# ETN's position on the SET-Plan Issue Paper 9

## Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)

The European Turbine Network (ETN) welcomes the European Commission's initiative to clarify and prioritise the actions and research needs within the updated SET-Plan and matching them to the pillars of the Energy Union. We appreciate the opportunity to participate in the dedicated stakeholder's consultation on the "Issue Paper No. 9: Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)".

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 challenge from policy and regulatory actions being taken to achieve the agreed $CO_2$ emissions reduction targets. 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.

ETN believes that the objectives and targets in the Issue Paper n. 9 do not reflect the technical reality and technology maturity. Also, some commercially available CCS technologies should be rearranged for load flexibility to balance fluctuating renewables.
It is observed that CCS deployment is occurring too slowly due to high costs (55 and 80 US$/ton of $CO_2$, respectively for Supercritical Pulverized Coal (SCPC) and Combined Cycle Gas Turbine (CCGT) power plants)[1] and a lack of political and financial commitment. Some commercially available CCS technologies should be rearranged for load flexibility, where this is possible, with unavoidable penalties both in efficiency and costs. Some other $CO_2$ capture concepts are not (or nearly not) compatible with the load flexibility requirements.
From the point of view of the final cost of electricity, CCGT are more competitive than SCPC plants, with or without CCS[2], although the cost of the ton of $CO_2$ captured is lower for coal plants. This remarkable result is explained considering that both the relative net efficiency penalty due to CCS and the final net efficiency with capture favour CCGT[1].
To take seriously the 2°C scenario, the European Union should consider to have at least three to five full-scale or medium-scale demonstration projects by 2020, each using a $CO_2$ capture method listed below.

1) **Post-combustion**, with the capture unit located on the gas turbine exhaust;
2) **Pre-combustion**, where the carbon is largely removed leaving a hydrogen-rich fuel gas;
3) **Oxy-combustion**, where the $CO_2$ is readily separated from the steam in the exhaust gas stream.

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[1] Energy Technology Perspectives, Technology Roadmap, Carbon Capture and Storage, International Energy Agency, 2013.
[2] Giacomazzi E. and Messina G., "Exploitation of Supercritical CO2 Properties – An Holistic Solution for the 21st Century Power Generation", Impiantistica Italiana, n.5, p. 40-49, September-October 2015.

ETN believes that more research activities should be performed in the following areas:

**1. Integration of post-combustion $CO_2$ 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 $CO_2$ capture is included. Selecting the most suitable capture technologies and optimising their integration (while maintaining plant flexibility) provide significant challenges. Among others, the following areas are worthy of further research:

(a) Investigation of alternative post-combustion capture technologies, such as Ca-looping cycles or solid sorbents using 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. $CO_2$ separation membranes.

(b) Studies of the impact of exhaust gas recycling, including enhanced recycle options (e.g. using $CO_2$ separation membranes), to enhance exhaust gas $CO_2$ 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.

Adopting EGR and $CO_2$-rich (with a $CO_2$ content higher than in EGR) gas turbine concepts contribute to largely increase gas turbine efficiency by allowing higher turbine inlet temperatures while maintaining pollutant emissions within the limits imposed by the Industrial Emission Directive[3,4]. A significant pollutant emission reduction is expected even at lower minimum environmental loads. The higher $CO_2$ content in the exhausts makes it possible to reduce the costs of $CO_2$ captured and thus the final cost of electricity. Due to the current and future renewables dominated scenario, flexibility and cost effectiveness are the first requirements for the sustainability of CCS technologies. Implementation of EGR in CCGT meets both requirements: in fact, the exhaust volume to be decarbonized can be reduced by nearly 50%, consequently the size of the capture facilities are reduced significantly, thus increasing the operational flexibility and reducing the capital and operational expenditures.
Besides adopting EGR/$CO_2$-rich strategies, current CCGT power plants can be "recoded" by replacing the steam power section with a closed supercritical carbon dioxide (S-$CO_2$) cycle. This solution, while maintaining similar, or even better, efficiency, enhances the plant's flexibility: this is due to the synergic combination of several factors, such as the huge compactness of the S-$CO_2$ bottoming plant and its consequent low thermal inertia (turbine rotor included), the single-phase heat recovery, the absence of demineralized water requirement and the absence of a sub-atmospheric condenser.

In the end, adopting both EGR/$CO_2$-rich concepts combined with a S-$CO_2$ bottoming cycle can result into near/mid-term flexible, efficient and cost effective solutions for CCS exploitation.

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

Gases such as hydrogen ($H_2$), biomass-derived and other low carbon gases are often less clean than their fossil-derived counterparts and so can lead to combustion and hot gas path challenges.

[3] Tanaka Y., Nose M., Nakao M., Saitoh K., Ito E., Tsukagoshi K., "Development of Low NOx Combustion System with EGR for 1700°C-class Gas Turbine", Mitsubishi Heavy Industry Technical Review, Vol. 50(1), March 2013

[4] Evulet A.T., ElKady A.M., Brand A.R., Chinn D., "On the Performance and Operability of GE's Dry Low NOx Combustors utilizing Exhaust Gas Recirculation for Post-Combustion Carbon Capture", Energy Procedia 1:3809-3816, 2009.

Therefore more research should be performed in order to improve fuel flexibility and the use of $H_2$ used either in direct firing, or in dilution of natural gas distribution networks (such as reformed natural gas, $H_2$–rich syngas from gasification processes with pre-combustion capture, from $H_2$ generated by electrolysis (from unused renewable electricity) or from biomass-derived sources).

**3. Advanced, high-efficient cycles using oxy-fired gas turbines**

A range of advanced, high-efficient cycles are under development to provide higher efficiency alternatives with inherent $CO_2$ separation to the application of post-combustion capture options. These use oxy-combustion to provide a nearly pure $CO_2$ exhaust gas stream (after water condensation) from which it is easier to separate the $CO_2$. Some of these cycles operate at very high pressures, up to 300bar, and present significant operational and component manufacturing challenges. Examples are supercritical $CO_2$ power cycles (e.g. the NetPower cycle), where the exhaust gas $CO_2$ is recycled, or the Clean Energy Systems cycle where steam is used to moderate the combustion conditions.

Supercritical $CO_2$ cycles with internal oxy-combustion are a highly cost effective and (fuel- and load-) flexible technology, that allows a highly integrated $CO_2$ capture process, with high efficiency, minimum environmental and space impacts. Furthermore, the S-$CO_2$/oxy-combustion strategy can be an effective solution for the full integration of Power-to-Gas, CCS, and S-$CO_2$ pumping (Enhanced Oil Recovery, water-free shale-gas extraction).

While offering significant potential for the generation of low cost, low carbon electricity, these cycles require major developments in combustion, hot gas path environments (high steam/$CO_2$ 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.