Geological CO\textsubscript{2} Sequestration: Prognosis as a Clean Energy Strategy

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University Tor Vergata, Ingegneria, Course “CO2 transport and sequestration”
Introductory items

• CCS costs in and of itself, is not a barrier. The foremost economic barrier is the price of carbon.

• CO₂ is a resource. At the present time an important limiting factor in new CO2-EOR project is a shortage of CO₂.

• CO₂ currently injected for CO2-EOR in USA comes both from natural and anthropogenic sources, which provide 79% and 21% respectively of CO₂ supply (NETL, 2008). Historically, CO₂ purchases comprise about 33 to 68 % of the cost of a CO₂ EOR project, as much CO₂ as possible is recovered and transported to other ER facilities to be used again. However, a certain incidental amount of CO₂ remains underground.

• Currently 10 countries (China, US, India, Russia, Japan South Africa, Germany, Republic of Corea, Australia and Poland - ordered by annual emissions) account for 83 % of the Global CO₂ Emissions from coal use: these countries have to do the maximum CCS efforts.

• The recent established Global Carbon Capture and Storage Institute has catalogued and analysed potential CCS projects worldwide (Global CCS Institute, 2010). A total of 80 large-scale integrated projects in 17 countries: Algeria, Australia, Canada, China, Czech Republic, Finland, France, Germany, Republic of Korea, Netherlands, Norway, Poland, Spain, United Arab Emirates, United Kingdom and US)
IEA Road Map 2009 foreseen a multiple, synergic use of underground: who decides?

- CCS industry
- CCS power generation
- Nuclear 6% (nucl. wastes)
- Renewables 21%
- Power generation efficiency
- & fuel switching 7%
- End-use fuel switching
- End use electricity efficiency 12%
- End use fuel efficiency 24%

= technologies using underground

IEA Committee on Energy Research and Technology
EXPERTS’ GROUP ON R&D PRIORITY SETTING AND EVALUATION
The different industrial lobbies interacting with the use of underground, being a limited resource, have to plan its use in a synergical manner towards a sound energetic mixing.
Does a sound energy mix need a planned use of the underground geological structures?

- The Post-Kyoto energy revolution suggested by the IEA and IPCC urgently requires:
  - Clean Coal Technologies by adding CCS (CO₂ Capture & Storage);
  - Last generation Nuclear Power (up to IV generation) & geological disposal
  - Innovative renewables as deep geothermics (dry direct use) producing 365 day/year electric power;
  - strategic storage of natural gas (mostly for “noble” uses, not electric power).
Low carbon energy production requires:

- space;
- water:
- underground storage/heat flow volume;
- dedicated scientists (full “staff”)
- public awareness about technologies against the “NUMBY SYNDROME”
- energy mix planning “BEFORE” both at nationally and regionally (Italy towards “federalism”? …. But the underground structures are common among regions!!)

UNFORTUNATELY WE ARE LACKING OF ALL OF THAT REQUIREMENTS
Deep Geological Structures.

Can coexist CO$_2$-CH$_4$ storage, nuclear wastes disposal and geothermics?

Storage capacity of CO$_2$, CH$_4$, geothermics and nuclear waste. What Priority?

You have to PLAN the underground destination BEFORE storing geogas and nuclear waste (i.e. the IAEA criteria for nuclear waste disposal are not considering the CO$_2$ and CH$_4$ storing sites!!) European Community Research plans (now FP7) has to take care of that.... for the FP 8 planning!! Public awareness is required!
EXAMPLE: Why a so “perfect” structure should be destined to a CO₂ storage and not to a CH₄ one, irreversibly? (figures INGV-CNR IGAG)

Who plan ?? Who decide ??
Planning before define the storage/use priority !!!!
Public research could do it …
Awareness positive for public !!

es.: geological profiles along the Po basin.

