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Characterisation of European CO₂ storage**

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Minutes of the Closing Conference**

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1 Introduction

The SiteChar Closing Conference was organised and hosted by IFP Energies nouvelles (Rueil-Malmaison, France) on Thursday 28 November 2013.

The conference was dedicated to the learning's of the project in the purpose of storage permitting with a morning session dedicated to site characterisation for storage permitting and an afternoon session dedicated to the SiteChar workflow for integrated and accountable site characterisation. Outcomes and guidelines were illustrated at the five feasible European storage sites studied in SiteChar.

The objective of the SiteChar Closing Conference was in addition to provide an opportunity to discuss necessary activities to meet storage permit requirements.

This report gathers the minutes of the workshop (Section 2), the workshop agenda (Section 4), the list of posters (Section 5), the participant's list (Section 6) and the press release (Section 7). A full copy of the workshop presentations is available in the appropriate section of the project web-site (<http://www.sitechar-co2.eu/>).





2 Minutes of the Conference

2.1 Welcome address

François Kalaydjian (IFPEN) formally opened the SiteChar Closing Conference and welcomed the participants with a special thanks to the members of the SiteChar consortium, the members of the SiteChar Advisory Panel and the sponsors of the SiteChar project.

He pointed out how SiteChar has been productive and attractive in delivering appealing results and tackling important issues. SiteChar is remarkable not only because of the numerous publications it leads to, but also because it provided an unique opportunity to test and possibly improve the process for issuing storage permits in the current and so challenging period.

The speaker acknowledged that Carbon Capture and Storage (CCS) is experiencing a number of difficulties, regarding financing issues, implementation of a regulatory framework, securing a high enough CO₂ price that would make CCS a viable option. He completed the picture recalling that the first round of NER 300 has not delivered any CCS project and that only one project has been submitted in the second round. He noted that, even when including CCS projects financed at national level, only a limited number of CCS projects will be in operation in Europe by 2020. He finally recalled the challenging issue of public acceptance without which CO₂ geological storage, and as a consequence CCS, will not be deployed.

The speaker pointed out that to some extent SiteChar has been able to supplement the lack of industrial demonstration projects by delivering both technical and social related results that should enable to optimize and better shape the future CCS industrial projects.

He concluded that, under IFPEN coordination, the SiteChar project has been able to gather academics, industrials (oil companies as well as utilities), public institutions and has reached all its objectives leading certainly to a major contribution to the implementation of CO₂ storage. It should help kick starting of CCS industrial activities when the market conditions will be met.

2.2 The SiteChar project – Scope of the Closing Conference

Florence Delprat-Jannaud (IFPEN) outlined the research objectives of the SiteChar project and introduced the research institutes, academics, industry partners, and the public institutions involved in the project as well as the two external partners. The speaker thanked the European Union, Enel, PGNiG, Statoil, Vattenfall, the Scottish Government, Veolia Environnement and Gassnova for participating and funding the project. As coordinator, she also thanked the whole SiteChar team for their impressive work and the very nice collaboration.

She pointed out that it will not be possible to present all the results obtained during these three years and that the Closing Conference will focus on the learning's related to storage permitting. She encouraged participants to have a look at the posters that present some results of the project.

Then, the speaker introduced the five sites chosen for the detailed characterisation for CO₂ storage during the course of the research: a North Sea offshore multi-storage site (hydrocarbon field and aquifer) in Scotland, an onshore aquifer in Denmark, an onshore gas field in Poland, an offshore aquifer in Norway and an aquifer in the Southern Adriatic Sea. It was highlighted that this portfolio provides a range of representative potential CO₂ storage sites, well spread in Europe and providing credible options for CO₂ storage. Out of the five aforementioned sites, two were identified for preparation of 'dry-run' storage permit applications to be submitted to the competent regulatory authority. The sites chosen for this exercise are the northern North Sea site (UK) and the Vedsted site (Denmark). The related project concept and the main interest of the research conducted at these sites were presented. The studies conducted at the three other sites focused



on specific barriers related to the site characterisation methodology. Sites and scope of their characterisation were presented.

It was reminded that, in parallel to these technical characterisations, SiteChar has investigated the social dimension of two prospective storage sites, the onshore Polish site and the offshore Scottish site and drawn learning's relevant to operators and also policy makers. SiteChar has also addressed at an interesting range of various sites the costs of the storage which are an important element of the final decision process. The results demonstrated that the structure of costs for a CO₂ storage project is very heterogeneous and the storage cost is consequently very site dependent. Main influential parameters were derived.

The speaker then outlined that these five sites have been characterised using a uniform methodology that consolidates existing workflows and that in addition is in line with requirements of the EC Storage Directive. The SiteChar methodology has been validated from insight from research on the SiteChar sites portfolio and all steps have been addressed, even if with variable levels and variable objectives due to the specifics of the site, the project concept, the available data and the associated uncertainties. This led the speaker to present the agenda of the afternoon session which was dedicated to the SiteChar workflow for integrated and accountable site characterisation with insights from research to answer the issues of a storage permit.

Then F. Delprat-Jannaud pointed out that a key innovation of the SiteChar project was the development of internal 'dry-run' permit applications that were evaluated by a group of independent geological experts and regulators who were thanked for their precious advice. Such a process allowed to identify the best approaches to site characterisation to enable robust and defensible permit applications to be developed by operators. It is also hoped to help regulatory authorities to identify the necessary levels of evidence required to assess the safety, the containment and the capacity of the storage site.

Outcomes of SiteChar thus consist in practice of technical recommendations for storage site characterisation and best practice guidance for storage permitting from the perspective of both applicant and regulator, for further use by storage site operators and regulatory bodies.

This opened the morning session that was dedicated to site characterisation for storage permitting aiming at providing and discussing guidelines for the preparation (for operators) and review (for regulators) of a CO₂ storage permit application.

2.3 Statement of Support from the Scottish Government

Stuart McKay (Scottish Government) expressed that the Scottish Government recognises CCS as a critical low carbon technology which is an essential component of the Scottish future energy portfolio. The Scottish Government was pleased to be part of the SiteChar project and believes that the information gathered in SiteChar's outreach exercises to communities in Poland and in Scotland provides important and very useful insights into public perceptions and public awareness of CCS. Likewise the geotechnical information and modelling data generated through the SiteChar project will be of great interest to Government's, public bodies, regulators and industry.

Scotland is blessed with a very large CO₂ storage capacity in the North Sea, Scotland also has access to a ready supply chain through the oil and gas industry, and as a nation it has the academic ability, and of course experience and skills in working offshore, to make CCS happen. All these things place Scotland in a good position on the CCS starting grid and the outputs from the SiteChar project bring another important step nearer to realising the potential of CCS and will also be of great help to the wider EU CCS community.



