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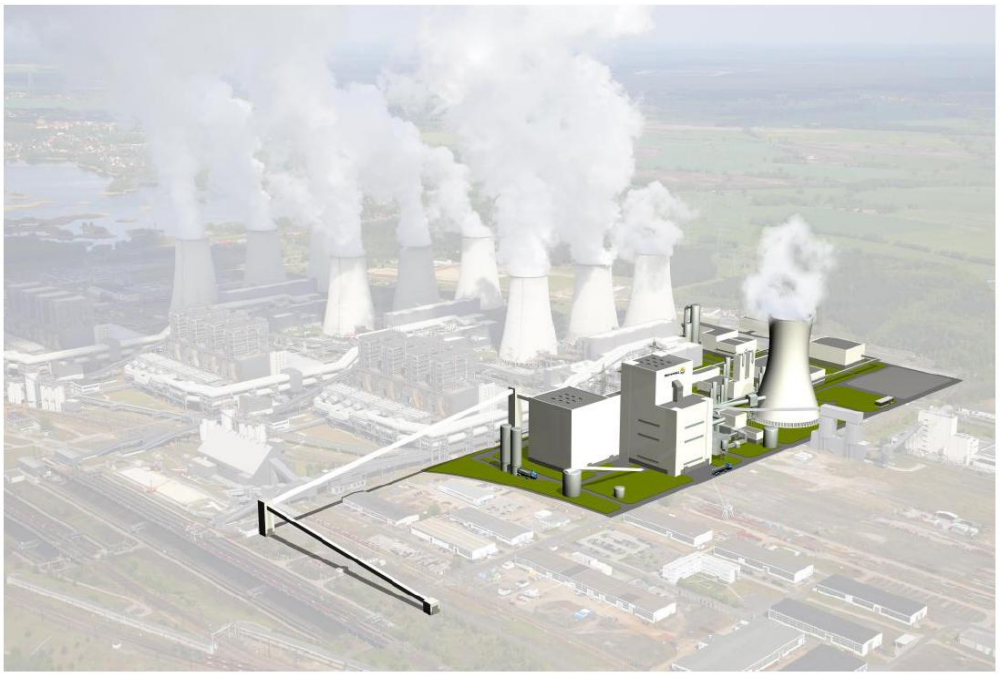

Lessons learned from the Jänschwalde project

Summary report

A European CCS Demonstration Project Network Report

Knowledge Sharing Event Cottbus, May 2012

Executive Summary

The power plant Jänschwalde is a lignite fired plant owned by Vattenfall and located in Germany in the state of Brandenburg, approximately 120 km southeast of Berlin. The project was planning to store around 1.7 million tonnes of CO_2 per year. This CO_2 was to be captured from two units -a new build 250MW_e (gross) oxyfuel capture unit operating at a net efficiency of 36%, and capable of flexible operations between 50-103% and a 50MW_e (gross) post combustion capture unit retrofitted to an existing 500 MW lignite block. The CO_2 would have been transported via a steel pipeline. It was intended that the captured CO_2 would have been safely and permanently stored in the Birkholz-Beeskow or in the Neutrebbin structure at a depth of approximately 1300m depth, with 2 caprocks. The detailed front end engineering and design (FEED) studies are available from the Network's website (www.ccsnetwork.eu).

Vattenfall were relatively far advanced with their applications for all of the permits required for the capture, transport and storage components. However, as the CCS law had not been passed by the Bundesrat the decision was taken to cancel the project.

Public acceptance has also been a challenge throughout the project, despite Vattenfall's good public engagement activities which included a local information centre, road shows and newsletters. A lack of political support on national level and ultimately the impasse in the German CCS law forced Vattenfall to cancel the project.

Nevertheless Vattenfall will continue to monitor and actively support developments in CCS; with the expectation that full-sized commercial CCS plants will be an essential part of the generation fleet of Europe during the 2020s onwards – complementing renewable generation – as the most realistic route to a future where average global warming is limited to 2 ^{o}C.[1] This is articulated within Vattenfall's strategic ambition to reduce its specific CO_2 emissions by 50% by 2030 and to produce heat and electricity in a manner that is neutral to the climate by 2050, even if fossil fuels are still required for security of supply.[2]

[1] EU Energy Roadmap 2050 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011PC0885:EN:NOT

[2] http://www.vattenfall.com/en/environmental-sustainability.htm

Table of Contents

Introduction

The power plant Jänschwalde is a lignite fired plant owned by Vattenfall and located in Germany in the state of Brandenburg, approximately 120 km southeast of Berlin. The facility was constructed unit-wise between 1976 and 1988 and was subsequently retrofitted multiple times.

Vattenfall has been developing the demonstration plant to test and develop oxyfuel and post-combustion capture technologies at the site – aiming to capture and store 1.7 million tonnes of CO_2 per annum. However, In December 2011, Vattenfall announced its decision to cancel the project. The company cited a "lack of political will" to provide legislation needed for CCS in Germany. Prior to that, the project had been ranked as the most advanced CCS demonstration plant within the European Union.

Prior to leaving the demonstration project network, Vattenfall presented their lessons learned to the network at the May 2012 knowledge sharing event. This report summarises the presentations that were kindly given, and will complement the FEED studies that will shortly be released by Vattenfall and hosted on the European CCS Demonstration Network's website.[3] It is hoped that these lessons learnt by Vattenfall, and offered to the community, will assist other the CCS demonstration projects which will demonstrate both the safety and cost effectiveness of this key technology needed to combat global warming.

