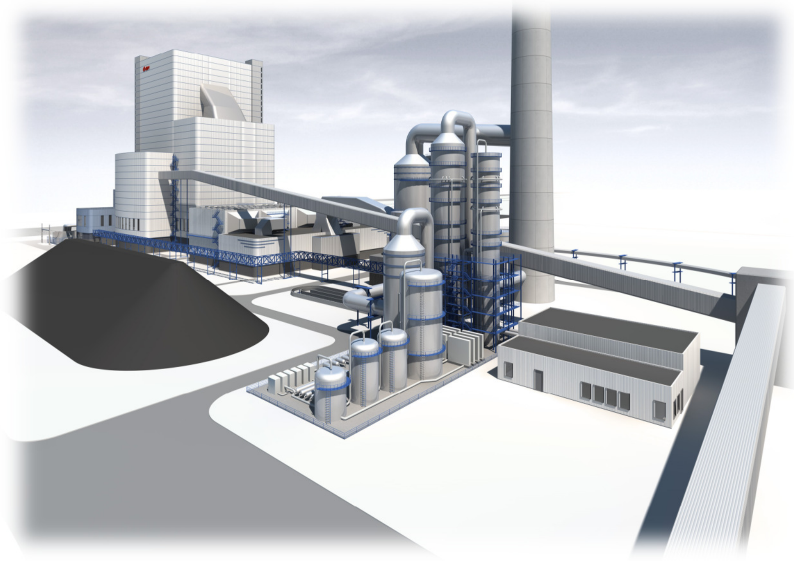
CO_2 capture technology selection methodology

Special report for the Global Carbon Capture and Storage Institute



ROAD | Maasvlakte CCS Project C.V.

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Executive summary

In July 2009 Maasvlakte CCS Project C.V. ('MCP') submitted a project proposal to the European Commission. This marked the start of the 'ROAD project' ('Rotterdam Opslag en Afvang Demonstratieproject'; Rotterdam Storage and Capture Demonstration project). By applying for European funding, ROAD committed itself to the funding program requirements, mainly related to the project schedule. The project team had to select a post combustion capture plant supplier within the given time constraints, while still respecting other important constraints. For this reason, the project team developed a tailor made selection methodology.

The main constraints on the design of the selection methodology can be allocated to the following categories:

- schedule (funding related, e.g. timing of commitments and operational date);
- cost (funding requires proving value for money, business case should be acceptable);
- health, safety & environment (emissions; permitting process); and
- technology (performance, potential for improvement, ability to deliver).

Respecting the constraints, the following considerations were taken into account when designing the selection methodology:

- Competition between suppliers should be maintained as long as possible (commercial reasons, avoiding the situation that no supplier would remain and demonstrating best value for money).
- Applying technology with a proven track record (on pilot scale or in other industries) maximizes the chance that the plant will perform as predicted on this scale and in this context.
- Selecting a supplier that can offer both technology and engineering and constructing capabilities reduces ROAD's co-ordinating efforts and related risks.
- Technical and commercial risks should be allocated to the suppliers, as they are in the best position to evaluate these risks.

Based on both constraints and the considerations a selection process consisting of three steps was designed. In each of these phases the technical design was further detailed and the commercial terms were further elaborated, whilst the number of eligible suppliers was simultaneously reduced from nine initial candidates to one selected supplier.

The selection between each of the phases was performed in a workshop in which professionals from various professional backgrounds participated. The main selection criteria applied were:

- technical confidence;
- ability to permit;
- project delivery;
- commercial conditions;
- economics; and
- effectiveness of technology demonstration.

In the first and second selection step technical confidence (mainly supplier experience) played the most important role. In the final selection step technical confidence was not a real differentiator anymore; here economics and potential permitting issues were decisive.

In a lessons learned workshop the selection methodology was discussed. The project team feels that both the selection process and the outcome of the process were satisfactory. The project team drew a number of lessons from the selection process, related to:

- benefits and challenges caused by working in a joint venture;
- the selection strategy in general;
- decision making and timing;
- selection criteria; and
- the importance of managing relationships with suppliers.

1. Introduction

In July 2009, Maasvlakte CCS Project C.V. ('MCP') submitted its project proposal to the European Commission, to apply for funding under the framework of the European Energy Program for Recovery ('EEPR'). This marked the start of the 'ROAD project' ('Rotterdam Opslag en Afvang Demonstratieproject'; Rotterdam Storage and Capture Demonstration project).

By applying for the EEPR funding, ROAD committed itself to the requirements applicable to this specific funding program. With respect to the capture supplier selection approach, the most prominent requirement introduced by this funding program was adherence to the challenging project schedule. As the development and construction of the capture plant are on the critical path of the project schedule, the project team had to find a way to select a capture plant supplier within the given time constraints, while still respecting other important constraints, such as cost, technical performance and health, safety and environment ('HSE') performance. For this reason, the project team developed a tailor made CO_2 capture technology selection methodology.

In this report, the selection methodology developed by the ROAD project team is described and evaluated, starting with the request for proposal ('RFP') for preliminary studies and ending with the final selection of the capture plant supplier. This report aims to help similar projects (carbon capture and storage ('CCS') projects using post combustion capture technology) to design their own capture plant supplier selection methodology. In a broader sense it is envisioned that also other CCS projects or projects involving other novel technologies can learn from the analysis provided in this report.

The structure of this report is as follows:

- The project factsheet, providing a high level overview of the ROAD project, is presented in chapter 2.
- Chapter 3 starts with setting out in detail the considerations and constraints underlying the development of the selection methodology. The selection methodology developed is subsequently described.
- In chapter 4, the selection criteria applied at different points in the process where the set of potential suppliers was narrowed down are described. The chapter concludes with the main considerations in the final choice between the two potential suppliers that performed a Front-end engineering design ('FEED') study for the capture plant.
- A discussion of the lessons learned, developed during a workshop with experts from within and outside the project team, is presented in chapter 5.

This report is part of the knowledge to be shared under the Funding Agreement between the Global Carbon Capture and Storage Institute ('Global CCS Institute') and Maasvlakte CCS Project C.V.

2. Project factsheet

2.1 Project Overview

ROAD is the **R**otterdam **O**pslag and **A**fvang **D**emonstratieproject (Rotterdam Capture and Storage Demonstration Project) and is one of the largest integrated Carbon Capture and Storage (CCS) demonstration projects in the world.

2.1.1 Project objectives

The main objective of ROAD is to demonstrate the technical and economic feasibility of a large-scale, integrated CCS-chain. In the power industry, to date, CCS has primarily been applied in small-scale test facilities. Large-scale demonstration projects are needed to show that CCS is an efficient and effective CO_2 abatement technology within the next 5 to 10 years. With the knowledge, experience and innovations gained by projects like ROAD, CCS could be deployed on a larger and broader scale: not only on power plants, but also within energy intensive industries. CCS is one of the transition technologies expected to make a substantial contribution to achieving climate objectives.

