summary of the ieaghg / cslf workshop on lca in ccus

12th - 13th November 2015, London, UK

in collaboration with

carbon sequestration leadership forum

IEA GREENHOUSE GAS R&D PROGRAMME

International Energy Agency

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'IEAGHG, "Workshop on LCA in CCUS", 2016/03, March, 2016'

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Summary

A workshop on Life Cycle Assessment (LCA) in Carbon Capture Utilization and Storage (CCUS) was held in London, UK, 12th and 13th November 2015, hosted by IEA Greenhouse Gas R&D Programme (IEAGHG) and the Carbon Sequestration Leadership Forum (CSLF). The workshop built on the IEAGHG report 2010/TR2 and review work by the CSLF.

The workshop looked at the state-of-the art of LCA for CCUS in terms of goals and scope definition, inventory analysis, impact assessment and interpretation as well as social LCA and Life Cycle Costing (LCC).

The workshop showed that progress is being made in the field of LCA. It revealed that the interpretation and use of LCA is variable and that there is a need to better communicate the benefits and limitations of LCA, also when applied to CCUS.

The workshop concluded that transparency is a must and that improvements are needed in the way the goal, scope and assumptions behind an LCA are presented. A checklist on how to document scope, functional units, data inventories, allocations, weighting (if used), uncertainties and how to communicate results would be useful.

Introduction

The background for the workshop was the report IEAGHG 2010/TR2, which looked at 17 LCA studies and identified 14 papers that represented relevance and significance in terms of Carbon Capture and Storage (CCS). These papers were examined in more detail to compare scope, methods and outcomes.

A similar survey by CSLF in spring 2014 included several more recent LCA studies of CCS but the common outcomes were:

- There are many LCA studies on CCS but the transparency is not always as one could wish
- There is a need for consistency between studies (e.g. functional unit, reference system, system boundaries and impact categories and impact assessment methods)
- Impacts other than Global Warming Potential (GWP) show large variations (e.g. toxicity potential, eutrophication, acidification, resource depletion)
- Impacts like water and land use and abiotic depletion seldom included
- Aggregation and end point results are seldom included
- Scale-up and uncertainties must be handled
- Policy-making needs (attributional vs. consequential LCA) and market effects should be included

The IEAGHG 2010/TR2 concluded:

"IEAGHG could consider playing a role in setting up some reference points to allow benchmarking and hence proper comparison of LCA studies."

CSLF challenged IEAGHG to follow-up on this conclusion and the IEAGHG Executive Committee decided to have a workshop to explore the need to develop guidance on the above points.

Aim and Organisation of the Workshop

The aim of the workshop was to explore the needs and possibilities to set-up guidelines for benchmarking and transparency of CCUS LCA with respect to e.g.

- Description of reference systems
- Battery limits
- Functional units
- Time horizon
- Climate and non-climate impacts (e.g. land use, water use, abiotic depletion)
- Inventories and weighting methods

In addition, the workshop set out to explore LCA for CCS for bioenergy, Life Cycle Costing (LCC) and social LCA.

The workshop was divided in five sessions, each with an introductory presentation followed by discussions. Originally, the intention was to have the discussions in groups, with an ensuing plenary discussion. However, with 23 eloquent participants all but one session discussion (Session 4) was conducted in plenary.

Session 1: Setting the Scene

The purpose of this session was to set the scene by having a keynote presentation on the state-of-the-art and recent developments in LCA and have key stakeholders present their perspectives on CCUS LCA.

State-of-the-art and Current Developments in Life Cycle Assessment, Bhawna Singh, Norwegian University of Science and Technology, Norway

LCA is a holistic and systematic environmental impact assessment of a product, process or system. The term 'life cycle' indicates that all stages in the product's life, viz. resource extraction, manufacture, distribution, use and end disposal, are taken into account. Uses of LCA include:

- Technology/product selection
- Optimizing environmental performance of a product/company
- Green labelling, marketing
- Support to policy decisions

The LCA methodology includes goal setting and scope definition, inventory analysis, impact assessment, including the selection and use of indicators, and interpretation. The presentation gave a thorough review of LCA methodology and the recent developments in LCA, including different types of LCA, Life Cycle Inventories (LCI), impact characterization and assessment, and indicators.