[3] https://www.ccsnetwork.eu

Knowledge sharing from Jänschwalde

Capture

The lignite fired power plant at Jänschwalde consists of 3 modules each with 2 units of 500MW_e each, forming a plant with a total capacity of 3000MW_e. The oxyfuel capture plant was designed to use a 250MW boiler and a new coal drying ASU. When the project was first conceived it was expected that the existing turbine, generator and cooling tower would be used, however this was later changed and the final concept was to use new equipment. Furthermore during first concept, it was planned that the oxyfuel components would be integrated into the existing block of equipment. However this was later changed and a new, separate oxyfuel block was conceived. During the first concept the net efficiency was expected to be 28%, but this was increased for the final concept to 36%.

The post combustion capture plant was originally planned to be 125MWe, with 0.9Mtpa of CO_2 expected to be separated, however the concept was later changed to 50MWe (gross) and 0.4Mt of CO_2 separated per year. The operating figures for the demonstration blocks can be seen in figure 1.

		Unit G Oxyfuel	Unit F with PCC (PCC: 50 MW behind boiler F2)	Unit F (conventional)
mode of operation		demo	base load	base load
fuel		dry lignite	raw lignite	raw lignite
gross output capacity	MW	250	519	530
own consumption	MW	83	37	30
net output capacity	MW	167	482	500
efficiency (gross)	%	53	39	39
efficiency (net)	%	36	35	36
lignite demand (raw lignite)	million t/a	1.5	4.1	4.1
specific CO_2-emission	g/kWh_{net}	78	933	1,004
captured CO_2 (7.700 operating hours/a)	million t/a	1.3	0.4	-

Figure 1: Operating figures for the demonstration blocks.

The Plant

The lignite drying plant at Jänschwalde uses a pressurized fluidised bed technology, with three drying lines producing 103tonnes per hour of dry lignite. The dryers use an operating pressure of 4 bar_a and a throughput of up to 3 x 79t/h of raw lignite, which has a water content of 53.4%. The water content of the dried lignite is approx. 8 – 12 %.

The oxyfuel boiler is a forced-circulation boiler which uses parameters of a live steam temperature of 600°C, a live steam pressure of 286 bar and a live steam quantity of 178kg/s with a high load flexibility.

The de-dusting unit has an outlet dust loading of 10mg/Nm^3 dry and a design pressure of 150mbar. It has a proportional SO_3 removal with optional use of a sorbent. The technology specification allows offers for electric static precipitator (ESP) and bag house filter technology. ESP was the preferred version because the technology offers a low pressure drop, low power consumption, low costs for operation and maintenance, uncomplicated performance in service during start up and shut down and it is an established, proven technique at Vattenfall. The only disadvantage is that it has a low SO_3 removal efficiency. The flue gas desulphurisation aimed to achieve 99% SO_2 removal, with Figure 2 illustrating the data associated with the system.

flue gas flow rate	m^3/h i.N. wet	596,000
	m^3/h i.N. dry	406,000
SO_2 content raw gas	mg/m^3 i.N. dry	13,300
SO_2 content clean gas	mg/m^3 i.N. dry	100
SO_2 removal efficiency	%	99
pressure flue gas components	mbar	+150
Flue gas inlet temperature	°C	130

Figure 2: Flue gas desulphurisation data

The air separation unit (ASU) produces 115,500Nm^3/h gaseous oxygen at 95% purity. It uses a single line cryogen and has a load range of between 50-100%. The energy consumption is between 28-34$MW_{e,}$ which was one of the main evaluation criteria for the unit

The gas processing unit (GPU) processes 350t/h of raw gas at 28bar, resulting in a CO_2 production of 175 t/h at a pressure of 125bar. The 275,000Nm^3/h raw wet gas has a CO_2 content of 45-58% volume, and the processed gas has a content of 95% CO_2 and a maximum O_2 content of <0.8%.There is a final recovery rate of between 90-93% (depending on the CO_2 content of the raw gas).The energy consumption was expected to be between 23 and 35 MW_e.

With load following requirements of 50-100%, the compressors would have had a 5%/min load change requirement (the 50-75% load range requiring a bypass for 4% of annual hours).

The net efficiencies of both the oxyfuel unit and the post combustion unit, taking into account the efficiencies of the new operating unit, would have been 36-35% - effectively matching the net efficiency of the conventional units in use at the plant. Remarkably, while requiring significant capital expenditure, this effectively means that there is no energy penalty between a new unit with carbon capture on it (including compression), and an older operating plant (retrofitted in the mid 1990s).

