Project no : SES6-CT-2004-502816

CO2GeoNet

Network of Excellence on Geological Sequestration of CO_2

Instrument : Network of excellence

Thematic Priority : FP6 – 2002 – Energy 1, Sustainable Energy Systems

Publishable Final Activity Report

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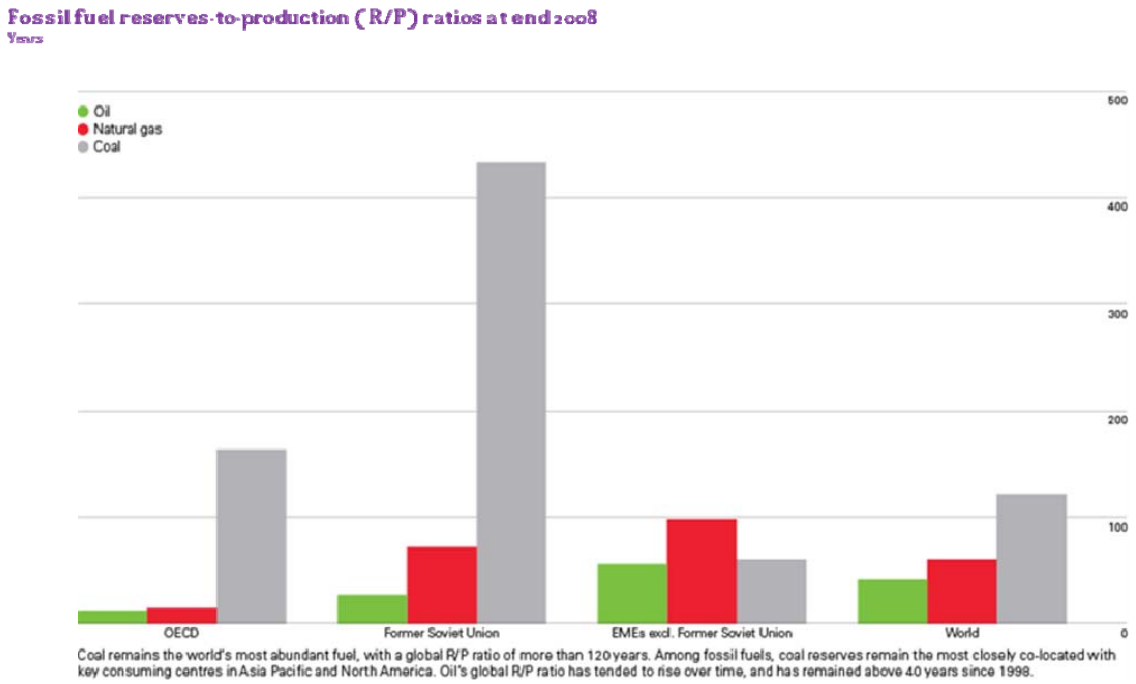
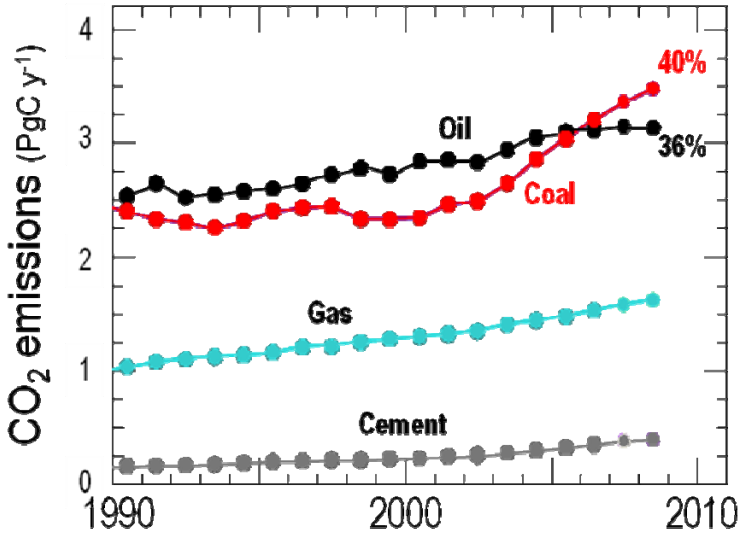
Project coordinator name : Dr Nicholas Riley
Project coordinator organisation name : British Geological Survey (NERC)

The need for European research in geological CO_2 storage & the focus of CO2 GeoNet

This Network of Excellence called "CO2GeoNet" (comprising13 institutes from 7 countries, with over 300 researchers involved in CO_2 storage) received an Grant of €6m over 5 years from April 2004 until March 2009. The Network also invested €4.5m of its own resources (target was €3m) during this period. The Network contains a critical mass of research activity in the area of underground geological carbon dioxide (CO_2) storage of CO_2 captured from large stationary sources such as power plants, cement works, metal smelting, oil & gas production, petrochemical refining and hydrogen production. The whole chain process is known as Carbon Capture & Storage (CCS). Effective geological storage of CO_2 is the most crucial part of the CCS chain as significant leakage from storage would undermine the whole point of investing in CO_2 capture as a greenhouse gas mitigation technology. It is also possible that leakage might cause harm to people and ecosystems, hence understanding the meachanisms by which leakage may occur & can be avoided, as well as being able to detect leakage, should it occur, and its impact is a very important aspect of research. It is difficult to see how the world can reduce emissions at the required rate from the present day out to 2050 and beyond without the deployment of CCS. Fossil fuels will remain a significant component of world primary energy supply for the foreseeable future, with coal being the most emission intensive and abundant fossil fuel.

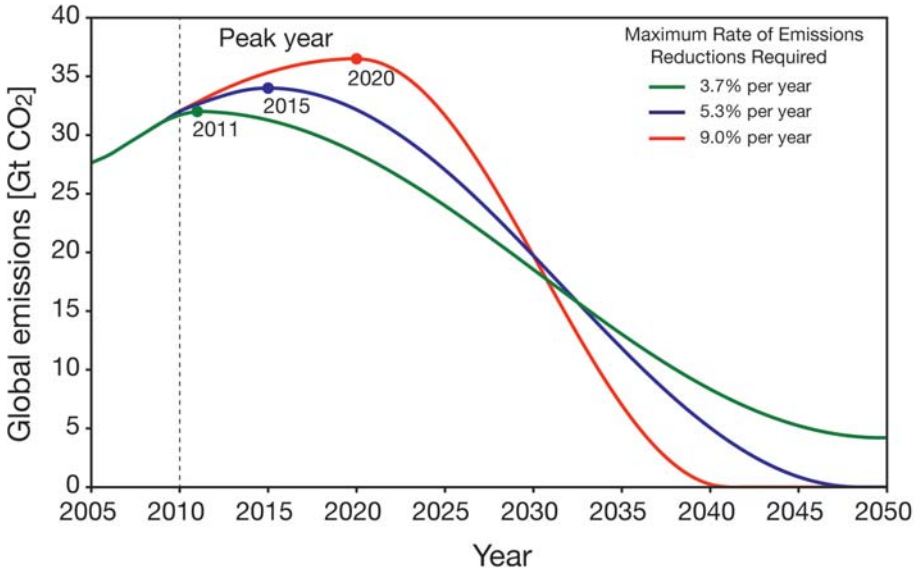


World fossil fuel reserve/production ratios for 2008. Note the dominance of coal with more than 120 years of reserves at present consumption rates and economic conditions (source- BP world energy statistical review 2009).

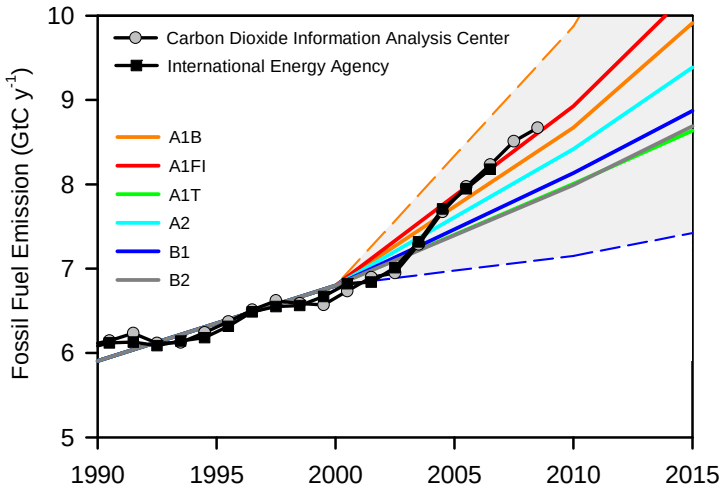


CO_2 emissions from coal have now overtaken oil & gas. This trend is set to continue as coal's share of the fossil fuel mix increases. (source Global carbon Project 2009)

In the future it may be possible to remove CO_2 directly from the atmosphere and store the captured CO_2 underground (Royal Society report on geoengineering, Sept 2009), which indicates that CO_2 capture directly from air, or indirectly using waste biomass, could be a negative emission technology retained beyond the period of fossil fuel use. The Copenhagen Diagnosis (2009) produced a briefing document to inform world leaders attending the UNFCC Conference of Parties (COP15). The document states that*: "If global warming is to be limited to a maximum of 2 °C above pre-industrial values, global emissions need to peak between 2015 and 2020 and then decline rapidly. To stabilize climate, a decarbonized global society – with near-zero emissions of CO_2 and other long-lived greenhouse gases – needs to be reached well within this century. More specifically, the average annual per-capita emissions will have to shrink to well under 1 metric ton CO_2 by 2050. This is 80-95% below the per-capita emissions in developed nations in 2000."* Limiting global warming to a maximum of 2^{o}C above pre-industrial is the policy commtment of Europe and the G8. Most policy commentators (e.g. IEA) envisage that widespread deployment of CCS as a routine technology needs to be underway by 2020 in order to obtain the required global emission reduction pathway. Europe has committed itself to hosting 12-15 large scale CCS demonstration projects to help faciliate this objective.