concept of “LEARN BY DOING”
CO₂ storage/CH₄ storage

**SIMILARITIES?**

- Both CH₄ and CO₂ must be contained underground, i.e. they need cover rock.
- Both CH₄ and CO₂ need permeability (for injection) and porosity (for storage), i.e. they need reservoir rock.
- Both CH₄ and CO₂ need lateral containment, i.e. they need a structural trap.
- UNI norms EN-1918-1 are fit for both.
- Priority to CH₄ storage? Strategic reserves!
- Both can co-exist with shallow low enthalpy and very deep (5-6 km) EGS geothermics.
CO$_2$ storage/CH$_4$ storage
DIFFERENCES:

- CH$_4$ is stored to be retrieved (two ways)
- CO$_2$ is stored forever (one way)

- We need minimum trapping of CH$_4$ (minimum cushion gas)
- We need maximum permanent trapping of CO$_2$
European Directivity on CO\textsubscript{2} storage: hints from public research

- the first 10-20 years the CO\textsubscript{2} storage networking, monitoring and managing should be in public hands;

- Planning of subsurface versus energy should be done in densely populated countries (Europe): coexistence between CO\textsubscript{2} storage, natural gas (CH\textsubscript{4} strategic reserves storage, nuclear wastes storage, deep geothermics).

Why this Directivity is not strictly linked to the Natural gas storage and deep geothermics (exploration phase at least)??
- around 350 project recorded;
- around 80 integrated projects (G8 criteria for 20 demonstration projects to be implemented for 2020);
- around projects with post combustion;
- around projects with storage in saline aquifers.
EEPR CCS Project in Europe

Costs associated to storage have been estimated in USA to be approximately $0.4-20/tonne CO₂, depending on numerous factors, including type of reservoir, existing information/infrastructures for the site, onshore versus offshore storage, extent of monitoring, regional factors. Active projects: $11-17 per tonne (Sleipner); $20 per tonne (Weyburn), $6 per tonne (In salah).
EEPR projects based on costs of CCS by EU-ZEP data 2011

Levelized Cost of Electricity (LCOE) for Integrated CCS projects (coal and gas)

The Levelised Cost of Electricity (LCOE) of integrated CCS projects (blue bars) compared to the reference plants without CCS (green bars).

Includes three levels of EUA costs and is based on the following assumptions: costs for an OPTI plant with CO₂ capture; Middle fuel costs; 180 km onshore CO₂ transport; Medium storage costs for an onshore deep saline aquifer.
### Transport of CO₂

USA: 95% are within 50 miles of a possible storage site.

**Needs of pipelines:**
- 4-10 times the amount of CO₂ transport in USA in 2009 for CCS projects by 2020 and 2030 respectively (namely 180 and 480 million tonnes and from 13000 miles in 2020 to 36000 miles in 2030).

The longest existing pipeline system, the Cortez Pipeline, delivers CO₂ over a distance of 500 miles in the Permian basin of Texas, Colorado and New Mexico (Parformak and Folger, 2007). Other systems transport CO₂ along Gulf Coasts (Mississippi and Louisiana), through Colorado and Wyoming, from North Dakota into Canada, and in the Northern Michigan. In addition, there are many smaller CO₂ pipelines connecting sources with specific customers.

### Security

- **SCADA system:** control room management using Supervisory Control and Data Acquisition.

### Carbonic Acid Generation

The main problem of the generation of carbonic acid from ambient moisture in the pipeline.

### Design Considerations

- **CO₂ composition, impurities and phase behavior**
- **Line pipe material selection and fracture control & Excavation damages as primary cause of failures**
- **Valve, seal, elastomer and pumping material selection**
- **Thickness of the steel and use of mechanical crack arrestors**
- **Possible leak paths from the valves themselves**
- **Gaseous CO₂ must be odorized using hydrocarbon-based odorants.**

### CO₂ Transport Cost Estimates for Demo Projects

#### Table 1: Cost estimates (in €/t CO₂) for commercial natural gas-fired power plants with CCS or coal-based CCS demonstration projects with a transported volume of 2.5 Mtpa