2.4 Developing a storage permit: A risk assessment-led characterisation

Maxine Akhurst (BGS) introduced the UK northern North Sea site and the related project concept highlighting it is a multi-store CO₂ storage site especially relevant, as hydrocarbon fields are planned as stores for demonstration projects and saline aquifers are anticipated for commercial scale projects. She presented the objectives of the research conducted within SiteChar that were to evaluate a storage site that combines a hydrocarbon field and a saline aquifer sandstone, to test an injection strategy aiming at maximising the capacity at a site appropriate for commercial-scale storage, to investigate the relationship between the predicted performance of the storage site and adjacent hydrocarbon fields and finally to undertake site characterisation sufficient to inform a 'dry-run' storage permit application.

She pointed out the role of risk assessment in site characterisation aiming to develop a storage permit. Site characterisation aims at understanding the risks to secure containment of CO₂ at a specific site. The characterisation of the UK northern North Sea site as well as those of the Vedsted site which also developed a 'dry-run' storage permit was led by a risk assessment aiming to anticipate, reduce, mitigate risks and monitor unmitigated risks. An initial risk assessment conducted as a first step of the project thus determined what site characterisation activities were needed and aimed at ensuring that resources, time and effort were focused to meet the objectives.

The speaker noted that it was not possible to fully address all the aspects of a storage permit within the resources and data available within SiteChar. Some remaining issues and challenges, such as the need to investigate the environmental standards and the cost implication of pressure relief, were listed.

She presented the key learning's from the SiteChar experience:

- A first-pass storage permit can be prepared from publicly available data;
- 'Pre-characterisation' of a site highlights additional investigations and targets information and activities needed;
- Even where there is abundant site-specific data, additional information will always be a sought;
- Greater anticipation of risks and alternative site parameters will be required where data is sparse;
- Pressure footprint and pressure management is a key issue in an area with other users of the pore space.

She concluded with the recommendations drawn from the development of the 'dry-run' storage permit on the UK northern North Sea site:

- It is essential to make readily available data required for storage site characterisation;
- Risk assessment should lead site characterisation from the very start;
- Successful multi-disciplinary characterisation requires very close integration of all investigations;
- The implications of emerging characterisation results in one discipline must be considered by all other disciplines;
- The project concept is expected to evolve, reinforcing the need for close communication between disciplines. Revised planning of site characterisation activities has to be anticipated.



2.5 Developing a storage permit for an onshore aquifer

Carsten Nielsen (GEUS) introduced the Vedsted site and the related project concept highlighting it is an onshore aquifer identified as a candidate for CO₂ storage by GEUS in 2003 and processed by Vattenfall till late 2011 to be an industrial scale demo project but today abandoned due to the lack of political support for CCS deployment in Denmark until at least 2020. He presented the objectives of the research conducted within SiteChar that were to complete a site characterisation comprehensive enough to fulfil a 'dry-run' storage permit application, to investigate different ways to supplement a sparse data set, to explore and mitigate impacts on the surrounding area from the storage operation and especially undesirable pressure footprint, to set up a monitoring strategy for best risk management including relevance of baseline survey(s) and to assess the old well integrity.

He developed the solution applied to handle the lack of data, the issues related to the regional pressure development and the definition of the complex storage. He detailed the monitoring plan pointing out the need to develop adequate baselines. He emphasised that the characterisation of the Vedsted site has followed a similar process as for the UK North Sea site, *i.e.*, driven by the risk assessment.

He noted that, as for the UK northern North Sea site, it was not possible to fully address all the aspects of a storage permit within the resources and data available in SiteChar. Some remaining issues and challenges, such as the need for production data and well tests to calibrate hydrodynamic models, were listed.

He ended with the key learning's from the SiteChar experience:

- It appeared very instructive to build the model framework as early as possible in the characterisation process so as to guide the risk assessment, the model being simple with complexity added according to characterisation key findings;
- An iterative process was applied updating models as the project progresses and at different scales;
- The risk assessment controlled the individual elements of a storage permit application;
- Regional pressure development appeared not fully defined in the EC Storage Directive, and this uncertainty made the definition of the storage complex difficult.

He concluded with the recommendations drawn from the development of the 'dry-run' storage permit on the Vedsted site:

- For the modelling part, it is recommended to start a simple characterisation and then to introduce more complexity as the project experience and knowledge progresses;
- For onshore (maybe also offshore) sites with sparse data coverage, an incremental development can reduce risks and costs;
- Baseline surveys are essential;
- Pressure footprint on the surrounding areas from the injection operation must be assessed and potentially mitigated through water production.



2.6 Dry-run storage permit applications: Lessons learned from the perspective of operators and regulators

Jonathan Pearce (BGS) acknowledged that permit development needs to be tested at credible sites since to date only one application has been made for a storage permit under the EC Storage Directive and that, even if demonstration projects are working towards submitting permits, they are not yet ready. It was the objective of SiteChar to develop credible storage permit applications and ensure site characterisation is fit-for-purpose and complies with the regulatory requirements.

The speaker summarized the scopes of the 'dry-run' applications that were developed at the contrasting sites highlighting that this process allowed evaluation of some of the more challenging aspects of storage permitting requirements without the constraints of a commercial project. He came back on the issues related to the definition of the storage complex that definitively needs a clear and prior agreement with the Competent Authority indicating that, within SiteChar, it was proposed to define the complex boundary on the basis of the extent of the CO₂ plume. He also pointed out that, if the nature and extent of interactions with other users is a key consideration for regulators, assessing future interactions might be challenging for operators. Finally he noted that disposal of water offshore is not considered particularly challenging, as it is widely practiced in oil and gas production, but that it might be a key topic in the storage and environmental permits for onshore sites.

The speaker then presented the Permit Performance Conditions developed within SiteChar to define the limits to site behaviour which, when exceeded, indicate that a significant irregularity or leakage has occurred. He recommended to include some flexibility in the storage permit to reflect changes in operation based on a prior agreement on conditions under which permits should be changed.

He also argued that it is crucial to agree, during permit negotiations, exact evidence required to enable site closure and transfer of responsibility.

Finally he pointed out the importance of communication and management of uncertainties, concluding that the operator and the Competent Authority will need to agree on acceptable levels of uncertainty as well as evidence needed to support the permit application.

The speaker concluded on the important role of the Competent Authority that may need to undertake its own risk assessment and that should support investigations to provide guidance to operators, including around third party access.

Questions arose regarding the consideration of the cost of the storage project per tonne of CO₂ within the Permit Performance Conditions. It was answered that the SiteChar reasoning was that the permit would be submitted on the basis of the available knowledge at the time of the characterisation. The economy of the storage was not considered as a proper criterion for the Competent Authority. However it was acknowledged that such an assessment is essential for the operator to take a financial decision and that consequently operators might include some considerations about costs to evaluate whether the project is viable.