Examples of global emission pathways where cumulative CO_2 emissions equal 750 Gt during the time period 2010-2050 (1 Gt CO_2 = 3.67 Gt C). At this level, there is a 67% probability of limiting global warming to a maximum of 2°C. The graph shows that the later the peak in emissions is reached, the steeper their subsequent reduction has to be. The figure shows variants of a global emissions scenario with different peak years: 2011 (green), 2015 (blue) and 2020 (red). In order to achieve compliance with these curves, maximum annual reduction rates of 3.7 % (green), 5.3 % (blue) or 9.0 % (red) would be required (relative to 2008). (Source: German Advisory Council on Global Change; WBGU 2009).

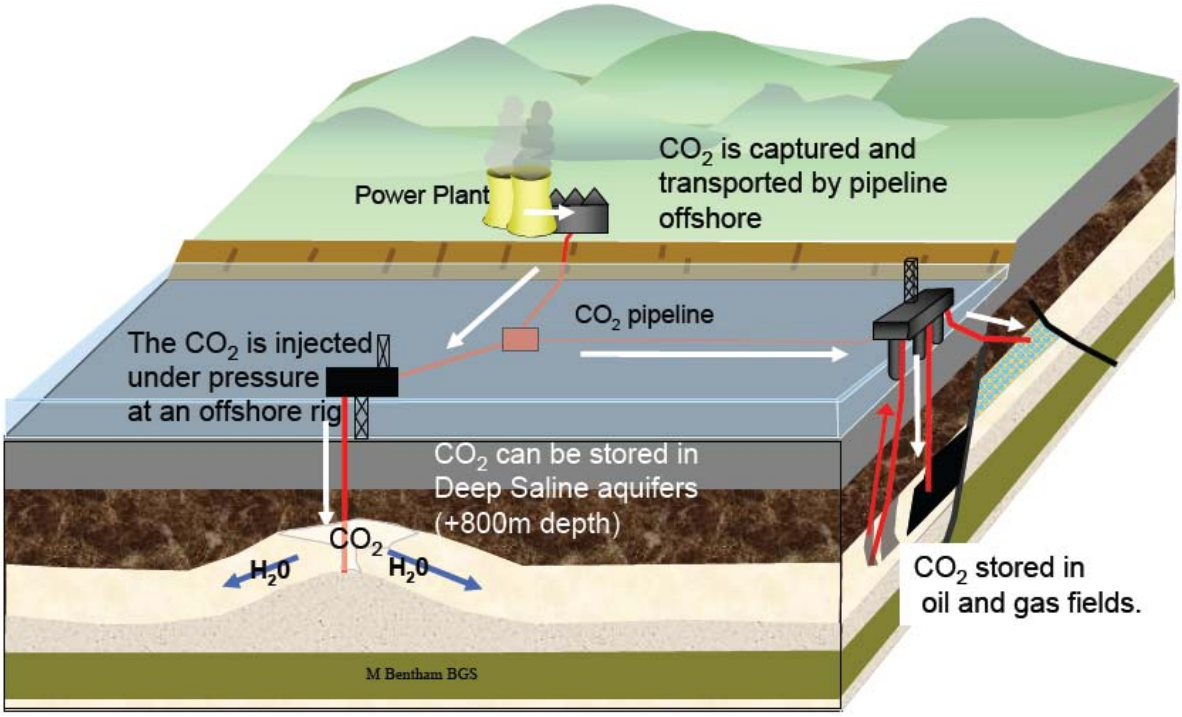


The world is failing to curb emissions using present policy and technology deployment. Emissions are tracking at the worst case (A1B) IPCC scenario despite the recent global recession. Without CCS it will be impossible to deal directly with fossil fuel emissions at the scale required, if fossil fuels remain a significant component of world primary energy out to 2050. (Global Carbon Project, Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature-geoscience; International Monetary Fund 2009)

Since the early 1990's through the European Commission's Joule 2 and Framework 4 & 5 projects, Europe has led the world on R&D in geological CO_2 storage, with rapid growth since 2000. National programmes in Europe's Member & Associated States are also

accelerating; most notably France, Germany, Denmark, The Netherlands, the Republic of Ireland, the United Kingdom and Norway. Research programmes in new member states such as Croatia, Hungary, Poland & Romania are also gaining momentum. This growth in research has a downside, by creating fragmentation through diversification. The Network of Excellence (NoE) Instrument was introduced in the Framework 6 Programme. It was specifically designed to enable a durable integration of Research Institute activities, to counteract fragmentation. Unlike ERA-NETs, which are formed from collaboration between government research funders of countries within the ERA-NET topic, the NoE instrument can be a bottom up process, formed from high quality, strategic, research partners aligning their research together, and building capacity by sharing, developing, working together and integrating their research infrastructure, knowledge, experience, staff and postgraduates. The NoE instrument also differs from Thematic Networks, as TMs have a more limited remit, primarily that of information sharing & dissemination amongst stakeholders within the topic. The NoE has a role for spreading excellence in CO_2 storage research across the European Research Area and beyond Europe. Research programmes in N. America, Australia, China & Japan have also `grown significantly during this decade and the NoE has collaborated with them. This is excellent, as the technology of CCS needs to be deployed world wide, bearing in mind the global dominace of fossil fuels that will remain in the primary energy mix over the coming decades. An aim of CO2GeoNet is to integrate, strengthen, and build upon the momentum of previous and existing European R&D in geological CO_2 storage, as well as project European excellence internationally, so as to ensure that Europe remains at the forefront leading to implementing large scale CO_2 storage in a timely and safe manner.

Today, CO_2GeoNet's activities continue to span joint research, training, providing scientific advice, and communicating information to stakeholders and the wider public. This includes site selection and characterisation, modelling and monitoring of CO_2 movement and site behaviour, as well as risk assessment, including potential impacts of CO_2 storage on ecosystems and the local environment. Its strength lies in its ability to harness a truly multi-disciplinary team of specialists (the most experienced in Europe) covering every facet of CO_2 geological storage. In June 2008, the Network was transformed into a non-profit, legally registered Association under French law. This milestone marked a major step in achieving durability of the CO_2GeoNet Network of Excellence beyond the end of the five-year EC contract, thus reinforcing its identity as the European scientific research authority on CO_2 geological storage. Through the lifespan of the Framework 6 funding of CO2GeoNet, Europe enlarged and the Carbon Capture & Storage Directive came into being. The Network is now in a position to expand its membership to other strategic research institutes across Europe. It also wants to play its part to help ensure that the CO_2 storage is effectively deployed within those member states that wish to geologically store CO_2. The network will also continue to be an important voice for the European CO_2 storage research community to communicate to policymakers, industry & the public, and it will also continue to foster collaboration and knowledge exchange internationally.



CO_2 Capture and Storage (CCS) requires the capture of CO_2 emitted from large point sources such as power plants, oil refineries, cement works, oil & gas production, metal smelting, and hydrogen production. The CO_2 is usually sent by pipeline and injected through boreholes into a geological formation which has a large enough volume to receive the CO_2 and the appropriate geology to retain the CO_2 for thousands of years. The main geological targets are salt water filled aquifers (saline aquifers), and oil and gas fields. These can be located onshore or offshore (as in the above diagram).

The network's objectives

CO2GeoNet had several objectives over the 5-year period of EC funding

- To form a durable and complimentary partnership comprising of a critical mass of key European research centres whose expertise and capability becomes increasingly mutually interdependent. The initial partnership was between 13 institutes, most of whom have a long and established history of research in geological storage. Some new players are also included, either because they are expected to have significant national strategic profile in future CO_2 storage projects, or have capabilities which can be realigned to strengthen the Network, or even bring uniqueness. For the first time in an EC Framework project, marine and aquatic biologists are drawn into this research topic.
- To maintain and build upon the momentum and world lead that Europe has on geological CO_2 storage and project that lead into the international arena.
- To improve efficiency through realignment of national research programmes, prevention of duplication of research effort, sharing of existing and newly acquired infrastructure and IPR.
- To identify knowledge gaps and formulate new research projects and tools to fill these gaps.
- Seek external funding from national and industrial programmes in order to diversify, build and strengthen the portfolio of shared research activities.
- To provide the authoritative body for technical, impartial, high quality information on geological storage of CO_2, and in so doing enable public confidence in the technology, participate in policy, regulatory formulation and common standards.
- Provide training to strengthen the partners, bring in new Network members and sustain a replacement supply of researchers for the future.
- To exploit Network IPR, both as a revenue earner to sustain the Network and to equip European industry to be competitive in the emerging global low carbon energy markets.