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>180</th>
<th>500</th>
<th>750</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore pipeline</td>
<td>5.4</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Offshore pipeline</td>
<td>9.3</td>
<td>20.4</td>
<td>28.7</td>
<td>51.7</td>
</tr>
<tr>
<td>Ship</td>
<td>8.2</td>
<td>9.5</td>
<td>10.6</td>
<td>14.5</td>
</tr>
<tr>
<td>Liquefaction (for ship transport)</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
</tr>
</tbody>
</table>
Liability – Insurances - Indemnizations articulate all potential liabilities; CCS is unusual for insurances (too much site specific the storage part of CCS) - site specific risk assessment, that attempts to value potential liabilities and future costs (including such costs as the cost of long-term monitoring and any needed remedial action); create flexibility to account for site variability and be adaptive to accommodate learning; State liability - State ownership of underground pore space and relative storage projects; "Long term" liability arises during the post-closure period; local regimes for long-term liability transfer; if stakeholders know they will not face liability, such a circumstance arguably may create a disincentive to proceed in a safe manner and environmentally sound manner; the operator remains liable for damages related to CO₂ migration or leaks; how long? In USA two states (Washington and Wyoming) have disclaimed State liability from long-term CO₂ sequestration unless otherwise specified by law; monitoring for long-term the cleanup or other obligations; compensatory liabilities include tort liabilities under Federal/regional or State law pursuant to various personal injury or property damage theories; federal/regional legislation facilitating private insurance coverage for certain aspects and establishment of a liability funds for the long-term risks or risks known not enough; contract liability between parties; if future legislation imposes a variable price on CO₂ emissions a release of CO₂ could give rise to a claim for the replacement variable costs of lost CO₂; liability funds construction (i.e., Price-Anderson Act for nuclear industry as analogue)
European Platform ZEFFPP:
ZERO EMISSION FOSSIL FUEL POWER PLANTS (Eu-ZEP)

- Advisory Council
  - CO₂-Capture
  - Communication & Public Acceptance
  - Infrastructure & Environment
  - Market, Regulation & Policy
  - SRA/SDD Overseeing Responsibility
  - Strategic Research Agenda (SRA)
  - Deployment Strategy (DS)

- Mirror Group of Member States

- Coordination Group

- Secretariat

- SRA Responsibility:
  - Appert
  - Soothill
  - Valero

- SDD Responsibility:
  - Haege
  - Hill
  - Sweeney

Why the EU Platforms using underground (i.e. ‘ZEP’, renewables, IV generation nuclear, biomass) do not work together in some way?

Last news = ZEP Newsletter #3 - Apr 2010

Agreed
Cooptimization ECBM + saline aquifer + geothermics

ECBM Sulcis Project (Sardinia Italy)
Issues and Gaps I

- Non economic barriers could prevent projected CCS deployment, but public acceptance.

- Financial Incentives & carbon price. Lack of comprehensive climate change legislation is the key barrier to CCS deployment;

- Government intervention & means for overcoming or compensating for the market failure

- The private market has a limited incentive to invest in "shared learning" that would lead to an improved economic outcome for society as a whole

- Compensation of the parties for various types and forms of losses or damages that occur after the site closure & transfer of liability to the federal government after site closure

- Long term Liability and property rights (i.e., those arising after the closure of a CO2 storage site);

- Site specific risk assessment and liability, "learning by doing" concept: portion of the gain from that knowledge cannot be captured by the firm making the investment.

- Need to conduct a periodic review of CCS and identify any additional research, risk management or regulatory needs;

- Though CCS technologies exist, "scaling up" these existing processes: a typical 550 MW net output coal-fired power plant capturing 90% of the CO2 would capture about 5 million tonnes of CO2 per year:

- Creation of regional partnerships promoting CCS

Need to assist the Administration in targeting any remaining technology gaps;

- Need to define eligibility criteria for projects to receive federal/state support (i.e., peer review of the results, modeling tools and methods as well as sharing the results);
Issues and Gaps II