2.1.2 Partners

ROAD is a joint project initiated by E.ON Benelux N.V. and Electrabel Nederland N.V. (GDF SUEZ Group). Together they constitute the limited partnership Maasvlakte CCS Project C.V. The intended partners of ROAD are GDF SUEZ E&P Nederland B.V. for the CO_2 transport and TAQA Energy B.V. for the CO_2 injection and permanent storage. The ROAD-project is co-financed by the Government of the Netherlands, the European Commission within the framework of the European Energy Programme for Recovery (EEPR) and the Global CCS Institute.

2.1.3 Project specifications

ROAD applies post combustion technology to capture the CO_2 from the flue gases of a new 1,100 MWe coal-fired power (Maasvlakte Power Plant 3) in the port and industrial area of Rotterdam. The capture unit has a capacity of 250 MWe equivalent and aims to capture 1.1 million tonnes of CO_2 per year. The capture installation is planned to be operational in 2015.

Location of the ROAD-project CCS chain: Rotterdam port and industrial area and North Sea

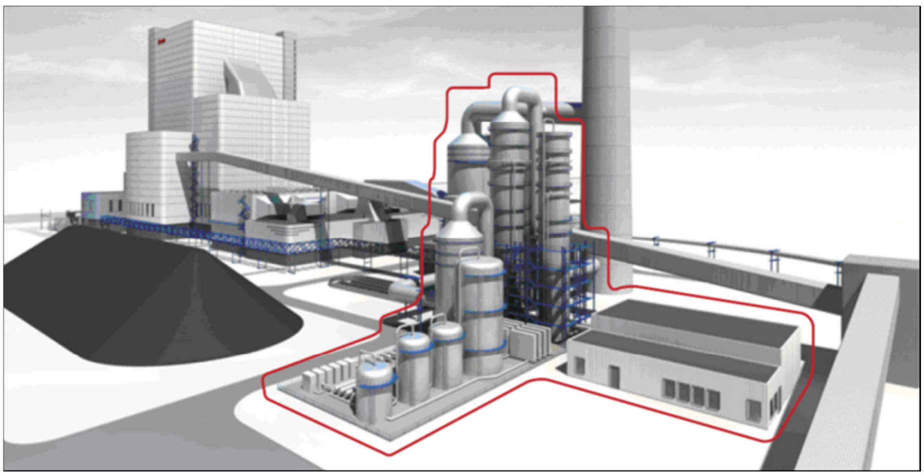
Location of the capture unit: Maasvlakte Power Plant 3 (photo: E.ON)

From the capture unit the CO_2 will be compressed and transported through a pipeline: 5 kilometers over land and 20 kilometers across the seabed to the P18 platform in the North Sea. The pipeline has a transport capacity of around 5 million tonnes per year. It is designed for a pressure of 175 bar and a maximum temperature of approximately 80 °C.

ROAD plans to store the captured CO_2 in depleted gas reservoirs under the North Sea. These gas reservoirs are located in block P18 (P18-6, P18-4 and P18-2) of the Dutch continental shelf, approximately 20 kilometers off the coast. The depleted gas reservoirs are at a depth of around 3,500 meters under the seabed of the North Sea. The CO_2 will be injected from the platform into depleted gas reservoirs. The estimated storage capacity is approximately 35 million tonnes.

2.1.4 Rationale for Rotterdam port and industrial area

The Rotterdam port and industrial area has a number of advantages that create favorable conditions to implement a CCS demonstration project like ROAD. The Rotterdam port and industrial area has many CO_2 point sources. Several new power stations prepared for the application of CCS (capture ready) are under construction. The Port of Rotterdam is relatively close to a large number of (almost) depleted gas reservoirs on the continental shelf under the North Sea, allowing for a small transport distance. These gas reservoirs meet the physical and geological properties for CO_2 storage and will become available in the next few years (from 2014 onwards). The Netherlands has a lot of knowledge and experience with both oil and gas extraction and storage of gas in aquifers and gas reservoirs. In addition, the complete CCS-chain is remote from residential areas.



250 MWe capture unit (post-combustion)

P18-A platform at the North Sea (photo: TAQA)

2.1.5 Facts & Figures

Base installation: E.ON Maasvlakte Power Plant 3 (Rotterdam, The Netherlands)

- Output : 1.070 MWe
- Efficiency : 46%
- Operational : End 2012
- Capture ready

Capture Plant

- Technology : Post-combustion
- Capacity : 250 MWe equivalent
- Capture rate : 90%
- CO_2 captured : ~ 1.1 megatonnes / year
- Operational : 2015

Transport

- Pipeline
- Diameter : 16 inch
- Distance : 5 km onshore, 20km offshore
- Capacity : Gas phase :1.5 megatonnes/year
  Dense phase : 5 megatonnes/year
- Design specifications : 175 bar, 80 °C

Storage

- Depleted gas reservoir : P18
- Operator : TAQA
- Depth : 3,500 meters
- Estimated capacity : ~ 35 megatonnes
- Available : 2014

2.1.6 Planning

The high level schedule of the ROAD project is as follows:

14 July 2009	:	Application submitted for funding under European Energy Programme for Recovery
September 2009	:	Project selected for funding by European Commission
May 2010	:	Ministerial order Dutch funding published
	:	Grant Agreement signed by European Commission and ROAD Project
September 2010	:	Front-End Engineering Design studies Capture Plant completed
		Starting note Environmental Impact Assessment published
June 2011	:	Submitting Environmental Impact Assessment, permit applications
Q4 2011	:	Final Investment Decision
Q4 2011	:	Start execution phase (procurement, construction, etc.)
2014	:	CCS chain mechanically complete
2015	:	Start of operation CCS chain
2015-2019	:	Demonstration operation phase CCS chain
2020	:	Start commercial operation CCS chain

2.2 Maasvlakte CCS Project C.V.

The initiating parties of the ROAD project are E.ON Benelux and Electrabel Nederland / GDF SUEZ Group. Together they constitute the limited partnership Maasvlakte CCS Project C.V.

2.2.1 E.ON Benelux

E.ON Benelux concentrates on the production and supply of electricity and gas to private customers and business customers in the Netherlands and Belgium. E.ON Benelux is primarily an electricity-generating company; the company can trade internationally and has its own professional sales organisation. The company was established in 1941 and since 2000 has been part of E.ON Energie AG. E.ON Benelux's power stations with a total capacity of 1,850 MW are located in the province of South Holland, the economic heart of the Netherlands. The company has approximately 600 employees. E.ON Benelux is based in Rotterdam.

