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Progress Towards Implementation of IGCC-CCS in Europe

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EXTENDED ABSTRACT

This paper covers development and demonstration initiatives of Integrated Gasification Combined Cycle (IGCC) technology with Carbon Capture and Storage (CCS) in Europe. It will also present technical and political barriers blocking the way for early commercialisation of the IGCC-CCS technology in Europe.

Integrated Gasification Combined Cycle (IGCC) is currently one of the most attractive technologies for the high-efficiency use of coal in Europe especially when considering the application of CCS. It enables the conversion of coal and other solid or liquid fuels to a gaseous syngas fuel, while still maintaining ambitious emissions targets and high efficiency. For capturing CO_2 in IGCC systems the pre-combustion methods are preferred. An IGCC plant equipped with pre-combustion CO_2 capture combined with low emissions of other gases, e.g. NO_x, SO_x, can be realised through major advancement in IGCC gas turbine technology.

The continued need to use coal as a primary fuel combined with requirements to cut CO_2 emissions generate a genuine demand for the development of reliable, low-emission, cost-competitive gas turbine technologies for hydrogen-rich syngas combustion in an IGCC plant with CCS.

Economic growth and prosperity in Europe have been built on oil, coal and gas. Therefore, reinventing the energy system to a low carbon model will be one of the most critical challenges of the 21st Century. Today, in the EU, primary energy supply is 80% dependent on fossil fuels[1]. This dependency has made Europe vulnerable to energy supply disruptions from outside the EU, volatility in energy prices and climate change.

Even though increased energy efficiency is high on the political agenda, forecasts of European power demand predicts an increase in the order of 24% by 2030 and that fossil fuels will still contribute to around 44% of the power generation by 2030.

[1] EEA report No6/2008

The EU is therefore making a major effort to develop a low-carbon economy with a reduced dependence on external fuel supplies. The EU climate change policy includes a 20% (up to 30%) reduction of CO_2 by 2020 and in the longer term, an 80% cut in greenhouse gas emissions by 2050 compared to 1990 levels.

There are various possible pathways to a low carbon economy and it is very important to follow up on the different options. First of all, no single measure or technology will be sufficient and secondly the precise energy mix in each country will depend on the particular combination of political choices, market forces, resource availability and public acceptance.

In March 2007 the European Council formally recognised that the CO_2 reduction targets are not achievable without CCS[2]. As a result, the European Commission together with industry and the research community have drawn up technology 'roadmaps',[3] which identify key low carbon technologies with strong potential at an EU level in six areas and CCS technologies is one of them.

It is clear that CCS technologies have to be widely commercialised in order for the EU to achieve almost zero carbon power generation by 2050. The markets and energy companies acting on their own are unlikely to be able to deliver the required technological breakthroughs within a sufficiently short time span to meet the EU's energy and climate policy goals. Therefore the EU has developed a comprehensive policy framework which now is in place to create the necessary push for CCS technologies:

ETS Directive 2009/29/EC[4] - The revised Directive on the EU's Emissions Trading Scheme came into force on the 5 June 2009 with the goal to improve and extend the greenhouse gas emission allowance trading scheme of the Community. 300 million allowances will be used to finance innovative renewable energy and CCS installations.

[2] 2007 Spring European Council: Reduction of 20% GHG by 2020 and financing of up to 12 CCS demos by 2015
[3] Strategic Energy Technology Plan (SET-Plan) COM (2007) 723 final
[4] Directive 2009/29/EC

European Energy Recovery Programme EC 663/2009 - EERP – This programme came into force on the 1st of August 2009 to aid economic recovery by granting Community financial assistance to projects in the field of energy with a budget of €1.05bn for CCS-demonstration projects (in total €4bn). Six CCS projects have been selected by the European Commission by the end of 2009.

CCS Directive 2009/31/EC - This directive doesn't make CCS mandatory but it brings a Carbon Capture Readiness (CCR) policy which applies to new combustion power stations with a generating capacity at/or over 300 MWe.

However, it is clear that the only credible route to meet the goals is joint public and private cooperation and investment. The Zero Emission Platform (ZEP) is an EU supported initiative for all the stakeholders to commonly push CCS as a key technology for combating climate change.

The European utilities, petroleum companies, equipment suppliers, scientists, academics and environmental NGOs that together initiated the ZEP have three main goals:

1. Enable CCS as a key technology for combating climate change.
2. Make CCS technology commercially viable by 2020 via an EU-backed demonstration programme.
3. Accelerate R&D into next-generation CCS technology and its wide deployment post-2020.