- Need to assist the Administration in targeting any remaining technology gaps;
- Need to define eligibility criteria for projects to receive federal/state support (i.e., peer review of the results, modeling tools and methods as well as sharing the results);
- CO₂ sequestration may potentially conflict with other subsurface uses, including existing and future mines, oil and gas fields, coal resources, geothermal fields and drinking water sources.
- Further efforts to generate a comprehensive, catalogue of national sequestration potential using their recently finalized methodology - including risks assessment objects (i.e., seismogenic sources, degassing sites, sink-holes; Buttinelli et al., 2010 as done in Italy).
- Early projects: data sharing (site selection criteria and monitoring) must be totally spreaded and available also to NGOs.
- Access to monitoring wells mostly in the offshore framework and corrective action on pre-existing wells.
- Access to world-class foreign researchers, who often look at the problems associated with taking a technology from the lab to the marketplace through different "lenses" : NO CLOSED LOBBIES (i.e., in Europe) YES NETWORK OF EXCELLENCE BASED ON PEER REVIEW SELECTION.
- Biomass co-firing with CCS towards "net negative"
CO2GAPS Vision proposed at EU FP7, by INGV and partners
CO2GAPS Vision proposed at EU FP7, by INGV and partners
GAPS in selecting pilot and demonstration test-sites: inland (better monitoring/modeling comparison) or offshore (better public acceptance) ??
Workflow of a typical project of CO$_2$ storage

Pre-Operation Phase
- Site Selection
- Site Characterization (SCP)
- Field Design
- ~ 5-6 year

Operation Phase
- Site Construction / Site Preparation
- Injection
- ~ 10-50 years

Post-Injection Phase
- Site Retirement Programme (SRP)
- ~ 100+ years

Only in Weyburn M&V done over a regional scale, but not fully complete nor a managed multidisciplinary approach. Still poor for public acceptance.
Storage of CO$_2$ is highly site specific

Aquistore – Deep Saline Aquifer Project

- Demonstrate CO$_2$ storage in deep saline formations is a safe solution for emissions reductions.
- Develop a transportable, integrated suite of technologies
- Create linkages among financial institutions developing trading mechanisms; policy makers; industry and public acceptance.

Current project runs from December 2007 – December 2008

Capture 600 t/d

Transport CO$_2$ injection site.

CO$_2$ injection into deep saline aquifer from depth.

Implement comprehensive Measurement, Monitoring and Verification Program.

- Construction of Demonstration Pilot Plant
- Design and construction of CO$_2$ capture facility
- CO$_2$ capture from two pilot scale retrofits of Mature Refineries
- Construction of upgrader complex
- Plant expansion
- Enhanced capture process
-工程项目潜能600 t/d; potentially up to 1600 t/d
  - > 99% purity CO$_2$
- Delivery of CO$_2$ late 2012 or 2013
- SaskEnergy & Enbridge to build pipeline

$3.5$ billion being allocated in public funding from federal, Alberta and Saskatchewan governments for large demo projects
Six sites have been selected in Europe in the frame of EEPR European Energy Programme for Recovery.

Not only power plants could have access to CCS but also refineries, cement and steel plants, biomasses: trace contaminants in flue gas could be different. **Co-sequestration concept**

Trace contaminants are really natural! Welcome underground!
**CO₂ Flue Gas contaminants**

- Different CO₂ streams will have different compositions. For example, certain industrial processes (e.g., ammonia production and biofuels production) produce streams that are nearly pure CO₂.

- Natural gas combustion also produces a relative pure waste stream.

- Purity of the injected CO₂ stream is a consideration for storage because co-captures impurities could affect the storage processes.

- Excess O₂ (oxyfuel) in the CO₂ sequestration stream.

- Arsenic, lead, selenium, cadmium, mercury organic compounds.

- H₂S, SO₂, NOx, NH₃, organic matter. H₂S is known to promote steel corrosion.

