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1. Objectives

CGS Europe is a Pan European action and one of its main goals is to widespread CCS technologies and related activities within all participant countries. To reach that goal, CGS Europe programmed an entire Work Package (WP4) dedicated to "Knowledge Development", including a specific task that aims at helping the members to (at least) partially align their research programmes.

The first step to achieve this narrow cooperation between members is to have a global overview on research activities carried out by members, research opportunities that can be found in each of their countries and other research opportunities that can be found in bigger regions or all across Europe. Once this information is analyzed at a global scale, the goal is to identify research areas where different participants can establish fruitful cooperation and promote the development of this cooperation through participation in common projects in national, regional or European funding schemes.

This action is in particular dedicated to participant countries that have not yet well established, large R&D structures/organisations in CCS and that are thus not yet part of the EERA CCS Joint Programme. This action can help those smaller organisations to get ready, within the timeframe of CGSEurope, for applying for membership in the EERA CCS JP.

2. Methodology

To obtain global information on research activities, a questionnaire was sent to all participants. This questionnaire consisted on five questions about participant and national activities related to different technologies and a variety of research areas related to those technologies. To establish these technologies and research areas ZEP document on "Recommendations for research to support the deployment of CCS in Europe beyond 2020" was used.

This questionnaire was planned in a fixed-answer base (yes, no, partially) in order to obtain a quick classification of the activities. The results of questionnaires supplied by all participants were then compiled and analyzed in order to obtain some common profiles of research activity in different participants, regions, etc. Funding schemes in participant countries are also analyzed, having the goal of identifying research areas that need special attention in the short term.

This analysis will then give some advice on how to develop these different research areas in Europe with economic and temporal effectiveness. Furthermore, it will be necessary to quantify human resources that are being committed in different research areas by CGS Europe partners, linking these results with the goals of the EERA CCS JP sub programme on CO_2 geological storage.

3. Research activities analysis

3.1 Research areas related to wells technologies

Wells are the key tools needed to get access to reservoirs, both at the exploration and the injection phase. Existing wells can be paths for leakage and this can become a main issue, especially when existing oil and gas fields are used for CO_2 storage. New wells have to be drilled with security factors that enable isolating reservoir blocks from leakage paths and also preventing CO_2 corrosion.

Just three partners consider some well related technologies as part of their core business and six of them have no activity at all in them. The rest of the partners have some partial initiatives, with specific detail in exploration, monitoring and leak characterization. Those research areas linked to engineering of wells, such as drilling or fracturing technologies, have a low activity from CGS Europe partners. This can be caused by the lack of field activities that can contribute to research in these areas and also because of the lack of funds for them, as 90% of the partners have answered there are no public or private funds for this research and it is not likely that there will be funds in the future.

Anyway, many of the partners have expressed interest in cooperation in different research areas. Therefore, a further study of possible cooperation has to be done in order to define better how these groups can make this will of collaboration effective.

3.2 Research areas linked to capacity assessment

Capacity assessment is the key question in many political decisions as capacity numbers define if CCS is applicable or not in a given country. Capacity assessment is very complex and may be very differently oriented in participant countries. Some of them are very interested in the use of depleted hydrocarbon fields while others need to assess saline aquifers capacity because of their lack of oil and gas resources. A few of them might be interested in coal seams evaluation and ECBM recovery. It is also dependent on technical, economic and regulatory factors that may have strong variations from one country to another.

A high majority of partners considers capacity assessment as the core of their business or at least as a part of their activity. Many of them have been part of GESTCO or GeoCapacity projects, or both of them. It is also frequent that partners are or will be soon participating in national programmes that aim to assess the CO_2 storage capacity of geological formations, i.e. a storage atlas, expressing their will to participate in a European project that could have, as a final result, a European Carbon Sequestration Atlas that could be homologous of those published in the United States, Canada or Australia.

There is less strength in the development of methodological standards as many partners do not consider this area as their core business, mainly because national programmes tend to fund storage atlas and saline aquifers research but it is not as common to fund methodological research or refining storage coefficients in order to establish more precise capacity calculations that can lead to the determination of practical or matched capacities at local scales.

3.3 Research areas linked to mitigation and remediation

Mitigation and remediation measures aim to provide safe storage of CO_2 even in the case some undesired events occur. As it was stated in the case of well technologies, most of the proposed research areas are linked to reservoir engineering. Moreover, many of these technologies have been previously developed by oil and gas industry and research is needed to prove that these technologies are applicable to CO_2 storage and the new legislation.