The network comprises the following 13 partners:

Denmark
Geological Survey of Denmark and Greenland – GEUS
France
Bureau de Recherches Geologiques et Minieres- BRGM
Institute Francais du Petrole – IFP
Germany
Federal Institute for Geosciences and Natural Resources – BGR
Italy
Istituto Nazionale di Oceanografia e di Geofisica Sperimentale- OGS
Università di Roma "La Sapienza" - URS
Netherlands
Netherlands Organisation for Applied Scientific Research – TNO
Norway
Norwegian Institute for Water Research – NIVA
International Research Institute of Stavanger – IRIS*
SINTEF Petroleumsforskning AS – SPR
UK
British Geological Survey (BGS- Natural Environment Research Council) **Co-ordinator**
Heriot-Watt University – HWU
Imperial College of Science, Technology and Medicine- IMPERIAL

Further information can be obtained at www.co2geonet.eu, or by contacting the Co-ordinator, Dr. Nick Riley at njr@bgs.ac.uk, tel +44 115 9363312

**(previously known as Stiftelsen Rogalandsforskning - RF)*

Joint Programme of Activities Years 1-5

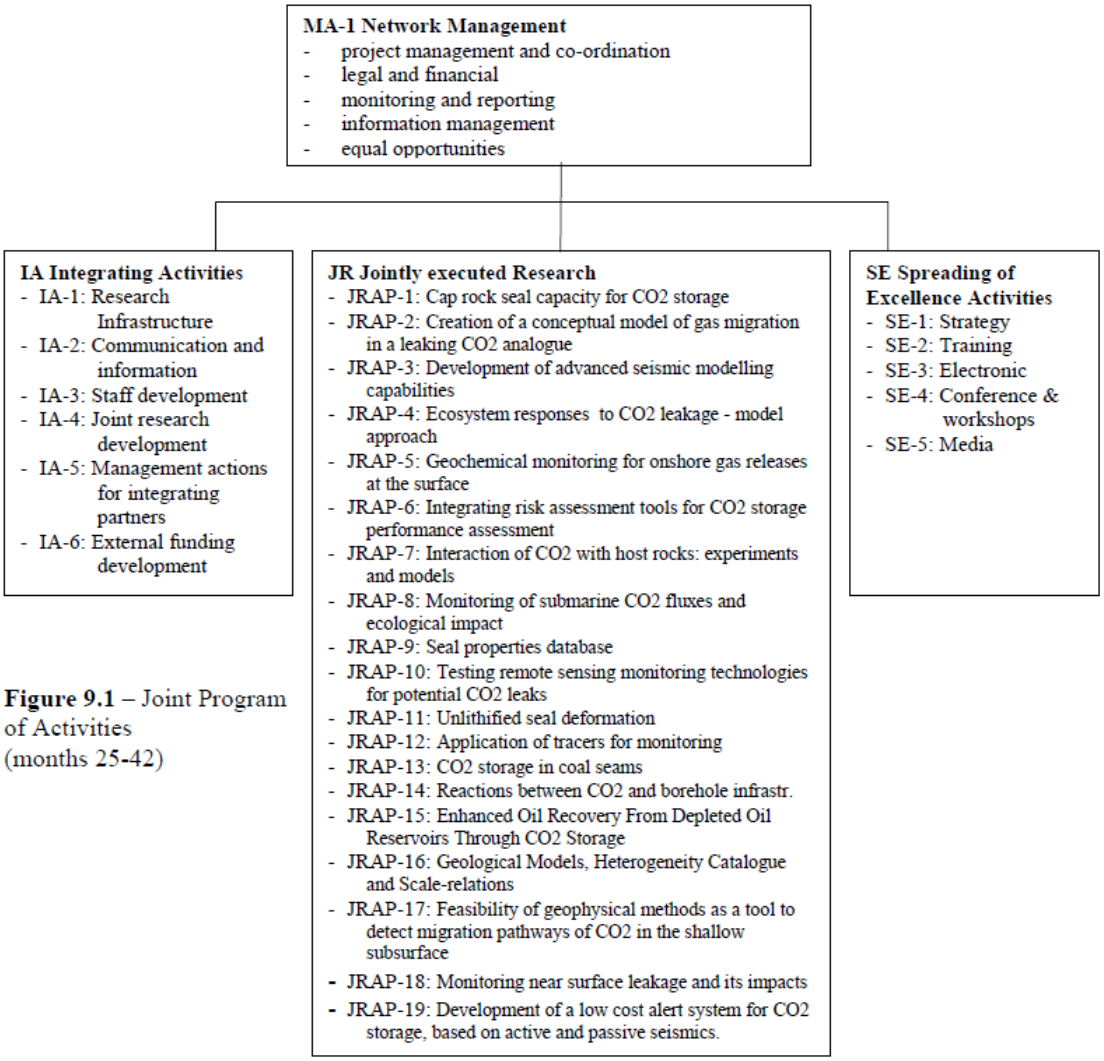


Figure 9.1 – Joint Program of Activities (months 25-42)

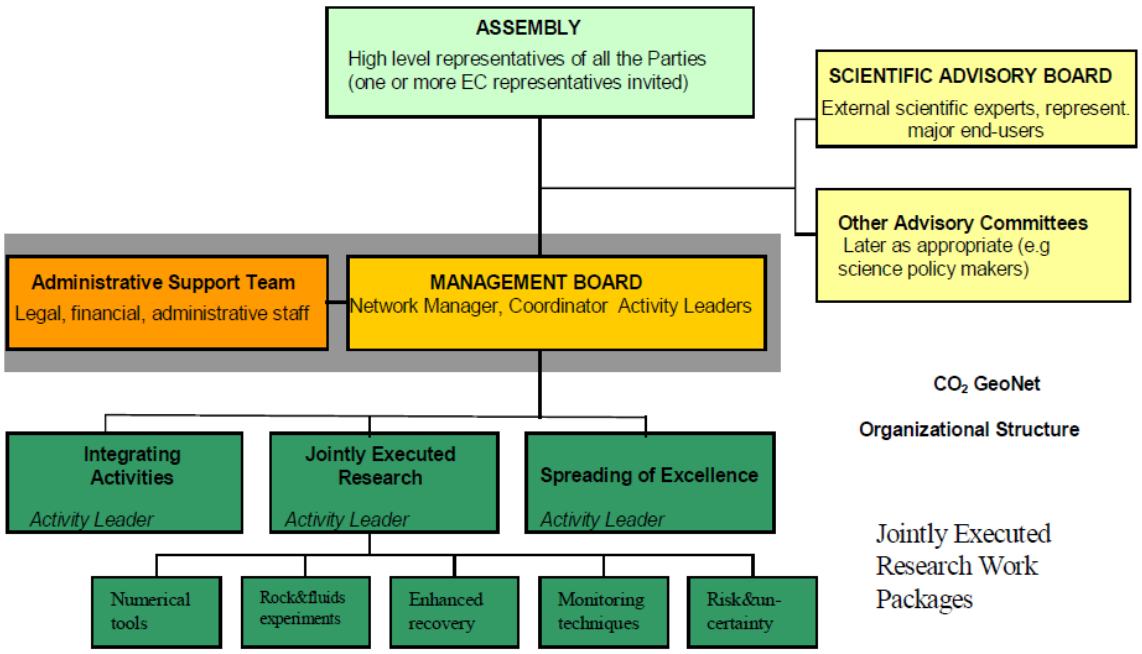
Network workpackage structure at the start of Year 3

Integrating Activities

Year 1 (April 2004-March 2005) Required the setting up of the network governance and management operations. Joint Research Workshops were held and proved very valuable events where the broader research community in the Network were able to give input to the network direction and organisation and build linkages/alliances with colleagues from partner institutes. The inventorising of Research Infrastructures in the Network was a very tedious, but necessary exercise in order to develop further Network integration and staff development. Having the website set up early, with a secure area for uploading and downloading shared files was a major bonus in achieving joint working and information sharing between our disparate research centres.

Since this is a research network, it became clear that an early way to achieve integration was from "bottom up"- i.e. getting the researchers to propose projects on which to work together.

A tactical way of doing this rapidly was to develp the "Quick Start" proposal process, where small < €10k projects could be achieved quickly. This had mixed success- and because of delays in starting some of them, we had to extend the life of the successful proposals into Year 2. Some Quick Starts, although authorised by the Network, did not start at all, but were subsequently merged with larger proposals. These larger proposals were achieved through setting up a longer term Joint Research Activity Proposal (JRAP) mechanism (18-24 months duration). The JRAP process forced partners to align their research activities and harnessed partners own research funds and infrastructures in the Network. In September 2004 the Network was also invited by PTRC to submit proposals for involvement in Weyburn 2 (Weyburn 1, which finished in June 2004, was an international research project monitoring CO_2 injection into an oilfield in Canada). The majority of partners responded and submitted. As a result collaboration on shallow gas monitoring continued.



Overall Governance, Advisory and Operational structure of the Network in Year 1

Year 2 (April 2005-March 2006) Large scale research infrastructure was mobilised and shared, such as aircraft and marine facilities for use in airborne CO2 monitoring. The Network made its first modest purchase of new analytical and sampling equipment for use by the network partners in the field. **The network's** first joint design, build and deployment of equipment (marine buoy adapted for sea- bed gas sampling at a submarine gas seep) was also made. The Network partner's own financial contributions toward the network budget doubled in order to facilitate the Joint Programme of Activities. The Network began setting up new and further developed previously known field sites as full scale European Field Laboratories with a particular emphasis on understanding CO_2 leakage processes, CO_2 monitoring and ecosystem responses to geologically sourced CO_2. Involvement of post-graduates in the Joint Research Activities began and the PhD programme funded by the Network was initiated. The Internal part of website was continually upgraded to try and keep pace with increasing partner use in the sharing and lodging of data. Partners also began to share of numerical codes for modelling and simulation purposes.