- Note that "a solid waste is a hazardous waste if it is a listed hazardous waste or exhibits any of four characteristics (ignitability, corrosivity, reactivity or toxicity)"
GAPS in merging modeling: mass transport, geochemical and geomechanical
3D modeling must consider very carefully the fault peculiarities (porosity, permeability, mechanics)

3D Depth View Top Scaglia Calcarea (Eocene) con Sovrascorrimento
Merging modeling software: mass-transport, geochemical and geomechanical

CO\textsubscript{2} underground move, react and trigger failures: at present does not exist a unique software allowing doing it to the injected gas
Rock Physics and Geomechanics applied to thermo-hydro-mechanical processes

Characterisation of rock samples

- Microstructural state of rocks (e.g., porosity; density; voids space; mineralogy)

- Dynamic elastic moduli
- Seismic inner structure

Vinciguerra et al., IJRM, 2005

Permeability/velocity under increasing effective pressure

- Full inversion (elastic wave velocities, porosity, and permeability)
Benson et al., JGR 2006,
Vinciguerra et al., Pageoph, 2005

Mechanical parameters

- UCS
- Static elastic moduli
- Thermo-chemical reaction and mechanical parameters

Heap et al., Tectonophysics, 2008
Benson et al., GRL, 2007
- Degradation of elastic moduli under cyclic stress

Seismic signals and thermo-hydro-mechanical coupling

Monitoring microearthquakes during:
- Faulting
- Fluid Flow

Burlini et al., Geology, 2007
Benson et al., 2008

'Microseismic' (AE) event
Micro-earthquakes in the laboratory

High Frequency

(A) Photo shows broad, complex fault zone from linking of many microcracks.
(B) AE locations superimposed on fault showing good spatial agreement

[Grey box and white line indicate volume investigated in CT scan and plane of projection in (D)]

High resolution X-ray CT scans of the deformed sample, with AE (black dots):

(D) Fault zone and large crack (X) appear as lighter colour due to lower local density

(C + E) Orthogonal elevation views of the fault zone and large crack
Key mechanisms in thermo-hydro-mechanical coupling of rocks to be investigated in the laboratory

- Compaction, dilatancy and failure modes
- Localized and distributed deformation
- Coupling of mechanical response with fluid flow
- Fracture growth, interaction and network development
- Thermo-chemical reactions, high temperature fluids and rock deformation
- Geophysical/geochemical signatures and deformation processes
GAPS in monitoring strategies and choice of a sound “leakage and induced seismicity early alarm” system
“Public Acceptance”: INGV monitoring in Weyburn deep reservoir and soil gases to discriminate CO₂ leakage

“Oil waters”

“Soil gas”

“Reservoir” profondo tramite sismica 4D and microseismicity
The 300 Italian Diffuse Degassing Structures could be considered as 300 “failure” in selecting CO$_2$ storage sites in the past: risk managed in Italy since decades.

Public awareness could start from the natural flux of CO$_2$
Monitoring tools already exist: maximum expertise in Italy being full of CO₂ underground (faults, volcanoes)

INGV installed more than 200 monitoring station over the Italian territory (CO₂ related parameters under monitoring h24 on line)
Low cost and highly efficient monitoring in inland and offshore: research... no commercial

No remote control of CO\textsubscript{2} from far field (Lidar, Eddy Covariance, etc.)

No complex seabottom stations (i.e., benthic laboratory). Too much punctual, too much costly...?
Offshore strategies could be cheap

(INGV have different criteria against some commercial European lobbies)
Prototipi Geochemical Monitoring System (GMS 2-GMS3)

UF “Fluid Geochem., Geolo. Storage and Geothermics, Section Seismology–Tectonophysics, INGV
Seismic detection of CO$_2$ leakage along monitoring wellbores

Bohnoff et al., 2010

Detection of non shearing events (no S) can be used as a precursor of leakage
It is possible that during strong-moderate earthquakes the deeply injected CO\textsubscript{2} could squeeze out as a burst? NO!
GAPS in the CCS communication and “public awareness”
CO$_2$ is not a waste!

It is a climate-alterant gas.
GAPS in the CCS communication and “public awareness”

Non-economic barriers could prevent projected CCS deployment.: two main fears: induced seismicity and escaping/leakage of CO$_2$

- CCS project cancelled (case histories: Spremburg, Germany, Greenville, Ohio, Barendrecht, Netherlands, etc...)
- Whether the public will support or oppose commercial-scale CCS projects is largely unknow (Malone et al., 2010) and the public reaction may be project-specific.
- public is less likely to trust information coming from a single source, particularly coming solely from industry or government;
- the public feels that several factors serve to widen the gap between the social and private returns to CCS technology development.

