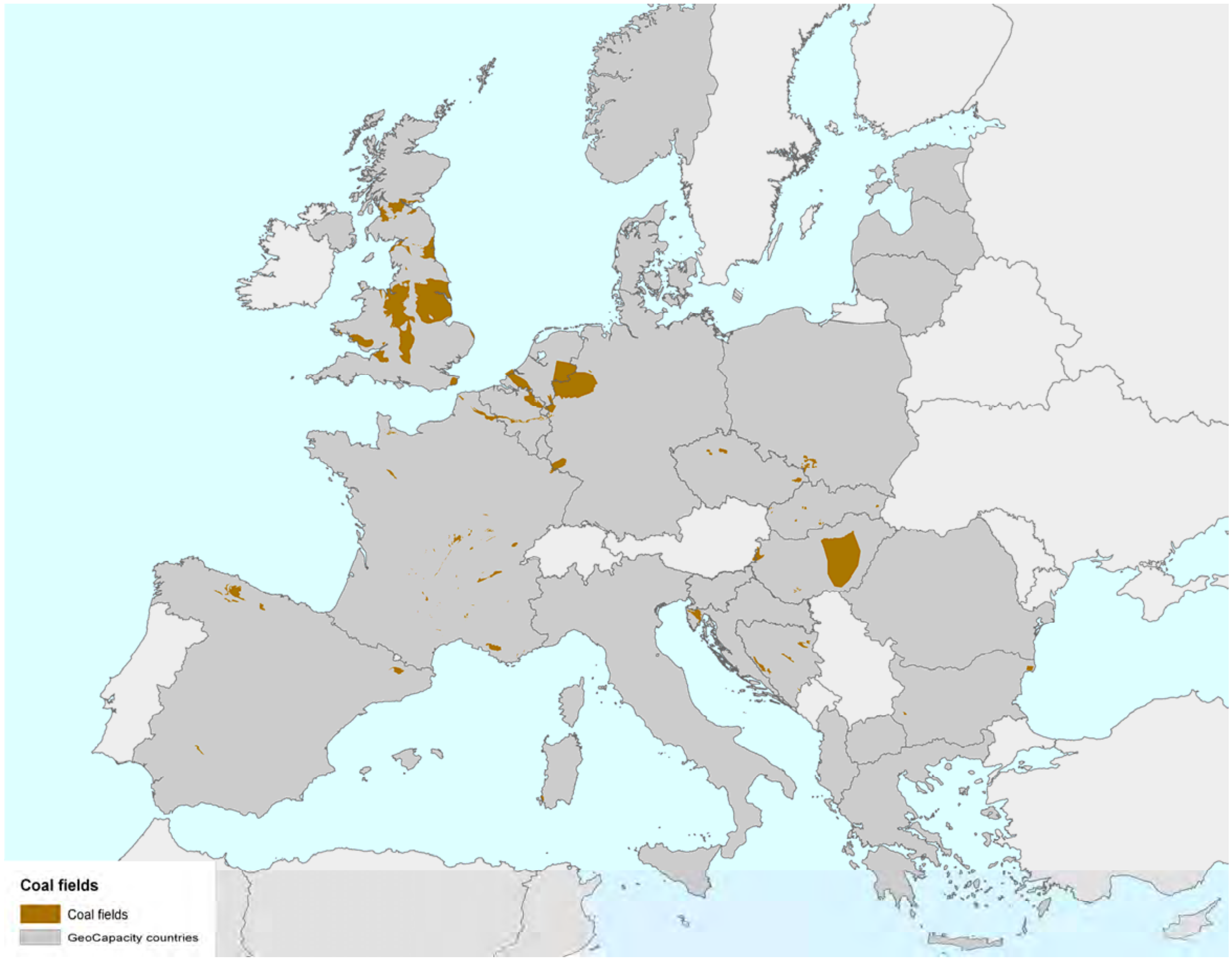
Aquifers


Aquifers
Aquifer injection points
Aquifers, detailed
Aquifers, regional
GeoCapacity countries