Stakeholder Perspectives were presented by Christopher Balzer, Shell Projects and Technology, representing industrial users of LCA; Sean McCoy, International Energy Agency (IEA), representing "consumers" of LCA; and Aicha El Khamlichi, Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME), representing expertise and advisory services.

The session showed that LCA can be a useful tool to assess environmental sustainability, to identify the needs for environmental change, to look at trade-offs and possibilities for environmental improvements in product development, and that the research frontier seems to be that LCA integrates with techno-economic assessments and Integrated Assessment Models (IAMs).

It also revealed that some users, policy makers in particular, do not fully understand what LCA is about and the results may therefore be misused. Aspects of concern include:

- The right questions need to be asked, e.g. so that system boundaries of the LCA meet policy requirements
- That LCA is just one of several tools
- That there is a difference between generic and specific LCAs and that generic ones do not give results at the same detailed level as specific ones, rather trends
- That there is a difference between attributional and consequential LCA and that e.g. a changing energy system and supply chains may need the latter
- If an "LCA" considers GWP as the only indicator, then it is not LCA but carbon/GHG accounting or foot-printing
- GWP has a global coverage but most other indicators would ideally need a regional resolution, e.g. water stress
- That uncertainties are not always sufficiently communicated.

Session 2: Goal and Scope Definition

This session set out to explore the importance of goal and scope definitions and started with the presentation **A Life Cycle Analysis Perspective of CCUS – Goal and Scope Definition, Timothy Skone, National Energy Technology Laboratory, USA.** The complexity and diversity of LCA outcomes was illustrated by application of LCA to Enhanced Oil Recovery (EOR) using CO_2 as a driver. The use of CO_2 creates a complex life cycle system, and the result will depend on whether CO_2 is treated as waste or a product. Furthermore, the case allows for defining more than one product, e.g. electricity, crude oil, refined fuel, captured CO_2, or some combination of the above. The outcome will depend on which of these is considered the product and which other service/product it will replace, as well as the degree of substitution. Thus, it is necessary to redefine the system boundaries or apply an assignment that splits life cycle burdens between products when performing LCA on each of the possible products, and rather detailed models will be necessary to give confidence to broader system applications.

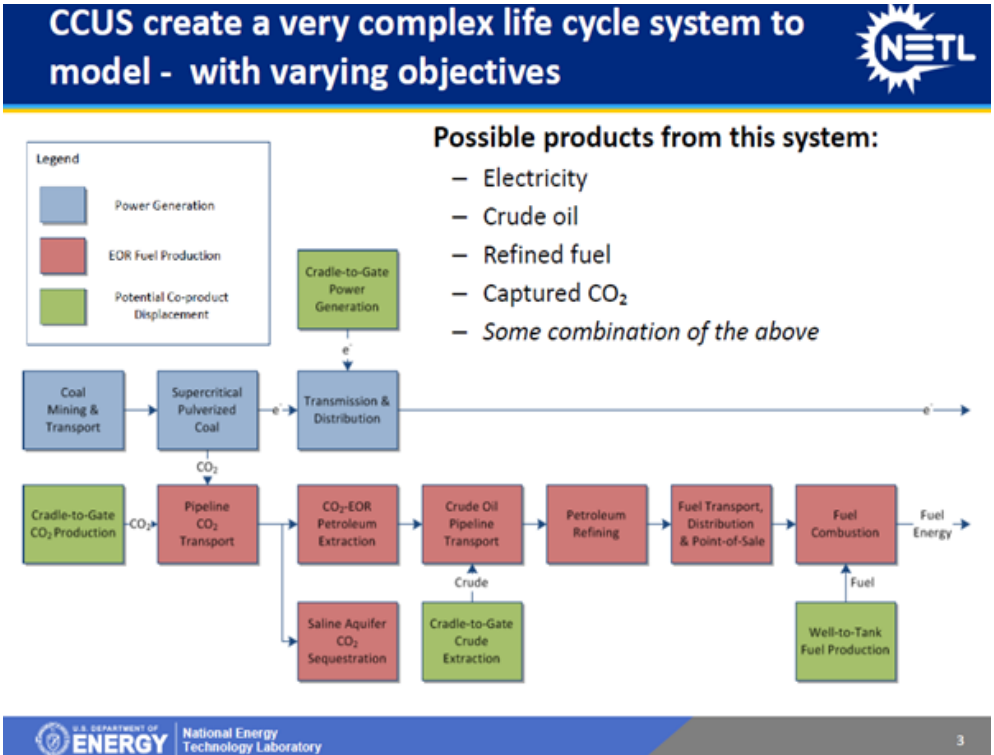

Figure 1 Slide presented by Tim Skone (USDOE NETL)

