3. Technology Screening

Task - 0.3 - Develop & Apply Common Economic Model

Highlights:

The technology screening process continues to be used by the technology teams in their work.

Summary:

Early in the technology development program, it became obvious that the best way to derive a truly consistent comparison of all technologies and all scenarios is to fully design each complete system and estimate costs to a high standard. The cost of using the independent cost estimation contractor to complete that work for every combination of technology and scenario would be prohibitively expensive and would detract from the technology development effort. Furthermore, the technology development effort could be best focused if the CCP was able to choose high potential technologies early in the program and focus resources on those most likely to succeed.

The CCP formed a Technology Screening Task - Force (TSTF), comprising representatives from all the technical teams and a cross-section of the participating companies. For each case, a preliminary process design and description was prepared that included estimates of the key process variables (fuel, power, CO_2 captured & emitted etc.). Capital and operating expense estimates for each case were prepared as input to and analysis by the Common Economic Model (see below). Design and costs were benchmarked against the baselines established for each scenario by the common cost estimation contractor. Twelve cases were completed in 2002 All of the economic and screening work to date was funded directly by the CCP.

Reports and Publications:

None.

4. Economic Modeling

Task - 0.3 - Develop & Apply Common Economic Model

Highlights:

A "compact" version of the common economic model was developed and is used by the technology teams for internal evaluation of the technologies in their studies.

Summary:

A primary objective of the CCP is to develop technologies that can be applied in various commercial applications. Business investments require accurate estimates of the costs to build, commission, and operate the resulting plant. At the outset, the team found that there was little consistency in the way that the cost of CO_2 mitigation was estimated. Wildly varying numbers were published and used throughout the CO_2 mitigation community. Consequently, CCP set an early goal to develop a transparent and straightforward way to estimate the full cost of CO_2 mitigation by the subject technologies. The resulting common economic model has been used by the CCP team to evaluate technologies for further development and is used to help the teams judge the potential of new technologies.

Much of the existing work on CO_2 abatement technologies is reported inconsistently. The data are very difficult to use for comparisons between technologies. The CCP required a consistent method to ensure that the technologies it developed could be compared on an "apples to apples" basis.

The Common Economic Model (CEM), developed by a small CCP team, is a multi-technology economic screening tool that uses a set of economic assumptions and high-level technology and scenario input data. The objective of the model is to establish best estimates of CO_2 avoidance costs to enable economic decision-making. All CO_2 costs are calculated as normalized differentials between the capture and non-capture cases. The target for each model run is to establish the lowest cost per tonne of CO_2 avoided and to calculate the cost of CO_2 captured.

The definitions of those two terms are:

> **Captured CO_2 Cost** = total capture-related cost (capital expense, operating expense, energy) per tonne of CO_2 directly captured by the process.
>
> **Avoided CO_2 Cost** = Captured CO_2 Cost (above) adjusted for the volume of CO_2 associated with imported energy (i.e. indirect CO_2).

The first draft of the model, available in June 2001, was peer reviewed by two independent advisers (Ed Rubin, Carnegie Mellon University, and Howard Herzog, MIT. Following that peer review, a simplified version of the model (CEM Compact) was developed and was used to support the technology screening effort.

The common economic screening model used to enable evaluation and comparison of the various CO_2-capture technologies addressed these overarching concepts:

- Early cost estimation
- Economic screening model
- Overall technology scoring criteria.

Early cost estimation: The basic approach was to test CO_2-capture technologies for application in the CCP scenarios. The resulting Scenario-Technology (S-T) matrix contains S-T cases to be evaluated costwise to allow fair and consistent economic comparisons. The CCP technology program includes a large number of technologies completed by numerous suppliers. After each project is completed, the external technology suppliers will establish cost estimates for their particular units or technologies. CCP must evaluate new capture technologies for application in the CCP scenarios that include costs of all integration activities such as: energy/ utility supplies, transportation/ logistics, various site costs, etc.

Below is a brief outline of the cost estimation process used by the CEM and Technology Selection Task - Force:

- Each selected scenario-technology cases is technically described, outlined and documented by a "responsible process engineer" through flow diagrams, equipment lists, mass/ energy/ heat balances and CO_2-capture/ emission volumes.
- General scenario information and data are provided by the respective "scenario owner."
- Through close interaction between the process engineer, scenario owner and cost estimator, the physical scope and boundaries are established for each S-T case to set the case boundaries such as included/not-included functions, sizing, and capacities of incorporated units.
- The team evaluates utility supplies needed and agrees capex-opex tradeoffs to quantify needed utilities and supplies.
- After the physical scope is established and verified across the S-T cases, a common set of unit costs and prices for relevant equipment, utilities, and energy needs are applied to estimate capex and opex costs.
- The price list was established as US Gulf Coast standard. This means that the established cost estimates reflect the costs of the CCP specific scenaris USGC-prices. At a later stage, regional price adjustments will be applied to establish final cost estimates at some other location.

Economic screening model: A common economic model (CEM) was developed to compile key data and perform CO_2-capture and CO_2-avoided cost calculations on a case-by-case basis. The model is a multi-technology economic screening tool and not a traditional, detailed, single-project model designed to support a single plant analysis. It operates on a set of economic assumptions and high-level scenario/technology input data that provide a common basis for calculations with the goal to establish a "best-estimate" economic decision making analysis.