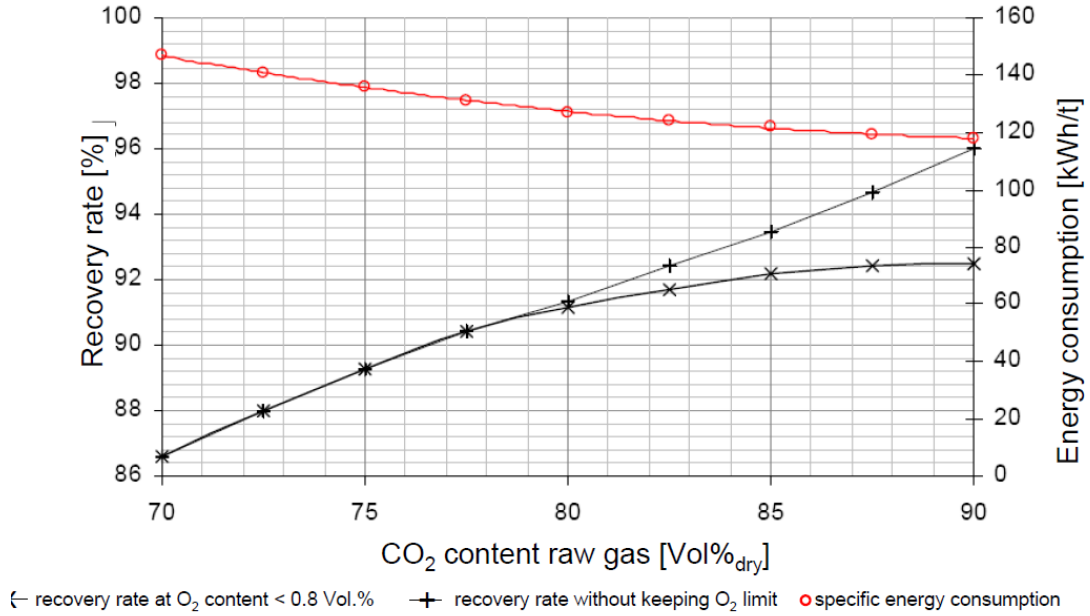

Figure 3: Energy consumption and recovery rate for the capture plant.

Further information is available in the project's 'Final technical concept'. This is the final document of the conceptual design phase for the 250MWe oxyfuel capture element of the project. (In German with an executive summary in English).
http://www.ccsnetwork.eu/assets/publications/Final_report_technical%20concept.pdf

Transport

The presentation given on the transport technical design of the project highlighted that there are a number of boundary conditions which have to be considered when planning the pipeline structure. These conditions are placed on the pipeline from:

1. The capture plant, where there are two capture instillations (oxyfuel and post combustion capture) and consequently two different CO_2 streams with differing qualities.
2. Corrosion of the pipe must be minimised by considering the material of the pipeline and the composition of the CO_2. Restrictions were also placed on the behaviour of the CO_2 in the pipeline, where it was decided that there should be no phase change (see figure 4).
3. The restrictions of the storage operation with regard to pressure, injectivity, number of wells, load change and CO_2 quality.

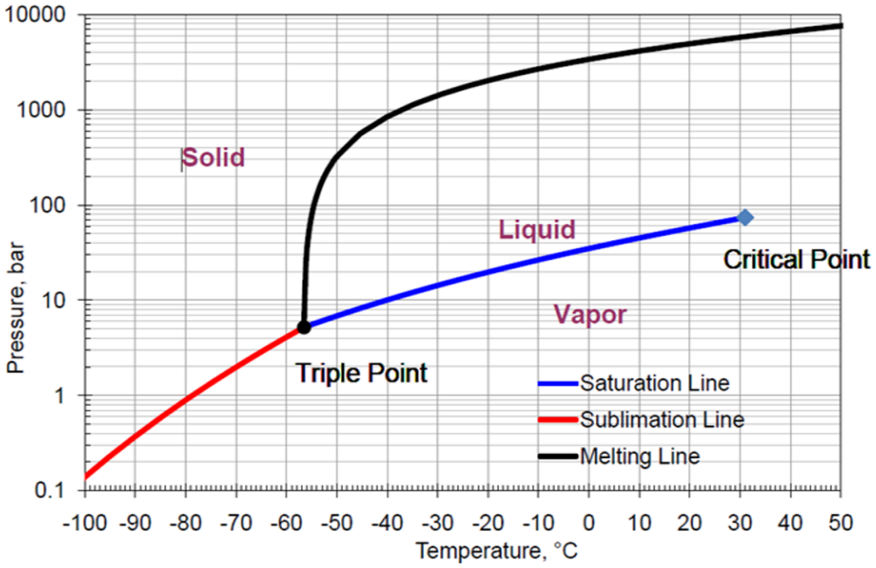

Figure 4: CO_2 phase diagram (Baxter, 2009)

One of the primary difficulties for the whole chain is the need for highly flexible load-following operations of the electricity production plant. The post combustion capture unit would treat 20% of the flue gas of one of the existing units and with a load range between 60-100% (without vent gas and recirculation) would produce between 30tonnes/hour to 50t/h of CO_2. The oxyfuel unit treats 100% of the flue gas and with a load range between 50-103% would produce between 91t/h to 188t/h of CO_2. However together this highly flexible plant has a power range of 13-100% - but which therefore produces a range of 30-238t/h of CO_2. Such load conditions have a significant impact on the design of the total system, and was the main technical issue being faced by Vattenfall.

The pipeline interface with the boreholes at the storage site was considered in detail.

It was also decided that the CO_2 should not change phase within the well, as it would put a great an unacceptable level of stress on the well. Three designs were therefore considered. Firstly heating the well (requiring a 20MW plant), a downhole stop to keep the pressure up (which was not deemed to be good operational practice), or insulating the pipeline to keep it at 40°C. It was decided that insulating the pipe was the most effective way of ensuring the CO_2 behaviour was controlled. With

no buffer in the system, 137mm PUR foam insulation material was going to be used to maintain the temperature.