2.2.2 Electrabel Nederland

Electrabel Nederland is a leading player in the Dutch energy market and part of the GDF SUEZ Group. With six state-of-the-art production locations and a total capacity of 5,103 MW Electrabel is the largest electricity producer in the Netherlands. Electrabel is a supplier of elektricity and gas to both private and business customers. Electrabel Nederland has 1,250 employees.

2.3 Intended Partners

Intended partners of Maasvlakte CCS Project C.V. are GDF-SUEZ E&P Nederland B.V. for the CO_2 transport and TAQA Energy B.V. for the CO_2-injection and the permanent storage under the sea bed of the North Sea.

TAQA Energy
TAQA Energy is part of the Abu Dhabi National Energy Company PJSC (TAQA), an energy company that has worldwide interests in power generation, combined heat and water, desalination, upstream oil & gas, pipelines, services and structured finance. TAQA has a workforce of 2,800 employees and is located in Abu Dhabi, The Hague, Ann Arbor: Michigan, Aberdeen, Calgary and Amsterdam. In addition, TAQA has sustainable partnerships with companies in Africa, the Middle-East, Europe, North-America and India. TAQA is listed at the Abu Dhabi Securities Exchange (ADX).

In the Netherlands, TAQA Energy explores and produces gas and condensates from wells located onshore in the Alkmaar region and offshore in the Dutch North Sea. TAQA also operates a gas storage facility in Alkmaar and has interests in Dutch North Sea pipelines. 200 people work for TAQA directly and indirectly in the Netherlands both onshore and offshore.

GDF SUEZ E&P Nederland
GDF SUEZ E&P Nederland is one of the largest operators in the Dutch sector of the North Sea. With more than thirty production platforms and 300 employees, it is at the basis of the provision of energy to the Netherlands and several other countries.

Since its first successful drilling results in the Dutch North Sea, approximately forty years ago, GDF SUEZ E&P Nederland has grown into a leading operator. It has ample expertise and experience, always chooses the safest option and is continuously working towards the development of new techniques and improved methods. Continuity is ensured through exploration, takeovers and acquisition.

2.4 Financial contributors

The ROAD-project is co-financed by the European Commission within the framework of the European Energy Programme for Recovery ("EEPR"), the Government of the Netherlands and the Global CCS Institute.

In response to the economic crisis, the European Council and the European Parliament adopted the Commission proposal for a European Energy Programme for Recovery ("EEPR") in July 2009. The EEPR funds projects in the field of gas and electricity infrastructure as well as offshore wind energy and CO_2 capture and storage (CCS). In total 12 CCS projects applied for assistance under the EEPR. In December 2009, the European Commission granted financial assistance to six projects that could make substantial progress with project development in 2010. These projects will receive overall funding of € 1 billion under the EEPR.

3. CO_2 capture technology selection process

Applying for EEPR funding imposed strict constraints on ROAD with respect to the timing of placing its major contracts. This was one of the main drivers behind the design of the selection process. In this chapter, constraints and considerations taken into account in designing the process are explained. The selection methodology based upon these conditions and considerations is subsequently described.

3.1 Constraints

Schedule related constraints, due to EEPR funding, were already introduced. Other sets of constraints are related to cost, health, safety & environment ('HSE') and technology aspects. Each of these sets is described below. It will become clear that most schedule and cost related criteria are related to the funding the project applied for, whereas technology and HSE related criteria are more related to the current state of capture technology.

3.1.1 Schedule

- **Capture plant contract to be signed in 2010** – In the EEPR proposal ROAD committed itself to awarding the engineering, procurement and construction ('EPC') for the capture plant in 2010, because stimulating economic recovery was one of the main goals of the EEPR and making early commitments to major contracts was an important selection criterion for the EEPR program.
- **Funding available for a maximum of five years** – Ideally all project expenditures are to be made within five years, as EEPR funding only covers expenditures made within the first five years of the agreement. As the ROAD project funding commenced on 1 January 2010, costs made until 31 December 2014 are eligible.
- **CCS chain to be operational by 2015** – The CCS chain should be operational before the end of 2015 to be eligible for EEPR funding.

3.1.2 Cost

- **Best value for money** – As a funding requirement, ROAD should be able to demonstrate that the selected capture plant supplier will provide 'best value for money'. This means that clear evidence should exist that the selected supplier offers at least the required quality at the lowest cost available in the market.
- **Having an acceptable business case** – Investment and operational costs should not be unacceptably high to the partners in Maasvlakte CCS Project C.V. Funding will cover only part of the project cost, all extra costs will be borne by the project initiators.

3.1.3 Health, safety & environment

- **Emissions, effluents and waste streams** – The supplier should have proven insight in the (levels of) emissions and effluents of substances which might pose a threat to public safety or to the environment. The supplier should furthermore have a convincing approach to guarantee that these emissions and effluents stay within acceptable levels. The supplier should also have good insight in waste streams and an approach that will reduce waste streams to the lowest possible quantities.
- **Permitting process requirements** – To obtain a permit for the capture plant, not only should the emissions be known and be within acceptable levels, the supplier should also be prepared to share proprietary information with the competent authorities to enable them to verify the supplier's claims and make a sound permitting decision.

3.1.4 Technology

- **Comfort on technical performance and operability** – As this is a demonstration project, it inherently involves technical risks. However, sufficient comfort on eventual performance of the capture plant (e.g. through guarantees, prior experience, etc.) is a prerequisite for taking the final decision to invest in the project.
- **Foreseen inability of suppliers to directly deliver an EPC proposal** – Based upon signals from the supplier market, it was foreseen that directly going to the market with a request for binding EPC offers based upon prescribed specifications would not be successful, as it would require the suppliers to conduct expensive prior studies at their own cost. Given the risk of not being selected, suppliers might not want to make those investments and either would not participate in the process or simply offer an EPC contract which would be unacceptably expensive.
- **Technological potential** – A modest energy penalty is required to keep operating costs low (see 3.1.2). Significant supplier research and development activities provide a chance to reduce the penalty even further later in the process (e.g. through improved solvents).

3.2 Considerations in designing the selection process

One of the most important aspects of the designed selection process was **maintaining competition as long as possible**, preferably until the EPC price was fixed and agreed upon. This was done for the following reasons:

- A lack of competition would improve the negotiating position for the supplier, potentially driving up the EPC price for the capture plant.
- Keeping different technologies in the process reduced the chance that at some point in time ROAD would be left with no capture plant supplier, e.g. due to emission problems, and ROAD would have to go through a new selection process, introducing unacceptable delays.
- Demonstrating best value for money is done best by applying measurable selection criteria on multiple offers.

