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A methodology for value chain assessment of CCS projects

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Abstract

The purpose of this paper is to describe a methodology for assessing the impact of different risks and uncertainties on the financial output of a carbon capture and storage (CCS) project. The Value Chain Assessment (VCA) methodology is developed by DNV as a decision making tool for project developers to assess the financial feasibility of the investment and for alternative concepts. The methodology can be applied to optimize the financial result and the performance of a CCS project for a given level of risk. In this paper the VCA methodology is described and applied on a case study with a CCS project developer selecting between different capture technologies.

Keywords: CCS value chain, financial assessment

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1. Introduction

Carbon capture and storage (CCS) projects are large and complex investment projects including novel technologies and different activities in each stage of the value chain. In carrying out CCS projects it is essential to manage the risks and uncertainties properly to target a risk and reward level acceptable to the project developer. In order to manage the financial risks and uncertainties of a CCS project DNV has developed a Value Chain Assessment (VCA) methodology.

The purpose of this paper is to describe this methodology. The DNV VCA methodology is a decision making tool for project developers to assess the economic feasibility of the investment and for selecting between different development concepts. Furthermore, the methodology can be applied to optimize the financial result and the performance of a CCS project for a given level of risk.

The structure of the paper is as follows. In section 2 the CCS value chain is described along with the main risks and opportunities, section 3 discuss issues related to the assessment of the full value chain and sections 4 and 5 describes the DNV VCA methodology applied on a case with a capture plant operator selecting between different capture technologies.

2. Risks and opportunities in the CCS value chain

The CCS value chain includes a CO_2 source (power plant or industrial plant), a capture plant, a CO_2 transportation system and site(s) for storing CO_2 (The CCS value chain is illustrated in Figure 1). The CO_2 emission source can be a coal or gas fired power plant or an industrial plant (cement, pulp and paper, steel mill, petrochemical industry or upstream oil and gas facility). There are several capture technologies that could be used for capturing the CO_2 – common for all these technologies are that they are only demonstrated in small scale and not in large-scale industrial application. The industry has some experience with full scale carbon capture from natural gas streams in gas processing. The main capture technology groups are Post-combustion, Oxy-fuel and Pre-combustion. The main alternatives for transporting CO_2 in this scale are pipelines and ships – pending upon the volumes to be stored, distance from source to the storage site and the cost. CO_2 could be stored in depleted oil and gas reservoirs, saline aquifers or if possible used in enhanced oil recovery (EOR) projects.

Today, there is limited experience in the industry with developing full scale CCS projects. Developing a full CCS value chain project faces the same risks and opportunities as other large complex industrial projects. In addition there are risks related to unproven technology and un-clarified framework conditions.

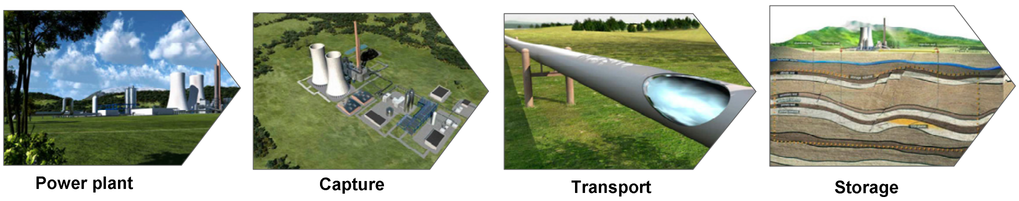

Figure 1 The Carbon Capture and Storage value chain.

The main risks and opportunities in each stage of a CCS value chain are:

Capture: The capture plant is the major part of the investment and operational cost of a CCS value chain. Capture technologies are currently novel technologies that have to be further developed and demonstrated in full scale operation. The capture plant is also the stage with the highest potential for improvements. In particular the cost level and the corresponding uncertainty are expected to be brought down when the industry gain experience from developing and operating full scale projects.

Cost reductions are expected through reducing the energy consumption and increasing efficiency in the capture process. This could be achieved by gaining operational experience from full scale demonstration projects, but also through improvements of current technologies and development of new technologies.

The total cost of a capture plant is strongly correlated with the site specific infrastructure needs at the capture site. Managing the risks related to HSE requirements, capture process support systems, i.e. steam, cooling and electricity, in the early concept phases of a project is important.

