INCREASING EFFICIENCY OF PULVERISED COAL-FIRED POWER PLANTS

RAISING COAL PLANT EFFICIENCY TO CUT CO_2 EMISSIONS

Increasing coal power plant efficiency means burning less coal for the same amount of electricity generated. Thus it is a way to reduce fuel costs and to make significant cuts to CO_2 emissions. Coal-fired power plant efficiency across different fleets varies widely; the current global average is 37.5% (LHV, net), whereas state-of-the-art plants such as RDK8 in Germany achieve efficiencies of over 47%. This means that around 2 $GtCO_2$/y emissions could be saved if the gap between the average and the state-of-the-art was closed. Such a reduction would amount to around 5% of total global annual CO_2 emissions or about 20% of total annual emissions from coal power plants. Of course, if the coal power plant's efficiency was increased beyond the current state-of-the-art units, the CO_2 savings would be even greater, as every 1% increase in efficiency equals about 2.5% saving of CO_2 emissions. Consequently, increasing power plant efficiency, both for new builds as well as for the existing capacity, can contribute to coal-dependent countries meeting their Paris Agreement pledges. In addition, such actions address the United Nations Sustainable Development Goals (SDGs), which support energy development in emerging economies.

This report reviews technological developments and options for increasing the efficiency of both new and existing coal-fired units.

MATERIALS LIMIT THE CURRENT TECHNOLOGY

Although there are many ways to increase plant efficiency, the greatest results are achieved by increasing the temperature and pressure of the steam cycle, known as the steam parameters. State-of-the-art plants currently use steam at 600–620°C but pushing beyond these temperatures has occupied researchers for almost two decades. Massive increases in steam temperature to 700°C (760°C, reheat, in the USA) and pressure up to 36 MPa are targeted to create advanced ultrasupercritical (AUSC) power plants, and research and development (R&D) programmes on this topic are ongoing in China, Europe, India, Japan and the USA. However, despite intensive research around the world since the late 1990s, the first AUSC plant is yet to be built. There are various reasons for this. The focus of this study is on the technical ones – to push steam parameters higher requires advanced materials such as nickel (Ni)-based superalloys for the hottest areas of the plant and improved steels for less demanding ones. These are expensive, need to be fabricated in new ways and tested before they can be used in a commercial plant.

AUSC R&D – A STEPPING STONE FOR OTHER TECHNOLOGIES

Of the countries carrying out R&D programmes, India could be the first to have a commercial AUSC plant. This is because of India's growing energy needs, substantial domestic coal reserves and supply, some supportive policies, and the allocation of funding to progress the technical development of AUSC designs. In comparison, China adopted an incremental approach to increasing steam parameters but also seems to be pressing towards 700°C plant. Regardless of where the first full-scale demonstration AUSC unit is built,

Asia is almost certain to be the initial market for AUSC coal-fired power plants, either for new units or for retrofits.

There is some interest in retrofitting power plants to reach AUSC standards. This is perceived by some as more economical than building a new plant as the use of existing plant infrastructure minimises the investment cost and time. While this approach has some clear potential advantages compared to greenfield construction, many hurdles remain. As seen from the EPRI-led work, increasing steam conditions above 650°C, using the existing boiler envelope, is a technical and economic challenge. Hence retrofit options need to be evaluated carefully and on a plant-by-plant basis.

The work on AUSC materials and fabrication methods can be seen as a step towards mastering the high temperature alloys being used in other advanced (high-temperature) power generation technology options. These include the supercritical CO_2 power generation cycle, nuclear and renewable energy technologies. Hence there is wide value in continuing the tests.

INCREMENTAL APPROACHES TO INCREASING PLANT EFFICIENCY

There is also some ongoing effort to developing 630–650°C coal power plant. This is planned to be achieved using new advanced steels and alloys that can be used in the temperature window between current operating temperatures of 600–620°C and temperatures >650°C where nickel superalloys are required. The next generation of plant being built in China are likely to take advantage of these materials.

DOUBLE REHEAT PLANTS AND OTHER SOLUTIONS

Double reheat, which is experiencing a revival in China, is another route to push efficiency towards the 50% mark. The Master Cycle 2, which is a modified double reheat cycle, yet to be applied in practice, and also conventional double reheat cycles with elevated turbine configurations, currently explored in China, both have the potential to achieve 50% efficiency and more if advanced Ni-based alloys are used.

A significant increase in coal power plant efficiency can also be achieved by the recovery of flue gas heat, especially by using low-pressure economisers, which are becoming more popular and can increase plant efficiency up to 2 percentage points.

KEY MESSAGES

Coal will be part of the energy mix in many countries, especially in the growing economies, over the coming decades. Hence deployment of the most efficient plants possible and advanced technologies is vital for these countries to meet their climate goals while continuing to rely on coal.

There are various technologies either under development or already available, which can increase plant efficiency to over 50%. Although some of these technologies take a long time to be developed and implemented, it seems a first AUSC demonstration is likely to happen in India by the end of this decade, while more double reheat and its various upgraded designs are likely to happen in China. There is no one-fits-all solution, and the choice of the most suitable technology will depend on many factors.

The development and deployment of new coal technologies require both relevant and predictable government policies and support to make it into the market. International collaboration is also an important factor in accelerating new technologies.

Each executive summary is based on a detailed study which is available separately from www.iea-coal.org.
This is a summary of the report: Increasing efficiency of pulverised coal fired power plants by Dr Malgorzata Wiatros-Motyka, ISBN 978-92-9029-633-1, 97 pp, April 2021.