Maintaining competition inherently comes at a cost as it requires duplicating work. Finding the right balance between increased costs for the process (short term) and reduced cost as outcome of the process (long term) was key. Upfront it was difficult to foresee the exact dynamics of the process. Recognizing this, the decision was made to fix the process, but leave some freedom in the numbers of suppliers entering the different phases. Strictly following the European tender procedures was not possible for the capture plant, as this would be too time consuming and costly.

Technological potential and comfort on performance are to some extent conflicting conditions. A large number of capture technology suppliers are interested in bringing their technology to the market on demonstration scale. Some of them have promising technologies, but have only applied them on lab-scale. Others have relatively extensive experience on pilot or even industrial scale, but the technology applied in these installations is often not the technology with the best predicted performance. Given the large size of the capture plant (first of its kind) and the required startup of the CCS chain in 2015, ROAD decided to opt for **technology with a strong track record**, to reduce risks, while the partners in MCP will continue performing pilot projects on a smaller scale with the more novel technologies.

Looking at the constraints it can be seen that some of them are related to the technological concept of the plant, whereas others are more related to engineering or construction. Some technology suppliers have preferred EPC contractors to work with; others are EPC contractors which have developed their own capture technology. Knowing this, it would be possible for ROAD to assume the responsibility for coordinating between a separate technology supplier and contractor. However ROAD chose to allow only **companies or consortia offering the full technology and EPC package** to participate in the selection process. Bidding consortia were required to nominate a single point of responsibility / contact for ROAD. For simplicity, both single companies and consortia participating in the selection process will be referred to as "suppliers".

One of the remaining considerations was to go for either an open book contract or a lump sum turnkey contract. If the parent companies would have been familiar with the technology on this scale, an open book approach would have been preferred, to keep costs low. However, as the suppliers are in a better position to evaluate potential risks with cost impact, cost certainty would be much improved by **allocating the technical and financial risks to the consortia**. This approach clearly would have been viable only if sufficient incentives existed for the consortia to offer a competitive EPC price.

3.3 Selection process

After evaluating the pros and cons of various possible selection processes[1], it was decided to perform the technology selection following a phased process. A schematic overview of the selection process is provided in appendix 1. It consisted of the following phases:

I. proposals for preliminary studies;
II. preliminary studies; and
III. front-end engineering design ('FEED') studies / EPC bids.

Each phase of the selection process will be discussed separately below.

3.3.1 Proposals for preliminary studies

A total of nine suppliers (all of them suppliers known to the two partners in Maasvlakte CCS Project C.V. who were to some extent deemed capable of delivering the eventual capture plant using post-combustion capture technology) were invited to submit a proposal for a preliminary study. This proposal was to include:

- demonstration of the supplier's experience on lab-scale, pilot-scale and industrial scale;
- demonstration of the supplier's ability and willingness to comply with the proposed project strategy; and
- an offer for a preliminary study as specified.

The motive for including the second requirement might not be obvious. ROAD realized that the time constraints it had and would demand from its suppliers were very tight. To manage expectations and thereby avoid future issues in compliance with the strategy, ROAD asked the supplier's explicit attention for the strategy and resulting schedule constraints via the requested demonstration of willingness to comply.

[1] The basic selection approaches considered were:
(1) directly bidding for EPC contract (one contracting party);
(2) FEED study and EPC bid (paid by supplier) (one contracting party);
(3) FEED study by technology supplier (paid by JV), subsequent EPC tendering (two contracting parties);
(4) FEED study and EPC bid by supplier (paid by JV) (one contracting party); and
(5) preliminary study (paid by supplier), subsequent FEED study and EPC bid (paid by JV) (one contracting party)

The companies had approximately one month to come up with these proposals. Beforehand, an information session was held with each of the invited suppliers. In the information sessions, organized at the airport to enable efficient face-to-face meetings with all suppliers within a short timeframe, ROAD presented its project and the envisaged technology selection process, with a specific focus on what was expected from the suppliers in the proposal phase. After the presentation a Q&A session enabled the suppliers to get clarity on any issue deemed relevant. Technical, commercial, legal and project management representatives from ROAD were available to answer the questions. Through the information sessions ROAD successfully aligned expectations on the requested proposals and on the selection process in general with the suppliers. This ensured supplier buy-in for the selection process and enhanced the quality of the proposals submitted.

The schedule did not allow lengthy contract negotiations for preliminary study contracts. Therefore ROAD informed the suppliers that the studies would need to be offered free of charge. Eventually all suppliers submitted a proposal for a preliminary study. Given the time and budget limitations, this clearly shows the suppliers' interest in getting a stronger position in the market by being involved in the project and their resulting willingness to make offers for staying in the competition.

3.3.2 Preliminary studies

Based upon the proposals for preliminary studies, a ranking of the suppliers was made (the evaluation process is discussed in section 4.1). The three most promising projects were invited to perform preliminary studies for the ROAD project. Numbers four through six were informed that the likelihood that they would be selected for performing a FEED study after the preliminary studies was very small, but that – if they wanted – they could perform the preliminary studies. All of them did, despite the fact that the costs for the studies could not be recovered in case the bid was not successful. The three lowest ranking bids were immediately rejected, offering an explanation to the rejected suppliers if desired.

To enable fair comparison between the different bidders, the suppliers were asked to design a capture plant 'within battery limits' with the battery limit conditions for utilities identical for all suppliers. At the end of the preliminary study phase the suppliers were expected to deliver:

- preliminary technical deliverables, amongst which for example:
  - various diagrams (process flow diagrams, piping and instrumentation diagrams, utility flow diagrams, electrical one-line drawings);
  - sized equipment list;
  - technical process description;
  - heat and mass balances;
  - overview of solvent characteristics; and
  - safety specifications (materials safety data sheets, atmospheric emissions, liquid effluents, solid waste streams, chemical storage volumes);
- a technical and commercial proposal for a FEED study;
- preliminary performance guarantees; and
- a budget estimate for the intended EPC contract (lump sum turnkey).

The suppliers had approximately two months for performing the preliminary studies. All suppliers complied with the agreed upon timeframe.

3.3.3 Front-end engineering design studies

To ensure that agreements with two suppliers could be signed in time, technical and commercial clarification and negotiation rounds were held with the three suppliers that delivered the most promising preliminary studies. FEED study agreements were subsequently signed with two of these parties. The FEED phase ran for six months.

It was decided to perform two parallel FEEDs to keep competitive tension in and maintain quality. Performing three or more FEEDs would have led to a significant cost increase (approximately six million euro per FEED, inclusive project management and supplier supervision) and spread ROAD's technical and project management expertise too thin.

The deliverables that were part of the FEED studies were divided in the following categories:

- general and project management (design basis, project implementation plan, project management procedures, quality assurance plan, guarantees, material selection philosophy, cost estimates, etc.);
- process design (incl. report on emissions, waste streams and waste disposal);
- HSE (incl. HAZOP);
- mechanical (equipment, compressor);
- piping;
- architectural, civil, structural;
- HVAC;
- layout;
- electrical;
- control and instrumentation; and
- communication and alarm system.