Transport: Transporting CO_2 is not fundamentally different from transporting natural gas and we can build on this experience. However, there are a number of CO_2 specific issues that have to be taken into account when developing systems for transporting CO_2. In a value chain perspective the main issues are the transport concept, distance, capacity, material quality and excess capacity. There may be an opportunity in investing in infrastructure with spare capacity to transport third party CO_2 volumes to the storage site.

Storage: The main challenge related to storage of CO_2 is to select and qualify a suitable storage site. The storage site has to meet the requirements from regulators regarding storage safety and environmental impact. Key storage risks are geological risks related to storage safety and uncertainty of the geological system including estimated storage capacity and injectivity. Other risks with the storage site can be related to the regularity of injection facilities and injection wells. Opportunities in the storage stage that can be considered are the potential for revenues from EOR or other use of the CO_2 or from investing in additional storage capacity to utilise the potential for storing CO_2 from other sources.

Full CCS value chain: It is challenging to integrate the stages in the value chain and manage the interfaces between the stages for the total CCS value chain. The project developer will also have to manage interdependencies between the different stages that influence the value chain. Examples of such interdependencies are how the regularity of the capture plant influences operation of the storage site or how the composition (CO_2, water, O_2, H_2S, amines etc) of the CO_2 stream influences transport and storage. Integration and managing interfaces and interdependencies are a source to risk in CCS projects and have to be managed accordingly.

Owners and operators: A CCS value chain can be owned, developed and operated by the same entity, for example the power plant operator, or a consortium covering the full value chain. As long as there is a need for public funding of CCS projects we may see governmental agencies as owners and operators of CCS projects. There may also be independent owners and/or operators in each of the stages of a value chain.

One reason for having different owners and operators may be that there are different core competencies needed for developing each stage of the value chain, for example power plant operation and geological assessments of a potential storage site. On the other hand, involvement of different industries and industry practices may be an additional risk element when integrating the full value chain.

3. Assessment of the CCS Value Chain

In managing a complex CCS project the project developers are concerned with the potential impact these risks might have on the financial output of the project in terms of net present value (NPV) and the overall risk profile of the project. To develop a technological and financial robust CCS project the developers will in the planning of the project compare different potential development concepts and decide on solutions that will optimize the financial value of the project with a risk profile in line with the risk appetite of the project investor. A key element of the VCA methodology is to quantify risks and uncertainties and integrate these in the financial assessments of the value chain.

VCA is a methodology and tool for supporting early phase decisions in CCS projects when there are still large uncertainties and unknowns. Concept selection, concept optimization and investment decisions are typical decisions that could be supported by a VCA.

The owners and operators of a full CCS value chain or part of a value chain may have different objectives and face different challenges. The VCA approach has to be customized to assess different CCS projects, parts of projects or project developers. For example, an area or regional approach is applied for stakeholders planning to invest in parts of the CCS value chain. Investing in CO_2 injection and storage facilities will, for example, require a VCA with several potential CO_2 sources. For investments in capture plant only, the VCA approach can help in the comparison and ranking of alternative transport routes and storage sites. VCA can also support commercial negotiations on tariff regimes between stakeholders, taking the stakeholders' risk exposures into consideration.

The objective of a VCA for a CCS project is to answer the main questions asked by the project developer in an early project stage. Examples of such questions are:

- What is the expected investment cost and main uncertainty drivers?
- What is the financial robustness of the CCS project?
- What are the main uncertainty drivers for the net present value of the CCS project?
- What is the value of investing in additional capacity in pipelines and storage sites?
- What is the value of including multiple storage sites?
- What is the value and uncertainty associated with alternative technologies or development concepts?

Answering these questions is an important part of the value creation process for a CCS project.

4. DNV Value Chain Assessment methodology

VCA is a problem solving approach, a work process and a calculation model tailor-made for providing investment decision support to the energy industry. The DNV VCA approach was developed for the upstream oil and gas industry and has been successfully applied in several field development projects. VCA has been expanded to other energy value chains, such as CCS.

The VCA problem solving approach involves all project disciplines participating in an integrated work process, illustrated in Figure 2.

