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CSLF Technology Roadmap vs. CSLF Gaps Analysis Checklist

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Recommendations

The CSLF Gaps Analysis Checklist (GAC) and Technology Roadmap (TRM) have been reviewed with a view to possible alignment. The recommendations are:

1. Capture: No need to change the TRM but the GAC would benefit from some cleanup to avoid duplicated gaps.
2. Transport: No need to change neither the TRM nor the GAC
3. Integration and Cross-cutting Issues:
    a. In the GAC: Make this a separate major headline
    b. TRM: Update Section 3.2 to include integration with existing infrastructure.
    c. TRM: Update Section 3.9 on Cross-cutting Issues by moving text on source/sink matching and either removing topics that are of non-technologic nature or add introductory text to table.
    d. GAC: Update by replacing second and third line items under Integration by one on large-scale demonstration projects.
    e. GAC: Consider the line item under Cross-cutting Issues for deletion.
4. Storage: Some gaps identified in the GAC could possibly be included in the TRM, but a communication/clarification between the Lead of the GAC Working Group on Storage and the Lead Author of Module 3 of the TRM is needed before changes are recommended to the CSLF Technical Group.

In March 2010 the CSLF Technical Group (TG) appointed a Task Force on Assessing the Progress of Closing the Gaps. The Task Force has produced a Gaps Analysis Checklist (GAC), a revised version of which was received from the TG August 17, 2010. Additional updates on the storage part were received August 20, 2010.

A revised version of the CSLF Technology Roadmap (TRM), including comments from PIRT, was also received August 17, 2010. The TRM has a Module 3 on Gaps Identification. The GAC and TRM Module 3 should have a certain degree of commensurability. This memo compares the two documents as a possible step towards alignment.

1. Form

Both documents have three major topics: Capture, Transport and Storage and both address Integration. The TRM does this in sections on demonstration projects and retrofitting at the start of Module 3, as well as in Module 4, whereas the GAC has sub-sections on Integration and Cross-cutting Issues under Transport.

The TRM is built around explanatory text, which identifies and describes the gaps, with priority actions listed in tables after each section. The GAC consists of tables with gaps described in telegram style in each line. The identified gaps are described with different levels of details in the two documents, in most cases the TRM is more detailed than the GAC.

The different presentation forms and levels of detail do not allow a word-by-word comparison. The following evaluation of the similarities of the two documents is subjective and includes extensive use of "benefit of the doubt".

For simplicity, the comparison is not made in the logical order of capture, transport, storage and integration, as the GAC working group on storage appears to have put most effort into the gap analysis. The comparison for storage has therefore been a bit more extensive and is presented at the end of the memo.

2. Capture

With the following exceptions the TRM contains all the gaps listed in the GAC:

1. Generation Efficiency. This is not a specific CCS topic. It is a continuous process in the energy industry, with or without CCS. It was removed from the updated TRM at an early stage.
2. Under Pre-Combustion: Polygeneration optimization. Same comment as above.
3. Under Oxyfuel Combustion: CO_2/N_2 separation technology for industrial processes. The TRM addresses CCS and industrial processes but has not identified this as a gap in CCS. If more details were supplied in the GAC, the item could be considered for inclusion in the TRM.

A few capture items in the TRM do not appear in the GAC. These include:

1. Bio-power and CCS
2. Under Post-Combustion: Enzyme technology, ionic fluids, cryogenic and hydrate based technologies
3. Under Oxyfuel Combustion: Environmental aspects

Other comments to GAC: The very short description of gaps can in a few cases make it difficult to know exactly what separates two gaps. Example: "Hydroge-rich turbines" (??) and "Develop high efficiency and low emission H_2 gas turbines" appear to address the same gap.

Conclusion: No need to change the TRM but the GAC would benefit from some cleanup or clarifications to avoid duplicated gaps.

3. Transport, general

This seems to be as close to a one-to-one mapping as one can get. All items in the GAC appear to be condensed versions of the TRM. Only one item in the TRM is missing in the GAC: Update of technical standards for CO_2 transport as new knowledge become available. But this is not a *technological* issue.

Conclusion: No need to change neither the TRM not the GAC.

4. Integration and Cross-cutting Issues

In the GAC Integration and Cross-cutting Issues are listed under Transport, which seems strange in the way the gaps are described. This could be a separate major topic.

Integration

Three of the four topics listed under Integration in the GAC are from the introduction of TRM Module 3, the fourth one (Integrate with existing infrastructure) appears only in the table in Section 3.9 in the TRM but could also have been addressed in Section 3.2.