Therefore, as it also happened with well technologies, many of the partners do not consider these areas as part of their core business and only three of them answered positively to that question. There is one

exception in the case of research about effects on the environment of storages and potential leakages and early remediation actions. More than 50% of the partners have an activity in that area and some more wish to start that activity and express their availability to cooperate in this area.

There is also a lack of funding for these research areas. Many participants confirm there is no funding programme in their countries and as far as they know there will not be a funding programme in the near future. Moreover, private companies do not seem very interested in developing these research areas at a European scale at least not in cooperation with research centres.

3.4 Research areas linked to land planning and infrastructure

One of the latest aspects that has been included as a large field of research in CCS technology is the correct planning of land use. This includes not only possible conflicts of use between different resources and CO_2 storage but also the development of tools for the design of optimized integrated networks of CO_2 capture, transport and storage. An adequate land planning is vital nowadays in order to develop a more efficient and sustainable integration of industrial activities with the environment. Moreover, CCS can easily become an international activity that may have sinks in one country that may be used to store CO_2 captured in a neighbouring one.

Land planning is not considered a core activity by many participants, especially in Eastern and Northern Europe and just in some cases there is interest in studying mechanisms that can lead to the resolution of conflicts between uses of land for gas storages or groundwater production and CO_2 storage. There is very limited interest in other fields like cross-boundary systems or integrated infrastructures, possibly because it is not a priority in Eastern countries at this point and it is not an issue for oil & gas producers.

Western countries are more active in this field and there is strong activity in the development of models for integrated CCS networks and combined uses of land, including cross-border issues. Some national programmes are funding these activities as well as the European framework programme through several projects (Europipe, COMET,…) and partners that are doing research in this area express their will to strengthen the cooperation in different research areas.

3.5 Research areas linked to storage complex management

Management of storage complex means optimization of capacity, injectivity and safety in the storage formation. In the case of capacity, specifically in the case of saline aquifers, it is very important to manage pressure variation, in some cases through water production and disposal, increasing pore volume use but taking care of avoiding collapse of rocks. Injectivity may depend on the interaction of CO_2 injected and rock and brine composition. Careful characterization of them and the development of more precise simulation models are needed in order to optimize gas stream and enhance permeability.

Management of the storage complex is considered core activity by those partners participating in pilot or demonstration projects and field tests. There is also large interest in some New Member States in dissolution and mineralization, where partners express strong will of cooperation. Other partners do not consider these research areas as part of their priority activities.

As it was stated before, only some international pilot projects are funding storage complex management research at this point, although it is a key part of technical annexes of the EU Directive on geological storage. It is likely that when demonstration projects are active, management of the storage complex will become one of the main activities of CGS Europe partners.

3.6 Research areas linked to environmental impacts

A detailed study of environmental impacts is also one of the requirements of EU Directive on geological storage of carbon dioxide. As the extent of environmental studies will depend on fragility of potential receptors (groundwater, animals, vegetation…), impacts need to be characterized and quantified. Moreover, a cost effective and technically successful environmental study will increase confidence on CCS technologies, and this confidence will lead to an easier and wider deployment of them.

Environmental impacts are part of the core activities of most CGS Europe members in Western Europe, and most of them are intending to be the reference for environmental impacts study within the EU Directive. Less activity is registered in the development of remote sensing techniques which are mostly linked to pilot field tests, but cooperation in these areas is considered interesting for these partners. On the other hand, many New Member States are not interested in this issue.

Very few countries are now financing activities related to environmental impacts and a great part of the funds come from pilot test projects. This can be a hazard for CCS deployment, as only two participants have declared that private companies are investing in these research areas in their countries and environmental impacts assessment is one of the requests imposed by the EU Directive for CO_2 storage authorization.

3.7 Research areas linked to modelling

EU Directive on geological storage of carbon dioxide states modelling as a technical requirement for CO_2 storage exploration and exploitation. Modelling is required not only as a geometrical description of the storage complex but also as a tool for predicting capacity and injectivity, designing monitoring programmes and also as a key information for risk assessment. Modelling research needs are mostly related to dynamic modelling, including multi – physics analysis including upscaling methodologies.