Elements of a successful outreach strategy

- integrating public engagement and education into core project management systems from the earliest possible point in time. "Best practices guide for public outreach and education for carbon storage Projects" (DOE 2009, INGV, 2010, 2011);
GAPS in the CCS communication and “public awareness”

- provide easily *accessible information* about CCS projects;
- engage the community during the planning stage and *maintain engagement throughout the project lifetime*;
- communicate the potential benefits of future CCS projects as job creation and stimulus to the *local economy*, and decrease in local air pollution;
- provide local communities with *several opportunities to raise concerns*, and address those concerns in a timely manner;
- focus on creating an open dialogue with the public, as opposed to a one-sides conversation;
- create mechanisms and systems to *monitor and gauge public reactions and opinions*;
- discuss *why CCS is important* (climate risks, need for sufficient and reliable energy);
- misinterpretation above this new technology: the monitoring case history… *information about monitoring influence negatively, in a first stage, not local, the laypeople’s perception of CCS* (Quattrocchi, 2009; Selma L’Orange Seigo, 2011)
- there can be interaction effects between the content and the sender of communication (Euristic affect). Future research should investigate the possibility that the *effect of monitoring information depends on the communicator*.
- Match communication strategies to the mental models of the people (gender differences in CCS have been highlighted): i.e., *higher risk perception induced from more information*…
- More information does not always lead to views that are more balanced and might even
The better communication of the CCS technologies, and in particular of the storage part of CCS, passes through the faith to who is communicating the technology: public research accredited people.
Short communication

Communication of CCS monitoring activities may not have a reassuring effect on the public

Selma L’Orange Seigo*, Lasse Wallquist, Simone Dohle, Michael Siegrist

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Available online at www.sciencedirect.com

Energy Procedia


www.sciencedirect.com/locate/procedia

GHGT-9

Communication Strategy for a public information campaign on CO₂ geological storage and on CCS as a whole: the case history in Italy from 2003 to 2008

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• Seismicity (INGV Catalogs CSI–CFTI–CPTI–NT 4.1–ISIDE–WAVES)
• Seismogenic segments (DISS 3.0.2.2)
• Diffuse Degassing Structures (DDS) INGV catalogue

Closer identification the real national storage capacity of CO₂
I processes base riconosciuti da noi geologi essere importanti nel muovere verso la superficie del suolo dei geogas naturalmente o industrialmente conservati nel sottosuolo (processi noti come: leakage e seepage) attraverso gli strati di roccia del sottosuolo ed I sedimenti sono: la diffusion, la advezione, oltre alla convezione.

Se il trasporto attraverso il mezzo (roccia e acquiferi) avviene per diffusione, il flusso stazionario, diffusivo, $\Phi_d$ è proporzionale al gradiente di concentrazione, $dC/d\lambda$, come espresso dalla Legge di Fick:

$$\Phi_d = -vD(dC/d\lambda) \quad (1)$$

Dove $v$ e $D$ rappresentano la porosità del mezzo (i.e., la frazione di volume di poro rispetto al totale del volume del suolo o della roccia e il coefficiente di diffusione rispettivamente, il segno meno indica che le molecole di gas (CO2) si muovono verso l’alto cioè dal punto a maggiore concentrazione al punto a minore concentrazione. Al contrario, l’advezione implica movimento di massa conseguente ad un gradiente di pressione $dP/d\lambda$. Il flusso advettivo $\Phi_a$ è descritto dalla Legge di Darcy:

$$\Phi_a = (k/\mu)(dP/d\lambda) \quad (2)$$
Start to communicate the CCS maximum risk as very near to the natural one: human beings coexist with this kind of low risk from millennia.