It appears strange to list periodic reviews and updates of the TRM under this heading, as is done in the GAC. It would be more logical to keep the first and fourth line item under this heading in the GAC and replace the second and third line items by addressing the need for large-scale demonstration projects.

Cross-cutting Issues

The topic listed in the GAC is from the table in Section 3.9 in the TRM. It is not a *technological* CCS issue. However, the line item on Cross-cutting Issues in the TRM Section 3.9 includes other topics as well that are not *technological* CCS issues.

Conclusion:

The TRM should be update so that integration with existing infrastructure is also included in Section 3.2, not only in Section 3.9

The row on Cross-cutting Issues in Section 3.9 of the TRM should be changed. Matching sources and sinks should be moved to above Standards and Best Practice Guidelines. The remaining topics under Regulations should be deleted, as they are not *technological* CCS issues, or text should be added before the table with comments on these items.

In the GAC, Integration and Cross-cutting issues should be a separate major point. The second and third line items under Integration should be replaced by a point on large-scale demonstration projects. The line item under Cross-cutting Issues should be considered for deletion.

5. Storage

The list of storage gaps in the GAC is extensive and presented in a form that resembles that of the TRM. Three priority activities listed in the TRM that are not directly addressed in the GAC have been identified, but they can probably be considered under other gaps in the GAC These are:

1. Improve tools for automated history matching of models with field observations. Could be considered part of the more general modelling gaps in GAC.
2. A compilation of baseline surveys. The meaning of this point could, however, have been clearer in the TRM.
3. Impact of oil and gas production from shale's on the CO_2 storage capacity. However, the GAC lists this as a gap for deep saline formations.

The GAC list of storage gaps includes several elements that appear not to be addressed in the TRM. Attachment 1 to this memo is the latest version of the GAC storage gaps (August 20, 2010 from Stefan Bachu) with comments on how the gaps are addressed in the TRM. The comments are based on subjective interpretations of the texts in the two documents and others may have different opinion in cases where the status is "partly addressed" or "indirectly/implicitly addressed". It will probably not be necessary to do anything with line items marked A, PA or IA but items marked NA should be considered for inclusion in the TRM.

Conclusion:

Some gaps identified in the GAC could possibly be included in the TRM, but communication/clarification between the GAC and TRM authors is needed before changes are recommended to the CSLF Technical Group.

ATTACHMENT 1

In this document, the following acronyms are being used for storage options:

- **DSF**: deep saline formations;
- **DOGR**: depleted oil and gas reservoirs;
- **EOR, EGR, ECBM**: enhanced oil recovery, enhanced gas recovery and enhanced coalbed methane recovery, respectively.
- **UCS**: unmineable coal seams;
- **OGF**: other geological formations;
- **MC**: mineral carbonation

If no acronym is being used to specify the type of storage unit, it means that the respective gap applies to all categories.

For status in TRM, the following acronyms are being used:

- **A:** Addressed
- **IA:** Indirectly or implicitly addressed, i.e. the wording is different in the two documents but interpreted as being addressed by the TRM
- **PA:** Partly addressed, i.e. only part of the gap in GAC is addressed in TRM
- **NA:** Not addressed

Storage site characterization and capacity assessment	Status in TRM
Improve coefficients for storage capacity efficiency considering the wide range of in-situ conditions likely to be encountered in various geological settings, using knowledge gained from existing projects and from numerical simulations, including probabilistic methods	IA
Develop a robust storage capacity classification system and consistent methodology for storage capacity estimation that will inform industry, policymakers and the tenure and permitting/regulatory authorities	IA
Produce digitally-based national, regional and worldwide atlases of CO_2 storage capacity, including both quantitative and qualitative assessments of storage potential, and covering separately DSF, DOGR and UCS	IA
Improve estimates of storage capacity potential in EOR and EGR	PA
Improve methodologies and standards to determine practical and matched storage capacity for all types of geological media under current consideration	A
Summarize data needs for storage capacity estimation and site characterization	A
Understand better the effects of variability in rock properties and characteristics on injectivity	A (for DSF)
Understand better the effects of caprock variability and properties on containment and storage capacity	A (for DSF)
Improved recognition and interpretation of the nature and characteristics	A