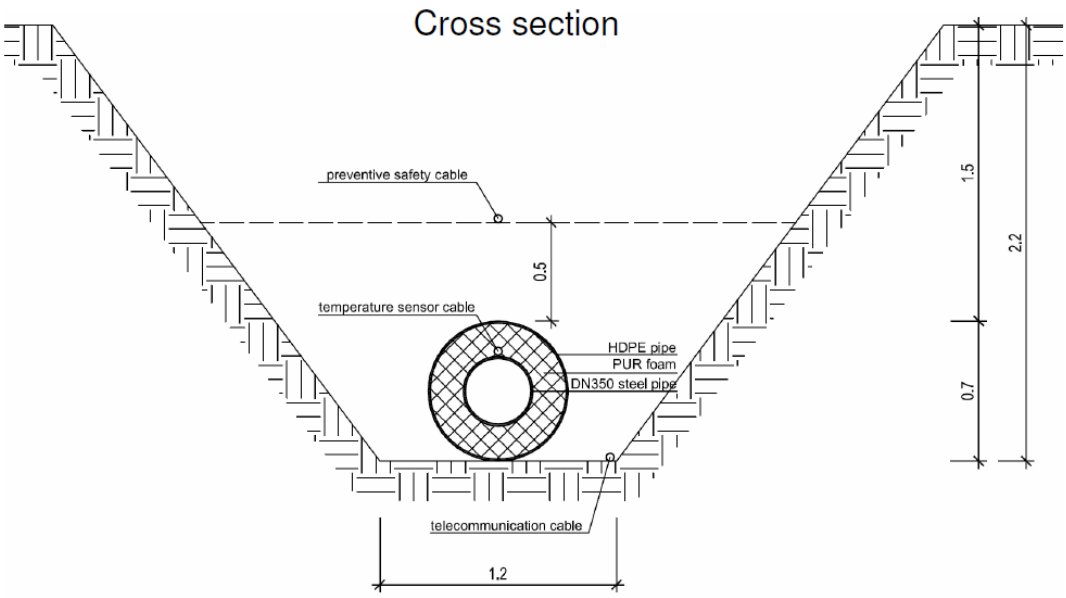

Figure 5: Cross section showing the proposed pipeline laying technique.

As mentioned, two different capture techniques were going to be employed resulting in two different sets of gas composition (see figure 6). This would have an impact on the design of the pipeline, with the O_2 limits in particular being imposed on the capture unit.

Block F/2

CO_2	>99,5	Vol %
O_2	<200	ppmv
N_2 + Ar	<500	ppmv
H_2O	<50	ppmv
NO + NO_2	<5	ppmv
SO_2	<1	ppmv
SO_3	<1	ppmv

Block G

CO_2	>95	Vol %
O_2	<0,8	Vol %
N_2 + Ar	<4,2	Vol %
H_2O	<25	ppmv
NO + NO_2	<50	ppmv
SO_2	<25	ppmv
SO_3	<10	ppmv

Figure 6: The composition of CO_2 from the post combustion capture unit (Block F/2) and the oxyfuel unit (Block G).

Vattenfall considered using either Composite GFK (glass reinforced plastic) or L485MB (steel) for the pipeline material. Composite GFK offered advantages such as resistance against acids, non-corrosive and stable behaviour even at high temperature. However the Composite GFK has a high capital

expense (CAPEX), low resistance against mechanical impact and doesn't have any comparable references. L485MB steel was advantageous because it has a low CAPEX, numerous references and positive results in corrosion tests. However mechanical stress at low temperature has to be considered in the design and it is at risk to corrosion if the CO_2 stream carries impurities.

Vattenfall made the final decision to go with the steel pipelines, material L485MB, material number 1.8977 (API5L standard X70). The pipelines had a design pressure of PN140, a length of 52.090 m, a total volume of 4.453 m³, no inner coating, an inner diameter: 330,6 mm, wall thickness: 12,5 mm and an isolation material PUR-foam: 137 mm. The outer coating HDPE: 40,2 mm with a total diameter of 710mm, a roughness of 0,15mm, a steel density of 7.850kgm^3, a PUR density of 70kgm^3, a HDPE density of 950kg/m^3 and a steel thermal conductivity of 48,4W/mK.

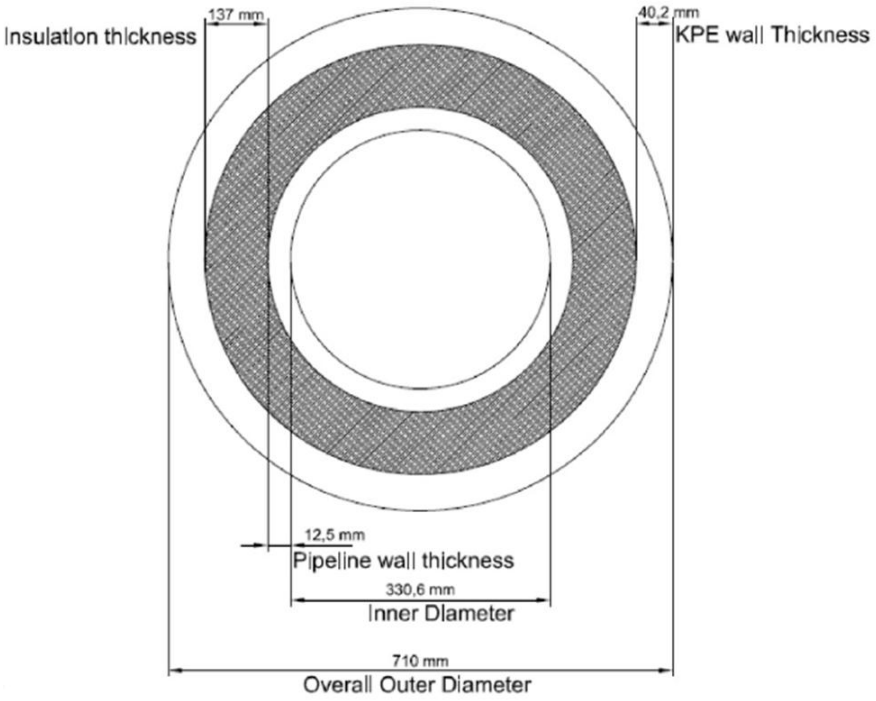

Figure 7: Schematic of pipe design.