The presentation and the following discussion brought out several points that suppliers and users of LCA must be aware of in addition to the points from Session 1. The points include:

- The results are driven by the choice of boundaries and the desired outcome, which is often dictated by policy, and there is the possibility to tweak these boundaries
- It is important to define the value chain

- There are common elements to LCA and Risk Assessments (RA) and thus experience transfer should be possible
- Integrated Assessment Models (IAM) do not capture sufficient impacts
- There may not be sufficient data to do a consequential LCA, and one may have to look only at trends
- A consequential LCA can build upon an attributional LCA or direct data sources, such as industry or technical documentations. Crucial point is the quality of the process data
- Transparency is a MUST (CAVEAT: transparency does not automatically infer the LCA is of high quality)
- Communication of how and why LCA has been performed is necessary to avoid apparent inconsistencies in results (may not remove all inconsistencies, though)

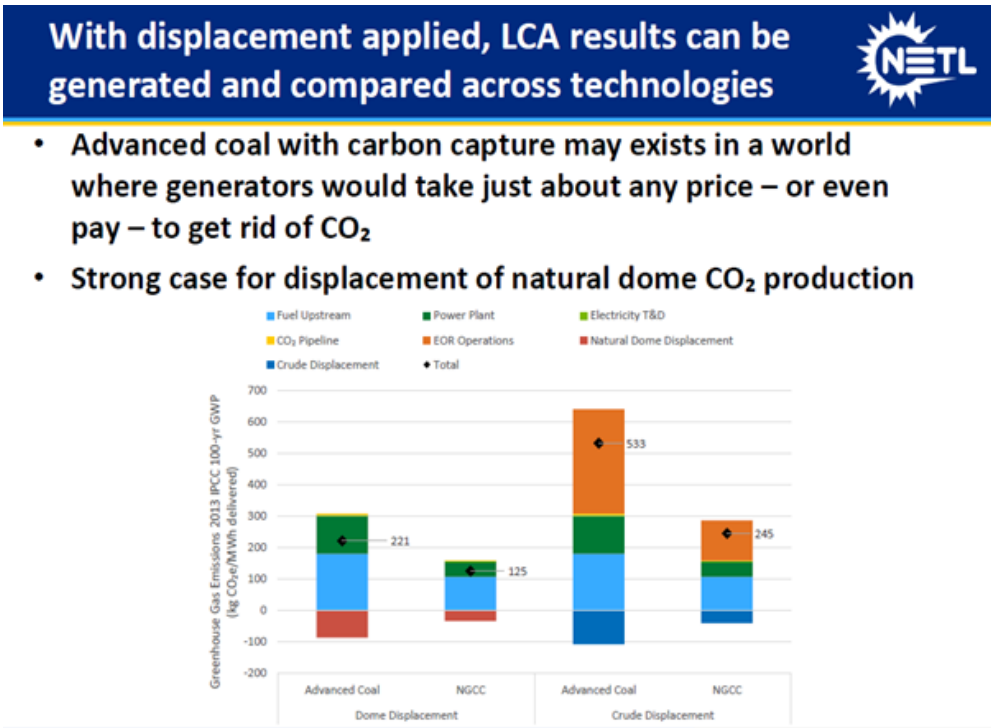

Figure 2 Slide presented by Tim Skone (USDOE NETL)

- Data quality is not sufficiently discussed – may need to apply traffic lights to databases
- The databases are usually five or more years behind and this needs to be kept in mind
- More data sharing from industry is necessary to improve databases

No clear and unified answer on the question "What guidelines are needed to set up system boundaries and increase comparability among studies?" was received from the group.