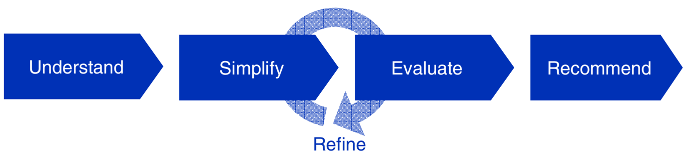

Figure 2 VCA problem solving approach

Understand: To gain an overall understanding of the decision problem at hand and the purpose of the decision analysis. Issues to be addressed include: decisions and alternatives; decision criteria, questions to be answered; main assumptions.
Simplify: To structure the problem and establish a basis for further analysis by simplifying and pre-processing decision alternatives.
Evaluate: To evaluate and rank decision alternatives. In this step, a VCA calculation model is implemented based on the approach chosen in the *Simplify* step. Analysis is performed and results assessed and ranked.
Recommend: To consolidate and communicate results to decision-makers.
Refine loop: To refine the decision model/analysis through one or more iterations between *Simplify and Evaluate*.

The VCA methodology is a work process, involving a multidisciplinary project team covering all aspects of the value chain in an iterative process to define the problem(s) and suggest solutions. In the next section the VCA methodology is described for a case study.

5. Case study: Application of VCA on a CCS project

In order to illustrate how the DNV VCA methodology works a case will be presented and the different steps of the methodology will be demonstrated.

The case study is a planned coal-fired power plant for which the owner is looking into different options with regard to CO_2 management. The main challenge for the power plant owner is to decide whether to implement CCS, using either Post-combustion or Oxyfuel technologies for CO_2 capture, or to emit the CO_2. In this case the CCS value chain consists of a coal-fired power plant with CO_2 capture, CO_2 pipeline and injection and storage of the CO_2 in a geological formation. The power plant owner controls the whole value chain; tariffs between operators are therefore not included.

What are the main questions the project developer need or would like to answer? In this example the scope has been defined as follows:

- What is the financial performance of the different alternatives, i.e. what is the NPV and associated uncertainty distribution?
- What are the main risks influencing the financial value of the project and what is the impact of those risks?
- How sensitive is the NPV to the CO_2 price?
- What CO_2 price makes CCS implementation more financially viable than emitting the CO_2?

Every CCS project has unique characteristics with respect to the capture, transport and storage of CO_2. Therefore the VCA calculation model is tailor made for the case in question and has necessary functionalities to answer the project-specific questions. An essential part of a VCA project is to design and describe the calculation model conceptually before implementing it in the software. Such a conceptual model describes all the value chain building blocks and their interdependencies, all the model input, the information and calculation flow and how the results are to be presented. The interdisciplinary project team review and verify the model design.

Essential variables are included in the model – the level of detail depends on the challenges the model is expected to meet. The VCA model for the CCS value chain studied in this case study is built up around a schedule, volume flows and economics as illustrated in Figure 3.

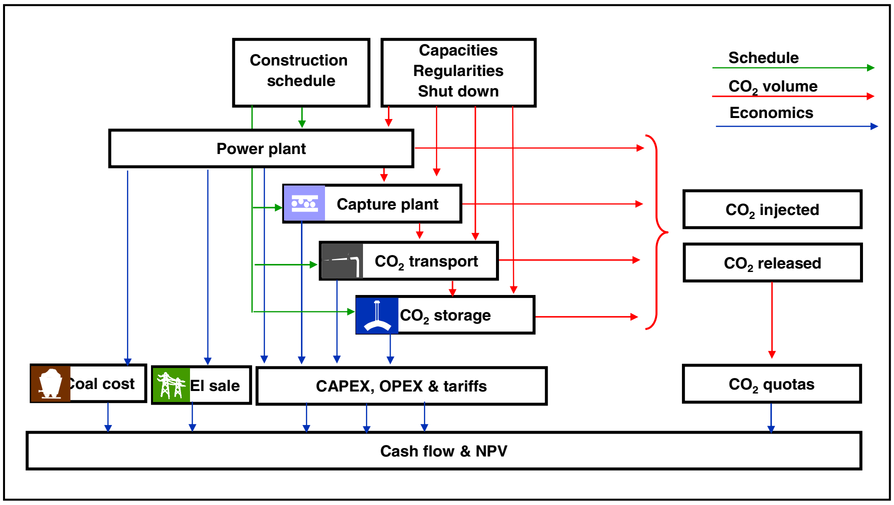

Figure 3 Overview of the integrated VCA model for the studied CCS case.