The pipeline process flow figure is shown below, which illustrates the following items that were considered in the pipeline design (including distance from the capture site):

- Start / Blow-off / Pig-trap Station 0 m
- Valvestation 11.3 km
- Blow-off / Valvestation 26 km
- Valvestation 40.6 km
- Blow-off / Valvestation 52.1 km

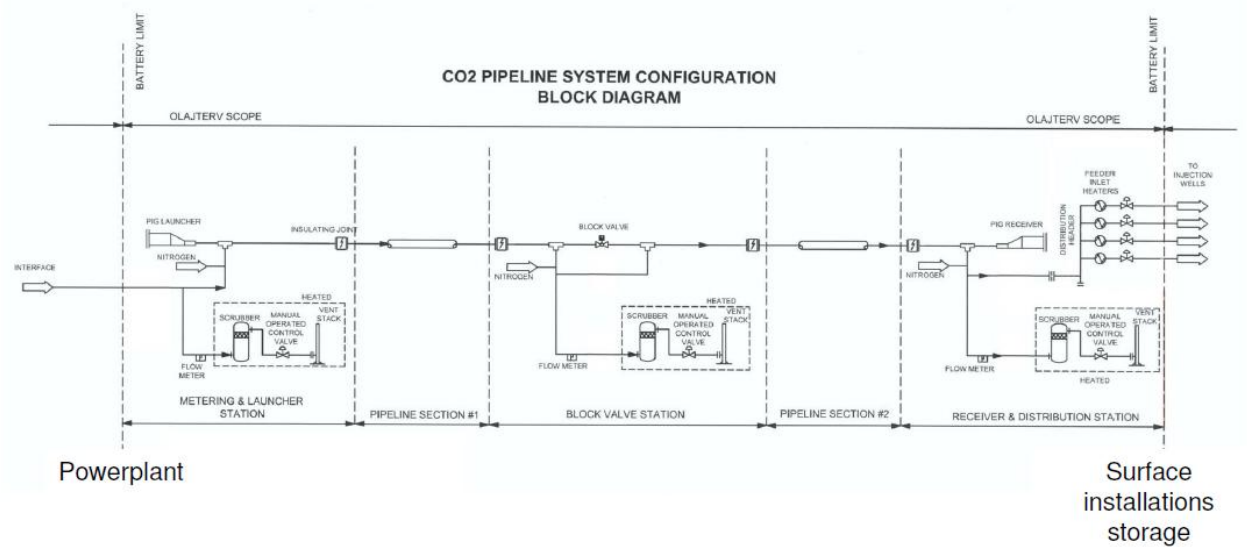

Figure 8: The configuration of the pipeline.

The monitoring concept for the pipeline had a primary system and secondary system. The primary system would have monitored massflow, temperature, pressure and composition in the pipeline at defined intersections. The secondary system would have monitored the temperature outside of the pipeline via fibre cable. Additional monitoring would have come from mechanical impact sensors and baseline, environmental and meteorological monitoring.

Vattenfall applied the DNV guidelines on pipelines and invited experts to evaluate the assessment already in an early stage of the planning.

Conditions for a successful permit were very promising as the routing mainly followed existing linear infrastructure elements through a very sparsely populated area.

Further information is available from the Transport Concept document. This FEED study provides the main parameters of the proposed 52km long pipeline. (In English)

http://www.ccsnetwork.eu/assets/publications/Feed_study_pipeline.pdf

Storage

Site selection for the safe and permanent storage of the CO_2 captured at Jänschwalde started in 2004, with a desktop 'screening' of the north of Germany by:

1. Defining pre-selection criteria such as: estimated storage volume, geology (reservoir and seals properties), potential conflicts with other users of the sub-surface and surface, and distance from the Capture power plant.

2. Reviewing the data available from years of intensive O&G exploration, mainly in the form of 2D seismic data and deep drilling.

As a result of this work, three sites were pre-identified as being potential suitable storage sites: the gas field of Altmark, the Neutrebbin structure and the Birkholz-Beeskow structure.

In 2006, Vattenfall started negotiations with O&G companies (Altmark). Finally, the Birkholz-Beeskow structure was selected for further exploration as the permit was the first one to be received. No permit was obtained for Altmark.

The geology of the Birkholz-Beeskow structure indicates a storage reservoir in the Buntersandstone at approximately 1300m depth with 2 main caprocks, the first in the Bundsandstein made of a 100m thick layer of clay with a 10m thick salt layer at approximately 1000m depth and the second in the Keuper which is made of clay from 200 to 600m depth. Fresh water is separated from salt water by the Rupelclay (Oligocene) Northern Germany. The Muschelkalk at 800m above the first caprock is an indicator horizon that would have been used for monitoring purposes.