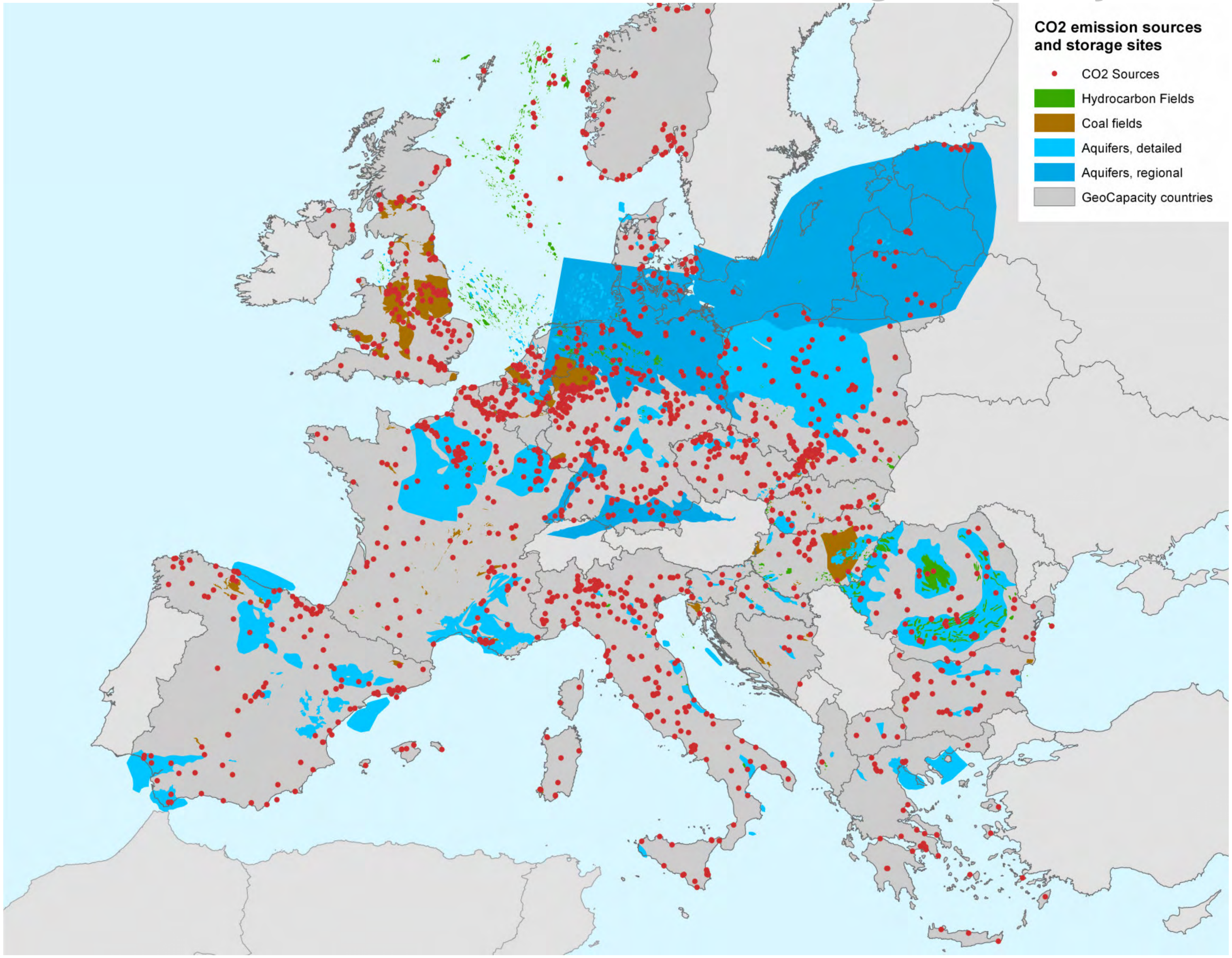
Hydrocarbon fields



Coal fields



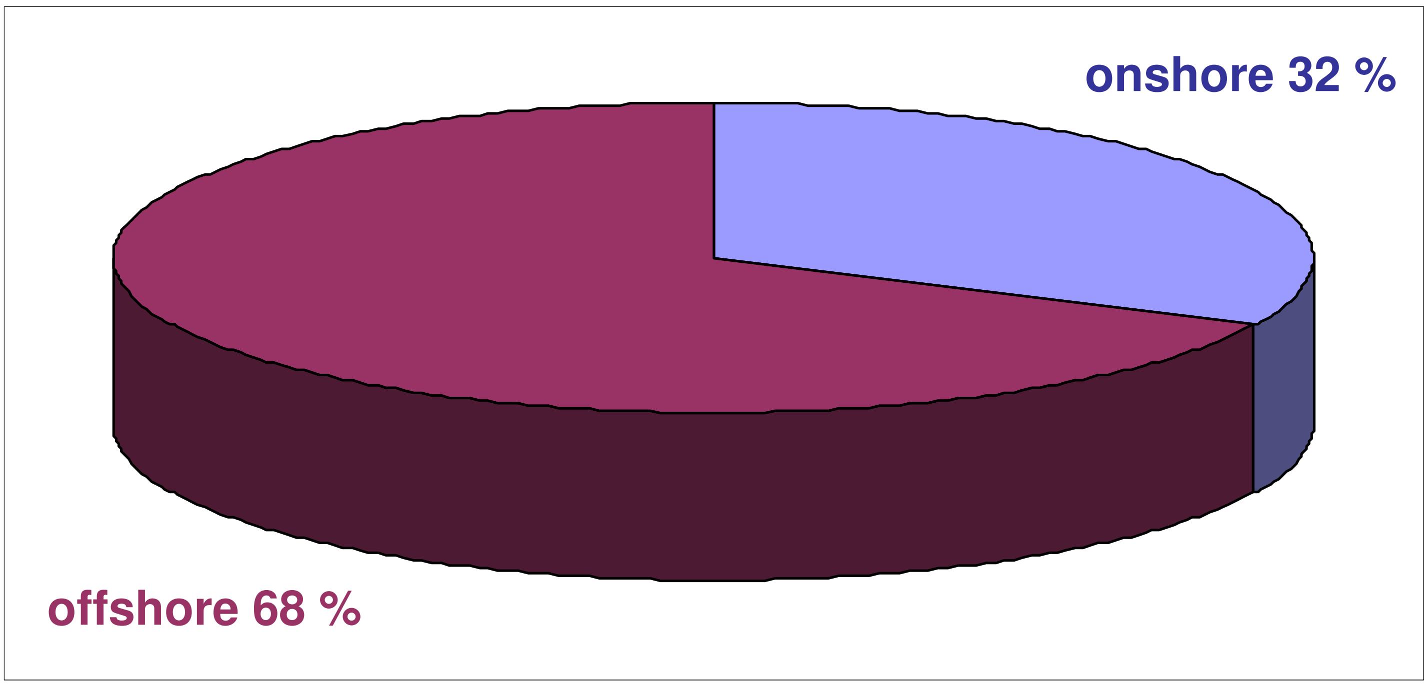
All data

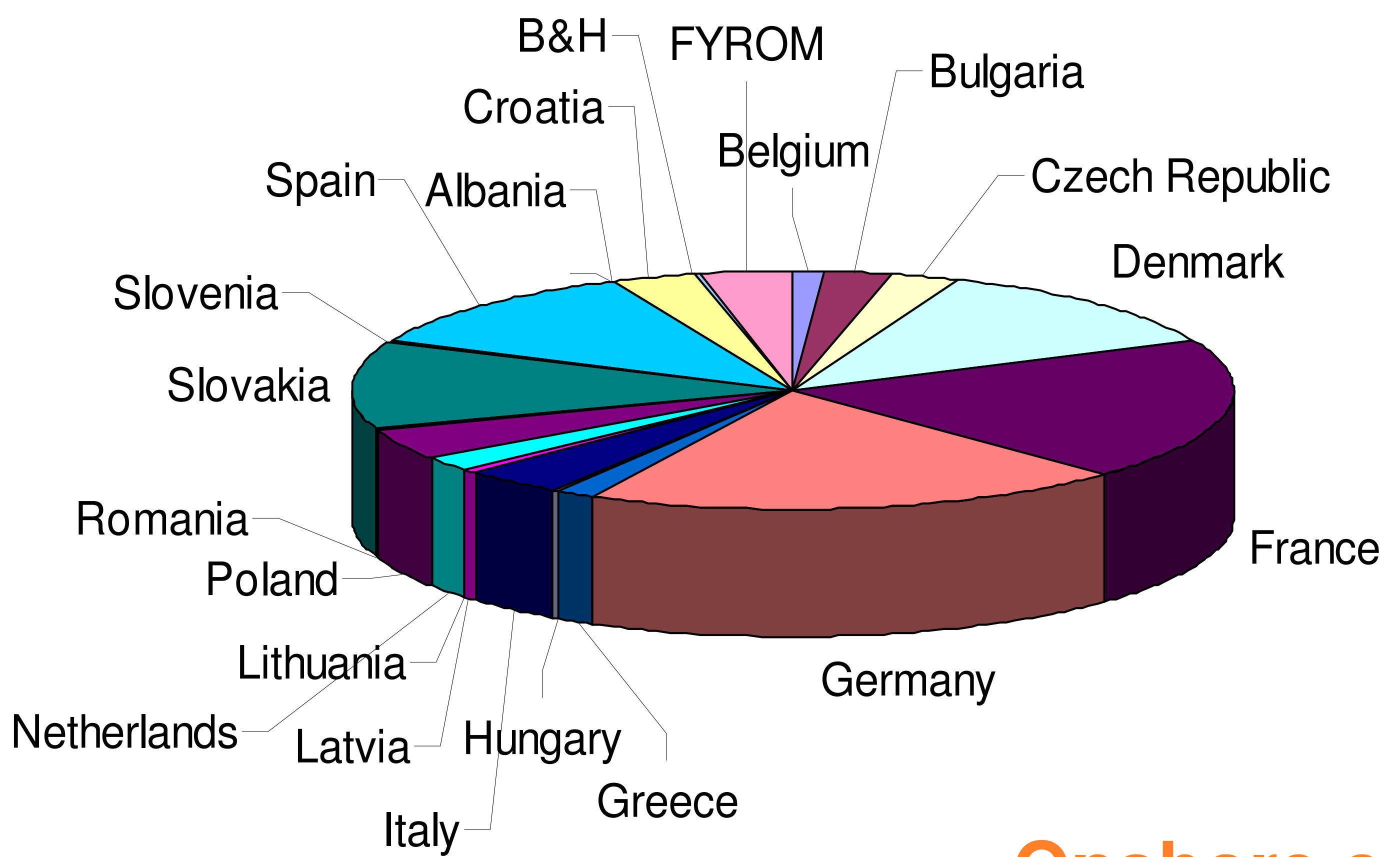

CO2 emission sources and storage sites
CO2 Sources
Hydrocarbon Fields
Coal fields
Aquifers, detailed
Aquifers, regional
GeoCapacity countries

Conservative European storage capacity estimates

- Emissions from large point sources in database is 1.9 Gt CO_2/year
- Total conservative European storage capacity is 117 Gt CO_2
  - 96 Gt in deep saline aquifers
  - 20 Gt in hydrocarbon fields
  - 1 Gt in unmineable coal beds
- Corresponds to more than 62 years of storage of emissions from all large point sources in database
- 25 % is storage capacity offshore Norway