These categories were divided in subcategories, each containing a number of deliverables. For each of the deliverables at least two mandatory review moments were scheduled. An overview containing all requested deliverables and the review planning was distributed to the suppliers prior to the FEED studies. The performance to schedule of the requested deliverables and corresponding milestones were strictly monitored and supervised. Each of the two suppliers performing a FEED study got assigned a dedicated FEED coordinator from within the ROAD project team. These FEED coordinators acted as liaisons between the suppliers and the project team, to ensure all issues were quickly resolved, as the tight schedules did not allow for any delays.

Based upon the technical deliverables, the suppliers were requested to make a binding offer for an EPC contract (lump sum turnkey) and give process, performance, emissions and delivery time (incl. construction and commissioning) guarantees. Starting three months after commencement of the FEED studies, negotiations on the EPC contract were conducted with both suppliers, to ensure all commercial conditions could be included as ranking criteria in the final supplier selection and the EPC contract could be signed as soon as ROAD would have selected its preferred supplier and taken its final investment decision. These negotiations were led by the technical project manager capture (supported by technical experts) and the commercial project manager capture (supported by legal and procurement experts).

4. Evaluation criteria & process

Apart from the different phases in the selection process, also the evaluation criteria applied to the bids in the different phases played an important role in the decisions made and therefore require explicit attention.

Generally speaking, the following sets of evaluation criteria were applied:

- technical confidence;
- ability to permit;
- project delivery;
- commercial conditions;
- economics; and
- effectiveness of technology demonstration.

However, the weight attached to the various sets varied significantly throughout the three phases of the selection process. In the sections below, the selection criteria and selection process are discussed for each of these three phases individually. The last section of this chapter concludes with a discussion on the two sets of criteria that were considered potential showstoppers and were therefore the main differentiators in the final selection step.

4.1 Evaluation of the proposals for preliminary studies

Since post combustion carbon capture on a coal-fired power plant has never been performed on the scale required for the ROAD project it was expected that all suppliers would encounter challenges in the engineering and construction of the ROAD carbon capture plant. Given the large scale, the high investments incurred, the risks related to other parts of the CCS chain and the flagship role of the project, ROAD deemed it preferable to reduce technical uncertainties in the capture plant by selecting a supplier with relatively extensive experience.

Technical confidence was therefore the main selection criterion in assessing the proposals for preliminary studies. Experience with pilot plants, carbon capture from different streams on industrial scale (e.g. carbon capture on flue gases from natural gas combustion) and participation in R&D programs were the main indicators used for assessing technical experience. Also the technical understanding demonstrated in discussions during an information session that was held with each of the suppliers formed a basis for determining their technical know-how.

Given the limited scope of the proposals for preliminary studies, information on other criteria was hardly used – except as an indicator for technical understanding.

Selection took place by a group consisting of mainly project developers, technology experts and engineers, from the project team and from the parent companies E.ON and GDF SUEZ. All participants in the process filled in a scoring form (appendix 2), of which a summary was made, distributed to the participants and discussed in a plenary meeting. Without much argument consensus was achieved and the bidders were divided into three groups: front-runners, followers and laggards, which were subsequently approached as described in the previous chapter.

4.2 Evaluation of the preliminary study phase

The evaluation of the preliminary studies also took place in a workshop with a broad selection of participants. In total six "decision groups", groups of participants in the workshop with a similar company background and professional discipline, had filled in scoring forms prior to the workshop. Focus on environmental issues was created by having a separate comparison of expected atmospheric emissions, liquid effluents and solid waste streams prepared by an expert.

The scoring matrix contained criteria divided in two categories: qualifiers and differentiators. In advance it was envisaged that if consensus would exist that a supplier scored unsatisfactory on a qualifier, the differentiators would not play a role anymore and the supplier would be eliminated from the selection process. The qualifiers were as follows:

- overall impression of preliminary study report, proposal and bidder;
- compliance to design basis;
- emissions acceptable for permitting process; and
- ability to comply with the timeline.

Eventually none of the suppliers was rejected for scoring too low on a qualifier. The differentiators and their weighting were agreed in advance (see appendix 3). The differentiators were categorized according to different categories:

- technology performance;
- drawings and diagrams;
- safety and emissions;
- level of experience; and
- commercial and general topics.

The information available at the end of the preliminary studies was considered insufficient to make a fully reliable judgment between the suppliers, both on technical and on commercial issues. However, the filled in scoring matrix provided a useful framework for discussion and identified the key issues. As was the case in the previous selection step, technical experience, contributing to **technical confidence** (which was also influenced by e.g. understanding shown by the suppliers in technical discussions), played a major role in the selection. Retrospectively, the initial weight attached to this differentiator in the ranking matrix was too low in the perception of the participants in the selection workshop.

Technical and commercial FEED contract negotiations were conducted with the three highest ranking parties. Based upon these negotiations, the three suppliers went through an additional evaluation step, taking into account both technical (compliance with schedule, technical confidence, co-operation) and commercial (commercial terms, ability to provide competitive EPC proposition, commercial culture, attitude on intellectual property) conditions. This ranking step provided a clear distinction on all aspects, but inflexibility in commercial conditions, less technical experience and non-compliance with requested timescales and deliverables were the main decisive factors in rejecting one of the three suppliers.

4.3 Evaluation of the FEED studies phase

By end September 2010 the two remaining potential suppliers delivered their front-end engineering design studies and EPC offer. To make the final choice between the two suppliers all sets of criteria were used. The ranking matrix used in the final selection meeting is presented in appendix 4.

The ranking of the two FEED suppliers was done in a workshop with 22 participants, the group consisting of members of the project team and representatives of the parent companies. Disciplines involved were project development, technology, engineering and procurement. Prior to the workshop operations and environmental stakeholders were extensively involved, e.g. through a HAZOP workshop.

Prior to the selection workshop a number of briefing documents was prepared, amongst which:

- technical summary;
- technical risk assessment;
- scope normalisation;
- permitting risks report;
- commercial summary;
- commercial risk assessment; and
- risk weighted cost evaluation.

Various experts who reviewed certain aspects of the FEED studies and EPC offers presented their findings in this workshop. Afterwards the scoring matrix was filled in and discussed. Based upon the scoring done in the workshop, the technology selection panel, consisting of two project directors, the technical project manager and the commercial project manager made the final selection.

Of the six categories of selection criteria, economics was the most heavily weighted category, with 40% of the total weight, as can be seen in appendix 4. This made economics one of the two most decisive factors. The other decisive factor was permitting, even though in terms of weighing it only ranked fifth out of the six categories. In the other categories differences were found, but weighted and averaged out their impact was minor.