No new data was acquired during the project. Time was dedicated to obtaining exploration licences and designing the exploration plans. These exploration plans were based on existing data that was collected, investigated, reprocessed and reinterpreted. 3D geological static models were built with this historical data.

The proposed exploration programme was designed to include:

- **Seismic Surveys:**
  - ~ 300 - 550 km² per structure
  - 3D-Seismic surveys (330km^2 at Birkholz-Beeskow) with 9 additional (67km total) 2D-Profiles
  - With an expected duration of 6 months (probably over winter)

- **Drillings**
  - 4+ drillings per structure (3 deep injection and monitoring and 4 shallow monitoring wells at Birkholz-Beeskow)
  - A high rate of core drilling

- **Hydraulic Tests**
  - Extraction of brine
  - Injection of brine

Monitoring

A monitoring methodology was designed and adopted for groundwater to create both a baseline and would have formed the basis for an ongoing monitoring programme during operations. The development of this groundwater monitoring involved obtaining, digitising, reprocessing and validating the data from old and existing wells. This data was being used to create a baseline, particularly of salinity, from which an operating monitoring plan would have been developed had the project proceeded. This baseline was going to be re-evaluated on an annual basis to ensure storage and further develop measurement to reduce any risks.

Storage Risk Assessment:

Vattenfall participated in the DNV CO2QUALSTORE JIP guideline, which is now referenced in the guidance documents to the European Directive 2009/31/EC on the geological storage of carbon dioxide (the CCS directive).

Following this guideline, the project followed a Risk Assessment matrix (also called criticality matrix) produced by a number of experts, based on probability versus consequences and labelling the identified risks as low, medium or high. This allowed the project to focus on and address the highest risk elements of the storage project, ensuring that the CO_2 would have been safely and permanently stored.

Lessons learned:

A number of lessons were learnt regarding the storage aspects of the project – with the greatest being the importance of the selection criteria for the storage site. There were three elements to this:

- It is vital to have clearly understood, accepted and transparent criteria for site selection.
- Early public participation is of the utmost importance.

Understanding who defines the acceptance criteria for exploration and site selection, and then deciding what the acceptance criteria is, should be understood and undertaken at an early stage.

Further information:

As per the permitting requirements for storage exploration under the Mining Law in Germany, following an exploration permit a main storage operating plan is required. A summary document of this plan is available for the Birkhoz site, and includes the plans for an exploration program and geo-physical investigation. This includes the Geo-technical exploration program for the geological structure Birkholz storage, which provides further details on the work that was proposed. (In German with an executive summary in English)

http://www.ccsnetwork.eu/assets/publications/Main_operating_plan_Birkholz.pdf

http://www.ccsnetwork.eu/assets/publications/Exploration_Program_Birkholz.pdf

Consent and Permitting

A thorough and concise overview of the permitting and consents procedure that Vattenfall undertook for the Jänschwalde project was provided. Germany had already started legislative procedure for the CCS Law even before the Directive 2009/31/EC came into force. This meant that the first Draft CCS Law was agreed swiftly on the 4th April 2009. However, public awareness and acceptance issues caused problems, even for the permitting aspect of the project, since 2009 and as a result the Draft CCS Law had to be abandoned in summer 2009 because of the low public acceptance and regional protests (many of these were covered nationally & internationally).

The new Draft CCS Law was presented in July 2010, but it was limited to demonstration projects submitting an application for the storage permit until 2015 with maximal storage volume of 3 Mt annually per project, and with a maximum storage volume for all projects in Germany of 8 Mt annually.

Despite this very limited application of the CCS Draft Law, support for CCS declined even further between July 2010 and April 2011. Despite the importance of using CCS within both the generation fleet (for coal and gas) and for industrial applications (CCS is the only effective way of stopping emissions from the industrial sector) the Government failed to promote it at all in the face of public and NGO opposition.

The revised Draft CCS Law that was put forward in April 2011 gave the Federal States the right to designate areas on their territory which may or may not be used for CO_2 storage. This meant that the competent authority could effectively halt or suspend storage permit proceedings within their jurisdiction. This Draft Law was passed by Bundestag in July 2011, but rejected in Bundesrat by the representatives of German federal states in September 2011.

Following this standoff between the Bundestag and the Bundesrat a Conciliation Committee was called in to find a solution. Each time in the numerous meetings of this committee the crucial decision on the Draft CCS Law was postponed to the next meeting. As there is no deadline for the Conciliation Committee to reach a decision, all CCS projects will remain in the state of limbo.

In terms of permitting Vattenfall was very far advanced, and the project would have been 'on track' with regard to having most permits and consents in place. The problems with the delay in the project came from external factors that influenced the Government's decisions on CCS - and now CCS is not seen as a priority politically, despite the environmental commitments that will need to be made in both the power and industrial sectors for which CCS is the only realistic option.