GeoCapacity – onshore vs. offshore

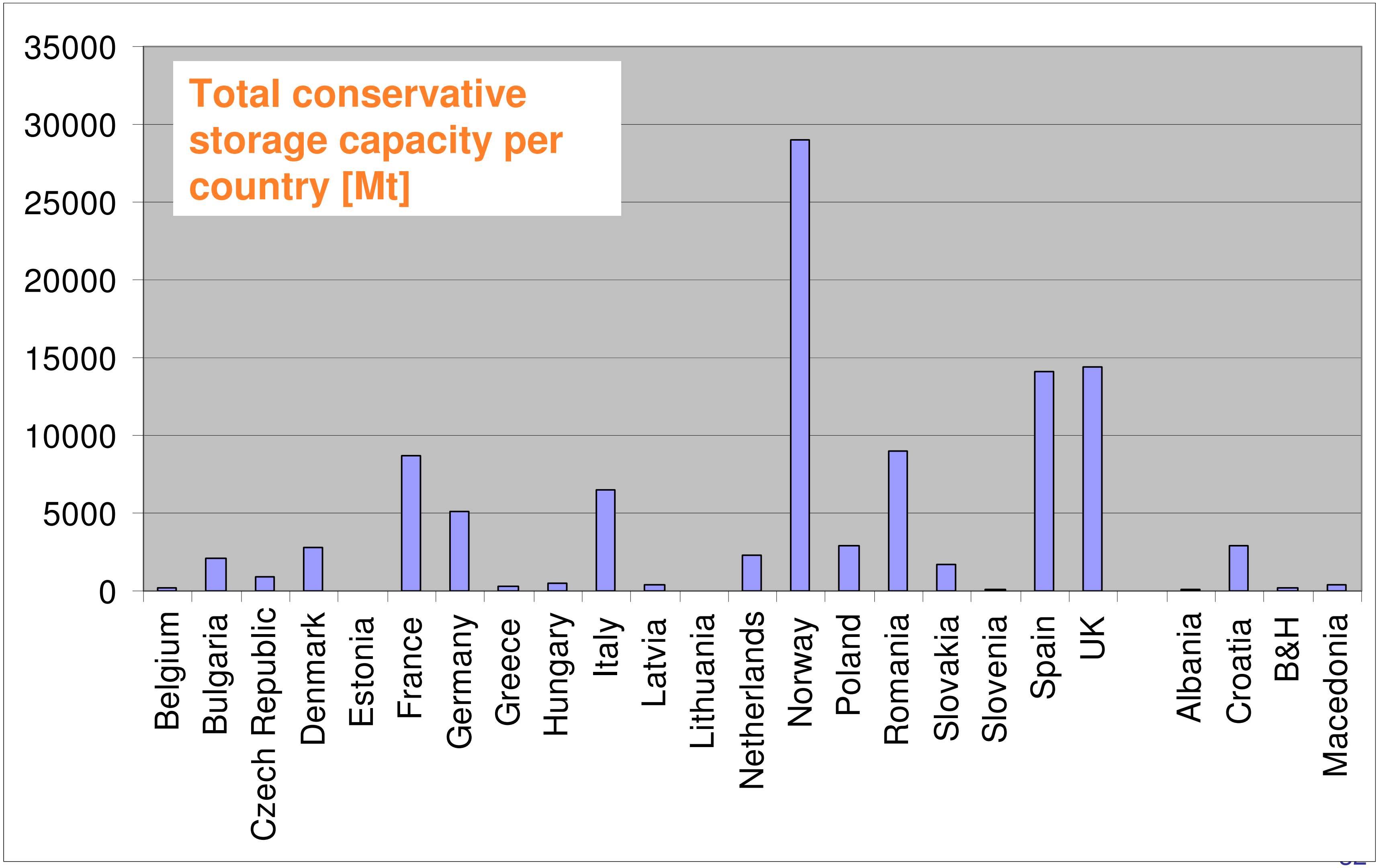




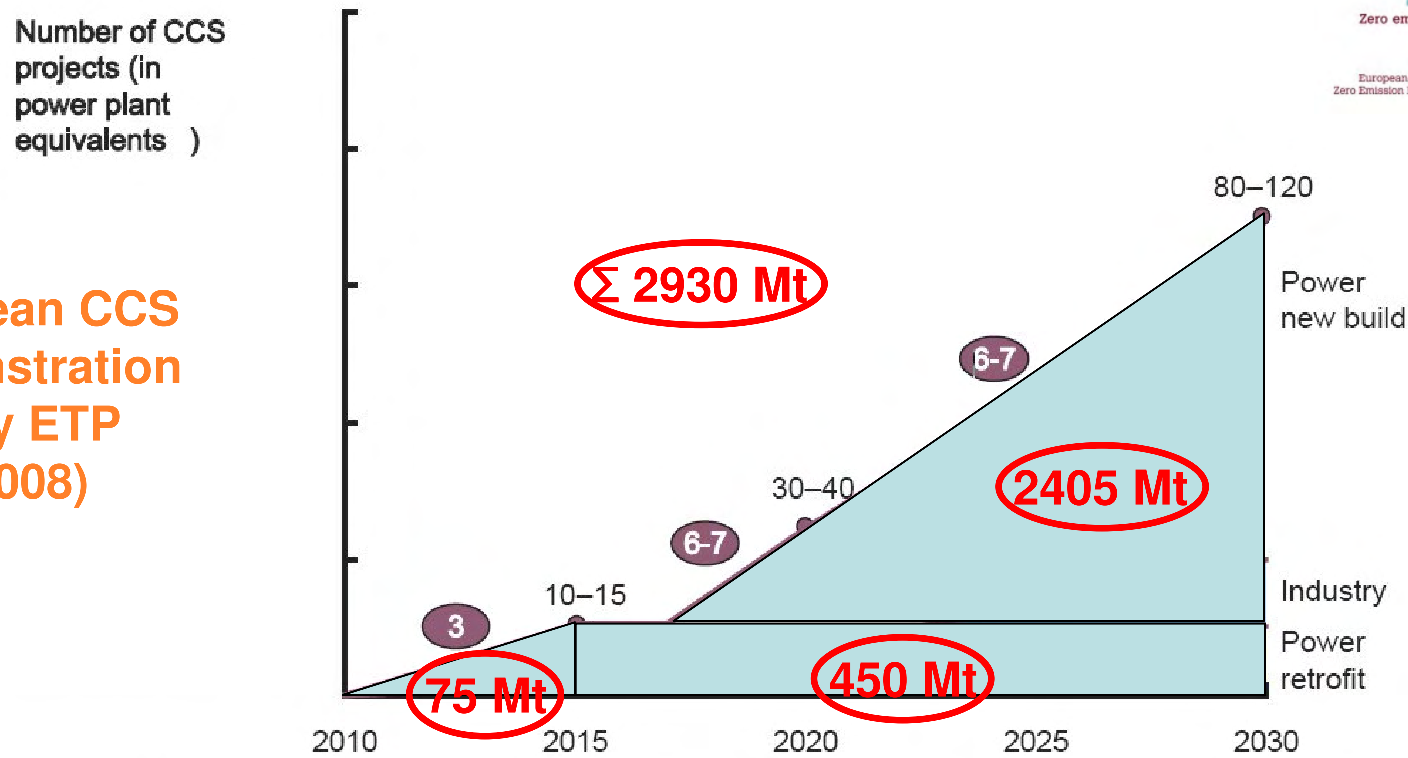
Onshore capacity

Issues of onshore CO_2 storage

- More difficult permitting process
- Conflicts of interest – natural gas storage, geothermal structures, coal deposits as strategic reserves
- Various protection regimes – nature protection, protection of raw material, groundwater protection, etc.
- Public acceptance issues – NIMBY (NUMBY) syndrome

