An international symposium on the reduction of emissions and geological storage of CO_2 was held in Paris from 15 to 16 September 2005. The event, jointly organized by IFP, ADEME and BRGM, brought together over 400 people from more than 25 countries. It was an opportunity to review the international stakes related to global warming and also to debate ways of reducing CO_2 emissions, taking examples from the energy and transport sectors. The last day was dedicated to technological advances in the capture and geological storage of CO_2 and their regulatory and economic implications.

In his opening address, François Loos, French Minister-delegate for Industry, paid tribute to "NETs", which stands for “new energy technologies”. Today, one of these new technologies enabling the production of renewable energies or energy savings is the capture and storage of carbon dioxide. The Minister recalled that two new agencies had recently been created: the “Agence nationale de la Recherche” (National Research Agency) and the “Agence nationale de l'Innovation industrielle” (National Agency for Industrial Innovation), with the aim of intensifying public and private research efforts in this field. The Minister concluded that: *“Capture and storage could help to reduce CO_2 emissions in numerous industrial sectors, particularly in the power generation sector, especially if worldwide use of coal is set to increase during the 21st century".*

A forecast confirmed by Jacek Podkanski, from the International Energy Agency (IEA): with global energy demand constantly increasing – coal production will peak around 2050 and oil and gas reserves will begin to decrease around 2020-2030 – we must not count on a reduction in fossil fuel consumption in the medium term to curb greenhouse gas emissions. Presented by Jacek Podkanski, the last energy scenario drawn up by the IEA is based on an increase in energy production between 2002 and 2030 ranging from 3% for OECD countries, to 12% for transition economies (Eastern Europe, Latin America) and 85% for developing countries, essentially China and India – in which production is still very low. Since fossil fuels will still have to satisfy more than 80% of requirements, CO_2 emissions will exceed 38 billion tonnes per year by 2030. Today, they represent 30 billion tonnes, i.e. twice the level that natural carbon sinks (biosphere and oceans) are able to absorb, the rest accumulating in the atmosphere year after year. Jacek Podkanski explained that global efforts (increase in energy efficiency, nuclear power, renewable energies, etc.) would make possible an alternative scenario, which would reduce CO_2 emissions by 6.5 billion tonnes per year. The use of carbon dioxide capture at the emission source at only 5% of industrial facilities worldwide would lead to the elimination of a further 1.75 billion tonnes.

Is this alternative scenario sufficient to prevent climate disaster on a massive scale? Dominique Dron, Professor at the Ecole des Mines de Paris, doubts it: "*We will have to find a way to reduce our carbon dioxide emissions fourfold to limit the rise in temperature to 2°C and avoid the worst disasters"*, she warns. To back up her fears, she quickly outlines the worldwide climate situation. Since the beginning of the industrial age, the world’s temperature has increased by an average of 0.6°C and sea level has risen by 10 to 20 cm. Six tenths of a degree does not seem much, but we are already seeing the negative effects: disrupted weather patterns, heat waves, floods, forest fires, drought, melting glaciers, increased severity of hurricanes, disruption of marine currents, changes in flora and fauna. "*The problem is both an ecological one and an economic one*", she explains. Between the 1950s and the 1990s, for example, global financial losses as a result of climate-related disasters multiplied tenfold (following adjustment to take into account inflation), an increase that can be explained by a steady rise in the number of natural disasters: thirteen extreme phenomena listed between 1950 and 1960, seventy-two between 1990 and 1998. In the United States, the economic losses caused by meteorological disasters rose from 5 to 11 billion dollars between 1980 and 1990. Hurricane Katrina alone, which ravaged Louisiana in September 2005, is likely to cost 125 billion dollars. Inviting all states to take into account ecological factors

when developing their economic growth plans, Dominique Dron adds: "*The damage caused by global warming is always more expensive for a country's economy than prevention.*"

David Reiner, of Cambridge University, is fully aware of this. This researcher, who works closely with the MIT (Massachusetts Institute of Technology) reminds us that a French person emits an average of 6.5 tonnes of CO_2 per year, and an American 19.9 – with Louisiana holding the world record at 45 t/year/capita. But there is hope! Initiatives to combat the greenhouse effect are now beginning to emerge in the US, under the pressure of the states (40 have compiled inventories of their emissions, 25 have adopted climate change plans), local governments (more than 135 local governments in 35 states have decided to bring their city into line with the Kyoto protocol) and industry (strongly committed to the capture and storage of CO_2). For their part, the Europeans have a global strategy to combat the greenhouse effect and are set to increase aids in this area, announces Pierre Dechamps, of the European Commission's Directorate General of Research: "*The 7th framework program (Community Research and Development Plan) will put 2.9 billion euros into energy-related projects, twice as much as FP6*." The primary sources of emissions are known: 39% are due to energy production activities and 22% to industry. These concentrated sources could be captured. Emissions due to heating of buildings, the tertiary sector and agriculture (16%) can be reduced through energy savings and the use of renewable energies.

