IEA CLEAN COAL CENTRE executive summary

Power plant CO_2 capture heat integration

This report is about reducing the energy penalty that accompanies adding CO_2 capture by flue gas scrubbing to coal-fired combustion plants. In such post-combustion capture, the CO_2 is scrubbed from the flue gases after they emerge from essentially conventional gas cleaning systems.

CO_2 capture requires substantial inputs of energy to operate, and reducing this energy requirement is key to making it economically more attractive. One of the best ways to do this is to reuse as much as possible of the 'waste' heats arising in the capture systems, that is, to improve the energy integration.

In post-combustion CO_2 capture, a solution of a type of amine, typically MEA (monoethanolamine) is contacted at about 40°C in an absorption column with the cooled flue gas from the boiler. The CO_2-rich solvent is then heated in a separate desorber vessel to release the CO_2 and regenerate the solvent for reuse. Substantial quantities of steam have to be taken from the main plant just before the low pressure turbine to provide heat for this duty.

Addition of CO_2 capture systems can result in up to 30% loss of electrical efficiency in the absence of integration measures. The steam extraction has the greatest effect: the consequent loss of power from the turbine typically accounts for about two thirds of the overall energy penalty of capture. Power to drive fans, compressors and pumps in the capture systems further reduces net output.

Utilising in the water-steam cycle some of potential sources of heat from the capture plant will reduce the required amount of steam extraction and associated drop in gross power. There are actually large quantities of waste heat available (*see* Table), but their temperatures are not high. The low grade nature of the heat is the greatest challenge to increasing the effectiveness of its use.

Temperatures of heat sources and sinks for a pulverised coal combustion plus CO_2 capture plant of 660°MWe

Stream	Inlet temperature,°C	Outlet temperature,°C	Associated heat change, MW
Hot streams			
Lean solvent	122.3	40.0	–928.45
CO_2 compressor intercooling (8 stages)	82.1–84.5	40.0	Total of –46.38
CO_2 cooling	82.1	33.0	–6.31
Stripper overhead condenser	107.8	40.0	–278.44
Cold streams			
Rich solvent	50.7	105.9	642.00
LP feedwater	46.5	151.5	71.20

So that steam arrives at the stripper reboiler at the correct temperature (typically 120°C) and to protect the turbines, particularly at times of variable load, pressure control valves would typically be added. Excess energy in the extracted steam would also be exploited, for example, by using a heat exchanger for LP feedwater heating or a let-down turbine. The latter may even provide additional flexibility in certain arrangements, by providing a spinning reserve for power grids. Different researchers have modelled these systems, and the report provides descriptions of the various different approaches.

IEA Clean Coal Centre is a collaborative project of member countries of the International Energy Agency (IEA) to provide information about and analysis of coal technology, supply and use. IEA Clean Coal Centre has contracting parties and sponsors from: Australia, Austria, China, the European Commission, Germany, India, Italy, Japan, New Zealand, Poland, Russia, South Africa, Thailand, the UK and the USA.

Each executive summary is based on a detailed study undertaken by IEA Clean Coal Centre, the full report of which is available separately. This particular executive summary is based on the report:

Power plant CO_2 capture heat integration

Colin Henderson

CCC/260, ISBN 978-92-9029-583-9, 51 pp, November 2015

This report is free to organisations in member countries, £100 to organisations in non-member countries for six months after publication, and free thereafter.

CO_2 compression to around 11 MPa, before transport as a supercritical fluid to storage, is carried out in stages, with cooling between the stages to control the working temperature and minimise the energy needed. The heat from this has been shown to be suitable for LP feedwater heating.

Omitting some of the compressor intercoolers will raise the temperature of the recovered waste heat, although at the cost of higher power consumption by the compressor. Another possibility is using compression before liquefaction followed by pumping. The electrical energy needed would be reduced, but it would be offset by the power decrease in the steam turbine as a result of steam extraction to drive the refrigeration cycle.

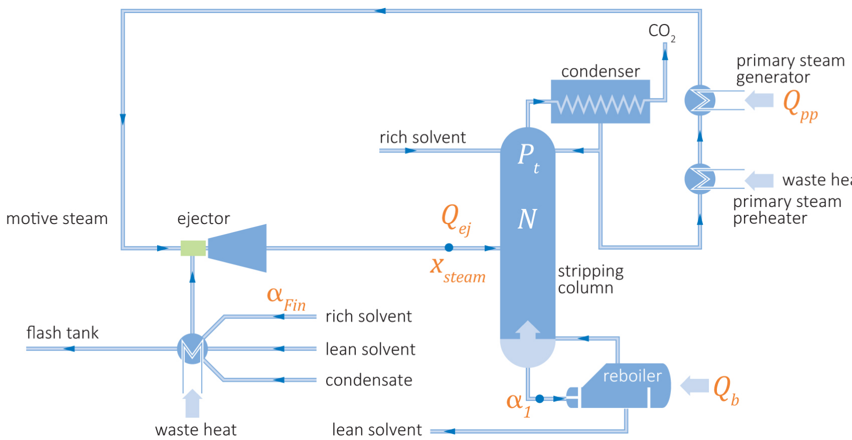
An unconventional CO_2 compressor (Ramgen) offers a higher pressure ratio and temperature rise per stage, so higher grade heat could be extracted. A study has shown that, if it were used, there would be an increase in overall net power compared to conventional compression. Economic gains could make the benefits more significant but the technology has not yet been commercialised.

Local ambient conditions may restrict options or offer greater opportunities for improvements in efficiency.

Heat pumps could aid waste heat utilisation and there have been simulations of how they might be incorporated in various ways, with potentially significant benefits.

Other methods of optimisation have included integration with combined heat and power systems, addition of low temperature bottoming cycles and addition of thermo-electrics. These could play a role, but the economics of the latter two are not currently favourable.

The energy penalty for capture on lignite plants can be reduced using similar methods. Lignite pre-drying is being developed for non-capture plants to enable higher efficiencies. Some of these systems use low grade heat that could make them suited to integration with CO_2 capture.



Ejector heat pump integrated into CO_2 stripper (Reddick and others, 2014)

Modifications to the details of the MEA process itself can aid integration. Using staged feed of the stripper could allow heat exchangers with closer approach temperatures to be exploited with efficiency benefits. Micro-channel heat exchangers might be suitable at some stage, but are currently at a small scale.

IEA Clean Coal Centre 14 Northfields London SW18 1DD
www.iea-coal.org | +44 (0)20 8877 6280 | email: mail@iea-coal.org