An existing marine oceanographic and meteorological buoy (MAMBO) was modified in order to carry a marine gas monitoring system. OGS, BGR and URS developed and contributed components of the monitoring system. Additional solar panels were installed for the increased power demand. The underwater sampling system for gas escaping from the seafloor and for gases dissolved in the seawater was built and added to the buoy. Gas analysis, control, data storage and transmission units were installed on the buoy. The off-shore monitoring buoy was deployed in September 2006 in the Gulf of Trieste

Year 3 (April 2006-March 2007) saw a significant increase in the joint use of infrastructure belonging to the various CO2GeoNet partners (Latera, Campino, Latchee, Storfjord, Tyrranean Sea). This occurred as the JRAPs were developing and maturing. Some rationalisation of partners' infrastructure relevant to CO2GeoNet was achieved. The joint field studies provided exchange of competences and know-how among the partners and between senior researchers and young researchers and students (IA-3). The first round of JRAPs terminated during Year 3, while five new ones started. These new JRAPs combined the topics and research teams from several previous ones, hence increasing the critical mass of researchers (some 150), while facilitating the transfer of knowledge between partners and research topics. This proved very efficient for the integration of the research teams through the JRAPs (IA-4). In terms of communication and information (IA-2), the main achievement was the creation of the Seismic database Network Access Point (SNAP) allowing sharing and processing, through the Internet, of seismic data from the NoE's consortium. SNAP makes use of GRID-like network. The main development has a generic character enabling extension to other types of data and processing tools to be shared among CO2GeoNet. Integration was also pursued through the staff development programme (IA-3). The PhD programme initiated during Year 2 became fully implemented during Year 3. Three PhD fellowships were granted on NoE funding and the students were attached to the three academic partners in the NoE, namely the University of Rome, Imperial College and Heriot-Watt University.. In Year 3 a number of training sessions were carried out in order to spread knowledge among the NoE partners. In particular, a training workshop on communication around CCS issues allowed us to formulate a common dialectic among the partners. The NoE slightly increased the number of Management Board (MB) meetings and General Assembly (GA) meetings (5 x MB; 2 x GA) in order to maintain a tighter relationship between members and an improved decision-making system.

Year 4 (April 2007-March 2008) saw the Network agree to form its legal entity, the **CO2GeoNet Association**, thus securing the long-lasting partnership of the NoE consortium. From Year 2 onwards considerable effort was invested in finding the proper legal model and in solving legal issues inherent to the creation of a pan-European research association. The CO2GeoNet Association was officially launched during our annual workshop in Venice, on April 17, 2008, and became recongnised under French law the following July. The NoE has

also continued its progress on the joint use of infrastructure belonging to or accessed by the various CO2GeoNet partners (IA-1), in particular the joint use of experimental field sites showed significant increase in activity. By the end of Year 4, the NoE had carried joint research at the following sites: Latera, Campino, Montmiral, Gulf of Trieste, Recopol site, Latchee, Storfjord, Panarea, and Sleipner. A number of infrastructure limitations were identified through JRAP activities, and these formed the basis of a proposal for the acquisition of new infrastructures by the NoE. During Year 4, it was decided to build a Benthic Chamber (used on loan during JRAP 8) as a unique piece of infrastructure, which would greatly benefit the NoE, as well as the wider European research community. Three proposals were submitted to research calls by the entire NoE consortium in the course of year 4. Two were submitted to the European Science Foundation, for supporting, among other, international workshops and exchange of scientists. The third was submitted to the EC FP7 Research Infrastructure programme. The ESF bid was successful.

Fig. 1

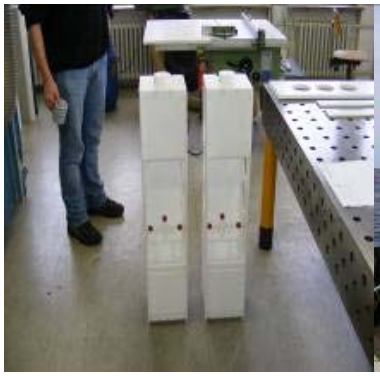


Fig. 2

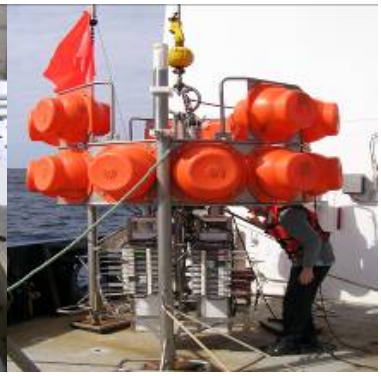


Fig. 3

CO2GeoNet's benthic chamber lander system under construction at NIVA. (1) benthic chamber lander frame, (2) benthic chambers and (3) a complete benthic chamber lander system in the Pacific Ocean in 2004

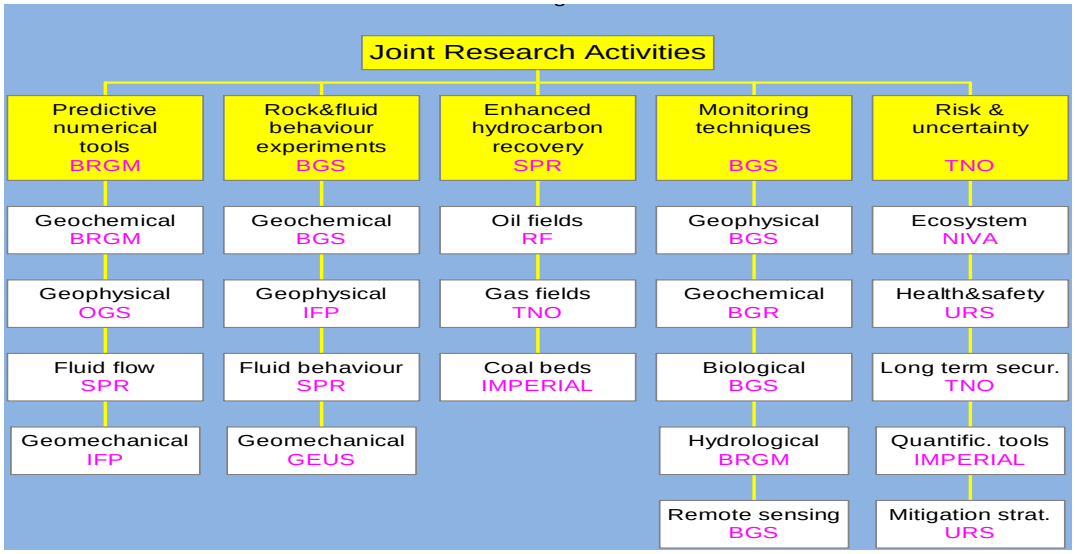
In Year 5 (April 2008- March 2009) a joint research infrastructure component, the "benthic chamber lander" (BCL), was designed and construction began in June 2008. There was further consolidation of other jointly developed research infrastructure. The SNAP program for multi-lateral use of the joint seismic record database was improved and completed. Four PhDs, linked to various JRAPs were successfully defended by the students involved. In Year 5 there were eleven ongoing PhD studies, including three funded directly by CO2GeoNet. Two Continuing Professional Development courses were given during Year 5. Staff exchange between seven CO2GeoNet partners involved nine junior and senior scientists for durations of 3 days to 3 months. Six JRAPs (JRAP 14-19) were completed and a new JRAP was launched and will continue beyond the end of the EC contract, under the umbrella of the CO2GeoNet Association. The Management Board and the General Assembly worked intensively for the successful deployment of the CO2GeoNet Association (e.g. consortium agreement, joint strategy, special agreement with BGR), for the effective implementation of the staff exchange programme, and for the purchase of a unique research infrastructure (BCL), and ability to bid for research funding as well as supplying expert services to government, intergovernmental bodies, NGOs and industry. The Association has already been successful in winning funding from industry, the ESF and an intergovernmental body which will come on stream after Year 5 .

International collaborations have been established with IEA-GHG (MoU), Zero Emission Technology Platform (EU) and the Global Carbon Institute (Australia).

Joint Research Activities

In Year 1 (April 2004-March 2005) most of the activity, apart from the inventorizing, was in formulating, submitting and negotiating proposals for longer term joint research (JRAPs) for Years 2 & 3. This proved to be a difficult and a very intense process. In February 2005, the Scientific Advisory Board (SAB) provided independent scorings and rankings of the JRAPs. The SAB also provided clear guidance on prioritisation, advising that we prioritised research that could assist in quickly enabling large scale CO_2 storage in Europe, and target research that was addressing gaps or was complimentary to other CO_2 research projects (not just European ones). Despite the difficulties (for some partners) that ensued from this process and advice, many of the proposals and partners merged and redirected their effort in response. The only area not well represented was CO_2 storage in hydrocarbon fields. This was a result of a low number of proposals received in this sector, and so a targeted internal call was planned for Year 2 to address this. Enhanced Coal Bed Methane was retained in a modified form, although the SAB suggested that the Network should not conduct work in this area in the first 5 years (because of the poor prospects for early implemention of coal storage on an industrial scale in Europe). This retention was to ensure as much involvement as possible of those partners active in ECBM and enable follow up on the RECOPOL FP5 project. Some early, tactical joint working was achieved through the Quick Start mechanism. In September, BGS, BRGM and URS jointly worked together to do an emergency soil gas monitoring campaign at Weyburn funded mainly externally (by PTRC and DTI), together with a small (<5%) use of CO_2 GeoNet funds.

