2016-IP36: Reducing the Cost of CCS

In May 2016, the UK's Energy Technologies Institute (ETI) published an Insight Report entitled "Reducing the Cost of CCS: Developments in Capture Plant Technology", which may be downloaded from www.eti.co.uk/reducing-the-cost-of-ccs-developments-in-capture-plant-technology-2/?platform=hootsuite. A brief outline of some important learnings from the paper is described below, together with a selection of points in italics drawn from the chapter summaries.

CCS uses proven technologies; individually, while full-chain CCS may not be considered mature, all the process operations – CO_2 capture, compression, transport and storage – have been separately proven and deployed successfully at commercial scale. Given its well-recognised, essential role in a low-carbon world, however, the cost of deploying existing CCS is currently considered too high.

> *"The diversity of technologies in early applications means that no individual capture technology has gone far down the learning curve, and there is significant scope for cost reduction"*

Technology development and technology innovation are often identified as the most likely routes to lower costs and risks but, according to the report, waiting for global technology advances will not address UK specific costs and risks in transport and storage. Major cost benefits associated with advances in capture technology are unlikely to materialise until post-2030.

The report illustrates how the theoretical energy to separate and compress CO_2 from the flue of a CCGT or coal plant is, in practice, exceeded by a factor of somewhere between 2.6 and 4.1. While it is not surprising that capture and compression are the most expensive and energy-intensive operations in the CCS chain, the scope for improvement is evident. While post-combustion amines and pre-combustion gasification technologies are the existing capture technologies of choice in power generation – and are likely to remain so for some years – continued technology development and further innovation will gradually lead to more effective solutions for both capture and compression.

> *"Post-combustion capture is reasonably efficient, but there is scope for improvement, and alternative capture technologies are developing"*

While these technology improvements are expected to bring longer-term cost benefits, ETI's report highlights how the cost of CCS might be markedly reduced in the shorter term. It makes the point that, in the UK, shorter-term cost reduction can only be achieved through the deployment of commercial-scale CCS plants, investing in infrastructure and by having a policy environment that is attractive for CCS investors. Economies of scale make it likely that CCS plants will be built in clusters, with much of the CO_2 transport and storage infrastructure a shared resource.

> *"Consecutive deployment near a large store reduces the early cost premium to a greater extent than technology development"*

It is well known that demonstration plants are expensive but, in the case of CCS, they would be even more so if they were to invest substantially in (oversize) transport and storage infrastructure to the benefit of plants that come after [as was the case, incidentally, and what appears to have contributed significantly to the cancellation of the recent UK CCS Commercialisation Programme]. Consequently, with the opportunity to share infrastructure, the costs of subsequent plants will be lower. Furthermore, demonstration plants are often designed and constructed sub-scale with high redundancy. Economies of scale and lower redundancy on subsequent plants will ensure they generate at a lower cost per MWh. Lastly, learnings based on early-mover commitment to sharing designs and operational experience will lead to improvements and reduced risk for the plants that follow. By combining economies of scale, shared infrastructure and risk reduction through deployment to cut costs, the ETI estimates savings for a 4th unit of up to 45% of the cost of the demonstration plant (1st unit).

> *"Adding CCS not only doubles the capital cost of a gas power plant, but the extra capex has a high-risk premium."*

Clustering not only benefits cost but, by delivering a small number of commercial-scale plants sequentially using proven technologies, the risk premium is also reduced.

> *"Risk reduction of CCS projects is a key driver for cost reduction, and will be needed to encourage private sector investment"*

Essentially, shared infrastructure offers near-term opportunities for cost and risk reduction. Achieving major cost reductions from technology innovation and incremental improvements in technology is likely to be longer term (post-2030). So, while both clustering and technology development are important, they operate on different time frames; shared infrastructure more important earlier on and the greater impact from technology development coming later.

Post-combustion capture is applicable to both gas and coal-fired power generation plants. While dilute mono-ethanolamine (MEA) was the benchmark solvent for post-combustion CO_2 capture for many years, more effective solvents now offer significant advantages with regard to CO_2 absorption rates, CO_2 loading, thermal stability, cost and energy to regenerate CO_2.

> *"Post-combustion capture technology based on amines is efficient compared to other gas separation technologies, but there are opportunities for further improvements based on absorbent chemistry and properties"*

At around 4%, the low concentration of CO_2 in the flue gas from a CCGT places sever constraints on the effectiveness of amine absorption. Exhaust gas recycle (EGR), where the air normally fed to the gas turbine is replaced with downstream flue gas, has a twofold benefit. It offers an effective means to enrich the CO_2 concentration while, at the same time, reducing NOx emissions.

> *"EGR lowers the capital intensity of CCS and reduces constraints posed by other emissions such as NOx. It is well researched, and has a relatively low risk"*

Of course, post-combustion capture technologies are not solely based on amines. However, while alternative solvents, solid adsorbents and membranes are among the technology options being tested at various scales, none has yet been tested at sufficient scale to be considered a viable alternative to the best amines now available.

> *"Many non-amine technologies have been piloted and promise better economics than amines. However, during engineering and development expected benefits can be eroded, as most processing steps involving low pressure gases will cause pressure drop (expend blower power) and need large, costly equipment"*

Nonetheless, there are some early-stage technologies that show great promise, e.g. NET Power's Oxy-Fuel Supercritical CO_2. Here oxygen and natural gas at high pressure react in a combustor to produce water and CO_2; after expanding through a gas turbine, the water is condensed out and the CO_2 pressurised and recycled back to the combustor. With a target of 58.9% (LHV) efficiency and only the costs of CO2 transport and storage above the cost of a conventional CCGT, expectations of an eventual breakthrough technology are high.

> *"The [Oxy-Fuel Supercritical CO_2] technology is still immature. It faces several challenges on equipment design and operation, but testing at scale is under way. It may be several years before NET Power can fully demonstrate an attractive package to the market"*

As coal is more carbon intensive than natural gas and modern CCGTs more efficient than either ultra-supercritical (USC) coal-fired boilers or integrated gasification combined cycle (IGCC), CO_2 emissions from coal are at least twice those from a CCGT.

> *"Abatement costs are slightly higher for pulverised coal than for gas on a 'per MWh of low carbon power' basis, even though abatement cost per tonne of CO_2 is lower (£45/te cf. £85/te)"*

ETI's Insights Paper provides a helpful counterpart to the IEAGHG's comprehensive report, "Assessment of emerging CO_2 capture technologies and their potential to reduce costs", published as Report TR4 in December 2014. The IEAGHG is planning a future study to assess the status of capture technologies, in particular to attempt to identify those technologies that are showing promise for early application at commercial scale.

Keith Burnard
27 September 2016