Some statements contra guidelines included:

- If CCUS does not require special approaches to LCA, guidelines may not be needed
- ISO TC265 has already put the topic on its agenda for WG4
- Should not dictate specific LCA methodology via guidelines
- Potential to end up with a mix of guidelines for different CCUS technologies
- Transparency more crucial than guidelines or standards

There were also several positive views, including the following:

- Guidelines can be a very useful tool to educate non-experts
- As the inconsistency in LCA studies creates problems regarding comparability and communication of benefit and drawbacks, guidelines might be a way to improve the situation
- Guidelines can allow for flexibility, e.g. implementation of different methods, as long as any deviation is documented and justified
- They could encourage practitioners to report everything in a transparent way (e.g. boundaries, goals, databases)

Session 3: Inventory Analysis

Questions for this session included "What about multi-functionality, allocation rules and harmonisation approaches?" and "How to deal with and communicate uncertainties?". The presentation **Current, Best and Future Practice of Life Cycle Inventory Modeling for CCUS, Arne Kätelhön, RWTH Aachen University, Germany**, addressed these questions and discussed issues connected to data collection, such as availability of data and LCI approaches at different stages of data collection, expansion of systems, avoided burdens, allocation and consequential LCA. The presentation also highlighted that LCA is not only useful for environmental assessment but is also a powerful tool for process optimisation.

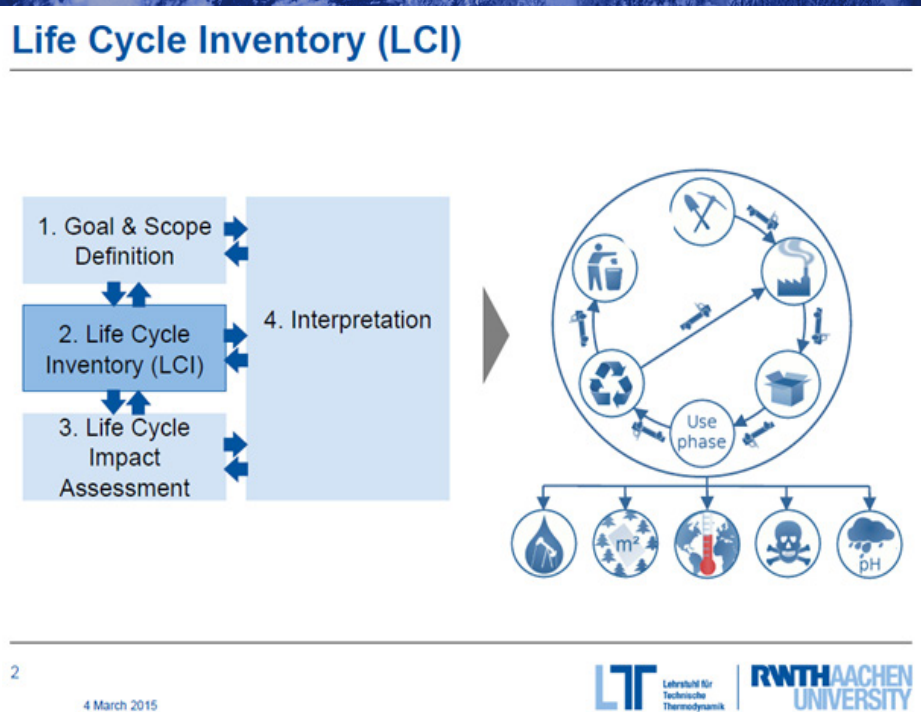

Figure 3 Slide presented by Arne Kätelhön (RWTH Aachen)