At the December 2004 workshop it was proposed that the Network needed an additional workpackage, called "Geological Models" to set all the JRA activities in geological context.



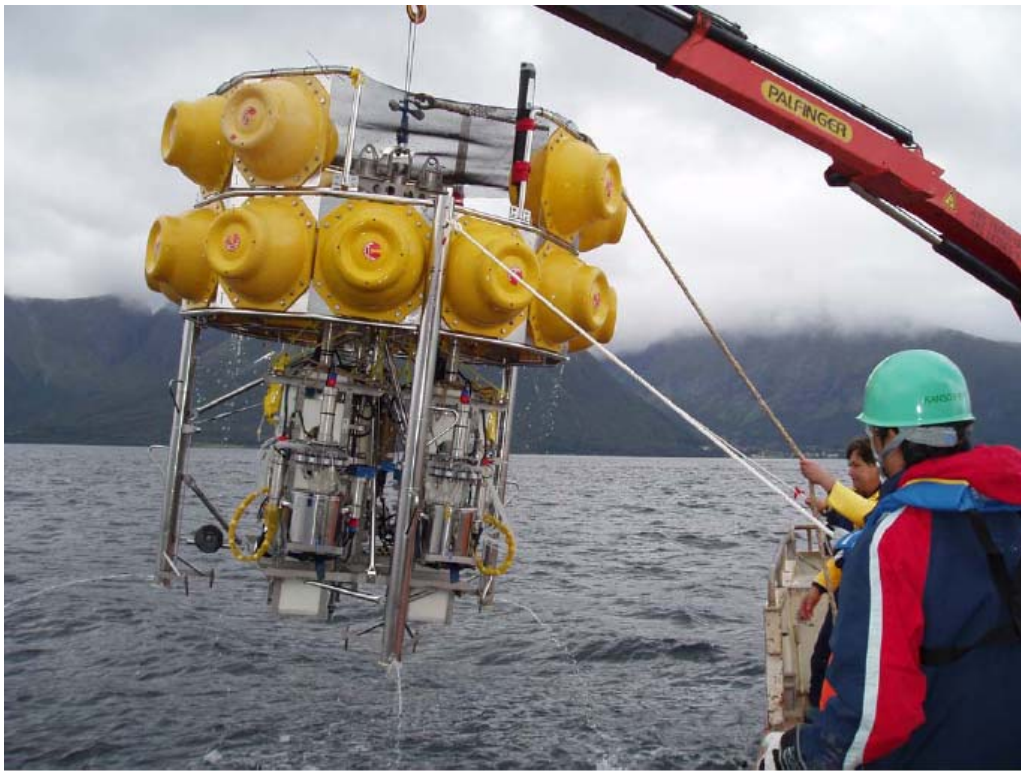
Research area and partner responsibities across the network (RF = IRIS)

Year 2 (April 2005-March 2006) saw the Network providing unique emphasis on CO2 leakage, surface and shallow subsurface monitoring and ecosystem responses to geologically sourced CO2. This included marine, freshwater and terrestrial settings, and, for the first time, human populations who live in proximity to natural CO2 seeps in Italy; with a particular reference to their attitudes to CO2 storage. It was hoped also to initiate a study on the

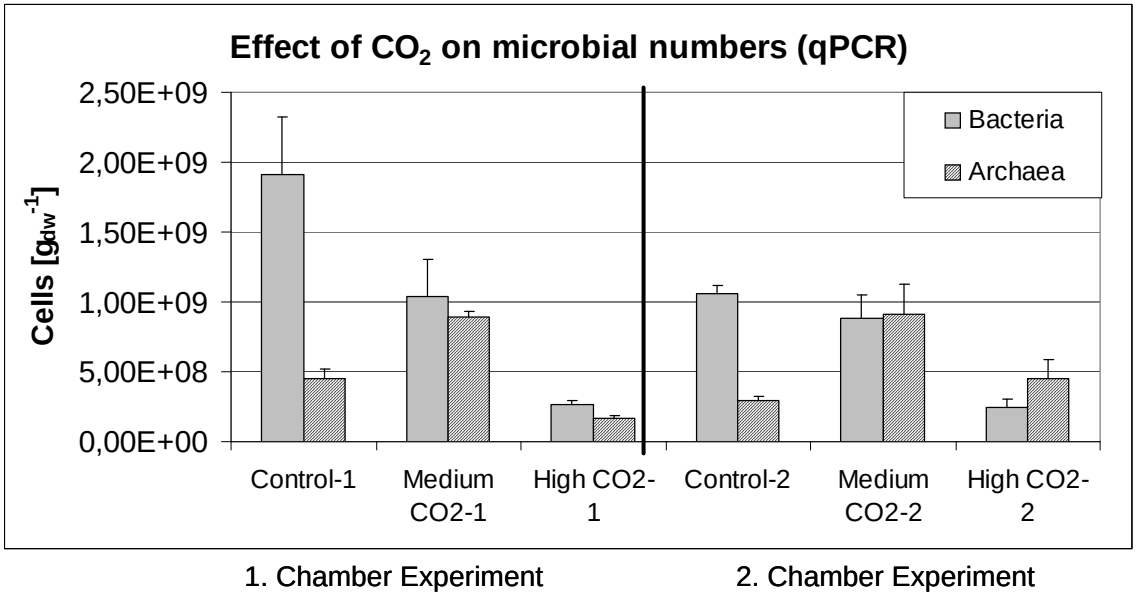
epidemiology of these communities to see if increased natural background CO_2 exposure had any epidemiological expression. No medical research partners were found who had an interest in this aspect, and so we were unable to pursue what we still think is an important avenue of research. The first wave of Joint Research Activity Projects (JRAPs) had now started and plans were in place for clustering of second wave of JRAPs, with fewer but more integrated research projects, comprising a wider spread of partners. Within the Network research teams with different disciplines but a common focus began to emerge, drawn from across the partners. There were succesful airborne campaigns for remote sensing made over Latera CO_2 Field Laboratory, Italy.

Airborne remote sensing (aquired by BGS and OGS) over the Latera natural CO_2 leakage site, Italy. The annotations show anomalies on the ground resulting from vegetation stress recognised by the airborne sensors. Once located these anomolies can then be investigated on the ground to see if the stress is due to CO_2 leakage or other factors. The technique recognised known leaks and found new ones, although most of the anomolies were not caused by CO_2. This technique could be deployed to monitor onshore CO_2 storage sites for signs leakage.

Testing, comparison and intercalibration of different CO_2 monitoring techniques at natural CO_2 leakage sites was also underatken. Marine experiments on CO_2 exposure effects on N. Sea benthic organisms and seabed sediments were conducted in the laboratory and in the field. Collaboration with RITE (Japan) was an essential part of this programme, through the field deployment of RITE's benthic lander chamber in Norway.



RITE's (Japan) Benthic Lander being deployed in a Norwegian Fjord near Ålesund during the Autumn of 2005, in collaboration with NIVA, in order to conduct experiments on CO_2 exposure to sea bed (benthic) organisms. Environmental impact assessments of CO_2 storage operations are a mandatory requirement of the EU Directive on CCS (2009). Experiments such as these inform such assessments and may lead to methods where biomonitoring of marine storage sites is possible.



Effect of CO_2 on microbe concentrations in sea bed sediments. Note that the ancient microorganism Archaea is much more tolerant of high CO_2 concentrations than modern bacteria. This should be no surprise as Archaea evolved billions of years ago before photosynthesis occured, when our atmosphere and oceans contained no free oxygen but significant quantities of CO_2. High relative concentrations of Archaea could be a potential biomarker for monitoring CO_2 leakage from storage sites.

Collaborative research began with various international projects/organisiations including Weyburn (Canada) and InSalah (Algeria) and the Russian Academy of Sciences, focussing around surface/shallow subsurface monitoring and CO_2 storage integrity. Testing and simulation of synthetic tracers for use in monitoring CO_2 breakthrough after subsurface injection also began. Various geomechanical and engineering related activities were conducted ranging from characterising regional reservoir seals to enhanced coal bed methane operations. New codes for conducting numerical simulations of CO_2 plume behaviour started to be developed.