2.7 First open discussions

The first discussion session started with an introduction from F. Kalaydjian who invited the members of the first panel of experts to join: Finn Dalhoff (COWI/Vattenfall), Hallvard Høydaalsvik (Gassnova), Angeline Kneppers (GCCSI), Lionel Perrette (French Ministry of Environment and Sustainable Development and Energy) and Rune Thorsen (Statoil).



F. Kalaydjian opened the discussion asking the panellists to provide insight on three starting questions. *What is good enough to gain a storage permit?* He acknowledged that answer to such a question requires to clarify to whom this question is addressed. He then reminded that the development of permit application should be driven by risk and uncertainty reduction so that the Competent Authority might ask for the maximum certainty and the minimum risks. He acknowledged that the operator might not be able to pay for a fully secure project if any and that he might also count on the improvement of methodology that will ensure the liability transfer 20 years after the end of injection. *What issues regarding permit application still need some clarification?* And what is the way to improve the different concepts that have to be addressed in the permit applications? *Which criteria to assess long-term security and support liability transfer?*

L. Perrette recalled that the French Competent Authority has some experience gained on the Lacq project where similar questions have been addressed at a smaller scale and which is now entering



the post injection phase and preparing the transfer of responsibility from Total to the State as well as on the Arcelor-Mittal project for which exploration permits have been delivered. He first confirmed that, from the Competent Authority perspective, some uncertainties should be acceptable as soon as the limit of these uncertainties are well known. However considering that all these projects will be incremental, he pointed out that it is important to have a plan on how the gaps and uncertainties will be closed during the process of operating the site, including an adequate baseline and an appropriate monitoring program to detect any irregularities. In addition to technical criteria, projects would need to be part of a local political approach regarding energy and use of the underground. The speaker stressed that such project will take time starting with the development of an exploration permit during which the operator, the Competent Authority and the citizens will learn each other and learn about the project. The definition of the storage complex is critical and the way it has been addressed within SiteChar seems reasonable. He noted that the financial security is a wide subject and that guarantees will have to be considered as dynamic and varying during the project. Regarding liability transfer, he argued that the legitimate end of the storage is the transfer of the site to the State. His opinion is that the transfer is not something obtained at the end but something planned at the beginning. This transfer is expected to be prepared for throughout the process. If the dialogue is there, if the understanding of the site is appropriate, he does not see any reason for the site not to be transferred to the State.

H. Høydalsvik expressed that his objective is to have CCS ongoing. He pointed out that main focus should be on how risks are met and reduced. He supported the idea to drive the site characterisation by risk assessment. He pointed out the importance of the storage definition. He mentioned the great variability of the storage sites and supported the need for dialogue with the Competent Authority. He indicated that he does not like 'worst' case assessments that give a too pessimistic idea of the reality and suggested to rather focus on risk mitigation and corrective actions. Finally he highlighted the need for some running demonstration projects, suggesting to start with small projects. He expressed that governments have to behave not only as regulator but also as funder. He emphasised the need for dialogue and estimated that the notion of transfer of liability has been too over focused. Transfer of liability without any problem will be the normal case.

A. Kneppers reminded that the ROAD project produced a report on permitting in which an early dialogue with the Competent Authority is defined. The permitting process is definitely a long process. The definition of the storage complex was also an issue solved with a compromise on what would be acceptable for both parties. The speaker also added that the ROAD experience shows the need for an agreement for financial contribution acceptable to both parties to avoid any unlimited requirements from the Competent Authority.

F. Dalhoff precised that Vattenfall submitted the application before the transposition of the EC Storage Directive into the Danish Subsoil Act. He confirmed the challenges related to the definition of the storage complex and the possible issues associated with the development of the overpressure and the financial security. He explained that disposal of water produced for pressure relief might help public acceptance since, associated with geothermy, it could lead to cheaper energy.

R. Thorsen pointed out that for an industrial partner from oil and gas industry, CO₂ storage is a new business with a potentially low reward. He agreed the need for dialogue to communicate the uncertainty and the need for both parties to trust each other. Starting early the development of an exploration permit is the key for a successful dialogue. He argued that the Competent Authority should play an active role in the process. He supported the definition of acceptance criteria as essential elements to define what is good enough for the storage permit and to accordingly design data acquisition and development plan. He estimated that transfer of liability first calls for the definition of the best available technology with balanced cost benefit.



F. Kalaydjian thanked the panellists for their interesting interventions and opened the discussions with the audience.

Owain Tucker (Shell) pointed out the issues related to the complete value chain of CCS from capture to storage. He wondered how an incremental permit associated to additional volumes could fit the potential requirements of a power station that needs to make a financial investment decision and consequently needs to have guaranteed volumes of CO₂ to be stored. L. Perrette precised that, when he spoke of incremental permitting, he did not mean starting with low amount of CO₂. He rather considered to demonstrate from the start that the storage capacity is sufficient, even if in the longer term the capacity could be increased. O. Tucker pointed out that solution to this issue is certainly related to financing according to the way capture and storage can be funded.

S. McKay wondered whether and how Enhanced Oil Recovery (EOR) may change the business. R. Thorsen answered that EOR offshore is challenging and very costly at least applied to existing fields. An extra field might be actually needed to have a place to store the CO₂ that arrives from the power plant even when the oil production does need any CO₂.

Hervé Quinquis (IFPEN) reminded that the need for consensus on the definition of important terms, *i.e.*, such as the storage complex, will be tackled at international level by the new ISO TC 265 on the normalisation of CCS.

2.8 The SiteChar workflow to answer the requirement of characterisation

Filip Neele (TNO) outlined the development of a systematic workflow aiming at describing how the elements of the EC Storage Directive can be addressed, clarifying the links between the areas of expertise and providing the basis for an efficient and focused site characterisation.

He gave an overview of the characterisation workflow starting with the screening study at regional scale and continuing with a detailed study led by the risk assessment.

He concluded with the key learning's from the SiteChar experience:

- Site characterisation is risk based; continuous update of the risk matrix during the site characterisation is of key importance;
- Regular contact with the Competent Authority is strongly recommended;
- The team should be aware of the links between the different areas of expertise, all the most that characterisation is an iterative process.

2.9 Estimating the storage capacity: The first but still challenging step

Ane Lothe (Sintef) reminded that one of the first steps of site characterisation is to secure sufficient storage capacity, assess containment security over tens of thousands of years including estimation of trapping mechanisms and evaluate migration pathways for injected CO₂. She pointed out that estimating the storage capacity is often challenging according to the availability of data and the uncertainties on the geology.

The speaker highlighted some specific issues of storage capacity estimation on the SiteChar sites portfolio that offers an interesting range of site geology, available data and site characterisation progress.

She pointed out the key learning's from the SiteChar experience:

- Every site is unique;



- Level of detail in models is dependent on available data;
- Models are important to predict the storage capacity and visualise the CO₂ behaviour.