Picture of the ENEL Torrevaldaliga coal-fired power plant, which was object of a CO₂ storage feasibility study: the little hill, highlighted by the red arrow is an ancient travertine deposit, accumulated in thousands years, due to a CO₂ leakage pathway located in the caprock of the deep saline aquifer, enriched by natural thermometamorphic CO₂ (TRAVERTINE = CaCO₃): this is a typical example of CO₂ sequestration at surface when a deep CO₂ reach the surface together with the hot saline water coming from the deep reservoir, as natural leakage point in a geometric form in a “new rock hill”.

People of the Torrevaldaliga surroundings! It is dangerous a little hill of a precious travertine arisen from CO₂? NO. We use travertine for building luxurious tables in our houses.

WE HAVE TO START FROM THIS “EURISTHIC AFFECT” MESSAGE FOR THE STORAGE ACCEPTANCE.
Conclusions on communication strategies

Only when all gaps are filled and discussed together, step by step (learning by doing) the people will fully accept the storage part of CCS.

Prezzi gas Italia: “Non c’è solo il caro petrolio”

Meno capacità dell’Europa, l’effetto Libia, le strategie dell’Eni nei commenti degli operatori. Ipotesi capacity release.

Le batterie dell’Enea

Con la Robin Tax al centro.

Ma c’è il nodo costo.

L’intervento “Economic geology” di Enzo Boschi* e Fedora Quattrocchi**

Dopo il sisma del Giappone, accanto ad una ovvia revisione ma anche una obbligata continuazione della ricerca nel campo nucleare, fosse solo per lo smaltimento dei rifiuti ancora sparsi sul nostro territorio ed il know how da e verso l’estero, con imprese italiane attive, in primis Ene, nuove parole si imporgono più di “nucleare”, nello scenario energetico italiano.
CONCLUSIONS I

• The complexity and novelty of CCS may present a formidable challenge to agencies in dealing with uncertainty in science and risk assessment, missing information, and consideration of new risks to human welfare or to the environment from the deployment of CCS. This last item is partially true in countries very well dealing since centuries with high CO2 content underground (volcanic and geodynamically younger countries).

• The integration of CO2 Capture, transportation and permanent sequestration at commercial-scale, coal-fired power generating facilities has not yet been demonstrated but very close (2015);

• Ultimately an honest assessment of a project’s risks and uncertainties is very necessary for CCS.

• The main question for the future legal controversial will be: the harm is or not in fact caused by the storage site, but would have occurred without the storage activity. A full baseline monitoring is the main sound pre-requisite.

• RD&D and learning by doing could transform CCS from a technology only affordable to industrialized nations to a cost-effective GHG mitigation option with a global impact.
CONCLUSIONS II

• The role of public research is strategic: efforts early in the process are necessary working with trustworthy messenger is an important first step since the credibility of the person or organization delivering the information can make a significant difference how the public reacts.

• No market is expected to develop for reuse (mineral carbonation, conversion of CO₂ in biofuels as methanol, urea production, ceramics, fertilizers, polyurethane and polycarbonate production) of CO₂ on a scale that would significantly affect the strategy to roll out CCS on a national basis by 2016.

• By 2016 in USA, Europe, Australia, China, etc.... complete small-scale field testing of 2nd generation CO₂ capture technologies and components that demonstrate significant reduction in CO₂ capture cost and energy penalties compared with current technologies. The field testing will be between 0.5 to 5 MWe scale from pilot plant facilities and/or slipstream at operating coal-based power plants.
FINAL CONCLUSIONS

- Importance of the deep geological structures.

UNDERGROUND VALUE

- CCS must be implemented widely and quickly as «BRIDGE» tech: ONLY BY SYNERGIES WITH OTHER ENERGY LOBBIES

- The mentioned technologies can coexist underground. PLANNING BEFORE

- «Risk objects» in the potential sites catalog

WHY SO LOW PUBLIC MONEY ON IT? ....

- We have 20 YEARS and we are in delay
CONCLUSIONS FROM A POLICY MAN

Coal with Carbon Capture and Storage: The Low-Cost, Low-Carbon Solution

“Clean coal technology is something that can make America energy independent. This is America. We figured out how to put a man on the moon in 10 years. You can’t tell me we can’t figure out how to burn coal that we find right here in the United States of America and make it work.” – President Barack Obama