WORK PACKAGES months 13-30		RESEARCH AREAS AND SUB-AREAS																							
		MODELLING				EXPERIMENTS				EHR			MONITORING					RISK					GM	
		Geochemical	Geophysical	Fluid flow	Geomechanical	Geochemical	Geophysical	Fluid	Geomechanical	EOR	EGR	ECBM	Geophysical	Geochemical	Biological	Hydrological	Remote sensing	Ecosystem	Health/Safety	Lon term security	Quantification	Mitigation strategy	Geolog. Model.	
		JR1				JR2				JR3			JR4					JR5					JR6	
		JR1-1	JR1-2	JR1-3	JR1-4	JR2-1	JR2-2	JR2-3	JR2-4	JR3-1	JR3-2	JR3-3	JR4-1	JR4-2	JR4-3	JR4-4	JR4-5	JR5-1	JR5-2	JR5-3	JR5-4	JR5-5	JR6	
	JRAP-1	Cap rock seal capacity for CO2 storage	■		■	■	■	■	■							■				■			■	
	JRAP-2	Creation of a conceptual model of gas migration in a leaking CO2 analogue					■						■	■						■				
	JRAP-3	Development of advanced seismic modelling capabilities		■	■								■											
	JRAP-4	Ecosystem responses to CO2 leakage - model approach	■											■	■			■	■	■	■			
	JRAP-5	Geochemical monitoring for onshore gas releases at the surface												■										
	JRAP-6	Integrating risk assessment tools for CO2 storage performance assessment	■																	■	■			
	JRAP-7	Interaction of CO2 with host rocks: experiments and models	■				■		■															
	JRAP-8	Monitoring of submarine CO2 fluxes and ecological impact												■	■			■	■	■				
	JRAP-9	Seal properties database				■	■	■	■														■	
	JRAP-10	Testing remote sensing monitoring technologies for potential CO2 leaks												■			■	■	■					
	JRAP-11	Unlithified seal deformation							■											■	■			
	JRAP-12	Application of tracers for monitoring CO2 storage	■		■			■			■			■										
	JRAP-13	CO2 storage in virgin seams and in coal seams stimulated by UGC			■	■						■												
			5	1	4	3	3	2	4	3	-	1	1	2	6	2	1	1	3	3	6	3	-	3	

Integration matrix of Joint Research Activity Projects (JRAPs) during Year 2

During Year 3 (April 2006-March 2007), most of the 13 initial JRAPs started in Year 2 came to an end (JRAP-1 to 13), while 5 new JRAPs started in the second part of the year (JRAP-14 to 17, JRAP-19), as planned. The Network had now engaged itself in a large range of activities covering a broad spectrum of CO_2 geological storage research including: reservoir performance, well-bore and cap rock integrity, potential leakage pathways up to the surface, potential environmental impacts in terrestrial and marine settings, Enhanced Oil Recovery (EOR) through CO_2 storage. The Network had developed in particular a unique world-class expertise on CO_2 leakage and environmental impacts through the study of natural CO_2 seepage areas in terrestrial systems (Latera and Ciampino in Italy), lacustrine systems (Laarcher See in Germany) and marine systems (Gulf of Trieste and Panarea in Italy). Had it not done so research into these topics, which are now more prominent in FP7, would have not been conducted during FP6 resulting a severe loss of momentum. The R&D workshops in Venice in the Spring of 2007 and Oslo in the following Autumn gave all researchers, having various expertise in geosciences and biosciences, the possibility to present and discuss their research results and to gain a broad overview of all aspects of CO_2 storage. External scientific collaborations were pursued (IEA-GHG networks, scientific institutes in the UK and Japan, etc.). Finally, during Year 3, some external funding to support JRA was raised (Dutch support

for JRAP-17, Vattenfall support for JRAP-18). These co-funds were an important first step towards the Network's durability beyond the end of the EC contract.

In Year 4 (April 2007-March 2008) Most of the work for the technical and experimental work of the first wave of JRAPs was completed in spite of delays caused by technical failures, necessary modifications of experiments, sample availability and delays in external projects upon which are JRAPs relied. As a result some of the reporting of results was still outstanding and had to put in the work plan for Year 5. JRAP 15 started pore and core scale experiments. Several separate JRAP workshops and field campaigns were carried out. JRAP 18, continued working on the natural CO_2 seeps at Panarea, the Gulf of Trieste and around the Laacher See. Monitoring devices developed and tested in CO2GeoNet, as well as from other national and EC funded projects, were tested at natural CO_2 seep sites. Several commissioned research activities, involving various partners, were facilitated through the network, financially supported by industrial stakeholders: Vattenfall R&D, CarboSulcis & ENEL.

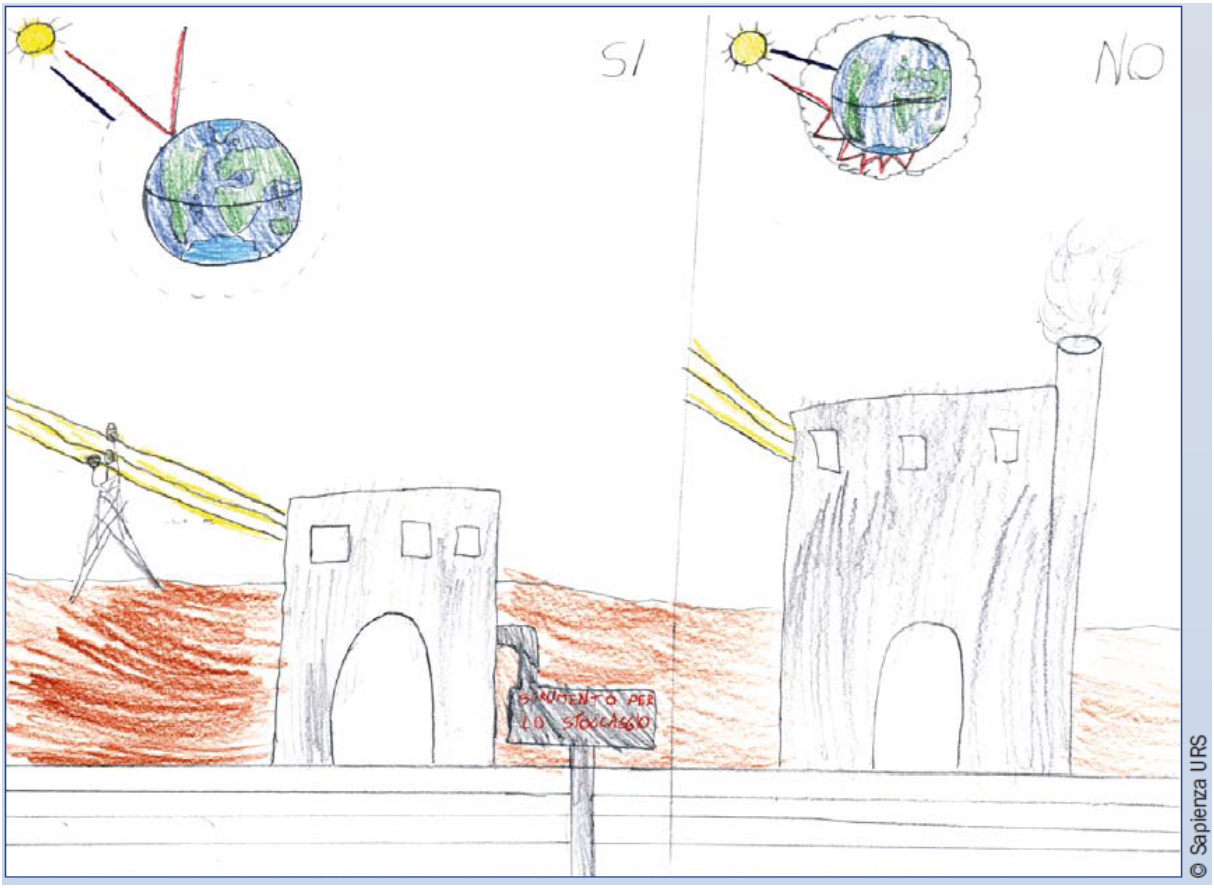
Year 5 (Apil 2008-March 2009) included field campaigns at natural CO2 seep sites Panarea, Latera (Italy) and at the Laacher See (Germany). Several staff members spent time working at partners institutes, exchanging knowledge, working on JRAPs, preparing publications and further research collaboration. A new JRAP "Benthic experiments for marine monitoring and ecosystems impact assessment" was launched to prepare experiments for marine monitoring and biological impact studies. Final research results were presented and discussed at the Full Workshop in Delft, in November 2008 and in the Annual Stakehlder Forum in Venice (March 2009). A work plan, extending beyond the period of the EC grant, including joint research activities arising from the alignment of partners own research resources was agreed**.** In order to establish new links to external research bodies, a collaboration agreement between CO2GeoNet and the IEA Greenhouse Gas Research and Development Programme was signed.

<u>Spreading of Excellence Activities</u>

In Year 1 (April 2004-March 2005) this was a relatively low key activity, a deliberate policy. Until the basic structure of the network was up and operating, and the network had a detailed plan of activity for the near and medium term it was premature to devote a large effort to Spreading of Excellence. Awareness of the network's existence was mainly made through starting up its public website and through presentations at scientific conferences and to policymakers, industry, the public and the media . Many network members were involved in organising and presenting at the NATO workshop on CO_2 capture & storage/climate change, held at the Siberian Academy of Sciences, Institute of Petroleum Chemistry, in Tomsk (November, 2004). This was funded by NATO and the partner's own resources, no network grant was used. In September 2004 the network signed a heads of agreement with the Petroleum Technology Research Centre (Canada), to agree to collaborate on risk assessment. The network held discussions with the RITE (Japan), CO2CRC (Australia) and the IEA.. The main difficulty in communication was the novelty of the Network of Excellence instrument. It was essential to make clear how the NoE differed from previous EC funding instruments (e.g. Thematic Networks), especially the point that the NoE is research network requiring real durable integration of its members, who bring in and share their resources and conduct research together in an aligned way.