Three promising methods have been identified for the capture of CO_2: **post-combustion, pre-combustion and oxy-fuel**. Each of them is being investigated and is intended to be validated through further research and demonstration projects within Europe. In a published technical review of the validation status of these three different CCS technologies, made by the Zero Emission Platform[5], it was concluded that validation of the pre-combustion technology blocks were more advanced than post-combustion and oxy-fuel blocks. However, the H_2-GT and the overall integration of pre-combustion blocks still requires considerable attention, which shows the importance of further validation and demonstration efforts.

Even though IGCC is one of the most attractive technologies for high-efficient/low emission use of coal, IGCC plants have still not made their breakthrough in terms of wide-spread application for power generation from coal due to commercial reasons (reliability & cost). Currently there are 3 large commercial plants in operation in Europe:

- Buggenum in the Netherlands. 253 MW. GT: Siemens V94.2
- Puertollano in Spain. 350 MWGT: Siemens V94.3
- Vresova in Czech Republic. 400 MW. GT: GE 9E

[5] ZEP report: CO2 Capture and Storage (CCS) – Matrix of Technologies-15 October 2008

The complexity of the plant design, operational reliability & availability of plant subsystems (gasifier, cleaning units etc.) and plant cost all becomes major issues of concern. For these reasons, in combination with the harsh operating conditions induced by the handling/combustion of synthesis gas (mainly CO/H_2) with certain corrosive trace gas species and particulates, mostly E-class gas turbines are applied which have a rugged design and operate at reduced firing temperatures.

Part of the plant complexity derives from the integration of the gasification island & gas clean-up processes with the combined cycle (steam + gas) configuration of the power island. Less interdependency between the individual subsystems – such as less/no dilution gas (N_2 from the air separation unit or steam from the heat recovery steam generator) requirements for the fuel gas to be burned in the gas turbine – would increase the operational flexibility and thus enhance plant availability.

The relatively low reliability and availability of the overall IGCC plant, the relatively low overall efficiency due to additional auxiliary power needs and the necessity of fuel gas treatment increase the operational costs of an IGCC plant compared to a natural gas combined cycle plant.

Despite all these challenges, IGCC technology is one of the two top contenders (the other being supercritical boiler technology) for most efficient power generation from coal. Due to recently reported achievements in plant availability and because of the technology options offered by IGCC systems with respect to carbon capture (and poly-generation of fuels & chemicals from coal), a large increase in the number of proposed new installations can be observed (about 12 in Europe).

Even though it has been recognized in Europe that IGCC with CCS is a very promising technology with a large potential market, the risks are currently too high and uncertainties to many for utilities to go into large scale demonstration without significant subsidies. As a result, only a few IGCC with CCS projects/ initiatives have been commissioned or being planned in Europe so far and some of them are still under consideration.

The Magnum Plant, NUON, Netherlands

This power plant is under construction and will have a production capacity of approximately 1.200 megawatts. Electricity will be generated from gas, coal and biomass with Mitsubishi F-class GT-technology. Nuon has split the development of the multi-fuel plant into two phases.

- Phase 1 is the construction of a natural gas-fired 450 MWe CC plant, planned to be operational in 2011.
- Phase 2 entails investments in coal and biomass gasification technology (750 MWe IGCC plant) planned to be operational at 2012 with an estimated partial CCS start in 2013.

The Goldenberg Plant, RWE, Germany

This lignite-fired plant is planned to be built in Goldenberg, Hürth (near Cologne) Germany with an estimated gross capacity of 450 MW, with CO_2 storage of 2.6 mill tonnes/year.

In view of insufficient public acceptance to store CO_2 in the storage region in northern Germany and the lack of a legal framework, the initial implementation date of 2015 for the project has been delayed.

The Hatfield Plant, Powerfuel Power Limited, UK

This independent power generation company was formed to develop a power station nearby Hatfield Colliery at Stainforth in the United Kingdom. The Powerfuel project was recently selected as one of the EU-funded CCS schemes and will receive a 180M Euro grant for its development. Powerfuel Power plans to construct a 900 MW IGCC with CCS plant with GE-GT technology in two phases:

- Phase 1 (2012) is the construction of an 800 MW (gross) power island (CCGT) which will operate on natural gas but specifically designed for optimisation and performance on syngas
- Phase 2 comprises the construction and commissioning of the gasification island allowing the power island to be converted over to a 900MW (gross) IGCC-CCS plant.

The captured CO_2 is planned to be used for Enhanced Oil Recovery (EOR).

Barriers for IGCC-CCS

Currently there are 4 barriers that needs to be addressed in order for the IGCC-CCS technology to take off:

- Technical
- Regulatory
- Financial
- Public acceptance

Technical barriers

This paper will focus on the technical barriers. At the moment, the combustion of hydrogen-rich undiluted syngas derived from coal in a gas turbine is not feasible with low NO_x premix systems and current gas turbine technology for power and heat generation is generally optimized for natural gas.