Below is a list of the permits that Vattenfall required for each section of the project:

Permits that were required for Capture

- Modification permit under Federal Emission Control Act (supposed to be submitted in the beginning of 2012)
  - concentrated permit including all permits necessary for the erection and operation of the new unit (except permits under Federal Water Act);

- preliminary framework for the EIA fixed by the Environmental Authority in December 2010; and
- executed studies regarding noise-measurement and evaluation of the air quality in the area;

- Permits under the Water Act:
  - Permit for the use of water for cooling and other purposes
  - Permit to lower groundwater during the phase of construction of the power plant
  - Permit for the operation of plants using hazardous substances
  - All permits combined with the modification permit under FECA

Permits required for Transport

- Planning assessment (compatibility of the project with the regional spatial planning with an EIA)
- Plan approval decision. The concentrated permit was to include all permits for the construction and operation of the pipeline, and the submission of the application documents to the authority was planned for 2012

Permits required for the Storage Site

Permits under the current Mining Law:

- Exploration permits – issued for Birkholz October 2009, Neutrebbin March 2010
- General operational plan for the exploration campaign – issued in January 2011 (see the storage section for a link to the summary document)
- Special operating plan for seismic submitted to the Mining Authority in January 2011
  Withdrawal of the exploration permits – January 2012

Key Lessons Learned

A number of lessons were learnt from the permitting exercise for Jänschwalde

- Planning and development of a big industrial project without a comprehensive legal framework bears risks at many levels;
- Early involvement of the public in the potential storage areas is essential for the progress of the project but also for the development of the legal framework;
- Public acceptance and political support for a new technology is of high importance for permit proceedings under existing laws (This was the key issue for Vattenfall as the government at first seemed that they would allow most of the permits under existing laws); and
- Political decisions and strategies may change extremely quickly.

Public Engagement

The lessons learnt from stakeholder profiling and engagement that were presented described the steps taken by the project and the changing political landscape that ultimately led to the cancellation of the project. The Jänschwalde project team conducted their public engagement on national, regional and local levels. On a national level, the project received a lot of media attention especially during the legislative process that ultimately failed. On a regional level, a lot of support was granted by the government of the Federal State of Brandenburg and the attitude of the most important stakeholders was positive towards the demonstration project. In the region were the CO_2 was planned to be stored, the project had a local information centre, road shows, brochures and leaflets and kept in continuous contact with the various stakeholders. When the project started in 2009 it was felt as though the issues and the messages were well understood: all the risks were identified and would be addressed. It was therefore felt that the public would acknowledge that this was a project for both environmental and public good, enabling a technology that reduces emissions - (and if biomass is used, it is the only technology that not only reduces emissions but can be 'carbon negative' – taking emissions out of the atmosphere)

The stakeholders that most strongly supported the Jänschwalde project were the Federal Governments of Brandenburg and Saxony, a number of regional interest groups, selected media, many national politicians (together with R&D and technical partners and academia).

Those against the project included "locals against CO_2", national NGOs, left-wing political parties, selected media and competitors from the renewable energies sector (in particular solar energy).

It was felt that the biggest mistake that was made by the project was underestimating the local opposition in the proposed storage area. In that region there was no coal production (unlike around the proposed capture plant) and Vattenfall was just one of four - not well trusted - national utilities in the area. Nationwide, there was a swing against CCS during the course of the years and political support gradually faded away. In the end there was no prominent support at the national political level. Most of the debate on the safety of CCS was driven by those who opposed coal-fired electricity generation – ignoring the importance this technology has to both the electricity and industrial sectors as a vital (transitional) tool in combating climate change that has to work with other renewable sources of generation.

As a result of this and other experiences with local resistance against planned projects (for example the Magnum project in Eemshaven, The Netherlands), Vattenfall developed a "stakeholder engagement model" (see figure 9) which has proved useful in recent projects. It is generally accepted now that "direct contact with affected stakeholders provides new and valuable information for the project - with possible new ideas for solutions and procedures".

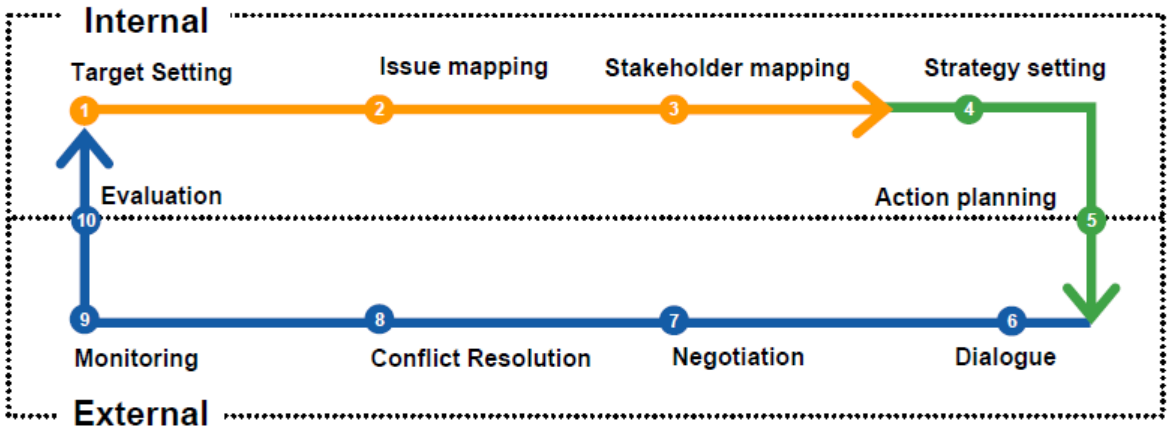

Figure 9: Stakeholder engagement model.