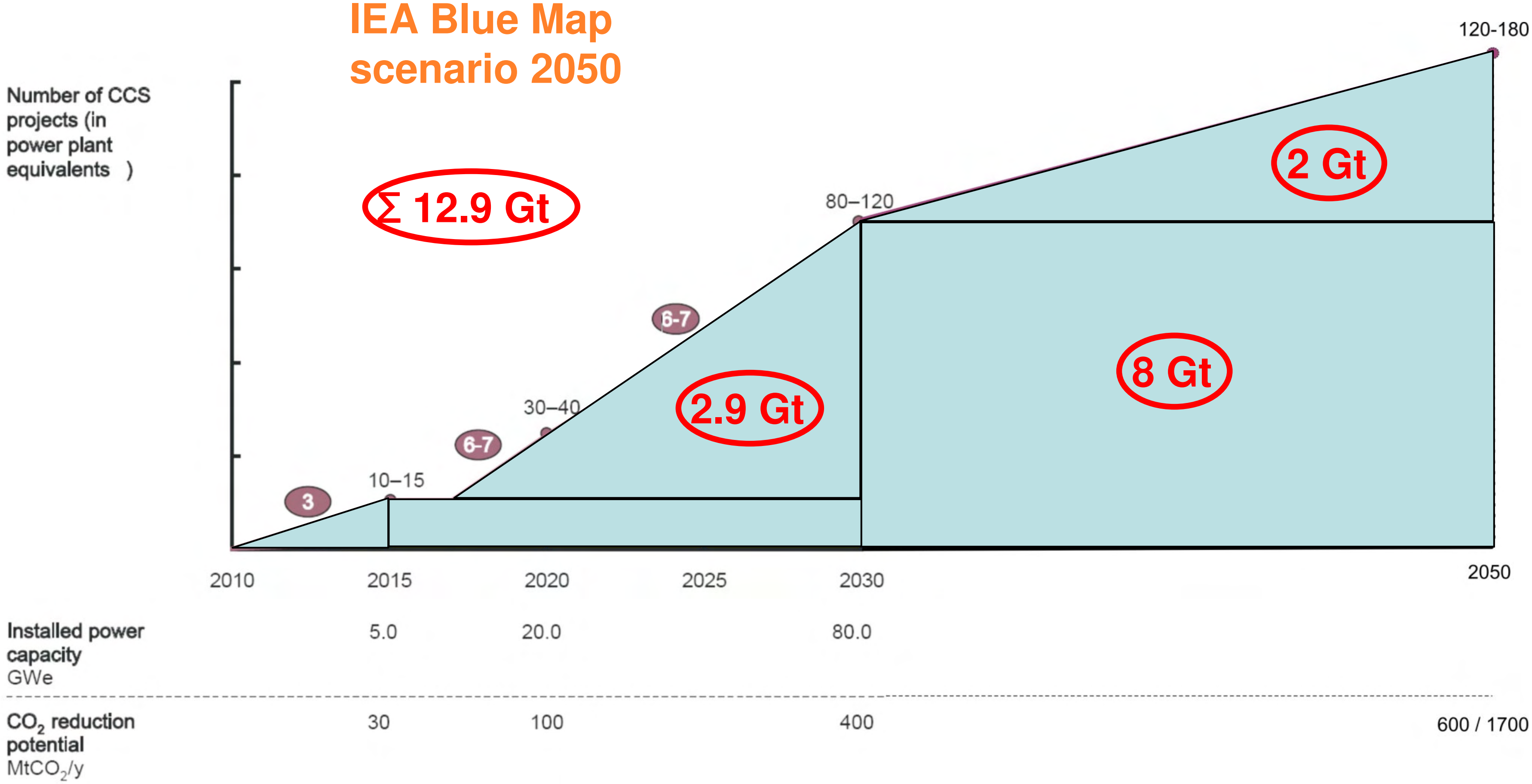

Total conservative storage capacity per country [Mt]
35000
30000
25000
20000
15000
10000
5000
0
Belgium
Bulgaria
Czech Republic
Denmark
Estonia
France
Germany
Greece
Hungary
Italy
Latvia
Lithuania
Netherlands
Norway
Poland
Romania
Slovakia
Slovenia
Spain
UK
Albania
Croatia
B&H
Macedonia

European CCS Demonstration Plan by ETP ZEP (2008)