The final capex and opex estimates for each of the S-T cases are imported into the screening model. Together with other inputs such as physical energy (electricity, fuel gas, petcoke) consumption, CO_2 capture/ emission volumes, non-CO_2 (NO_x, SO_2) emissions, plant availability, on-stream-efficiency factors, time-variable discount rates, and capital charge factors the model calculates the desired CO_2 reduction unit costs. The general results include:

- **Captured CO_2-cost** that includes: total capture-related cost (capex, opex, energy) per tonne CO_2 captured (direct)
- **Avoided CO_2-cost**: Total capture-related cost (capex, opex, energy) per tonne CO_2 captured (direct) minus CO_2-content in energy "imports" (indirect)
- All CO_2-costs are calculated as normalized differentials between capture vs. non-capture cases
- Avoided CO_2-cost is the key result calculated.

Overall scoring criteria: the cost estimation and economic screening tools focus primarily on evaluating the various capture technologies as if they are commercially developed and available for operations. The commercial risk and fact that most of these technologies are not matured to a commercial stage is disregarded in these estimates. To supplement the quantitative evaluations and to estimate the commercial risk, a set of qualitative/ semi-quantitative screening criteria that include the technology development and maturing phases for the technologies have been defined to provide a broader evaluation of technology options.

These results provide some early indications of the relative technical- economic performance of capture technologies. However, CCP still awaits important technology development results from external suppliers. At the end of 2003 the aim of the CCP-program is to identify at least one capture technology for each of the reference scenarios that have achieved the projects cost reduction objectives.

Reports and Publications

None.

Technology Advisory Board

Task - 5.1 - Project Management

Highlights:

The Technology Advisory Board (TAB) met to review CCP progress on May 9, 2003.

Summary:

The CCP is advised by a group of independent external experts formed into a Technology Advisory Board (TAB). The TAB is an integral part of the CCP program management process and serves to assure the funding government organizations that the CCP leadership are proper stewards of public funds and to providing assurance to the Executive Board on the technical soundness of the projects.

The roles of the TAB are to provide:

- Advice on, and oversight of, the technology development projects to the Executive Board.
- Provide assurance that the technology development work is in keeping with the project goals and objectives.
- Independent challenge to the technology directions of the teams.
- Assurance that best technical practices have been used in delivery of the project.
- Review of a High Level Plan for the process
- Selection of Peer Review participants
- Advise on external benchmarking that will serve to give assurance that the technology work is at the forefront of technology.

TAB members are:

- Vello Kuuskraa, Chairman (Advanced Resources International)
- Maarten van der Burgt (Independent Consultant)
- Dale Simbeck (SFA Pacific)
- Sally Benson (Lawrence Berkeley National Lab)
- Pierpaolo Garibaldi (Independent Consultant)
- Arnie Godin (Independent Consultant)
- Hans Roar Sorheim (Norway, Klimatek)
- Dave Beecy (USA, Department of Energy)
- Vassilios Kougionas (EU, DG TREN)
- Dennis O'Brien (EU, DG RES)

The CCP Technical Advisory Board held a technical review meeting at on May 9, 2003. The primary purpose of the meeting was to review the Common Economic Model (CEM) and its application to a select number of CO_2 pre-combustion cases. An update was provided to the TAB on the chemical looping

process. Based on the discussion during the meeting and the materials provided, the TAB offered the following observations, comments and recommendations.
The TAB finds that the structure and design of the Common Economic Model (CEM) is appropriate and when completed will provide an excellent tool for technology evaluators and R&D planners:

- The model provides a common, transparent and relatively simple framework for evaluating alternative CO_2 capture technologies.
- It provides the ability to perform sensitivity analyses on the impact of key variables, such as the future price of oil, natural gas or electricity, the cost of capital and assumptions on the expected performance of key technology components.
- It provides one important output measure for cross-technology comparisons, namely the cost per ton of net carbon avoided.

The TAB recommends that for each promising capture technology that the Technology and CEM Teams identify the points of "high leverage" and "high uncertainty" in process performance. This would help R&D funding and technology evaluators to quickly focus on the portion of the process that would benefit from future R&D. The TAB recommends that all of the capture technologies that are considered as promising should be subject to cost review. Detailed review should be directed at the two most mature and potentially most widely applicable technologies, namely: (1) advanced gasification for the petroleum residues "case study"; and, (2) the sorption enhanced water gas shift reactor for the natural gas power "case study." Cost consistency review, limited to checking the cost of major components and verifying the factors used for instrumentation, piping, etc. (the *f*-factor), should be directed at the remaining technologies.

The TAB found the presentation, research and progress to date on Chemical Looping Combustion to be most promising. Successful implementation of chemical looping combustion, with the promise of a 43% cost reduction in the oxyfuel technology, could introduce a most valuable CO_2 emissions avoided technology to the portfolio of capture options. A formal "stage gate" review of this technology should be conducted in midsummer to establish the likelihood that the pilot testing and cold flow modeling, plus work on particle testing, would bring the technology to a status ready for a full feasibility and CEM study. The use of iron oxide as the oxygen transfer agent appears promising because it is cheap and has been used previously in bulk processes for the production of hydrogen.

The TAB recommends that the CCP management and the technology teams define what technologies will not be completed within CCP. This would set the stage for the following options:

- Include the most promising "unfinished" technologies follow on to the CCP.
- Enable the participating companies the opportunity to consider their alternatives.

The TAB recommends that early attention be given to the nature, structure and contents of the Final CCP Report and that significant emphasis be given to prompt communication of the major accomplishments and results of the CCP to the funding bodies.

Reports and Publications

None

Conclusions

Subproject reports reported in the summaries above and included in the attached Appendices do draw conclusions for their segment of the project, where appropriate. The reader is directed to those attachments for interim conclusions stated therein.

References

Each subproject report includes appropriate references for the work being discussed. The summaries in this report refer the reader forward to the actual work documents included in the appendices to find the literature references.