One of the largest barriers towards the usage of syngas are the strongly different combustion properties (shorter ignition delay time, higher flame speed, higher flame temperature) of these H_2-rich gases compared to natural gas. For this reason diffusion burner technology with nitrogen, steam dilution and/or Selective Catalytic Reduction (SCR) is used in such systems.

These are recognised disadvantages of the current technologies for syngas combustion. The very high flow rates of cost-intensive dilution gas (N_2, H_2O) that are needed to combust the syngas in highly-diluted diffusion flames and to control the NO_x emissions at the current state-of-the-art increases the costs of plant operation. Minimizing and/or eliminating the dilution of syngas and implementing current state-of-the-art gas turbine technology are the first steps towards higher efficiency IGCC plants.

Existing assessments suggest that there is around a 7 - 10% reduction of cycle efficiency due to CO_2 capture and indicate strong dependence on the fuel and selected cycle.

Parameters influencing the thermodynamic efficiency of gas turbine-based processes include cycle pressure ratio, maximum allowable turbine inlet temperature and hot gas path cooling demand. The reduction in overall process efficiency is strongly determined by the required power for compression & gas cleaning of CO_2 and O_2 (used in the primary fuel gasification process step).

To date, the most advanced IGCC systems have not used the latest available generation of gas turbines giving a net efficiency in the range 43 – 45%, while with the application of G- or H-class gas turbines, the net efficiency is expected to increase to 48 – 50%. These values are comparable to or higher than those typical of the most advanced ultra-supercritical (USC) pulverized coal power plants operating in regions with advantageous environmental conditions. Moreover, the expected efficiency reduction for implementing CCS will be smaller for IGCC plants than for USC plants.

H2-IGCC[6]

In Europe an EC-funded project called H2-IGCC (Low Emission Gas Turbine Technology for Hydrogen-rich Syngas) recently started which addresses technical barriers of IGCC with CCS. It is a 4-year project with a total budget of 17.8 M EURO which ETN (European Turbine Network) co-ordinates.

The overall objective of the H2-IGCC project is to provide and demonstrate technical solutions which will allow the use of state-of-the-art highly efficient, reliable gas turbines in the next generation of IGCC plants, suitable for combusting undiluted hydrogen-rich syngas derived from a pre-combustion CO_2 capture process, with high fuel flexibility.

The recognised challenge is to operate a stable and controllable gas turbine on hydrogen-rich syngas with emissions and process parameters similar to current state-of-the-art natural gas turbine engines. This objective will have severe implications on the combustion technology, hot gas path materials, the aerodynamic performance of turbomachinery components and the system as a whole.

The project will address these issues in 4 subprojects: SP1: Combustion; SP2: Materials; SP3: Turbomachinery and aerodynamics; SP4: System analysis.

[6] EC Collaborative Project FP7-239349

The H2-IGCC project will aim to provide solutions to the technical challenge of burning undiluted syngas in a safe and reliable way, with efficiency and NO_X emissions similar to state-of-the-art gas turbines fuelled by natural gas (η>38% in open cycle with NO_X < 25 ppm at 15% O_2). In addition, the project will attempt to increase gas turbine fuel flexibility, by enabling combustion of back-up fuels, such as natural gas, without adversely affecting the reliability and availability of the gas turbine. This is an important operational requirement to ensure optimum use of the gas turbine.

Summary:
The technology for the next generation of IGCC plants with CO_2 capture systems is very promising but still requires development and demonstration of H_2-gas turbine technology as well as overall process integration. For the EU to meet its emission reduction targets as well as increase the security of fuel supply it is essential that the IGCC-CCS technology reach a commercial stage in the timeframe of 2020-2025. In order to make this happen:

- A technology push and further validation is needed for hydrogen gas turbines as well as for the overall plant process integration and optimization;
- The incremental costs of CCS-demonstration plant require financial support;
- Underlying legal and regulatory conditions are needed;
- The overall technical and commercial viability needs to be evaluated at future demonstration plants;
- Further investment incentives to facilitate full commercialisation of CCS technologies (for example directives, CO_2 reduction incentives, tax discount etc.) would be needed;
- Public acceptance for storing the CO_2 is required. Reaching public acceptance will play an important role in the technology's implementation.

Knowledge sharing both on a European and international level is also essential to significantly reduce the time and the cost of bringing CCS to the market.

The H2-IGCC project, with its 24 partners from industry and academia, addresses the technical barriers with the common goal to increase gas turbine efficiency and fuel flexibility without affecting the reliability and availability in a pre-combustion IGCC-CCS plant configuration. A successful outcome of this project will enhance confidence and significantly reduce deployment times for identified and developed gas turbine technology within this project. This would be an essential step paving the way for commercial deployment of efficient, clean, flexible and reliable IGCC plants with CCS by 2020.

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