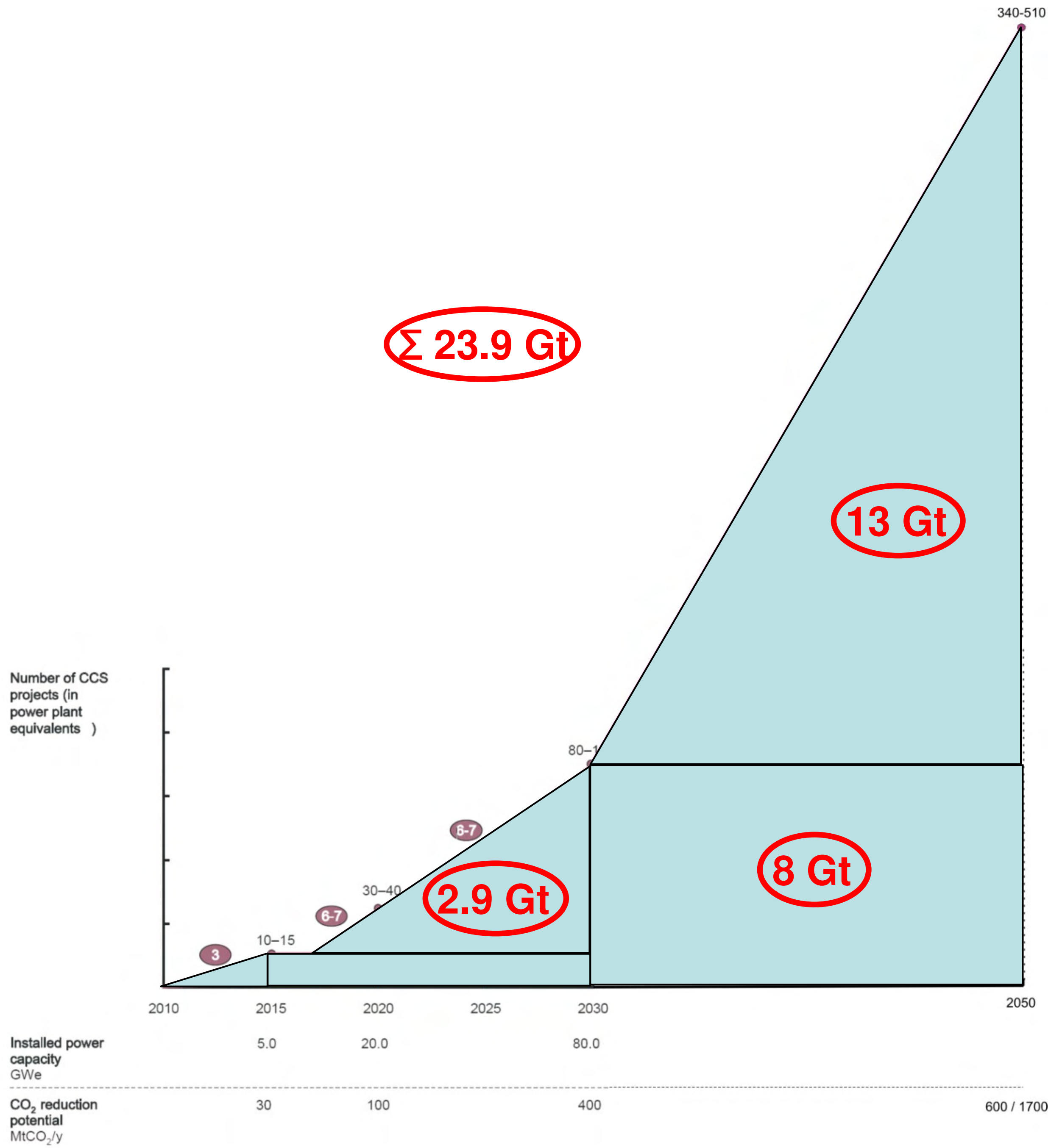


	2015	2020	2030
Installed power capacity GWe	5.0	20.0	80.0
CO_2 reduction potential $MtCO_2/y$	30	100	400