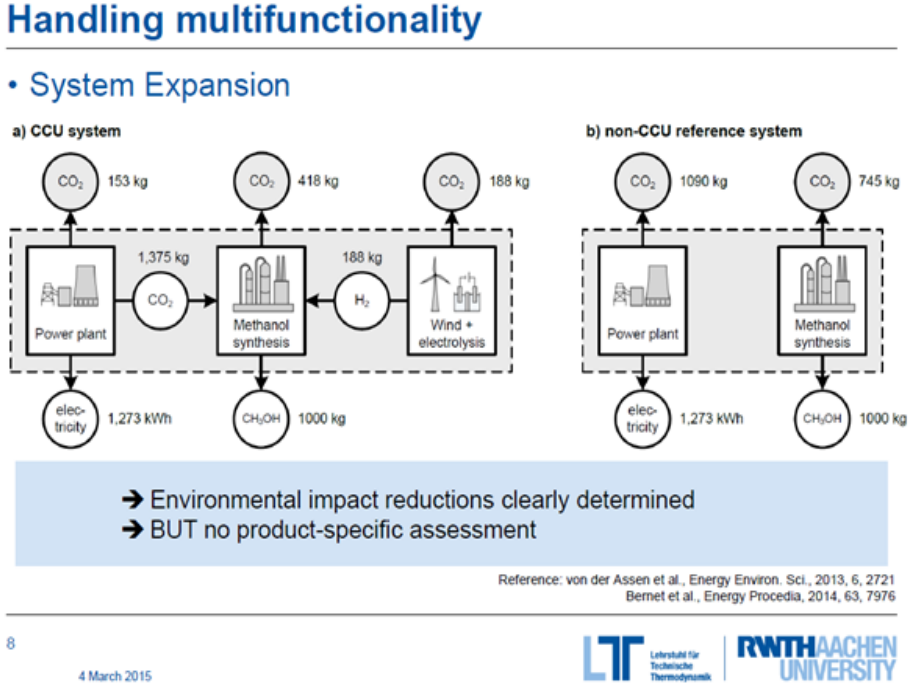

Figure 4 Slide presented by Arne Kätelhön (RWTH Aachen)

The ensuing discussion re-enforced several of the topics from earlier sessions. Additional points included:

- Uncertainties are as much a result of circumstances as of amount of data
- One must be aware that the variability/ uncertainty in natural systems is larger than in human engineered systems
- One approach could be to report error bars reflecting the uncertainty range instead of single numbers
- Laboratory results are not necessarily representative of full scale systems; a fact of importance to CCUS, where most data are from small scale systems or even only parts of the a system
- Reverse engineering can be a helpful exercise to better understand the development of uncertainties
- As more data become available it must be decided how these can best be included
- It is crucial to have both high quality data and models
- Sensitivity analyses are needed to get a grasp of which factors count and which can be excluded
- The importance of transparency and communication of uncertainties was once again emphasized.

Session 4: Impact Assessment and Interpretation

The intention was to introduce this session with the presentation **Some Thoughts and Questions Related to Bio-CCS (bioenergy with CCS) in LCA, Hanna Pihkola, VTT, Finland.** Unfortunately, the presenter was prevented from attending the workshop and Jasmin Kemper took the audience through the slides. Hanna's presentation highlighted that usually current climate policies did not consider Bio-CCS and guidelines for carbon footprinting only considered fossil CO_2. There was also an ongoing debate regarding carbon neutrality of biomass. An approach to tackle this could be the use of specific "GWP_{bio}" factors for different types on biomass feedstock but it might require some changes in LCA practices. Land use change (LUC) issues were very relevant for Bio-CCS and bioenergy in general but difficult to address within LCA frameworks. In addition, there were several other sources of uncertainty, and aspects to consider would include CCS technology applied, type of biomass feedstock, location, (by-)products and the reference case. In this regard, a case study approach might be helpful. For Bio-CCU, it would be important to avoid double counting. In existing EU regulation, transferred and utilised CO_2 could not be subtracted from operators' emissions. However, this would still leave open how to calculate and incentivise replaced products.

The rest of the session was dedicated to group work, for which the participants were split in two and posed with answering the questions

1. How to increase transparency in weighting? Do we need guidelines here?
2. Is it possible to agree on aggregation or end-point methods?
3. Is there a need for connecting to other regulatory requirements (e.g. toxicity to REACH, the EU regulation on chemical substances)?
4. How to communicate uncertainties in results?

One challenge in weighting and the end results is to decide who should weight – end user or people doing the LCA. This is often not revealed in published results but is important for transparency and confidence in results. One suggestion was to agree on weighting up front, before data collection. It was pointed out that no weighting is the same as assuming equal weights to all indicators. Further, there seems to be some confusion in the LCA community whether aggregation is really possible. The participants clearly stated their preference for mid-point methods but acknowledged that end users and decisions makers often demand end-point results. Regarding REACH, the expected increase in availability of toxicity data could strengthen LCAs but the regulation comes with its own complexity and issues. The discussion on how to communicate uncertainties mostly reflected earlier views, with the addition to not only look at stochastic uncertainty but also to grasp how good the model representation and the understanding of the underlying processes is.

In short, the answers to the four questions were:

1. No
2. No
3. Generally yes
4. Varying views

Session 5: Beyond Environmental LCA: LCC and Social LCA

Day 2 and Session 5 opened with the presentation **Social LCA, Andrea Ramirez, Utrecht University, the Netherlands.**

Stakeholders for social LCA include a variety of persons and organizations, including workers, consumers, local communities and the society at large. This mix of stakeholders leads to several challenges related to what and how to include e.g.

