**Carbon mitigation**

**P. Breuhaus**

Comments from the PB meeting

Previously :

* Change the title to *decarbonisation / low carbon solutions*

D. Orhon:

* Suggested title, *Carbon footprint reduction*

While there is significant momentum behind the continued use of gas turbines for power generation using gaseous or liquid fuels, such as natural gas, shale gas or renewable biofuels, there is a continuing threat from policy and regulatory actions being taken to reduce CO2 emissions. This underpins the strategic importance for the gas turbine industry to maintain their commitment to continuing R&D into the development of low carbon options and cost-effective CCS for both new designs and for retrofit to existing units.

Reducing CO2 emissions from gas turbines can be achieved through the improvement in efficiency, the use of flow carbon fuels or by the integration of CO2 capture technologies. The first of these options is addressed in another part of this document, while the second shares close linkage to the challenges from fuel flexibility. The application of CO2 capture approaches may be post-combustion, with the capture unit located on the gas turbine exhaust; pre-combustion, where the carbon is largely removed early on in the process leaving a hydrogen-rich fuel gas; or by using oxy-combustion where the CO2 is more readily separated from the steam in the exhaust gas stream. The following priorities reflect those not covered elsewhere.

**Integration of post-combustion CO2 capture technologies with gas turbines**

The decarbonisation of gas turbine power generation, whether for existing natural gas-fired units or for new build schemes will have significant impacts on operating costs and levels of dispatchable power, due to the energy penalties arising when CO2 capture is included. Selecting the most suitable capture technologies and optimising their integration (while maintaining plant flexibility) provide significant challenges. Among others, the following options are worthy of further research:

* Integration of ‘conventional’ post-combustion amine scrubbing, or competing liquid based technologies, to minimise costs and energy penalties, and to optimise operational flexibility.
* Investigation of alternative post-combustion capture tech- nologies, such as Ca-looping cycles or solid sorbents us- ing pressure or temperature swing concepts, which allow for improved heat integration, and hence lower operating costs. Also, the investigation of other post- combustion capture options, e.g. CO2 separation membranes.
* Studies of the impact of exhaust gas recycling, including enhanced recycle options (e.g. using CO2 separation membranes), to enhance exhaust gas CO2 levels and so reduce the size and costs of the capture plant. This approach will lead to significant changes to combustion and hot gas path environments, and may also impact on operability, materials and component lives.

**Operation with hydrogen, biomass-derived and other low carbon gases**

Such gases are often less clean than their fossil-derived counterparts and so can lead to combustion and hot gas path challenges. This links with research aimed at improved fuel flexibility and the use of H2 used either in direct firing, or in dilution of natural gas distribution networks, such as reformed natural gas, H2–rich syngas from gasification processes with pre-combustion capture, or from H2 generated by electrolysis (from unused renewable electricity) or from biomass-derived sources.

**Advanced, high-efficiency cycles using oxy-fired gas turbines**

A range of advanced, high-efficiency cycles are under development to provide higher efficiency alternatives with inherent CO2 separation to the application of post-combustion capture options. These use oxy-combustion to provide a low N2 exhaust gas from which it is easier to separate the CO2. In these cycles, the separated CO2 is compressed for transport and storage, and some of either the CO2 or the condensed steam may be recycled to the combustor to moderate combustion. Such cycles operate at very high pressures, up to 300bar, and present significant operational and component manufacturing challenges. Examples are supercritical CO2 power cycles (e.g. the NetPower cycle), where the exhaust gas CO2 is recycled, or the Clean Energy Systems cycle (which comprises natural gas/O2 combustion) where steam is used to moderate the combustion conditions.

While offering significant potential for the generation of low cost, low carbon electricity, these cycles require major developments in combustion, hot gas path environments (due to the impact of high steam/CO2 levels), materials, turbomachinery requirements, control strategies, etc., as these are very different to conventional systems and present many challenges and uncertainties which may limit the potential performance of the cycles and significantly hinder their development. Research into the impacts of these altered operating environments would help the identification of those cycles with most potential, and so provide a possible pathway for future turbine development.