In Year 2 (April 2005-March 2006) CO2GeoNet partners (BGS & BGR) led the CO2 storage session at the G8+5 Research Workshop, May 2005. Outputs were fed to world leaders at the Gleneagles G8 July 2006 Summit and reflected in Summit Policy Statement, which recognised CCS for the first time. CO2GeoNet became officially recognised by the Carbon Sequestration Leadership Forum (CSLF)**.** Presentations were given to members of parliament and high level government officials in member states, European Parliament and internationally. Existing collaborations continued (PTRC & Saskatchewan Industry & Resources Canada) and were joined by new ones (RITE Japan, Russian Academy of Sciences, and European universities and companies). Network research outputs and research activities were now being used for the first time in the training of undergraduates and postgraduates. Media outputs included radio, tv, press, brochures, dvd and webcast formats. The first peer reviewed research papers arising from NoE partner joint working were submitted and published

In Year 3 (April 2006-March 2007) activity was intensive. Many internal technical workshops were organised. The objective was not only to exchange ideas between researchers, but also to create a synergy and dynamics towards new propositions and collaborations. Three important internal workshops were devoted to the communication and dissemination strategy and, more specifically, how to communicate with the media, and how to present and promote the Network to stakeholders and the public at large. Finally, the Network's members organised workshops and technical sessions in parallel with major scientific and technical events. Network member also co-authored several scientific papers. In the training area, the Network confirmed its presence and role through a significant number of training courses for undergraduate and Masters course university students, as well as through specialised programmes focused on CO_2 geological storage. The first theses within the Network were completed, and several PhD theses started. Seminars were organised for the general public, decision makers, etc., and meetings and discussions held with school children (Rome) as a psychology experiment about public perception.



Engaging school children in thinking about reducing CO_2 emissions not only introduces them to considering important issues that will affect their future, but also engages their parents, friends and families too (picture by Massimo, aged 10, from Rome, Italy).

Finally, several undergraduate level trainees were involved in the various JRAPs.
The website was relaunched to make it more user-friendly.

During Year 4 SoE activities played an increasingly important role and major milestones were achieved. After a long process of consultation among the partners, the CO2GeoNet Association was finally launched to give the Network durability beyond the EC contract. All partners agreed on the importance of Network continuation for the role it can play in the European arena with regard to joint development of research, training, scientific advice and communication on CO_2 storage. The role of the Network also developed in the direction of its potential in terms of national research programmes: for the first time, partners involved colleagues working in their own institutes on national projects for CO_2 storage and cross collaboration among projects was encouraged. The Secretariat became fully operational acting as the formal interface between the Network and stakeholders and assisting the Management Board in a variety of important tasks. Its activities further enhanced the role the network can play both at European and national level. Training actions continued, including the ongoing and new training of undergraduate, Masters, and PhD university students, the organisation and implementation of workshops and seminars to the general public, decision makers, professionals and research scientists. External outreach progressed considerably. As the Network matured it was now in a position to more widely present its results at conferences and exhibitions. We also witnessed dissemination to a wider audience, including those

involved in CCS —but not necessarily experts, as well as the general public. A special mention must be made of the Network's first international event designed for a public audience, the Training and Dialogue Workshop, entitled 'What does CO_2 geological storage really mean?' held in Paris in October 2007.

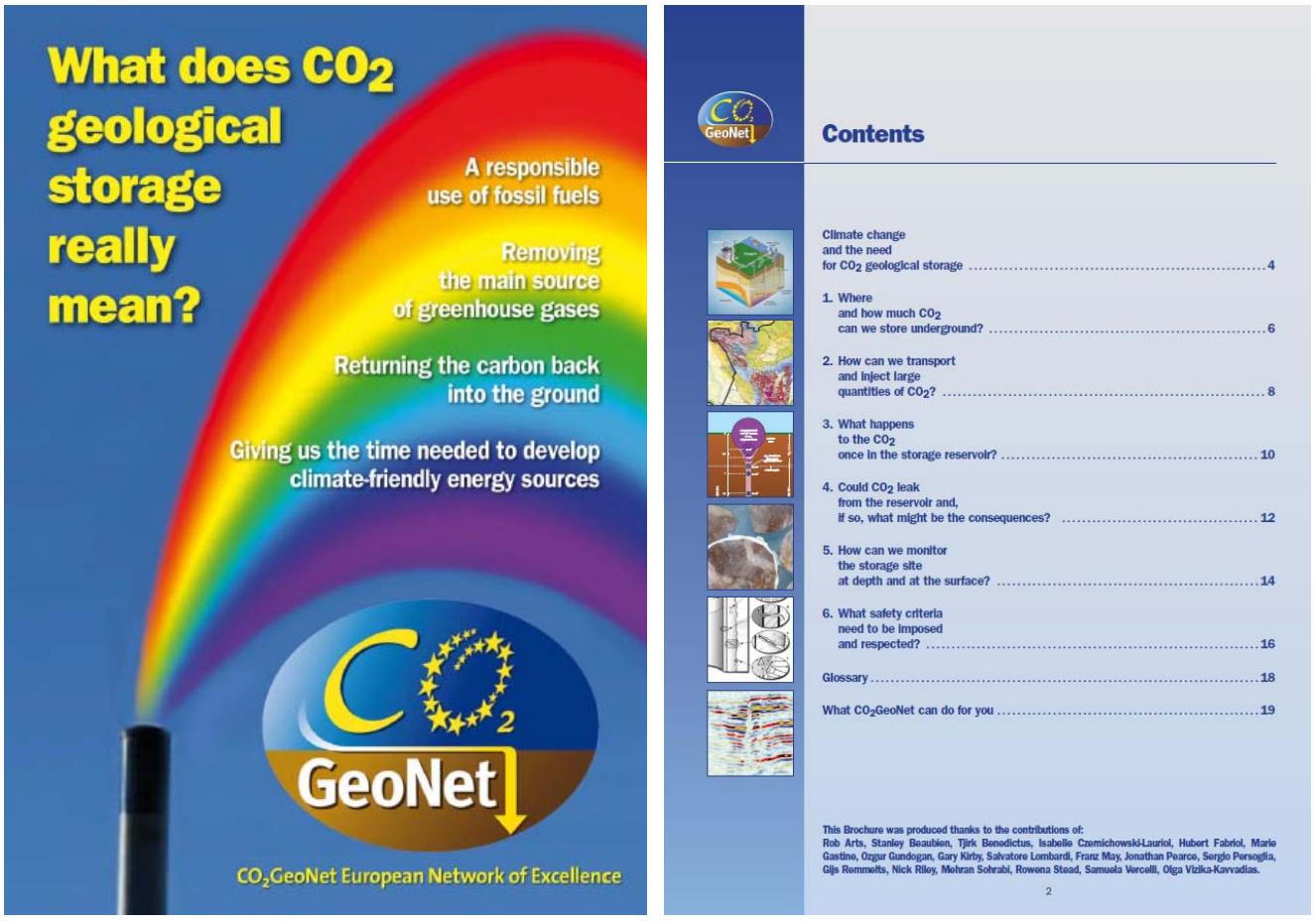
Panel Q & A session at a Training and Dialogue Workshop, entitled 'What does CO_2 geological storage really mean?' held in Paris in October 2007. Stakeholders from industry, finance, insurance, policy and research sectors attended

We intensified our interaction with other groups and initiatives involved in CCS, and strived to reach national and European authorities in the aim of scientifically contributing to the drawing up of sound European legislation. Another form of external outreach included the onset of preparation of material to inform a wider public in a user-friendly manner, and constant improvements and updates of our Website in terms of content, usability, and attractiveness. Efforts were made to increase public visibility of the network through a more organized approach to the media. A press officer's meeting was held in January 2008 to bring together the Network institutes' own media resources in the aim of working more efficiently together.

During Year 5 (March 2008-April 2009) training activities continued, with particular attention given to educating the future scientists and engineers that will be needed to implement CCS. University courses were given on the topic of geological CO_2 storage at all three CO2GeoNet university partners (Sapienza, Herriot Watt, and Imperial) as well as by CO2GeoNet researchers at other universities (such as the University of Delft). In addition, BRGM and IMPERIAL were awarded a Marie Curie Research Training Network grant called GRASP (Greenhouse-gas Removal Apprenticeship and Student Programme). A series of training courses were given, and planned, to meet the needs of stakeholders. These include

short courses on the technology of CO_2 capture and geological storage; reservoir characterisation; the modelling of geochemical reactions; and CO_2 storage safety. These events were attended by researchers and professionals from all over the world.