- Child labour
- Wages, e.g. legal minimum wages
- Gender and other aspects related to discrimination
- Corruption
- Human rights
- Health, safety and environmental issues

There is little guidance on how to do impact assessment or what indicators to use and a related question is whether jobs or economy can be used as indicators.

Social LCA involves a certain degree of subjectivity, due to the complexity and qualitative nature of many of its components, and it is unlikely that one will see harmonization on how to carry out and value social LCA. A common checklist may still be possible. Although many stakeholders/end users prefer a single resulting number, the current recommendation is to do environmental and social LCA separately due to their different levels of maturity. Because of the more qualitative nature of social issues, social LCA might never reach the same level of quantification as environmental LCA.

It was not quite clear how social LCA relates to CCUS but some possibilities were pointed out:

- Storage may take part in low income areas
- Social LCA does not work well for a single plant, the whole energy system should be subject to social LCA
- Changes in the energy system, energy security, access and liability are factors that may require social metrics to be included in an LCA.

The final presentation in the workshop was **Benchmarking LCA Studies for Fossil Fuel Based Power Generation Value Chains & Life Cycle Costing in CO_2 Storage, Anna Korre, Imperial College London, UK**, in which she presented an LCC model applied to CCS for conventional and non-conventional fuel sources. In the financial sector, LCC refers to the wide temporal aspect of the assessment, and hence this term clarifies the difference from the standard point-in-time costing for a product/ service. Due to much natural variability in the fuels and technical details of the processes and relative immature LCC methods for CCS, LCC

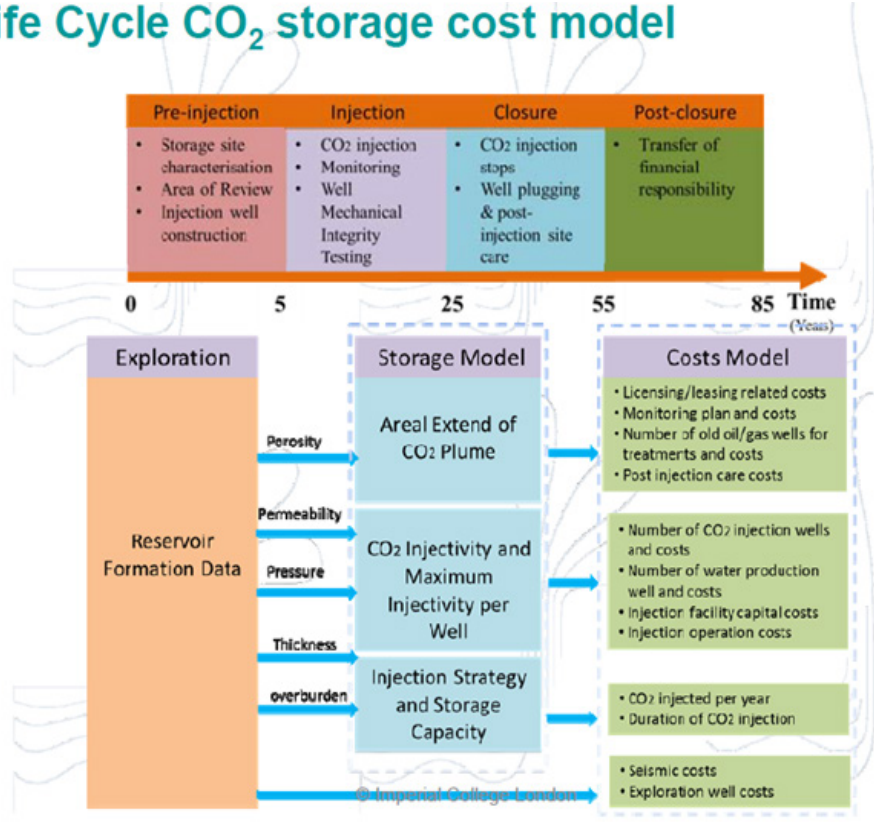

Figure 5 Slide presented by Anna Korre (Imperial College London)

will in this case only give sign in change from a baseline. LCC may be used to compare sites but not for the technology in general. Harmonization may be difficult and probably not needed. As before, the importance to know the uncertainties in input data and other parts of the chain was stressed, e.g. the cost of characterization of the storage site may vary a lot depending on what data exist and what new data are needed. A still open question is what the cost implications of CO_2 storage liability will be.