She concluded with the recommendations drawn from the application of the workflow on the SiteChar sites:

- The better quality data are available, the better models can be constrained;
- Size and resolution of the model should fit the resolution of the available data;
- Possible software incompatibility induces difficulties in defining a data exchange format. This requires a close interaction between geologists and engineers from the beginning of the project.

2.10 Evaluating the storage geomechanical stability

Valentina Volpi (OGS) recalled the two main objectives of geomechanical assessment: the evaluation of the storage complex integrity and the definition of geomechanical criteria that may constrain the design of injection strategy whilst reducing overpressure development. She pointed out two challenging issues: the lack of proper data and a too weak coupling between geomechanical modeling and hydrodynamic modeling that might limit the confidence on the results.

The speaker then illustrated, on the SiteChar sites portfolio, the various results that can be derived from an adequate geomechanical assessment: the evaluation of threshold overpressure for cap rock fracturing, the assessment of geomechanical risks related to fault reactivation and the prediction of seabed/topographic surface displacement.

She pointed out that availability of proper data, in particular reservoir heterogeneity, information on fault properties as well as overburden properties, initial stress conditions (pre-injection stress state) is a strong limitation to geomechanical assessment. She indicated that characterisation of earth movement has still to be developed in order to enable the definition of safety margins of operation.

She finally pointed out the key learning's from the SiteChar experience:

- Fault behaviour is a key element for site characterisation and risk assessment;
- Lack of proper data is a main limitation to geomechanical assessment of the site;
- Simulations of different scenarios allow to evaluate fault impact deriving by their geometry and property uncertainties;
- Close collaboration is required between teams during all phases of the project to share the purpose of the models, software/format compatibility, model extent and resolution;
- Interplay between regional and site scale models allows to assess pressure development outside the storage site and define the boundary conditions.

She concluded with the recommendations drawn from the application of the workflow on the SiteChar sites:

- There is a need for a close cooperation between teams/disciplines, in particular between geologists, fluid flow modellers and geomechanical modellers.
- Compatibility and interoperability of software appear to rise quite a number of issues. It should thus be tested at the outset of the characterisation process.



- Sensitivity analysis, as well as simulations of worst and best case scenarios, might be a practical way to address lack of proper data.

From the audience, Franz May (BGR) pointed out that worst case scenarios might lead to too pessimistic results and that it might be useful to extract cores from the faults so as to derive proper data.

2.11 Well integrity assessment

Łukasz Klimkowski (AGH) recalled that possible leakage through existing wells is recognized as the most probable pathway for CO₂ leakage. Identification of potential risks requires first the evaluation of the state of the well and second the assessment of well integrity. This is a challenging task considering the number of wells to investigate that might be quite high in case of CO₂ storage in a depleted hydrocarbon field, lack of proper data and additional issues related to well accessibility.

The speaker then illustrated the different steps of well integrity assessment that starts with a review of all existing data, *i.e.*, well construction, abandonment materials and methods, comparison with current legislation. Then leakage scenarios are simulated to allow the design of remediation and monitoring strategy. A thorough risk assessment ends the study, considering all possible cases (wells to be intervened, left for abandonment or reactivated) and including costs.

The speaker concluded with the key learning's from the SiteChar experience:

- A complete and relevant analysis of well integrity should include some financial as well as operational criteria, some insights about the accessibility of wells, regulation requirements and any possible issues related to public opinion;
- Main issues are the lack of proper data and proper abandonment documentation, the large amount of efforts required to conduct a proper well integrity analysis, the need for a specific analysis of each well that might be time consuming considering the possible high number of wells.

2.12 Public engagement activities to inform development of a storage permit

Suzanne Brunsting (ECN) indicated that the aim of SiteChar public engagement activities was to develop a tested format in which operators, regulators and local stakeholders can cooperate together in a constructive way so as to get projects off the ground. These groups should be aware of what the other ones are doing and they should have trust in the process and in each other. Operators need to familiarise themselves with the local area. Local stakeholders need to know about CCS and the specific project. Regulators need both types of knowledge to be able to decide whether the different interests have been properly weighted. She emphasised that the key to bring a project forward is not so much knowledge but trust.

The speaker explained that SiteChar has investigated format for informing cooperation and format for enhancing cooperation. Social site characterisation aims at building a social map of local opinion shapers. She compared the social maps of the offshore site in Scotland and the onshore site in Poland. She noted that both areas showed quite a high level of unemployment and some potential for tourism. She pointed out that expectations were rather economic benefits in Scotland and environmental risks in Poland which might be explained by the higher level of unawareness in Poland than in Scotland and the proximity of the Polish site to local communities. However, both in Scotland and in Poland, citizens were in general rather in favour of CCS.



Enhancing cooperation was based on focus conferences that are very intensive forms of focus groups (sixteen participants involved on two week-ends) to be informed about CCS, technology with representatives of all key perspectives on CO₂ storage: government, industry, NGO. At the end of these two week-ends, people wrote a position paper which is a statement on CCS and conditions for local acceptability of a CCS project. In Scotland, participants believed “it important that an exit strategy should be developed [...] to address how to scale down and then ultimately exit the CCS industry completely at a later point in the future”. In Poland, “the majority of the group thought that there are too many uncertainties to clearly opt for carbon capture and storage technology (CCS)”.

The speaker concluded with the remaining issues and challenges:

- Ethical challenges to experimental ‘one-off’ interventions;
- Hypothetical research project vs. real commercial project;
- Need for costs-benefits analyses of public participation efforts.

2.13 Second open discussions

The second discussion session started with an introduction from J. Pearce who invited the members of the second panel of experts to join: Wilson Hull (EON), Camilla Skriung (Zero), Derek Taylor (DMT Energy Consulting), Owain Tucker (Shell). He asked the panellists to open the discussions giving their position on following starting questions. *How should an effective risk-reduction strategy be defined for site characterisation? How do we priorities risk reduction activities and balance site characterisation with cost? What are the roles of operators and state authorities in supporting site characterisation? How do we get a ‘social permit’ for storage during site characterisation?*

C. Skriung estimated that there is a need for a political and financial framework for CCS and CO₂ storage, not only legal measures and standards but also market and financial mechanisms. Incentive for doing CO₂ storage could be for instance gas export with a kind of deposit. She estimated that governments and national authorities should have the responsibility to develop and administer storage sites. She highlighted the need to relate CCS to climate changes and to raise positive sites of CCS, e.g. employment, to associate CCS with cement rather than coal or gas production since easier to accept by the public. She added that payment by the company who emits CO₂ rather than by the State would more easily acceptable by the citizens. She supported the need for an early communication with the public, even before deciding to explore the site, being transparent, having open dialogue, developing the project in a democratic manner. She finally recommended to run the first demonstration project somewhere where people actually want to so as not to waste time.