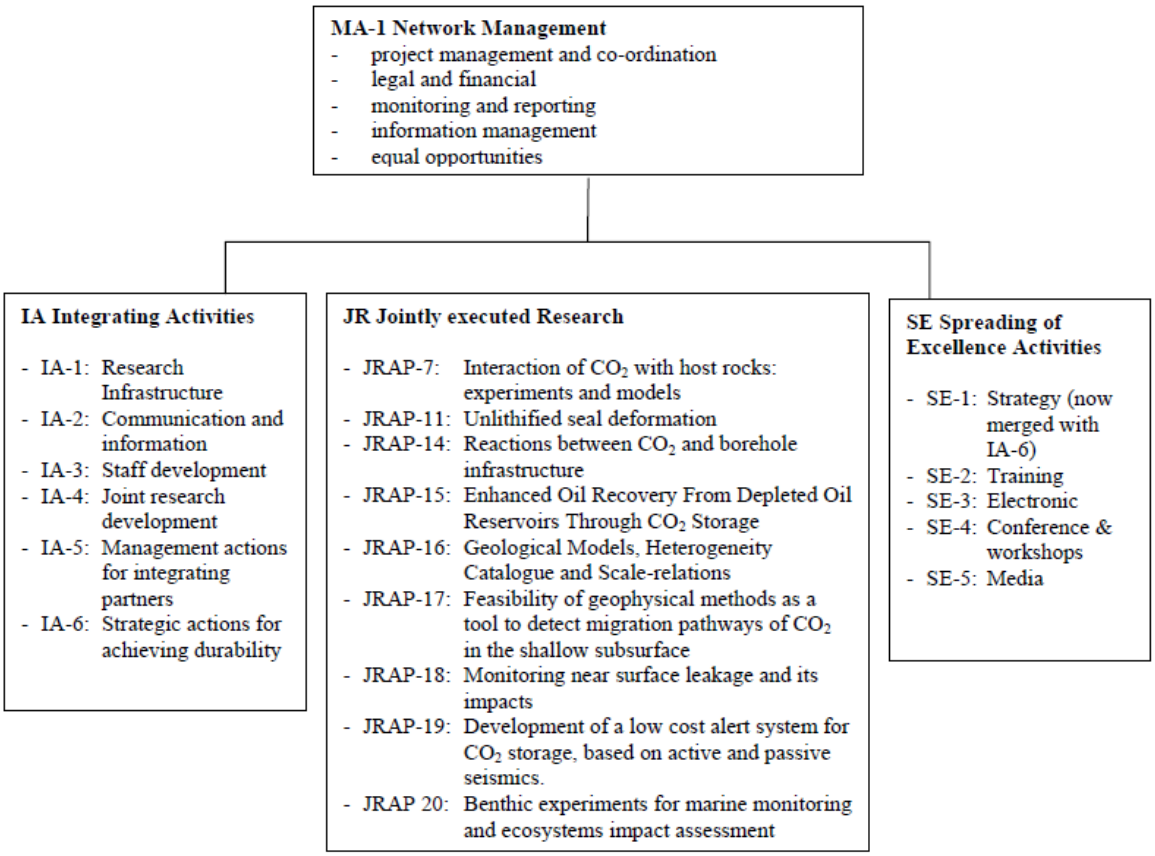
External outreach to a non-specialised audience was emphasized, with two major results characterising our commitment to this issue. First we produced a **scientific brochure** entitled "What does CO_2 geological storage really mean?". The brochure answers frequently asked questions regarding the scientific aspects of CO_2 geological storage, based on detailed discussions within the CO2GeoNet working group on the scientific content and the form/presentation that would best convey the concepts to the widest possible audience. The brochure has been widely distributed (including all Members of the European Parliament), and it has since been translated into other European languages. It is available on our web site for free download (www.co2geonet.com/brochure). Second, CO2GeoNet also led a public outreach activity on CO_2 geological storage at **ESOF 2008**, the largest European event for science exchange between scientists, journalists, policy makers, and the general public. Posters and dialogue sessions were used to illustrate the concept of CO_2 geological storage



CO2GeoNet's main communication brochure "What does CO2 geological storage really mean"

External outreach to a more specialised audience included our open forums, where industrial, government, and NGO stakeholders were invited to attend a series of presentations and round-table discussions. The Network organised two **Open Forums** in Venice, Italy, the first on April 17th, 2008 (the 3rd CO2GeoNet Open Forum) and the second from March 18-20, 2009 (the 4th CO2GeoNet Open Forum). Both high-level events were held to help spread knowledge and expertise to all European stakeholders interested in CO_2 geological storage research. These forums were well attended, with participants coming from public authorities, industry, regulatory bodies, NGOs, universities, research organizations, etc. The events allowed not only for the dissemination of CO2GeoNet results, but also two-way dialogue between researchers and stakeholders.

Another important form of external dissemination to a specialised audience was the organisation of, or participation at, scientific conferences and workshops. In particular, CO2GeoNet was a co-organiser of a workshop entitled "Promoting CO_2 Capture and Storage in Romania", which supported the diffusion of scientific knowledge on CO_2 geological storage in Eastern European countries. A large number of CO2GeoNet researchers also attended the 9th International Conference on Greenhouse Gas Control Technologies (**GHGT9**) held in Washington DC, USA in November 2008. This premier international event highlights global CCS research, and provided a unique audience for Network members to disseminate results of their recent research in the form of more than 10 presentations and posters. Finally, other events where CO2GeoNet researchers participated as speakers, or invited lecturers, included: the European Geophysical Union (EGU) conferences in April of 2008 and 2009; the IEA-GHG and BGS sponsored workshop on "Defining R&D Needs to Assess Environmental Impacts in CO_2 Storage"; the European Association of Geoscientists & Engineers (EAGE) workshop on CO_2 Geological Storage; the Clean Coal Technologies & Strategies Forum; the CERTH/ISFTA sponsored workshop entitled "Technological potential for CO_2 emission reduction"; the 2nd European CCS Summit; the 2nd Petrobras CCS conference; various CO2NET meetings; and the IEA-GHG organised summer schools on CCS. A particularly important element of the Spreading of Excellence activities has been the development of the NoE's website, where it is possible to reach and inform a large and global audience. Over year 5 we improved the website by improvement of the home page to highlight the more important topics; simple presentations of the scientific results from our joint research projects and other studies; a public Q&A forum where NoE experts answer questions from visitors to the website; access to the scientific literature produced by the NoE partners in the field of CO_2 geological storage; creation of a glossary search engine that accesses specific, NoE-chosen websites; and wide diffusion of all the NoE initiatives and offers in terms of joint research, training, information & communication, and scientific advice on CO_2 geological storage. In addition, Google Analytics results of website traffic are published regularly on the restricted part of the site to allow for constant improvement of the utility and accessibility of the website. Finally, work has also begun on an automatic news function and the translation of selected pages in the native languages of the NoE partners; this work is on-going and will be progressively rolled out on the site in the near future.



Network work package structure in the last 18 months of the EC grant

Collaboration with other projects/programmes

Europe

Other FP6 projects- Tracer research undertaken in support of CO2 Sink and CO2ReMove. Assistance with designing baseline CO_2 monitoring at InSalah (CO2ReMove). Collaboration on training with GRASP

Russian Academy of Sciences- RAS assisted in the supply and operation of specialised shallow subsurface surveying equipment at terrestrial Italian CO_2 seeps

Technology Platform for Zero Emission Power (ZEP). Several partners are involved with the ZEP's Advisory Council and task forces. They have contributed to and co-authored ZEP internal documents and the ZEP strategic research agenda and strategic deployment documents such as 'Recommendations for long term RTD plans beyond 2020 within EC and national RTD programmes in support of deployment of CCS in Europe' and outputs of the Communication Task Force.

CO2NET- Collaboration for the organisation of the CO2NET Annual Seminars and presentations of CO2GeoNet integrated talks and posters.

EuroScience Open Forum- COGeoNet participation at ESOF 2008 in Barcelona, July 2008.

European Science Foundation- CO2GeoNet organised an ESF Conference on CO_2 storage in November 2009.

Polish Geological Institute. Translation into Polish and printing of the CO2GeoNet brochure 'What does CO_2 geological storage really mean?'. Invited talk in Venice on the Polish national research programme on CO_2 geological storage. Preliminary discussions for establishing formal relationships between CO2GeoNet and PGI, as associated member.

Romanian CO_2 Club. Co-organisation of a CCS Workshop in Romania in September 2008. Translation into Romanian and printing of the CO2GeoNet brochure 'What does CO_2 geological storage really mean?'.

North America (Canada)
Petroleum Technology Research Centre (PTRC)
Collaboration with the Weyburn CO_2 monitoring project continues in terms of shallow subsurface CO_2 monitoring and core flood experiments with CO_2.

Australia
Global CCS Institute
During year 5, CO2GeoNet has been discussing with representatives of the Global Carbon Capture and Storage Institute (GCCSI), with was officially launched on April 2009 by the Australian Prime Minister. Funded by the Australian Federal Government, the aim of GCCSI is to accelerate worldwide development, deployment and implementation of carbon capture and storage (CCS) technologies. A representative of GCCSI attended the Venice Open Forum in March 2009. A collaborative agreement between CO2GeoNet and GCCSI is being prepared.

Japan
Research Into Technology for the Earth (RITE)
Collaboration on understanding possible CO_2 exposure effects on marine sediments and organisms in the event of CO_2 passing from the geospehere into the benthic environment

Japan Coal Energy Centre (JCOAL)
Collaboration with regard to understanding fundamental CO_2 storage processes on coal

Intergovernmental bodies
International Energy Agency Green House Gas Programme (IEAGHG)
Participation in workshops and working groups, especially CO_2 monitoring and verification, risk assessment , borehole integrity, saline aquifer, Co-organisation of the IEA GHG summer schools & CO_2 storage modelling workshop. There is Memorandum of Understanding between IEA GHG and CO2GeoNet. A Memorandum of Understanding between IEA GHG and CO2GeoNet was signed in November 2008.

Carbon Sequestration Leadership Forum (CSLF)
CO2GeoNet is a recognised project within the CSLF with CO2GeoNet supporting CSLF research workshops and technical groups on CO_2 storage.

United Nations Economic Commission for Europe (UNECE)

CO2GeoNet is represented on the working group on CO_2 Capture and Storage- this is a very useful forum to raise awareness of CO_2 storage issues with government officials and company representatives of countries from the Former Soviet Union, N. Africa and the Middle East which are important in the context of Europe's energy security and use..