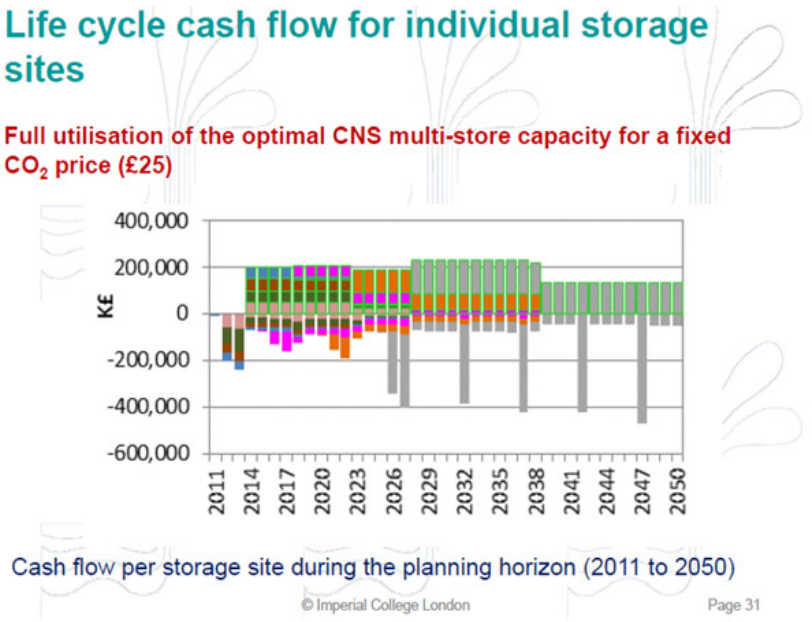

Figure 6 Slide presented by Anna Korre (Imperial College London)

Key Points, Conclusions and Recommendations

Conclusions

The workshop concluded on the following general topics:

- There is a need to communicate how and why differences in LCA come about
- Key principles
  - Transparency is essential and must be improved (but be aware that transparency does not equal quality)
  - The questions to be answered must be decided before the LCA work starts. It is also important to know who asks the questions.
  - Be aware why an LCA is performed – it is not for the sake of LCA itself
  - Clearly distinguish an LCA from carbon/GHG accounting and foot-printing
  - Generic LCAs are only useful for indicative comparisons
  - Preference for mid-point indicators
- Harmonization
  - No clear answer from the group due to different views
  - Can be a good tool to provide insights and deeper understanding but should be used with great care
- Weighting
  - May be done if assumptions and intentions are clear but caution is needed in use and interpretation
  - No weighting means to assign equal weights
- CCUS specific issues
  - Generalisations not possible due to a multitude of different CCUS technologies and their locations
  - Overall energy system related issues will apply

- Bio-CCUS
    - More LCA work is necessary here, as the biomass component brings along a set of new issues and increases complexity (e.g. land use change, food-water-energy-climate nexus)
- Social LCA
    - Is an emerging area but less mature and quantifiable than environmental LCA for the time being, so should be a parallel rather than an integrated exercise
- Guidelines
    - Definition of guideline varied between participants
    - No formal guideline prescribing a specific framework, methodology or tool is needed
    - A check list on how to document scope, functional units, data inventories, allocations, weighing (if used), uncertainties and how to communicate results would be useful
    - Guidance on how to read and interpret LCA studies for non-experts and end users, such as policy/decisions makers would also be helpful

Recommendations

The workshop participants

- Did not see the need to update the IEAGHG 2010/TR2 report
- Did not see the need for a special LCA session at GHGT-13 but recommended a keynote or plenary presentation to raise awareness
- Agreed to make the presentations from the workshop available on the websites of IEAGHG and CSLF
- Welcomed IEAGHG and CSLF to produce a summary report from the meeting
- Thought that IEAGHG could consider developing a guidance/good practice document with feedback from the workshop participants and publish it, e.g. in a journal
- Suggested to have another LCA event after a reasonable amount of time, e.g. to introduce the guidance document

Based on the comments and suggestions, IEAGHG will revisit the need for producing a guidance document and for future meetings/activities on this topic.

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