D. Taylor said that it is very important to distinguish the demonstration phase of CCS from its deployment. During demonstration, when it is often a simple one source - one sink model, probably operated by a limited consortium, public funding would be critical for success. During actual deployment, the role of the different operators would become increasingly more important. During the demonstration phase, for example, site characterisation should be mainly funded by governments. But when it comes to commercial deployment, site characterisation should be the responsibility of the site operators. The speaker pointed out that the regulator has a vital role to play not only concerning issuing permits for exploration and safe exploitation. The regulator should also put forward the views and concerns of the local population - acting as the ‘people’s champion’ - during the preparation of Environmental Impact Assessments (EIAs). The operators, for their part should regard such assessments as an opportunity for a full and open dialogue with all those who



have a valid interest in the safe operation of CCS and not only a legal requirement that has to be met.

W. Hull pointed out that there have been numerous conferences and research works investigating storage aspects and that significant progress has been made. He however expressed that costs reduction will have to be investigated and demonstrated at a much larger scale within Europe. He estimated that such an experience at large scale is likely to yield costs reduction together with improvement, understanding and knowledge. He reminded that some similar problems might be solved in different projects worldwide. It is thus essential to share the knowledge from projects undertaken around the world and not only in Europe so as to make operators and all stakeholders involved in CCS benefit from these experiences and ensure that the investment is not wasted. He argued that Member States and the European Union have a role to play in supporting site characterisation since CCS will have a role in short- and long-term energy generation. He noted that the EC Storage Directive has been implemented in 2009 and that there has been no CO₂ storage implemented under this Directive since. Therefore he called for cooperation both at European and national levels to de-risk some of the costs associated with CO₂ storage. He agreed that public engagement is key but added to previous statements that CCS is a chain with a CO₂ producer that will be a power plant or another industrial facility, a transport infrastructure and a storage site. In UK where storage will be offshore, the storage itself might attract less attention than the new power plant or the transport infrastructure. He thus recommended to make sure that all three pieces can be put in place before deployment. He confirmed that engagement with Member States and Competent Authority will be key to understand the issues of a specific project, define some of the risks and understand how these can be addressed and define relevant Permit Performance Conditions.

O. Tucker noted that the Australian legislation is not about containment but about impact of CO₂ leakage. He recommended to concentrate efforts where it might be important in terms of impacts, whatever there are associated with social or technical concerns. He argued that, as in the oil and gas exploration, the first project will cost the maximum. He confirmed that any issue that is solved at one site in Europe or worldwide will provide solution to similar issues at similar sites. Shell's experience confirmed that a good partnership with the Competent Authority is essential to support the characterisation such as the EPR financing for the North Sea. He argued that energy efficiency has to be pursued but that it will not be possible to turn off coal fired and oil and gas fired power stations and cement factories tomorrow. The only way to rapidly decarbonise energy is thus to apply all potential technologies. In this context, CCS is not an option but is mandatory to meet the 2020 target. He finally recommended to be completely open and honest with local stakeholders.

Jonathan Pearce thanked the panellists for their interesting interventions and opened the discussions with the audience.

Kirstin Anderson (GCCSI) confirmed that the perfect use of EIA is to get people involved. However she agreed that public engagement has to start prior to EIA. She supported communication with focus groups that should gather key stakeholders from the community and people who might have some influence.

A. Lothe suggested to force companies to launch CCS projects by fixing a deadline after which a plan for capture and storage will be required for any new power plant. D. Taylor remarked that, while he personally supported such a proposal, the European Commission had initially planned to do this but decided at the time that it would not be logical nor politically acceptable to require a technology to be used while, at the same time, strongly supporting a programme for its so-called 'early demonstration' / C. Skriung disagreed. She estimated that CCS technology has been proven,

at least in the US, for a while. She acknowledged that such statements require to clarify what proven means and what demonstration and tests mean.

Bob Pegler (BBB Energy) agreed to have early discussions at local community. He however noted that we are living in a society with national debates and that it is important to communicate also at regional and national levels. O. Tucker mentioned that clean power that comes from fossil fuels is often criticised. He noted that it is exceptionally difficult to switch to a fully renewable power mix without any high increase of the electricity price. He thus supported communication at all levels. D. Taylor voiced the opinion that public communications efforts should be focused on a limited interpretation of the word 'public'. It is of course vital to talk to all people living in relatively close vicinity to any storage site, but he did not believe that money should be spent on trying to obtain a much wider acceptance by the 'average man in the street'. This would be a very expensive exercise which is unlikely to succeed. However efforts should be made to talk to decision makers, such as politician and opinion formers, such as the Press.





3 Concluding remarks

F. Kalaydjian closed the conference with some highlights of the day. It was realized that the permitting process has to be driven by risk assessment. He however pointed out that talking about risk is risky because of the common confusion of the level of risk with the risk itself which in fact takes into account the level of risk and the probability of occurrence. In general, as soon as a risk is mentioned, people tend to forget about the probability of occurrence and only concentrate on the level of risk. He thus recommended to rather talk about uncertainty. He was pleased to hear that some representatives of Competent Authorities recognise that uncertainty is acceptable at the beginning of the process as long as there is some mitigation process. He pointed out the necessity to build trust between stakeholders in a process that aims at decreasing step by step the uncertainty to come up with a good confidence in the CO₂ storage. Adequate monitoring and proper baselines are essential. He noted that Permit Performance Conditions have been recognised as a way to introduce some metrics and to formalise the objectives of this de-risking exercise.

He highlighted that SiteChar has identified some challenges to permitting and compliance with the EC Storage Directive that are related to the availability of influential data, such as the boundary conditions for hydrodynamic simulations, the definition of the storage complex, the lack of clarity in the long term issues. He thus encouraged improvement of the regulatory framework.

He supported the distinction between demonstration projects and CCS deployment; demonstration projects have to be supported by public funding. He noted that renewable energy is heavily funded by public money. He agreed that CCS at least in its early stage of deployment could be helped by different financial mechanisms, e.g. Emission Performance Standards, but he acknowledged that EPS are difficult to accept by the utilities because of cost issues and lack of benefits due to the very low price of CO₂.

He finally confirmed the importance of social support. He agreed that there is a value chain from capture to storage and that the process has to be considered in a global way. He argued that gaining locally the public support is very important but that people are not isolated so that communication at higher levels is also important.

F. Kalaydjian closed the conference reminding that there is a need to build trust between stakeholders and that transparency is most important for CCS.