Although no separate evaluation was made on technology related or construction related issues, it should be noted that the capability of the construction contractor was also critically assessed in the selection process:

- Project management processes, HSE processes and construction organization & processes were part of FEED deliverables (see section 3.3.3).
- Prior experiences of parent companies with the construction contractors were taken into account.

Due to limited space at the construction site maximum modular delivery was a request from ROAD towards the contractors.

4.3.1 Key sensitivity: economics

As the economics of the ROAD project are still far from those seen in commercial projects, even with the significant funding received from the European Commission, the Government of the Netherlands and the Global CCS Institute, a significant cost increase compared to the initially foreseen costs could endanger the realisation of the project. Therefore the weight of project economics (life time cost evaluated over five and twenty years) in the selection process was set high.

4.3.2 Key sensitivity: permitting

An issue worth mentioning with amine-based post combustion capture technologies is the emission of the amine, its degradation products (in particular nitramines and nitrosamines) and ammonia. Because different process designs and different amines will result in different emission profiles, the impact of the technology (and thus solvent) selection could have a potentially high impact on permitting as well as public acceptance.

The selected supplier proposed the use of monoethanolamine ('MEA') as solvent. MEA is the most extensively characterized solvent for post combustion capture applications. For MEA degradation studies, identification of degradation products, liquid analysis of pilot plant samples and pilot plant emissions monitoring campaigns have been performed by a wide range of industrial technologists (including employees of the partners in MCP) and academics all over the world. Although the use of MEA does not avoid all emissions, the extensive knowledge base enables effective emission management. Countermeasures can be targeted at the expected degradation products in the expected quantities. Furthermore, this publicly available knowledge is a reliable source for the permitting authorities to base their permitting decision on.

Although other proprietary solvent - technology combinations may not result in more or more dangerous emissions, the supporting evidence is not in the public domain. For the permitting authorities in the Netherlands (and possibly elsewhere) applying a proprietary solvent would introduce the difficulty that they would have to permit the use of a chemical for which the emission risks are not publicly available, making the permit more difficult to defend.

5. Lessons learned

In chapters 3 and 4 the design of the capture technology selection method and the applied selection criteria were discussed. This chapter aims to share the identified lessons learned from the selection process. These lessons learned will not necessarily focus on issues already touched upon in the previous chapters; the quality of the selection process did depend not only on the designed method and applied selection criteria.

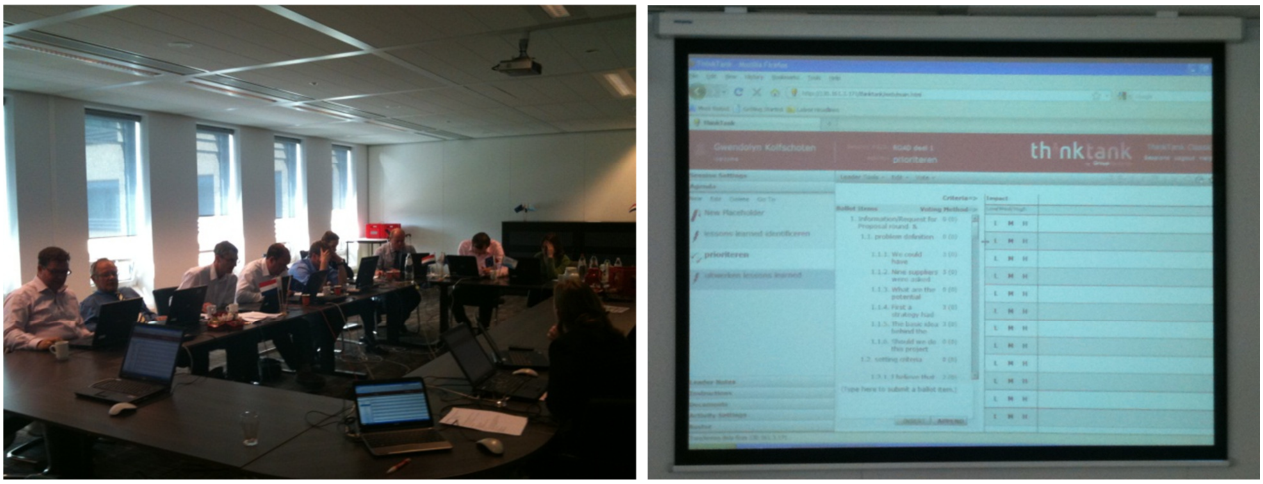
The lessons learned presented below were identified in a workshop attended by a mixed group of people involved in the capture technology selection process. Project team members as well as employees of both parent companies of Maasvlakte CCS Project C.V. were present. Junior specialists as well as senior management were involved. As the selection process was mainly technologically / commercially driven, these disciplines were represented. In total, ten people participated in the workshop which was facilitated by an expert of Delft University of Technology through the use of the group decision room ("GDR") of Delft University of Technology. The GDR is a suite of software and facilitation techniques to support collaborative processes, such as the generation of new ideas (brainstorming), the convergence and categorizing of ideas and the evaluation of ideas on different criteria.

During the workshop every participant had access to the GDR system through an individual notebook. In this way they could work in parallel and make anonymous contributions, which increased the speed, substance and creativity of the process. The workshop consisted of four main phases:

1. brainstorming to identify possible lessons learned and comment/elaborate on these;
2. entering lessons learned, theses, comments or questions to other participants via their notebooks (these entries were visible to the workshop leader and the other participants, who could immediately react upon them, also via their notebooks, resulting in many parallel discussions);
3. clustering and electronic voting to identify the lessons learned with the highest impact; and
4. elaborating on the most important lessons learned.

The workshop was concluded by each of the participants indicating what he or she learnt during the afternoon. Although not explicitly discussed during the workshop, it clearly showed that all participants considered the selection process as having been successful. Everyone recognized that the envisaged timeline had been ambitious, but by virtue of hard work of both the project team and the suppliers proved manageable in the end: all milestones were achieved. The eventually delivered technical studies were of the expected quality. Broad consensus exists on the choice for the suppliers that were selected throughout the process. All participants were satisfied with the choice for the envisaged EPC supplier. The people involved in the process were proud of the outcome. Summarizing: the capture technology selection process was a good building block for further project development.

Several key lessons learned were identified and agreed upon as a result of the workshop. Furthermore the workshop contributed to the knowledge sharing between the project team and the parent companies.



Impression of the workshop

5.1 Working in a joint venture

The fact that the project is carried out in a joint venture has had a generally positive impact on the selection process. Combining the knowledge and methodologies of two parent companies, assumptions were challenged more rigorously, group thinking was avoided and decisions were taken more objectively. The existing knowledge within the parent companies was crucial in timely and effectively assessing the technical and commercial aspects of the suppliers' proposals and studies. Therefore knowledge sharing between the project team and the parent companies is crucial before, during and after the project.