Modelling is considered part of their business by a high majority of CGS Europe partners in some or all research areas. Flow, geomechanical and geochemical modelling is carried out in many research institutes and results are used for guidance documents. Although cooperation is supported in all research areas, there is a specific will for sharing experience in experiments for further knowledge of trapping mechanisms, reactive transport and heterogeneities effect.

Although activity is high in the field of modelling, only one third of CGS Europe participants affirm there is (or will be) a national programme for funding research in modelling in their countries. Modelling is one of the key points of the EU Directive technical annexes and it is considered vital in the early stages for CCS deployment in order to build confidence on affected communities.

3.8 Research areas linked to monitoring

Geological storage demonstration projects have proven so far that available monitoring techniques are sufficient to detect CO_2 leakage. On the other hand, monitoring techniques have to be also used for performance analysis and closure and post – closure control. Therefore, research has to be oriented to design cost effective monitoring systems that are able to control wide areas providing early detection of CO_2 leakage, but also some non intrusive methods that may be required after the end of injection.

Monitoring is part of the core activities of about a half of CGS Europe partners. Some partners are specifically interested in leakage detection and quantification while others are researching on new monitoring methods and standards. Moreover, monitoring activities are mostly developed in “forerunner” countries and in those ones where an EEPR demo project is planned. Cooperation is needed, specifically in leakage detection, although it is considered hard to achieve.

As it was stated in the case of modelling research, monitoring research is funded in a minority of European countries and it is mostly linked to demonstration projects. However, it is very likely that monitoring research will receive a very strong impulse when demo projects are started and that is the reason why it is a priority to build cooperation in these research areas.

4. Conclusions and recommendations

4.1 Conclusions

As a first and positive impression, it can be concluded that all research areas identified by ZEP are currently part of the objectives of more than one CGS Europe partner, i.e. cooperation can be promoted in all research areas. Moreover, most partners have expressed the will of cooperation in the research areas they are researching at the present moment, plus in other areas where they might have a field of interest.

On the other hand, research is not well balanced, neither between CGS Europe participants nor their countries. Capacity assessment technologies register the highest activities, probably because in a wide range of countries there is a need to clarify if geological storage space is available for the great amounts of CO_2 that may be potentially captured. Therefore, in many other technologies, methodological standards and guidance documents are being defined, before researching new methods, especially in so called "follower" countries.

Meanwhile, those countries where demonstration activities are being carried out or planned have stronger research on technologies that need to be refined in the short term to allow CCS deployment, for example modelling or monitoring. Other research areas, like those related to wells or mitigation and remediation are being only partially studied because they might be considered for the mid term.

Many research activities around all these technologies are mainly being funded by the EU and there are very few countries (Netherlands, France…) with strong national funding programmes. It is very likely that some other countries will have stronger research when planned EEPR demo projects are finally developed. Moreover, very few private companies are funding research in all these areas all over Europe.

4.2 Recommendations

Advantage should be taken of the wide spreading of capacity assessment research in participant countries, towards the compilation of a European storage atlas that can be comparable to those developed in the United States and Canada. This cooperation should also be applied to land use planning and sources and sinks matching infrastructures.

Developments in "forerunner" countries must be used to build confidence in the rest of Europe, encouraging national and regional authorities to create stronger research programmes that will lead to new developments all over Europe. For example, reactive transport modelling will help mineral sequestration research and, therefore, cooperation between teams that are developing those models in some countries and other teams researching mineral sequestration must be promoted. CGS Europe staff exchange programme and internal knowledge workshops will be good tools for achieving these objectives.

Human resources committed by CGS Europe participants in different research areas have to be quantified in order to identify real opportunities of cooperation that may become real through an active participation in the EERA CCS Joint Programme. It is very likely that some countries will have to create joint research teams in order to have a critical mass for research in their fields at a European level.

Further analysis of CGS Europe partners abilities need to be carried out. CO_2 geological storage is a site specific activity and exploration and monitoring techniques needed may be very different from one country to another and also for different geological settings. National research programmes are a key issue in this point, as they will allow researchers from participant countries to be in the right position to participate in European programmes.

Many partners have suggested that legislation should also be considered a priority research area. Geological storage laws and their implementation in different countries but also the monitoring of exploration and use permits will deeply influence the deployment of CCS in Europe. Therefore, the study of conflicts and technical difficulties and their possible solutions should also be part of a research strategy.