Project Management

Timelines

Vattenfall have seen the potential for CCS as a clean, environmentally friendly, and economic part of their generation fleet. This has been clearly verified and articulated both on a European level – with the European Union's Energy Roadmap[4] – and an international one – with the inclusion of CCS into the CDM.[5] As a technology it will also play a vital part in reducing emissions in the industrial sector, where it is the only viable emissions reduction technology, and which will benefit greatly from the developments in CCS made in the power sector. The Jänschwalde project was to be an important step in the integrated upscaling of the technology in the power sector, but for Germany at least that step will need to be demonstrated elsewhere.[6]

In terms of the development timelines for the project:

In 2004 work first commenced on the feasibility of CCS operations in Germany with a first desktop evaluation of possible storage sites.

In 2006 negotiations started with GdF Suez (the owner of the Altmark site) and contracts for storage options were developed.

In 2008 the pilot oxyfuel plant at Schwarze Pumpe was developed – demonstrating very successfully the potential of the technology to obtain high efficiency rates when applied to newly built power plants, and a superior capture rate as compared to other options. Trucks were ordered to transport the CO_2 – and there was a growing body of expertise in the ASU, GPU, transport and storage elements. While at this point there was clear political support, but this soon changed with the delay to the CCS law.

In 2009 planning started for the Jänschwalde CCS plant. However the CCS law failed to be passed.

In 2010 €180m of European monies are offered to the project as part of the EEPR grant – reflecting its importance in demonstrating this key environmental technology at a European and global scale. The technical concept continues to be improved.

In 2011 the NER 300 application was submitted. However the CCS law stops for a second time. At this point the project is stopped due to the regulatory uncertainties of operating a CCS plant in Germany.

Key learnings

In terms of overall project management the capture elements were much like any generation infrastructure project. The oxyfired plant at Schwarze Pumpe had a development cycle that went

[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011PC0885:EN:NOT
[5] http://unfccc.int/resource/docs/2011/cmp7/eng/10a02.pdf#page=13
[6] www.ccsnetwork.eu

much better than expected, and it was fully anticipated that there would be no operating penalty of capturing the CO_2 on this new unit compared to an older operating unit.

In terms of operating expectations, it quickly became evident that load following was an important design element for any new CCS capture plant, as given the anticipated future generation mix - baseload operations cannot be necessarily assumed. This created some challenging design considerations for both the transport and injection elements in particular.

It was the transport and storage elements that proved to be significantly more challenging than originally anticipated. While only representing a relatively small fraction of the overall investment costs – these elements were the most attention consuming, and it would have been beneficial to consider them more fully earlier in the project development life-cycle.

The project had to create a new joint venture company for the Transport and Storage of CO_2. Vattenfall's Head of R&D commented that it was initially assumed that a number of independent organisations would be keen to pick up the storage operations, seeing it as a business opportunity. It turned out that was not the case, and as a consequence they had to start developing in-house competence. As a 'lesson learnt' it was felt that in any case having internal expertise regarding CO_2 storage was of great use.

Cost

In terms of capital costs, the Jänschewalde project was going to be a €1.5bn investment. €1.250 bn of that was dedicated to the capture component of the project. The procurement contract for the ASU alone took around 14 months, but was below the budgeted €150M. While only €250m of capex was required for the transport and storage, the required time and effort were much higher than originally assumed.

The operating costs for the capture of CO_2 would have resulted in an 8% point drop in performance, the equivalent of an 18% efficiently loss. Nevertheless, with the much higher operating efficiencies that can be achieved with a new unit using oxyfuel technology – the net operating efficiency would have been the same as a conventional unit refurbished in the mid-1990s (including compression), illustrating that if the high capital costs can be accounted for CCS is a very viable technology.

Conclusions

Jänschwalde was one of the most advanced CCS projects in the world. It would have been a 250MW oxyfuel plant operating at a net efficiency of 36% and capable of flexible operations between 50-103% and a 50MW retrofitted post combustion capture plant. Transport would have been by steel pipeline. Had the project gone ahead the 1,700,000 tonnes per year of CO_2 emissions could have been safely and permanently stored over 1000m underground in either the Birkholz-Beeskow or the Neutrebbin structure. The ongoing impasse in passing the German CCS law, as stipulated by the European Union's CCS Directive, has led to Vattenfall cancelling the project.

Vattenfall has consistently emphasised its commitments to CCS, and has invested extensively in the development programme. This was undertaken with the expectation that CCS will be a cornerstone of the future energy mix, and will be vital particularly by 2020-30. Vattenfall has consistently monitored and often contributed to R&D efforts in all three carbon capture technologies, (oxy fired, pre and post combustion), with close links to pilot plants across Europe.

Vattenfall will continue to monitor and actively support developments concerning the CCS technology with the expectation that full-sized commercial CCS plants will be an essential part of the generation fleet of Europe during the 2020s onwards – complementing renewable generation – as the most realistic route to a future where average global warming is limited to 2 ^{o}C.[7] This is articulated within Vattenfall's strategic ambition to reduce its specific CO_2 emissions by 50% by 2030 and to produce heat and electricity in a manner that is neutral to the climate by 2050, even if fossil fuels are still required for security of supply.

[7] EU Energy Roadmap 2050 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011PC0885:EN:NOT

The European CCS Demonstration Project Network was established in 2009 by the European Commission to accelerate the deployment of safe, large-scale and commercially viable CCS projects. The Network that has been formed is a community of leading demonstration projects which is committed to sharing knowledge and experiences, and is united towards the goal of achieving safe and CCS. The learnings that are gained will be disseminated to other projects, stakeholders and public to help gain acceptance of the technology –and support CCS to achieve its full potential as a vital technique in our fight against climate change.

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