This leaves transport. The role of this sector (23%) is consistently increasing, as is confirmed by Alain Morcheoine, Director of the Air, Noise and Energy Efficiency department at ADEME: "*Air transport is set to increase threefold by 2030 and the number of motor vehicles will double. The consequence of this will be an increase in world CO_2 emissions and the share of the transport sector's responsibility in this will increase from 23 to 25%.*" There are multiple tools designed to reduce emissions in the sector: improvements in motor technology, reduction in engine size, electric vehicles, clean fuels. "*A plethora of solutions are proposed, but these have limits",* he explains. For him, the real problem lies in the development model adopted by developed countries, which "*ought to modify their behavior in terms of transport and encourage emerging countries to do likewise before it is too late",* he concludes. The next speaker, Peter Wiederkehr, of the Austrian company, Est International, wholeheartedly agrees with this, providing an example of a change in attitude to cars: a car-sharing trial involving 60,000 people and 1,800 vehicles in Switzerland. Thanks to this system, users make 20% fewer car journeys and emit 60% less CO_2 as a result of car travel. More realistically, Ian Drescher, of Volkswagen, believes that the solution will come from the use of a range of different raw materials in the production of fuel, without changes to service stations or vehicles. He cites the experience of *Sunfuel*, a synthetic fuel (synfuel) produced by gasification of biomass and widely marketed in Germany. "*The planet is in danger and we need instant solutions"*, he claims.

In terms of the capture and storage of CO_2 too, there are several immediate solutions, none of which can claim to be a panacea at present. Opening the session dedicated to this option, the Chairman of BRGM, Philippe Vesseron, reminds us that we must explore all avenues today: both in terms of the choice of capture processes (post-combustion, oxycombustion, precombustion capture) and in terms of the choice of storage sites. Thus, Lars Stromberg, of the Swedish energy company, Vattenfall, explains that his company has invested in a pilot project that will be up and running in 2008: a coal power station in Schwarze, in the Ruhr basin, equipped with an oxycombustion capture system. "*As for Siemens, it is interested in precombustion*", states Gunther Haupt, the company's representative. It has developed a new burner system for gas turbines, enabling the recovery of hydrogen; "*the most promising avenue"*, in his opinion, "*but also the most ambitious technologically-speaking*". Finally, post-combustion capture is defended by Paul Feron of TNO (a Dutch research organization). "*This technology"*, he says, *"is the easiest to implement in existing power stations, and the most economical, especially if regeneration of solvents is integrated into the process".* A pilot power station of this type is scheduled to become operational in Denmark in 2006.

After capture, geological storage poses its own problems. Niels Christensen, of GEUS (Geological Survey of Denmark and Greenland, the Danish equivalent of BRGM), kicks off the debate on the subject by quickly outlining worldwide geological underground storage capacity. CO_2 can be stored in depleted oil and gas reservoirs. These have the advantage of being well known and their capacities have been calculated (5.920 billion tonnes of CO_2). In unmined coal seams, injection may be accompanied by recovery of methane, but their potential, which is still uncertain, appears to be low (around forty billion tonnes). Deep saline aquifers offer the advantage of an immense potential (more than 10,000 billion tonnes) and a presence in all the world's sedimentary basins. For Tore Torp, of Statoil, the field tests currently being carried out in the context of European or national programs (CASTOR, GESTCO, SACS, *CO2Store*, etc.) are all unique cases, *"but the feedback from each one provides a wealth of information for all scientists interested in the storage of CO_2*", he explains. This is the case, for example, with the tests conducted by Gaz de France and Statoil in the North Sea (K-12B, Sleipner), and described by Jean Hartman, of GDF, who believes that they "*have increased our knowledge and highlighted the benefits and drawbacks of the technique*".

However, in this field, time is just as important as space, as is demonstrated by Pierre Le Thiez of IFP and Isabelle Czernichowski of BRGM in their presentation of the main research avenues. "*In this area, the difficulty lies in the time aspect*", they explain, since the safety of storage must be guaranteed for periods of as much as one or two millennia. Controlling the long-term impacts therefore remains a technical obstacle, which must be overcome in order to guarantee development of this option. However, this is not the only handicap, warns John Roberts, of the UK Ministry for the Environment, pointing out that "*there is no legislation specific to the long-term storage of CO_2*". Thus, storage in the North Sea is governed by two laws focusing on protection of the marine environment (the London convention and the OSPAR convention), and underground storage depends on the legislation in force in each individual country. However, a debate on international environmental conventions is currently ongoing with the aim of clarifying the situation, states John Roberts.

Will the main problem be a financial one? Whichever technology is favored for capture or storage, all the speakers agree on the need to reduce its cost. Work in this field is currently burdened by the cost of capture, representing 70% of the estimated total, i.e. 50 to 70 dollars per tonne of CO_2 avoided. Guy Allinson, of the University of New South Wales (Australia), draws our attention to the fact that this is simply an estimate. "*Costs can vary significantly, depending on the choice of capture process, the distance to be covered to store the CO_2 and the storage site*", he explains. Furthermore, the implementation of emission permits scheduled by the Kyoto protocol is likely to further change the economic order, maintains Jean-Michel Gires, of Total. Today, "*all Total projects are analyzed in light of the quantities of carbon gas emitted and the current penalty of 20 euros per tonne of CO_2 emitted*", he says, *"and the issues of carbon dioxide capture and storage cannot be avoided*". One last point remains to be discussed: the social acceptability of CO_2 capture and storage. After having reminded us that the capture and storage option is not the only solution to reduce CO_2 emissions, Gabriela von Goerne, from the German section of Greenpeace, stresses the need to inform citizens and to guarantee the safety of storage for future generations. Olivier Appert, President of IFP, closes the symposium on an optimistic note, stating that: "*Prevention of the risks of climate change due to greenhouse gas emissions represents a crucial issue, for which research must be able to find solutions.*" A gamble on the future?

To find out more: IFP, ADEME and BRGM have just published a brochure devoted to the capture and geological storage of CO_2 in its *Les Enjeux des Géosciences* collection.