ESTIMATION OF CARBON CREDITS IN CARBON DIOXIDE SEQUESTRATION ACTIVITIES

K. Thomas Klasson and Brian H. Davison, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6226

Objective Statement

Our objective is to develop a general methodology for evaluation of carbon sequestration technologies. We want to provide a method that is quantitative but that is structured to give qualitative robust comparisons despite changes in detailed method parameters—that is, it does not matter what "grade" a sequestration technology gets, but a "better" technology should always get a better grade.

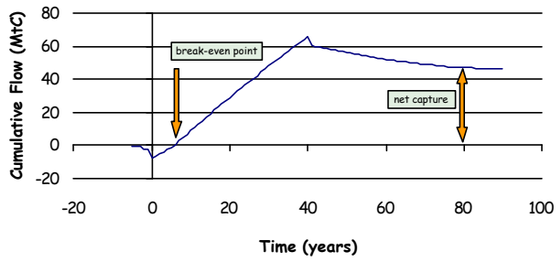
The performance objective for a sequestration technology is not necessarily zero emission of CO_2 but rather a reduction compared with the baseline of current practice. To make sure that all carbon aspects are considered, care must be taken to ensure that there are no hidden emissions when making an alteration from the baseline. The fundamental question underlying an analysis of merit of a process or alteration of a process is as follows:

How much CO_2 is generated as a result of the operation (or change) of this process, and what is its ultimate fate?

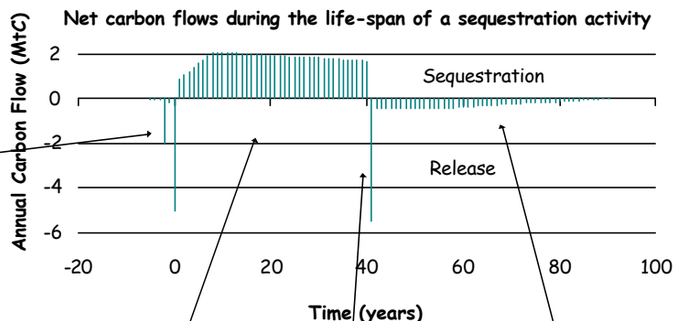
Approach

To address our objective, we have developed and elaborated on the following concepts:

- All resources used in a sequestration activity should be reviewed by estimating the amount of greenhouse gas emissions for which they historically are responsible. We have done this by introducing a quantifier we term Full-Cycle Carbon Emissions (FCCE), which is tied to the resource.
- The future fate of sequestered carbon should be included in technology evaluations. We have addressed this by introducing a variable called Time-Adjusted Value of Carbon Sequestration (TVCS) to weigh potential future releases of carbon, escaping the sequestered form.
- The Figure of Merit of a sequestration technology should address the entire life-cycle of an activity. The figures of merit we have developed relate the investment made (carbon release during the construction phase) to the lifetime sequestration capacity of the activity. To account for carbon flows that occur during different times of an activity, we incorporate the Time Value of Carbon Flows.



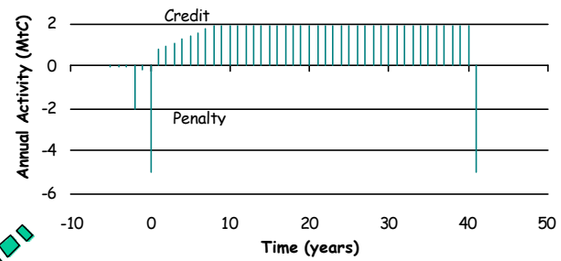
The life-cycle flows may be evaluated using simple techniques based on cumulative flow, and looking at such things as the break-even point and net capture. This does not address the carbon credit concept where the credit must be assigned in the year sequestration takes place.



Adjustment of Carbon Flows to Credits

The adjustment of the annual net sequestered carbon for future emissions may not just be a simple adjustment but may take the form of a more complex evaluation where the adjustment depends on the anticipated duration of the sequestration compared to a target goal, say 100 years.

A better approach is to convert net carbon flows to credits. These are value-based credits that takes into account future emissions from a sequestered material. The credit is calculated from the net sequestered amount in a year and the predicted future emissions from this material.



Startup Phase Emissions

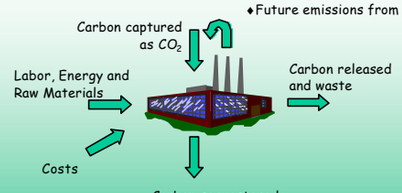
When we develop and build a sequestration technology, we will generate CO_2 and GHG before any carbon is sequestered. Thus, there will be an initial release related to, for example,

- Research and development
- Land use
- Facility construction via the use of materials for capital equipment
- Energy use associated with all of the above

Active Sequestration Phase Emissions

When the facility is operational it sequesters carbon but, at the same time, there will be emissions related to energy and other resource (e.g., materials) use. There may also be emissions from previously captured carbon. The net sequestration takes into account

- Process emissions
- Emissions from energy use (wherever they physically take place), incorporating, e.g., Full-Energy-Chain Emissions Factors for electricity use
- Emissions from raw materials production using Full-Cycle Carbon Emissions Factors
- Future emissions from carbon product or wastes



Future Carbon Storage Phase Emissions

During the carbon storage phase, CO_2 and GHG may be released from the stored carbon or there may be auxiliary releases associated with the stored material. These represent releases in the future when the main activity is over. Examples of emissions are

- Direct release from the sequestered material or from products made from the material
- Energy use associated with monitoring and maintenance to retain the sequestered material

Demolition Phase Emissions

A sequestration facility is likely to have a limited life-span. At the end of its useful life some demolition and land restoration may occur. Thus, there will be some generation of CO_2 and GHG at the end of the project related to

- Facility demolition
- Waste disposal
- Land restoration
- Energy use associated with all of the above

Present Worth of Credits in the Future

During the final evaluation of the life-cycle credits it should be realized that a credit in the future may not be worth as much as the same credit today. We approach this the same way as in cash-flow analysis through the time value of carbon flows, adjusting the credits through present worth calculations. The present worth of credits are then used in "profitability" calculations as a figure of merit that relates the credits to the penalties.

Figure of Merit for a Sequestration Activity

There are several profitability measures used in cash-flow analysis, which analogies appear appropriate as figures of merit for sequestration activities. For example, Present Worth Index and Annual Worth are noticeable. To summarize, the first method looks at the cumulative present worth of carbon credits over the life of the project and compares this with the present worth of carbon penalties by the initial carbon investment. The second type compares the present-worth-corrected average sequestration of carbon per year with the emissions from initial investment plus demolition, averaged over the active sequestration plant life.

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