Schedule: The model calculates the construction schedule for all units included in the model. The construction start and construction time together with the lifetime of the equipment set the frame for the operation.

CO_2 volume: The model then calculates the flow of CO_2 between the units and how this is affected by the capacities regularities and shut downs of the different facilities. This part of the model calculates how much of the CO_2 is captured and emitted respectively.

Project economics: The economic part of the model deals with the cost of fuel, incomes from sales of electricity, other forms of operational expenditures (OPEX), tariffs, capital expenditure (CAPEX) and the cost of CO_2 emissions. This ends up in cash flow and NPV calculations.

Since all these factors described above are inter-dependent, they are handled in one single calculation model. For example, delays in construction lead to increased costs. Down time in the power plant leads to lost electricity production and down time in the capture plant leads to emissions of CO_2 to the atmosphere, this in turn would lead to a cost for CO_2 quotas.

Based on the conceptual model the calculation model is developed. The calculation model integrates the complete value chain with dependencies for deterministic calculations and then risks and uncertainties are added to get probabilistic results. Monte Carlo simulations are used in order to handle the probabilistic input and to generate probabilistic results. The model is developed to assess all alternatives and options, securing consistency in the results and analyses. The benefits of this methodology are a more comprehensive analytical model of the value chain and a decision making tool that assigns cost to risks and revenue to benefits. This will help the project developer to make more informed decisions on a CCS project's development concepts and design.

The final part of the VCA methodology is to analyse and interpret the results. The data presented here are from a case based on information from the public domain and DNV's assessments of risks and uncertainties. However, all the values relating to the outcome of the Monte Carlo simulations have been removed from the figures in order to focus on the methodology. Looking back at the case studied here the first question was related to the financial performance. In Figure 4 the relative frequencies together with the cumulative frequencies of the NPVs for the two CCS concept options are presented.

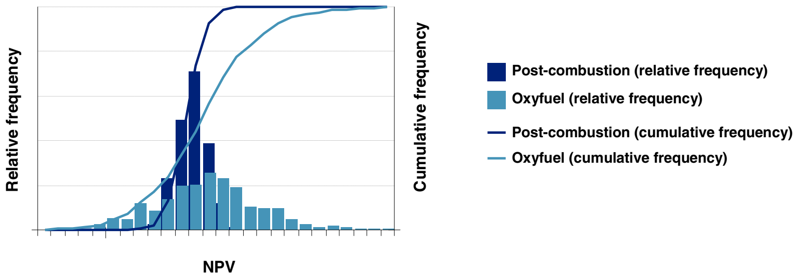

Figure 4 Comparison of the NPV distributions

In this case, the expected NPV for the Oxyfuel option is higher than the expected NPV for the Post-combustion option. However, the overlapping graphs (probability distributions) show that there is a certain likelihood that the Post-combustion option will turn out to be more profitable than the Oxyfuel option. If a deterministic approach had been applied this result would not have been shown. This means that the probabilistic approach gives the decision maker much more ample information. The steeper slope of the Post-combustion cumulative frequency graph tells us that the span of the NPV outcome is considerably smaller for Post-combustion than for Oxyfuel, i.e. the combined economic uncertainty is lower for Post-combustion compared to Oxyfuel.

The second question aimed at identifying the major risks impacting the financial value of the project. In Figure 5 and Figure 6 spider diagrams and tornado graphs for the two CCS technologies are presented. The spider chart shows the change in NPV resulting from a change of the input parameters within the range +/- 1 standard deviation, while the values in the tornado graph are the NPV values associated with +1 standard deviation change in each of the input parameters. The figures show that the NPV for the Oxyfuel alternative is most sensitive to power plant regularity followed by the capture plant CAPEX. For the Post-combustion alternative, the NPV is most sensitive to the capture plant regularity followed by the capture plant CAPEX. The result also shows that it can be profitable to invest in measures to increase the regularity of the power plant or capture plant and thereby reduce the financial risk of the project.