However, working in an innovative joint venture project also poses some challenges. First, it can lead to inefficient double reviewing procedures. Trust is the key success factor to reduce the need for double reviews. Even in a project organization under development, trust can be achieved through dedicated team work and face to face contact. Second, given the uncertainty surrounding such a project, it can be hard to get people to full-time dedicate themselves to the project. Funding dedicated specifically to project development could help solve this issue.

5.2 Supplier selection strategy

The ROAD project used an innovative selection strategy by commissioning two competing FEED studies and simultaneously awarding the EPC contract to the winning FEED. This required more effort and investment in the short run, but it helped in meeting the tight time schedule, effectively benchmarking the suppliers, ensuring competition and consequently ending up with a better design. Because the original design requirements might be ineffective or too demanding in a first-of-its-kind project, the selection process should be designed in such a way that suppliers and buyers keep challenging one another during the process.

5.3 Decision making and timing

The selection process requires decision-making on different levels within a tight time schedule. The project team had to balance senior management decision-making at the parent companies, over which it had little leverage, with the frequent information requests and required decisions by the suppliers. Furthermore the team had to deal with the changing interests, goals and considerations of several stakeholders.

To achieve this, the project needs effective decision planning and discipline, a clear and visible supplier selection strategy to drive forward suppliers and internal processes and a flexible and dedicated project team, which recognizes the strategic interests of other stakeholders. It is critical to keep in mind the resources this requires from both partners and the process flexibility needed in a first-of-its-kind project.

5.4 Selection criteria

During the selection process the focus of the selection criteria has shifted. Defining a scoring matrix for criteria in different selection stages has proved to be a good way to impartially define important success criteria before being influenced by supplier information; even if the actual scoring of proposals turns out to be too ambiguous due to limited available information and shifting selection criteria. The effect of using (dis)qualifying criteria is disputed. They are effective to speed up the process through exclusion and the selections made were considered good, however not every qualifying criterion performed as well as expected.

5.5 Managing relationships with suppliers

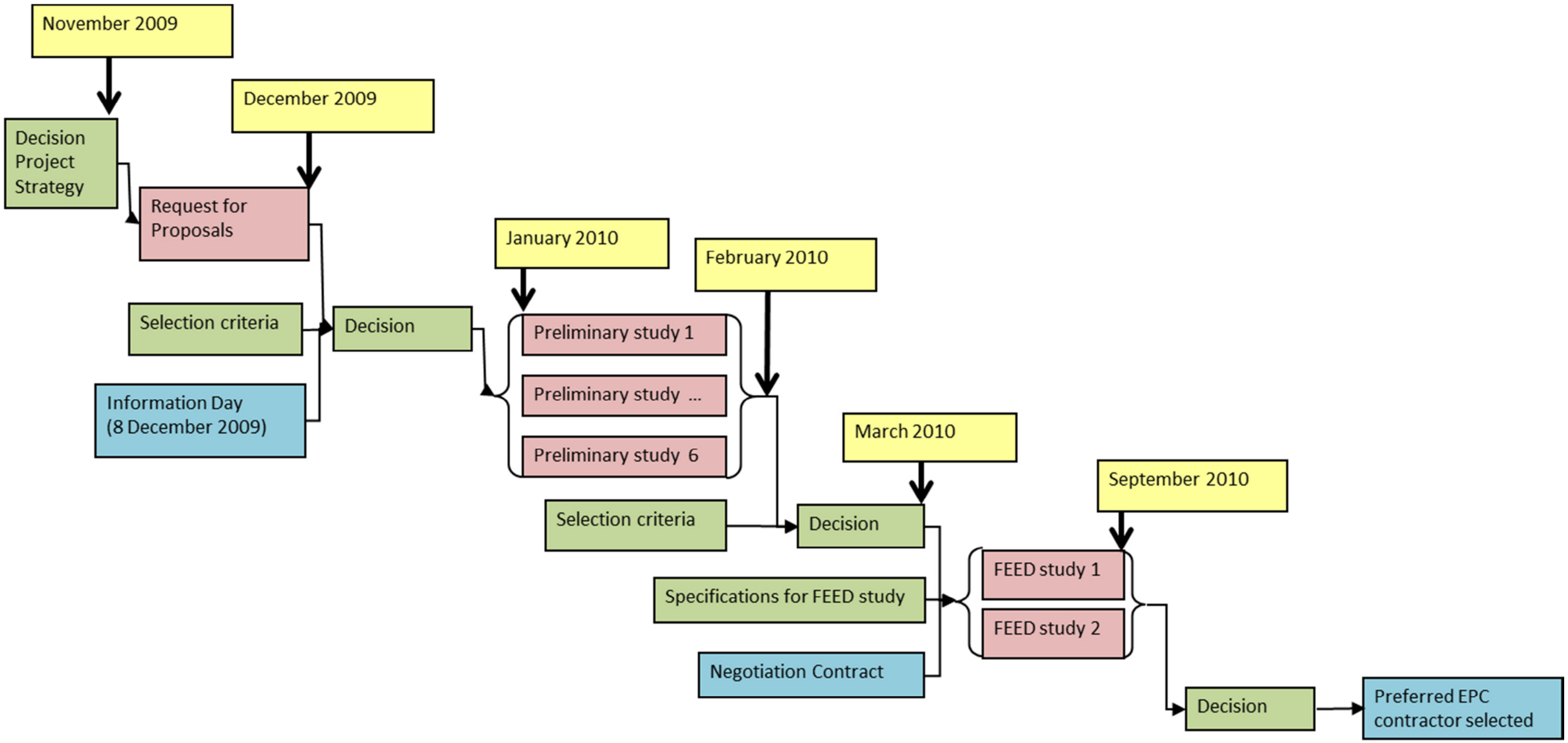
With ROAD being a highly visible, innovative project, the bidding suppliers recognized the strategic value attached to being selected as EPC supplier for the capture plant. Because of this strategic value, the suppliers were willing to deliver the preliminary studies for free and adhere to very tight time schedules.

Especially (but not only) because of the extensive efforts invested by the bidding suppliers, it is important to manage relationships with the rejected suppliers for future projects. Lack of time and resources can easily drive the project team’s attention towards suppliers that go on to the next selection phase instead of the suppliers that were not selected, which is a concern. To prevent this from happening, the project team organized feedback meetings for all suppliers that were rejected after the preliminary study phase. The suppliers rejected after the first phase were offered the option to request a feedback meeting. To set the right expectations, we informed the supplier upfront that we would not come back on our decision and that the feedback meeting was intended to give answers on their questions so that the supplier could learn for the next time.