4 Agenda



SiteChar Closing Conference 28 November 2013 ■ IFPEN Characterisation of European CO₂ storage



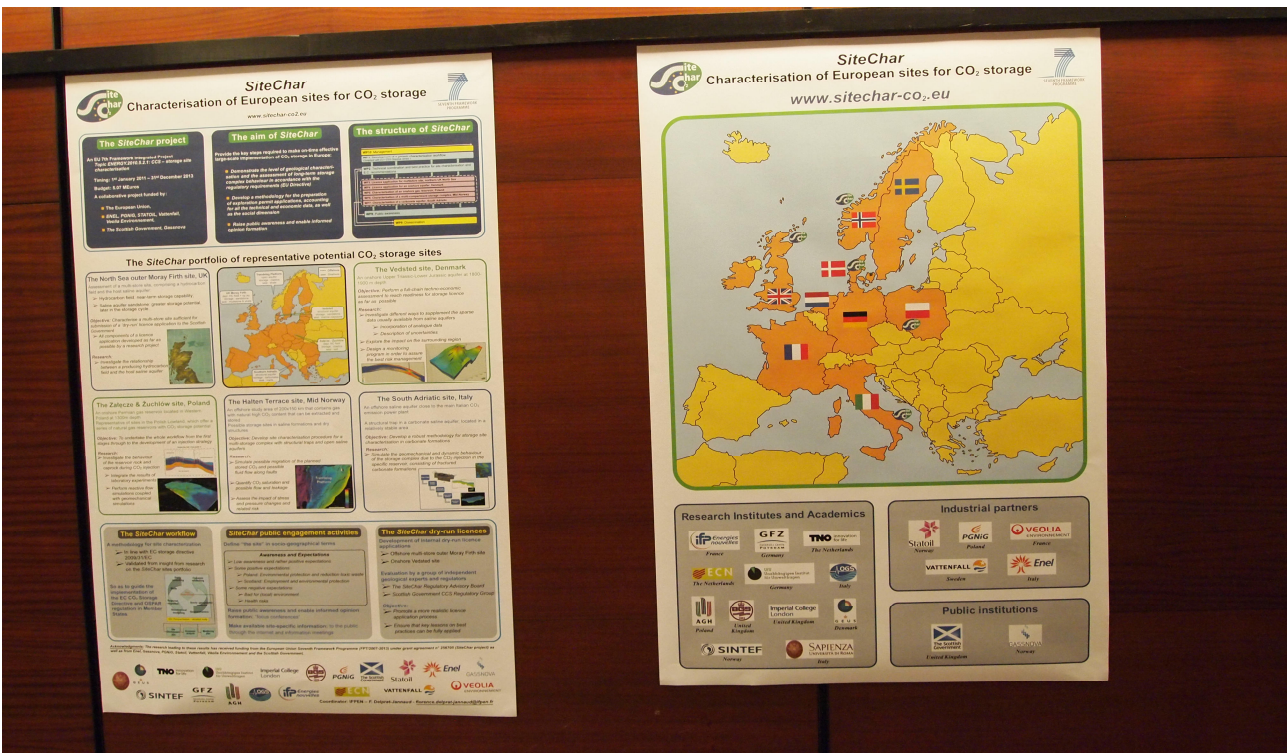
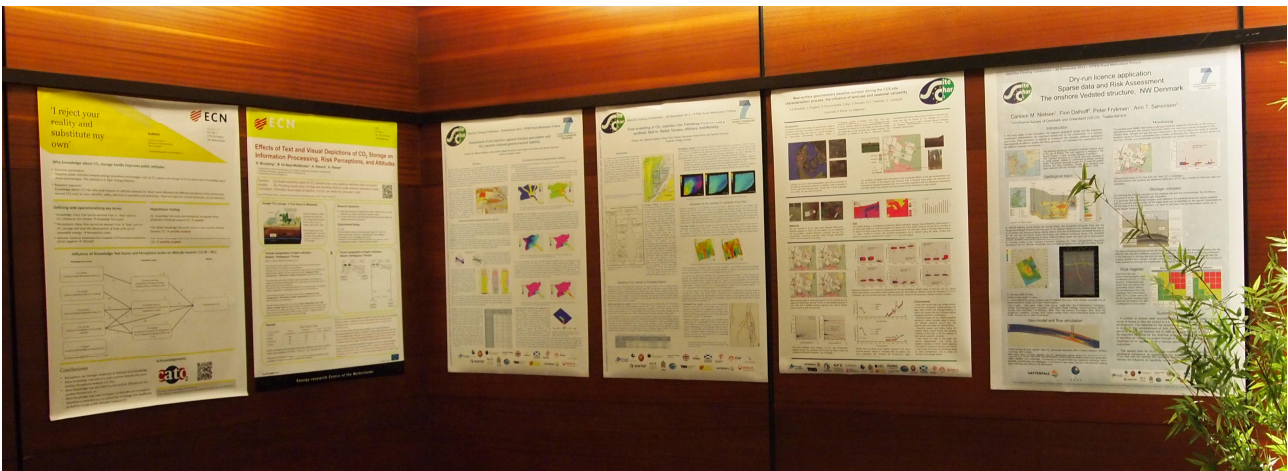
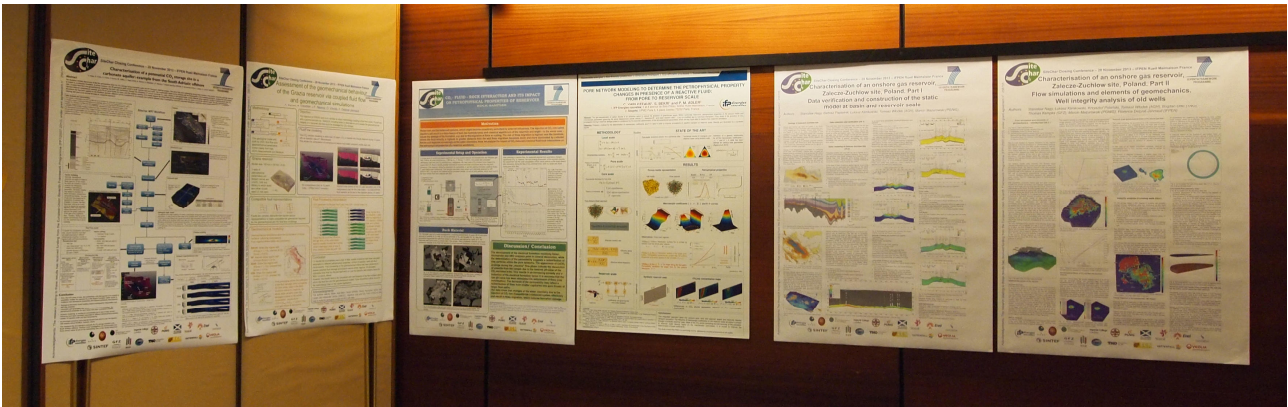
AGENDA