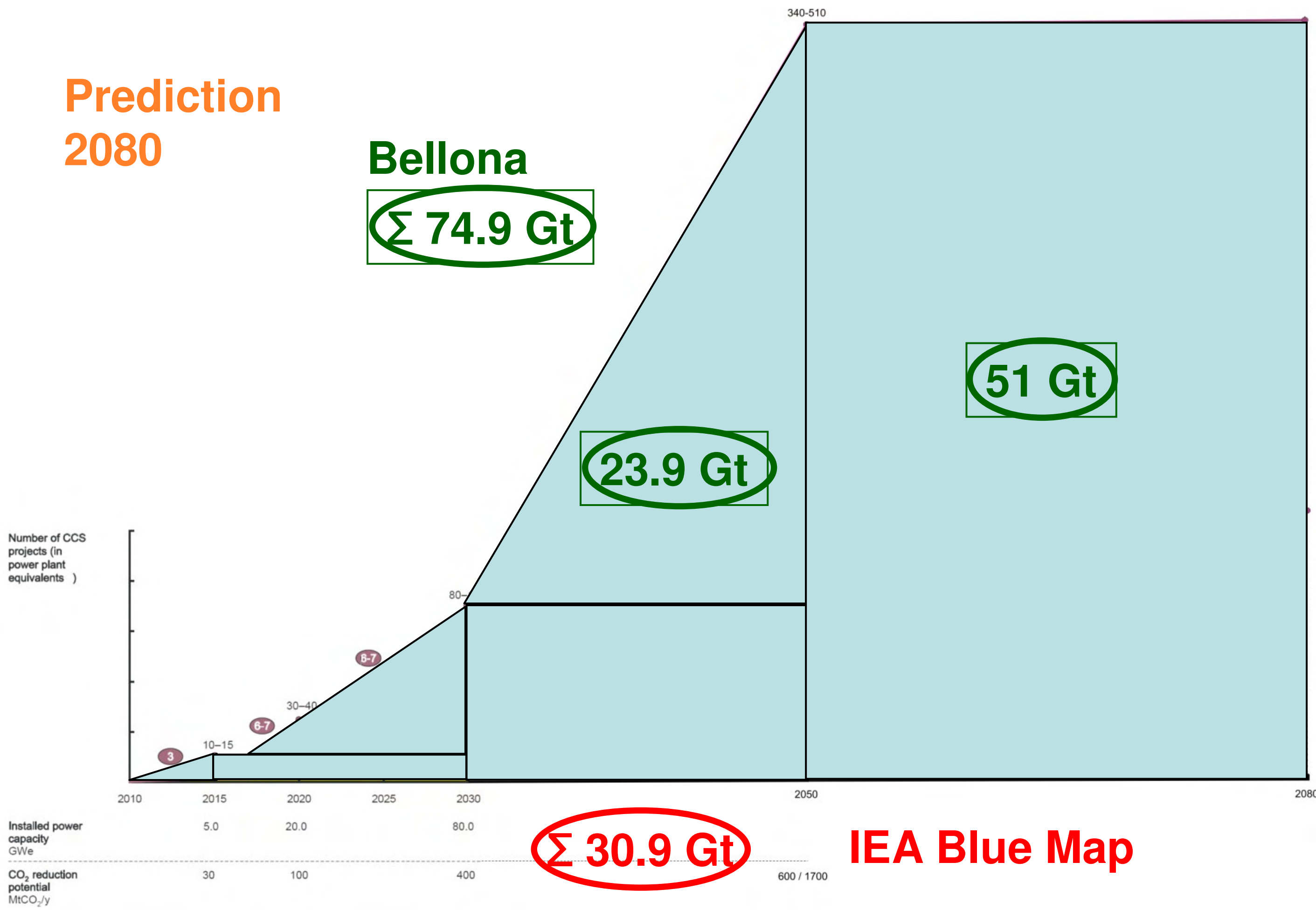
IEA Blue Map scenario 2050

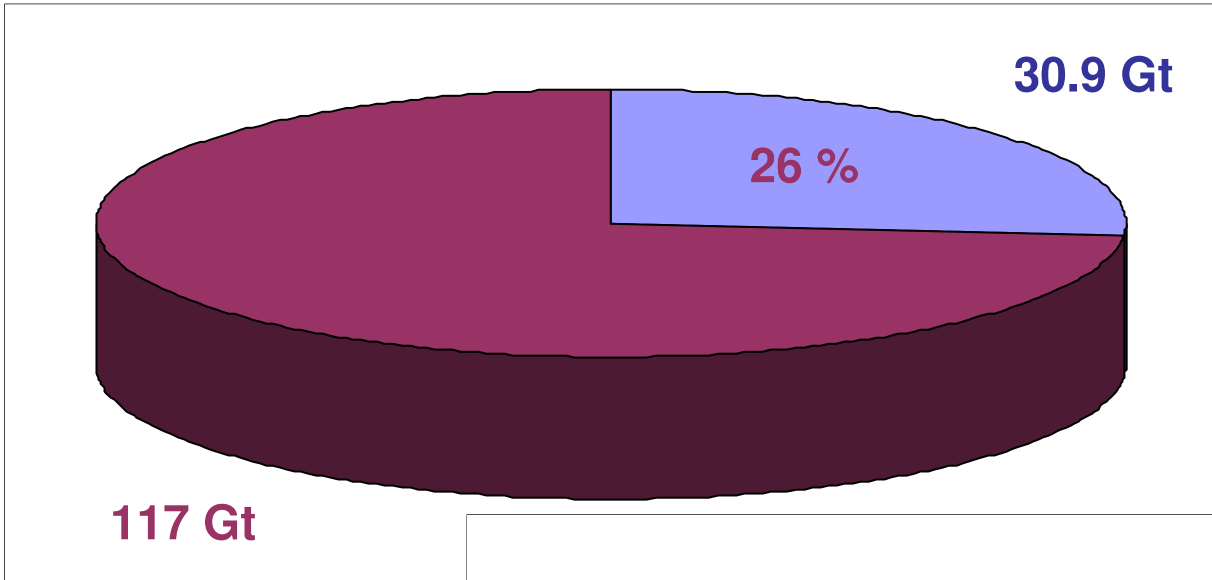


Bellona scenario 2050



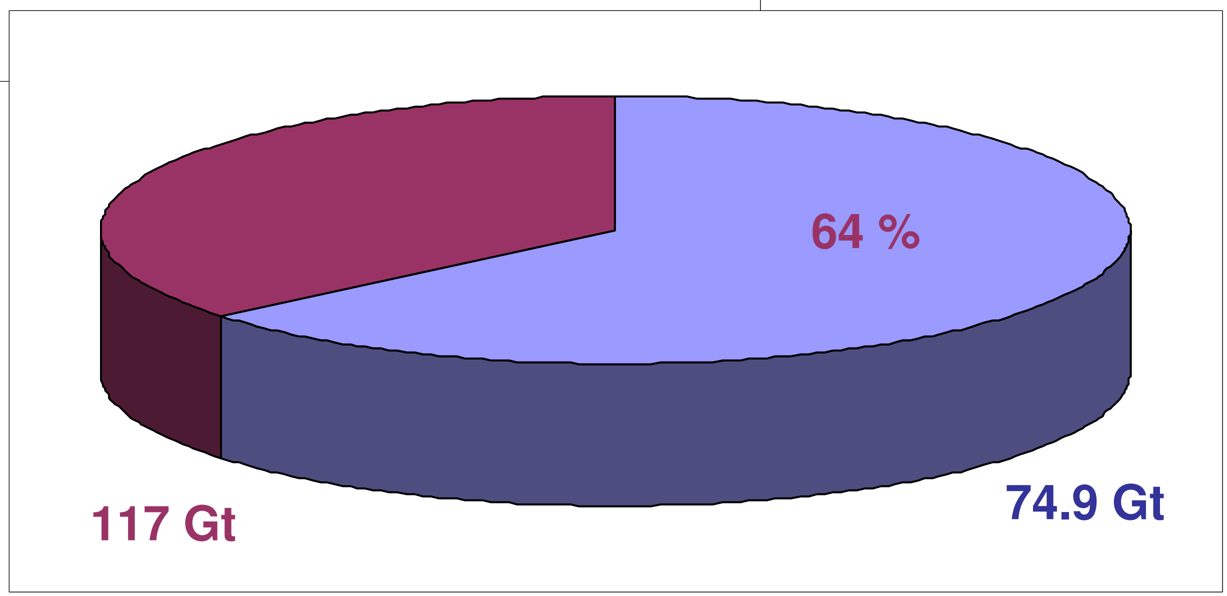
Prediction 2080



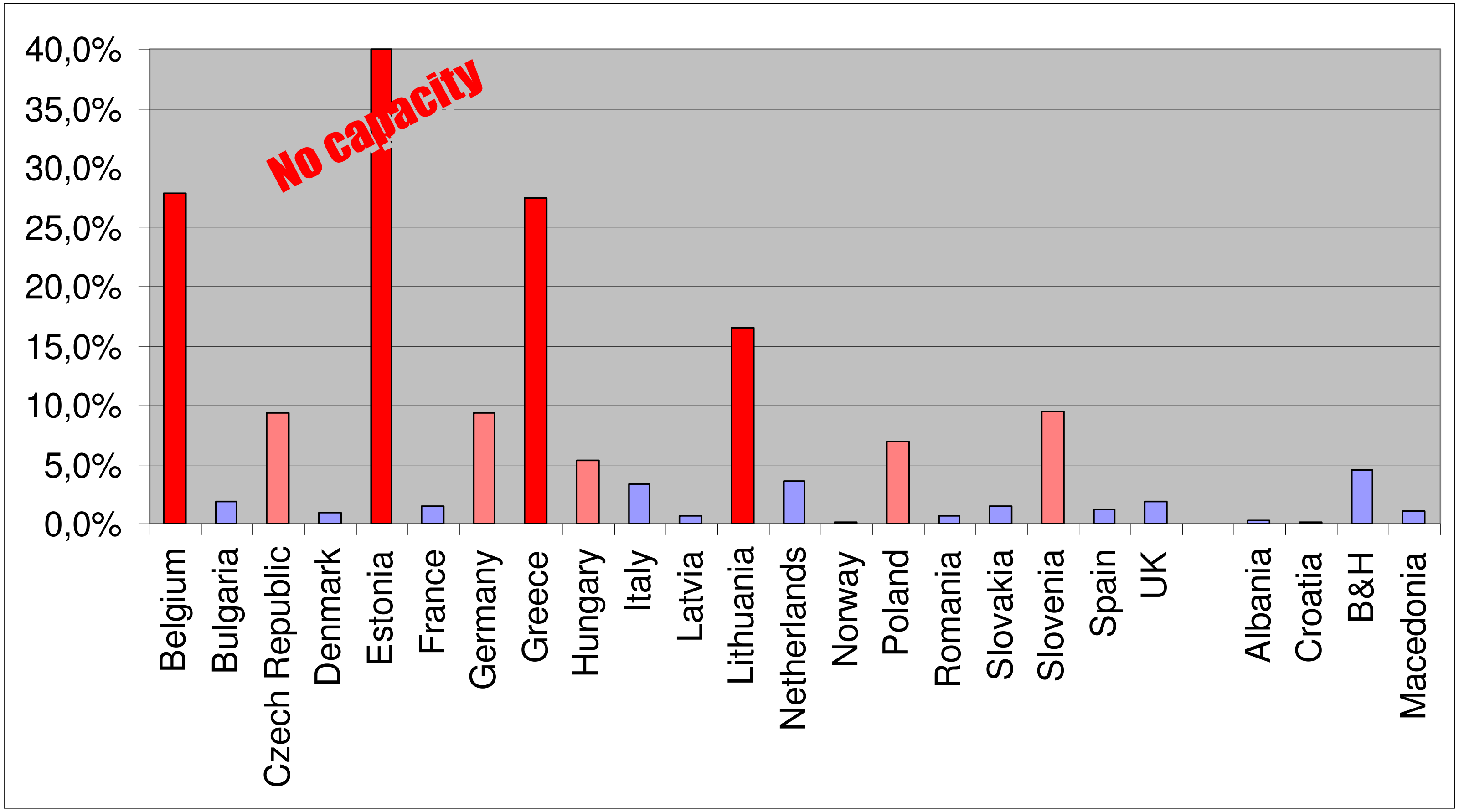


IEA Blue Map scenario

Bellona scenario



Ratio between reported CO_2 emissions (ETS, 2008) and storage capacity estimates per country



Conclusions

Conservative capacity for Europe is sufficient for storage of all CO_2 from current large point sources in more than 60 years, but:

- Ambitious CCS scenarios may suffer from lack of storage capacity
- Capacity estimations for aquifers are uncertain subject to storage efficiency factor and lack of practical experience
- Onshore storage will face difficulties due to conflicts of interest, various protection regimes and lacking public acceptance
- Several countries lack storage capacity, which hinders CCS implementation
- Some countries (incl. several big ones) may face lack of storage capacity in case of massive CCS deployment

Project website:

Assessing European Capacity for Geological Storage of Carbon Dioxide

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Home page

www.geocapacity.eu

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EU GeoCapacity

Assessing European Capacity for Geological Storage of Carbon Dioxide

Welcome to the website of the EU GeoCapacity Project. The main objective of the project is to *Assess the European Capacity for Geological Storage of Carbon Dioxide*. The project will include full assessments of a number hitherto not covered countries, and updates of previously covered territory. Also a priority is the further development of innovative methods for capacity assessment, economic modelling and site selection criteria. Finally, an important mission is to initiate scientific collaboration with China and possibly other CSLF members.

The GeoCapacity project will comprise all or parts of the sedimentary basins suitable for geological storage of CO2 and located within the EU and the Central and Eastern European new member states and candidate countries. In areas, which were part of the GESTCO project completed in 2003, the work will include only supplementary updates.

The project is co-funded by the EU within FP6 - the 6th Framework Programme of the European Community for Research, Technological Development and demonstration activities, contributing to the creation of the European Research Area and to innovation (2002 to 2006).

For more information not included in this web please contact

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Project News
The 5th Work Meeting took place in Heviz (Hungary) on 2-4 October 2008 in attendance of more than 30 participants.
More news...

Forthcoming Events
CCS events in 2008-2009
Calendar

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