Abbreviations

CCS	Carbon capture and storage
EEPR	European Energy Programme for Recovery
EPC	Engineering, procurement and construction
FEED	Front-end engineering design
Global CCS Institute	Global Carbon Capture and Storage Institute
GDR	Group decision room
HSE	Health, safety and environment
Institute	Global Carbon Capture and Storage Institute
MCP	Maasvlakte CCS Project C.V.
MEA	Monoethanolamine
RFI	Request for information
RFP	Request for proposal
ROAD	Rotterdam Opslag en Afvang Demonstratie

Appendix 1 – Capture technology selection process



Appendix 2 – Ranking matrix proposals

	Qualifiers	Score	Remarks
1	Single point of responsibility		
2	Experience of supplier on industrial scale		
3	Emissions acceptable		
4	Overall impression of Proposal and Bidder		
5	Costs estimate impression		

	Differentiators	Weighting	Score	Weighted Score	Remarks
	Total weighted score			0	
1	**Company Profile**	30%		0	
a	Single point of responsibility				
b	Credit rating				
c	Experience in coal fired power plants				
d	Competence of staff members on technology level				
e	Communication in English				
f	Location near Maasvlakte				
g	Willingness to improve, R&D track record				
2	**Technical**	30%		0	
a	Minimal Capture rate				*Minimum set*
b	Efficiency (GJ/ton)				*Evaluate on equal design basis*
c	Energy penalty (MWh/ton)				
d	Other utilities consumptions				
e	Availability of Capture plant				*Minimum set*
f	Footprint: one or two trains				
3	**Environment and Safety**	10%		0	
a	Waste streams (for permitting procedures)				*If available*
b	Purity of CO2 stream				*If available*
c	First impression HSE documents (for permitting)				*Not requested for Proposal*
4	**Others**	30%		0	
a	Ability to comply with the JV's timeline				
b	Scope of work (deliverables Attach. D) that can be performed during the Preliminary Study				
c	Clarity of the description of the scope of work in PS				
d	Clarity of the description of the scope of work in FEED				
e	Guarantees that can be given after the PS				
f	Guarantees that can be given after the FEED				

Appendix 3 – Ranking matrix preliminary studies

	Differentiators	
	Name of Selection Criteria	**Weight**
		100%
1	*Performance:*	17%
1	Technology can be applied for new future solvents	6%
2	Efficiency penalty	6%
3	Technology improvement potential	5%
2	*Drawings and Diagrams:*	21%
4	Process Flow Diagrams (PFDs)	2%
5	Piping and instrumentation diagrams (P&IDs)	2%
6	Block Flow Diagrams (BFDs)	1%
7	Utility Flow Diagrams (UFDs)	2%
8	Plot and Equipment lay-out plans	2%
9	Piping lay-out Diagram	2%
10	Sized equipment list	2%
11	List of Specifications for piping and equipment	2%
12	Technical Process Description including Reclaimer concept and Compressor	2%
13	Heat & Mass Balances at battery limits for all process and effluent streams	2%
14	Heat & Mass Balances for all main components	2%
3	*Safety and Emissions:*	14%
15	Specification (= type) of all atmospheric emissions, liquid effluents and solid wastes, including flue gas	3%
16	Materials Safety Data Sheets (MSDS) for all hazardous chemicals	2%
17	Quality of descriptions of HSE	3%
18	Composition of all emissions, effluents, and waste streams (Impact on FGD) (= amount of components)	3%
19	Purity of CO_2 stream / Contaminations in the CO_2 stream	3%
4	*Level of Experience:*	10%
20	Experience of supplier on industrial scale including: a) Number of operation hours of pilot plant; b) Difference between biggest built components and Absorber size in Study; c) Differences in Post Combustion Capture plant concepts; d) Number of CO_2 scrubbing applications build (not only coal).	10%
5	*Commercial and general topics:*	38%
21	Compliance with the FEED scope provided by the Joint Venture	5%
22	Guarantees that can be given after the PS (capture rate, electricity loss (kWh/tonne), emissions, real operation)	4%
23	Guarantees that can be given after the FEED (capture rate, electricity loss in kWh/tonne, emissions, real operation)	4%
24	Compliance to contract terms (e.g. single point of responsibility) (FEED Agreement)	2%
25	FEED Costs + Payment schedule	2%
26	Realistic budget estimates (if desired, you can compare these with the other Suppliers)	4%
27	Operational costs (OPEX) per year (incl. solvent costs, maintenance, etc.) (=long term importancy)	2%
28	Overall Costs in Euro's per tonne CO_2 (summary value of CAPEX & OPEX Evaluation sheet)	13%
29	Effective communication and attitude in IP right field	2%

Appendix 4 – Ranking matrix final supplier selection

					Supplier X Score			Supplier Y Score	Comment
	Name of Selection Criteria	**Weight**		**0-10**	**%**		**0-10**		
1	*Technical Confidence in the Design*	16%							
1	Safety of the Design (Hazid / Hazop)	2%							
2	Process Design	2%							
3	Layout (including difficulty in complying with the zoning plan)	2%							
4	Capture	2%							
5	Compression	2%							
6	Electrical	1%							
7	Control and Instrumentation	1%							
8	Civil Engineering	1%							
9	Auxiliary equipment (pumps, valves, heaters etc)	1%							
10	Forecast Availability	2%							
2	*Permitting*	10%							
11	Risk of failure or delays in permitting	2%							
12	Risk/Impact of environmental problems emerging in operation	3%							
13	Risk of failure to meet permitted emissions standards	3%							
14	Emissions minimization	2%							

3	*Project Delivery*	*12%*							
15	Health and safety management during construction	3%							
16	Quality control (supplier procedures and sub-contractor quality control)	3%							
17	ROAD involvement in the project - e.g. Ability to review, attend meetings and expedite, including ROAD quality control, inspection etc.	3%							
18	Project management processes and team	3%							
4	*Commercial Topics*	*18%*							
19	Change mechanism / change control	2%							
20	Enforceability of guarantees	2%							
21	Acceptability of performance and emissions guarantees	1%							
22	Acceptability of cost and schedule guarantees	2%							
23	Payment schedule	1%							
24	Risk of cost escalation (other than through agreed changes)	2%							
25	Schedule - risk of late delivery?	2%							
26	Knowledge sharing and compliance with EU / GCCSI terms	2%							
27	Ability to defer firm commitment (cancellation curve)	2%							
28	License Agreements + additional Confidentially Agreements	2%							
5	*Economics*	40%							
29	Through life cost (evaluated over 5 years)	35%							
30	Through life cost (evaluated over 20 years)	5%							
6	*Effectiveness of Technology Demonstration:*	4%							
31	Technology can be applied for new future solvents	1%							
32	Efficiency penalty	2%							
33	Technology improvement potential	1%							
	Total	**100%**		**Total**	**xx %**		**Total**	**xx %**	