Morning 8:30 – 12.30			
Site characterisation for storage permitting			
<i>Guidelines for the preparation (for operators) and review (for regulators) of a CO₂ storage permit application</i>			
8:00 – 8:30	Registration		
8:30 - 8:50	F. Kalaydjian (IFPEN)	Welcome address	
8:50 - 9:20	F. Delprat-Jannaud (IFPEN)	The SiteChar project SiteChar Closing Conference Agenda	Chair: H. Pagnier
9:20 - 9:30	S. Mc Kay (Scottish Gvt)	Statement of Support from the Scottish Government	
9:30 - 10:00	M. Akhurst (BGS)	Developing a storage permit: A risk assessment led characterisation	
10:00 - 10:30	C. Nielsen (GEUS)	Developing a storage permit for an onshore aquifer	
10:30 - 10:50	Break / Poster session		
10:50 - 11:20	J. Pearce (BGS)	Dry-run storage permit applications Lessons learned from the perspective of operators and regulators	Chair: F. Kalaydjian
11:20 - 12:20	<ul style="list-style-type: none"> • L. Perrette (MEDDE) • A. Kneppers (GCCSI) • H. Hoyadalsvik (Gassnova) • F. Dalhoff (Vattenfall) • R. Thorsen (Statoil) 	Discussion / Panel of experts <ul style="list-style-type: none"> • What is good enough to gain a storage permit? • What issues regarding storage permits still require clarity from the regulatory perspective? • Which criteria to assess long-term security and support liability transfer? 	Moderator: F. Kalaydjian
12:20 - 12:30	Group photo		
12:30 - 14:00	Lunch		
Afternoon 14.00 – 18.30			
The SiteChar workflow for integrated and accountable site characterisation			
<i>Insights from research to answer the issues of a storage permit</i>			
14:00 - 14:20	F. Neele (TNO)	The SiteChar workflow to answer the requirement of characterization	Chair: F. Delprat-Jannaud
14:20 - 14:40	A. Lothe (SINTEF)	Estimating the storage capacity: the first but still challenging step	
14:40 - 15:00	V. Volpi (OGS)	Evaluating the storage geomechanical stability	
15:00 - 15:20	S. Nagy (AGH)	Assessing the well integrity	
15:20 - 15:40	Break / Poster session		
15:40 - 16:00	S. Brunsting (ECN)	Public engagement activities to inform development of a storage permit	Chair: J. Pearce
16:00 - 17:00	<ul style="list-style-type: none"> • W. Hull (EON) • V. Kougiouas (EC) • O. Tucker (Shell) • D. Taylor (DMT Energy Consulting) • C. Skriung (Zero) 	Discussion / Panel of experts <ul style="list-style-type: none"> • How to prioritise risk reduction and balance characterisation with costs? How to define an effective cost-reduction strategy? • Role of operators and state authorities in supporting site characterisation? • How to get a 'social ticket to ride'? 	Moderator: J. Pearce
17:00 - 17:15	F. Delprat-Jannaud F. Kalaydjian	Key learning of the projects / Next steps required for the deployment of CCS	
17:15 - 18:30	Poster session / Cocktail		

5 List of posters

POSTERS

ULTimateCO ₂ : a FP7 project dedicated to the understanding of the long term fate of geologically stored CO ₂	P. Audigane (<i>BRGM</i>) & the ULTimateCO ₂ team
Assessment of the geomechanical behaviour of the Grazia reservoir via coupled fluid flow and geomechanical simulations	A. Baroni, A. Estublier, J.F. Nauroy, F. Delprat-Jannaud - <i>IFPEN</i>
Pore network modelling to determine the petrophysical property changes in presence of a reactive fluid: from pore to reservoir scale	S. Bekri - <i>IFPEN</i>
'I reject your reality and substitute my own': Why knowledge about CO ₂ storage hardly improves public attitudes	S. Brunsting, M. de Best-Waldhober, B. W. Terwel - <i>ECN</i>
Effects of Text and Visual Depictions of CO ₂ Storage on Information Processing, Risk Perceptions, and Attitudes	S. Brunsting, M. De Best-Waldhober, H. Riesch, D. Reiner - <i>ECN</i>
SiteChar: Characterisation of European sites for CO ₂ storage	F. Delprat-Jannaud (<i>IFPEN</i>) & the SiteChar team
CO ₂ – Fluid - Rock interaction and its impact on petrophysical properties of reservoir rock	J. Kummerow, E. Spangenberg, R. Naumann - <i>GFZ</i>
Characterisation of an onshore gas reservoir, Zalecze-Zuchlow site, Poland. Part I Data verification and construction of the static model at basin and reservoir scale	S. Nagy, B. Papiernik, Ł. Klimkowski, T. Włodek (<i>AGH</i>), M. Mazurowski (<i>PGNiG</i>),
Characterisation of an onshore gas reservoir, Zalecze-Zuchlow site, Poland. Part II Flow simulations and elements of geomechanics. Well integrity analysis of old wells	S. Nagy, Ł. Klimkowski, K. Polański, T. Włodek (<i>AGH</i>), B. Orlic (<i>TNO</i>), T. Kempka (<i>GFZ</i>), M. Mazurowski (<i>PGNiG</i>), F. Delprat-Jannaud (<i>IFPEN</i>)
Dry-run licence application. The onshore Vedsted structure, NW Denmark	C. Nielsen and P. Frykman - <i>GEUS</i>
Assessment of pre-injection caprock fracture percolation and CO ₂ injection induced geomechanical stability at a multi-store Scottish site	J.Q. Shi, M. Babaei, J. Smith, A. Korre and S. Durucan - <i>Imperial</i>
Flow modelling of CO ₂ injection into Trøndelag Platform and a synthetic field in Halten Terrace, offshore mid-Norway	J.Q. Shi, M. Babaei, D. Chen, R. Govindan, A. Korre and S. Durucan - <i>Imperial</i>
Characterisation of a potential CO ₂ storage site in a carbonate aquifer: example from the South Adriatic offshore	V. Volpi, E. Forlin, D. Civile, F. Donda, M. Caffau, C. Sauli (<i>OGS</i>), A. Baroni, A. Estublier, J.F. Nauroy, F. Delprat-Jannaud (<i>IFPEN</i>), S. Kuczynski (<i>AGH</i>), I. Larsen, A. Lavrov (<i>SINTEF</i>).