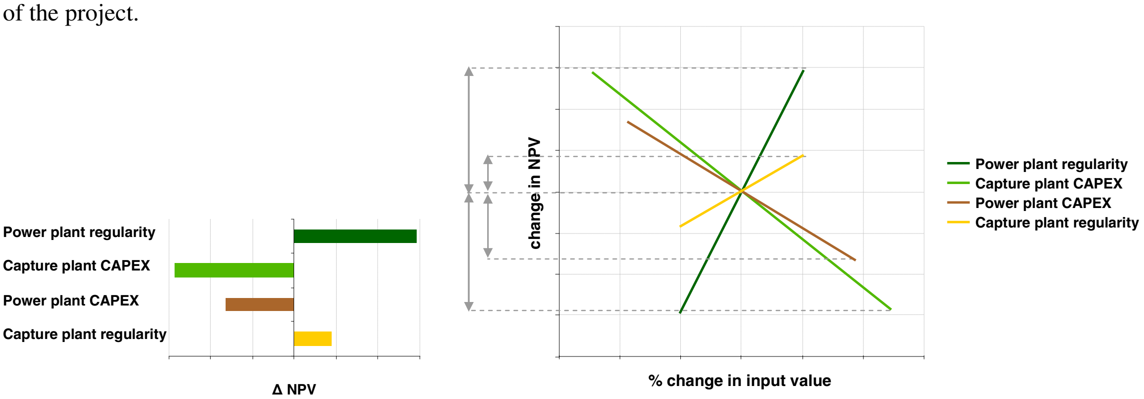

Figure 5 Main uncertainty drivers for the Oxyfuel alternative

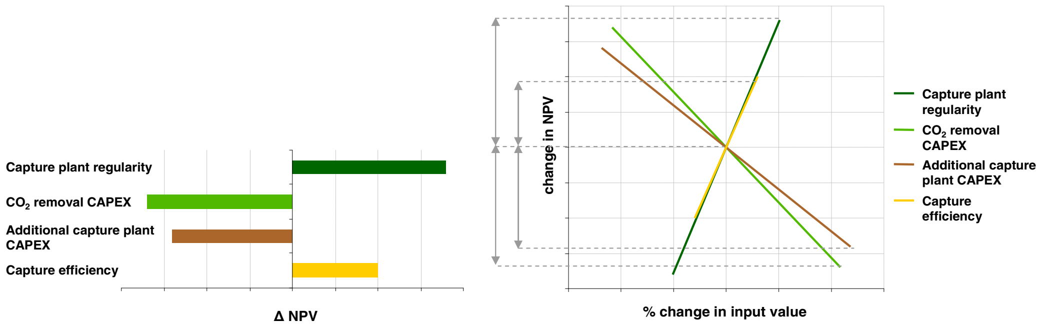

Figure 6 Main uncertainty drivers for the Post-combustion alternative

The third and final question that has been explored in this case study looked at how sensitive the NPV is to changes in the CO_2 price and at what CO_2 price CCS is a viable option. This is illustrated in Figure 7. The graph shows that power generation without CCS is expected to be more profitable than any of the two capture options as long as the quota price is less than the value given by the intersection of the grey and light blue lines. For all quota prices higher than this value, the Oxyfuel option is expected to be the most profitable.

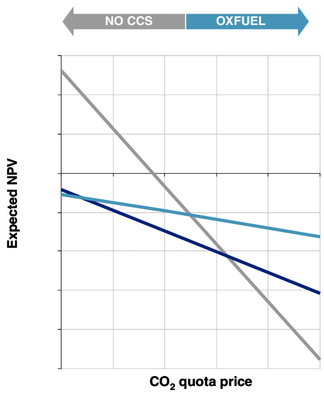

Figure 7 Sensitivity analysis for the CO_2 quota price

6. Conclusion

The described Value Chain Assessment methodology is a powerful decision support tool in the planning process. When managing a complex CCS project, the project developers are concerned about the potential impact that different risks and uncertainties might have on the project's financial output in terms of NPV and overall risk profile. Dependencies between the stages in the value chain have to be included in an assessment so that interface risks can be properly assessed and managed. All these issues are handled within an integrated VCA model. The key success factor is the work process, which involves working with a multidisciplinary group in an iterative process to define the problem and set up the model.

The case study presented in this paper shows that a value chain assessment methodology that do not take into account the risks and uncertainties of a CCS project may cause the decision maker to reach the wrong decision. Using the DNV VCA methodology may provide the decision maker with more comprehensive analyses and a basis for sound decision making throughout the project value creation process.