of faults and fractures	(in text, not tables)
Improved functionality and resolution of available logging tools for characterization	PA
Improved interpretation of cased hole logs for characterization	NA
OGF: prove the concept of storing CO_2 in basalts, organic-rich shales, unconventional hydrocarbon reservoirs (heavy oil, tar sands, tight sands)	A
DSF: improve data availability	PA in text
UCS: understand the effects of coal rank, quality and other properties on storage potential and capacity	IA
ECBM: prove feasibility on large scale	NA
MC: enhance trapping and reduce costs to improve viability	A
Demonstviability of storage in the shallow subsea bed (low temperature, high Demonstrate viability of storage in shallow subsea bed (low temperature, high pressure conducive to hydrate formation)	NA
Modelling the storage complex	
DSF: Understanding/determination and documentation of residual gas trapping (relative permeability effects) at laboratory and field scales	NA
DSF: Predicting and modeling spatial reservoir and cap rock characteristics with uncertainties	IA
DSF: Understanding CO_2/water/rock interactions and effects on CO_2 trapping and migration	IA
DSF: Evaluation of basin-wide pressure build-up as a result of CO_2 storage at multiple sites, including assessing sustainability of high injection rates in open and closed systems	NA
DSF: Evaluation of petroleum field development impact on aquifer hydrodynamic regime and storage capacity	NA (but addressed for shale etc)
DSF: Impact of the quality of CO_2 (composition of the CO_2 injection stream) on interactions with the aquifer water, rocks and caprock, including impact on storage capacity and containment	A
DSF: Development of coupled HTMC (hydro-thermo-mechanical-chemical) models for CO_2 injection, migration and leakage for a wide range of in-situ conditions (pressure, temperature, water salinity, rock mineralogy), including the feedback loop	A
DSF: Improvement of databases of parameters needed for modeling geochemical effects	IA
DSF: Improvement in models and software for basin wide geological, reservoir engineering and hydrodynamic modelling	A
UCS: Effects of depth, pressure and stress on coal permeability/injectivity	NA
UCS: Effects of CO_2-coal interactions, particularly for supercritical CO_2 (swelling, plasticization) and methane displacement	IA
MC: Thermodynamics and kinetics of chemical and microbiological reactions, and impact on injectivity, geomechanics and fluid flow	A
Improvement in understanding and modeling the effect of CO_2-rich environments on well materials, leakage, and fate and effects of leaked CO_2	A

Monitoring the storage complex at depth	
Monitoring frequency, resolution, methods and costs	PA (very broad in GAC)
Use of seismic and non-seismic geophysical techniques	PA (very broad in GAC)
Evaluation of permanent or semi-permanent sampling points in an observation well	NA
Improved integration of monitoring techniques	A
Improved wellbore monitoring techniques	A
Development of low cost and sensitive CO_2 monitoring technologies	A
Monitoring the storage site near the surface and at the surface	
Identification of measurement thresholds for natural and anthropogenic (leaked) CO_2	PA
Estimation of leakage flux rates of anthropogenic and natural systems, including Estimation of leakage flux rates of anthropogenic and natural systems, including use of improved remote sensing	A
Detection and monitoring of CO_2 seeps into subaqueous settings	NA
Use of vegetation changes in hyperspectral surveys changes to identify gas levels in the vadose zone	PA (meant to be covered by remote sensing)
Compilation of required baseline surveys for measurement, monitoring and verification (MMV) activities including site-specific information on CO_2 background concentration and seismic activity	A
Development of instruments capable of measuring CO_2 levels close to background and to distinguish between CO_2 from natural processes and that from storage	A
Monitoring impacts (if any) on the environment, including sub-aquatic and aquatic	IA
Managing the storage site	
Determination of optimum well spacing and patterns, and optimum injection parameters	NA
DSF: Development for pressure build-up management, including production and disposal of brine	A
EOR: Optimization of CO_2 storage and conversion from CO_2-EOR to CCS – lessons to be applied to other storage reservoirs	IA
EGR: Validation of enhanced gas recovery (EGR), including coalbed methane (ECBM)	PA
Development of improved well abandonment practices for CO_2-rich environments	A
Risk assessment, impact evaluation, remediation techniques	
Understand the effects of CO_2 and associated impurities on well materials and integrity	A
Remediation of existing wells	A
Quantification and modeling of potential subsurface leakage impacts	IA

Development of appropriate risk assessment models to understand likelihood and consequences of CO_2 leaks, and including induced seismicity and ground movement	IA
Development of risk minimization/mitigation methods	A
Assessment of long-term site security post-injection including verified mathematical models of storage	A
Evaluation of potential sterilisation of existing resources	NA (needs clarification, what resources?)
Costs evaluation	
Address costs associated with storage, including compression, drilling and establishing wells, and monitoring	A
MC: Assess the techno-economic viability of mineral storage of CO_2	A
Guidelines development	
Development of best practice guidelines for site selection, characterization, operation and closure, including monitoring and risk assessment	A
Development of guidelines for responding to, and remediating CO_2 leaks	A
Outreach and public concern	
Development of procedures and approaches for communicating the impacts of geological storage to the general public	NA (not a technologic issue)