6 List of participants

Name	Surname	Organisation	Country
Maxine	Akhurst	British Geological Survey	United Kingdom
Kirsty	Anderson	Global CCS Institute	United Kingdom
Aline	Aurias	Press	France
Masoud	Babaei	Imperial College London	United Kingdom
axelle	baroni	IFPEN	France
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Samir	Bekri	IFPEN	France
Habiba	Boulharts	IFPEN	France
Suzanne	Brunsting	ECN	The Netherlands
Dario	Civile	OGS	Italy
James	Craig	IEAGHG	United Kingdom
Finn	Dalhoff	Vattenfall	Denmark
Marcella	Dean	Shell Global Solutions International B.V.	The Netherlands
Jean Pierre	Deflandre	IFPEN	France
Sophie	Dehayes	Ministère de l'écologie, du développement durable et de l'énergie	France
Florence	Delprat-Jannaud	IFPEN	France
Federica	Donda	OGS	Italy
Sevket	Durucan	Imperial College London	United Kingdom
Andreas	Ehinger	IFPEN	France
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Edy	Forlin	OGS	Italy
Peter	Frykman	GEUS	Denmark
Bruno	Garcia	IFPEN	France
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Hallvard	Høydalsvik	Gassnova	Norway
Wilson	Hull	EON New Build & Technology Limited	United Kingdom
Silvana	Iacobellis	Enel	Italy
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David	Jones	British Geological Survey	United Kingdom
François	Kalaydjian	IFPEN	France
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Lukasz	Klimkowski	AGH UST in Krakow	Poland
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Anna	Korre	Imperial College London	United Kingdom
Szymon	Kuczynski	AGH	Poland
Michael	Kühn	GFZ German Research Centre for Geosciences	Germany
Thomas	Labatut	ECE Paris	France
yann	Le gallo	Geogreen	France
Pierre	Le Thiez	IFPEN	France
Ane	Lothe	SINTEF Petroleum Research	Norway
Jessanne	Mastop	ECN	The Netherlands
Franz	May	BGR	Germany



Name	Surname	Organisation	Country
Stuart	Mckay	Scottish Government	United Kingdom
Anthony	Michel	IFPEN	France
Federica	Modesti	University of Rome La Sapienza	Italy
Filip	Neele	TNO	The Netherlands
Carsten M.	Nielsen	Geological Survey of Denmark and Greenland (GEUS)	Denmark
Britta	Paasch	Statoil Research Centre	Norway
Henk	Pagnier	TNO	The Netherlands
Bartosz	Papiernik	AGH University of Science and Technology	Poland
Jonathan	Pearce	British Geological Survey	United Kingdom
Bob	Pegler	BBB Energy	Australia
Lionel	Perrette	Ministère de l'écologie, du développement durable et de l'énergie	France
Sergio	Persoglia	OGS	Italy
Hervé	Quinquis	IFPEN	France
Noalwenn	Sallee	IFPEN	France
Samuel	Saysset	GDF SUEZ	France
Ji-Quan	Shi	Imperial College London	United Kingdom
Camilla	Skriung	ZERO	Norway
Emmanuel	Soyeux	Veolia	France
Derek	Taylor	DMT Energy Consulting	Belgium
Rune	Thorsen	Statoil ASA	Norway
Alice	Tonnellier	OGS	Italy
Owain	Tucker	Shell	United Kingdom
Samuela	Vercelli	University of Rome La Sapienza	Italy
Olivier	Vincke	IFPEN	France
Valentina	Volpi	OGS	Italy
Tomasz	Wlodek	AGH University of Science and Technology	Poland



7 Press release

A methodological guide for the assessment of CO₂ storage sites SiteChar Closing Conference

A methodological guide for the assessment of CO₂ storage sites, incorporating all the technical and economic data as well as the social dimension, provides a valuable tool for the roll-out of geological storage of CO₂ on an industrial scale in Europe

On November 28th, 2013, the Closing Conference of the European SiteChar project, dedicated to improving the characterisation of sites for the geological storage of CO₂, was held at IFP Energies nouvelles (France). This event was hailed as a success having attracted significant interest and contribution from the wider community of stakeholders.

Coordinated by IFP Energies nouvelles, experts from academia, industry and government from 17 organisations in 9 EU countries (Denmark, France, Germany, Italy, the Netherlands, Norway, Poland, Sweden, United Kingdom) have gathered their experience and skills in the collaborative SiteChar project. The objective was to supply a methodological guide adapted to European geological contexts and European legislation for use by storage site operators and regulatory bodies. The project, launched in January 2011, was supported by the European Commission, Enel, PGNiG, Statoil, Vattenfall, Veolia Environnement, the Scottish Government and Gassnova.

The SiteChar research focused on five potential European storage sites, representative of the various geological contexts, as test sites for the research work: a North Sea multi-store site (hydrocarbon field and aquifer) offshore Scotland, an onshore aquifer in Denmark, an onshore gas field in Poland, an offshore aquifer in Norway and an aquifer in the Southern Adriatic Sea. At the Danish and Scottish sites, 'dry-run' storage permit applications have been developed on the basis of criteria defined by the relevant European legislation and evaluated by a group of independent experts. The studies conducted at the other sites have investigated some specific barriers related to the site characterisation methodology. SiteChar has considered the important aspect of the public awareness and public opinions of these new technologies in addition to technical problems.

Lessons learned from the SiteChar project, and the resulting transferable knowledge, inform assessment and permitting needs for CO₂ storage sites in Europe. These sites could be developed for the secure and permanent containment of millions of tonnes of CO₂ captured from power plants and industrial facilities. Crucially, the knowledge gained will help operators and researchers to conduct a proper assessment of potential CO₂ storage sites aiming at demonstrating safe and permanent storage. Results will feed into the development of regulatory frameworks for the CO₂ geological storage considered as a critical component in a portfolio of low-carbon energy technologies.

More details can be found at <http://www.sitechar-co2.eu/>

Dr Florence Delprat-Jannaud, of IFPEN and coordinator of the SiteChar project, said: "SiteChar provides a unique opportunity to test and improve the process of site characterisation so that it is both fit for purpose and meets the challenge of gaining a storage permit."

François Kalaydjian, IFPEN, said: "In some extent SiteChar has been able to supplement the lack of industrial demonstrations by delivering both technical and social related results that should enable to optimize and better shape the future CCS industrial projects. SiteChar is certainly a



major contribution to the implementation of CO₂ storage and should help kick starting CCS industrial activities when the market conditions will be met. ”

Stuart McKay, Scottish Government, said: “We were pleased to be part of the SiteChar project and believe that the information gathered in SiteChar’s outreach exercises to communities in Poland and in Scotland, provides important and very useful insights into public perceptions and public awareness of CCS. Likewise the geotechnical information and modelling data generated through the SiteChar project will be of great interest to Government’s, public bodies, regulators and industry.”

Rune Thorsen (Statoil) said : “Agreement of acceptance criteria between the operators and the Competent Authority, as recommended by SiteChar, are essential to build trust and promote development of a CO₂ storage project.”

Lionel Perrette, French Ministry of Environment and Sustainable Development and Energy said: “During the development of exploration permits and storage permits, the operator, the Competent Authority and the citizens learn about each other and learn about the project. The way this process has been addressed in SiteChar is an illustration of how to gain the required confidence.”

Camillia Skriung, Zero, said: “It is crucial when introducing any new project to be transparent and have open dialogue, as well as to develop a project in a democratic way, as advocated in SiteChar.”

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Notes to editors

The organisations conducting the research in SiteChar are: AGH, ECN, ENEL, IFPEN, GEUS, GFZ, IMPERIAL, NERC, OGS, PGNiG, Statoil, TNO, SINTEF-PR, UniRoma1-CERI, UfU, Vattenfall and the Scottish Government.