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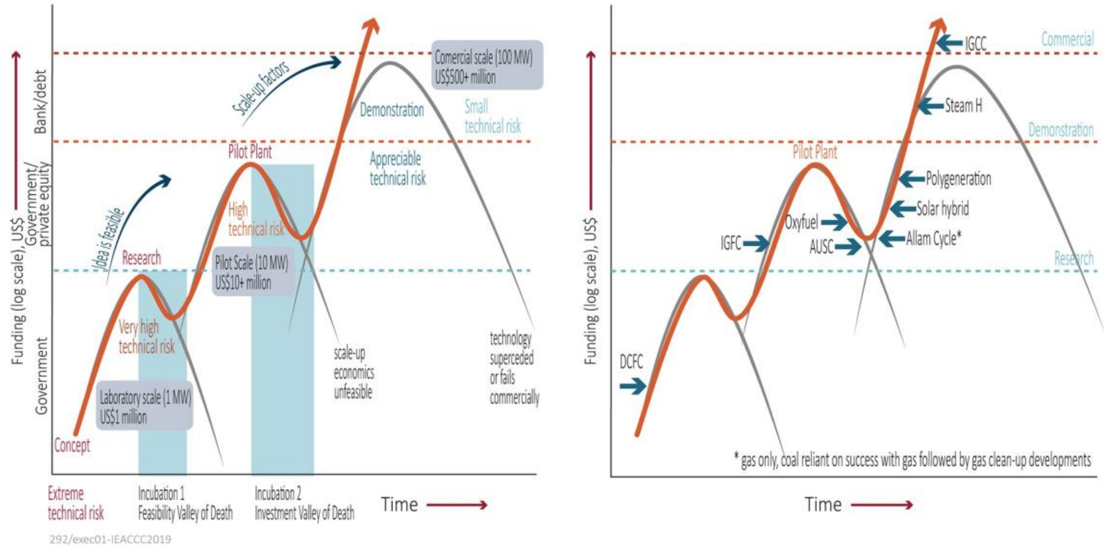
TECHNOLOGY READINESS OF ADVANCED COAL-BASED POWER GENERATION SYSTEMS

The Paris Agreement aims to limit the increase in global temperature to 1.5°C. Since coal is the most carbon-intensive of all fossil fuels, many countries plan to remove it from their energy mix. However, coal offers energy reliability and affordability in many growing and emerging regions and so its use must continue to advance through HELE status (high efficiency low emissions) towards becoming a zero-emissions option. The figure below shows the approximate stage of development of several advanced coal-based power systems on the curve from theoretical design through to practical readiness. There are two major hurdles between conception and commercialisation: the first is the transition from theory to research scale (laboratory- or small-scale pilot); the second is the move from pilot- to full-scale demonstration. Research-scale projects cost in the order of US$1–2 million and pilot plants are at least an order of magnitude more expensive. Many new technologies do not make it to full scale. And so, investment is perceived to be risky and often relies heavily on government support. Even then, not all systems will pass both hurdles.



Status of deployment of advanced coal-based power systems

THE CONTENDING TECHNOLOGIES

New conventional, subcritical, pulverised coal fired power plants are limited in terms of achievable efficiency, to an average of around 37%. Ultrasupercritical (USC) plants use innovative materials to allow higher temperatures and pressures and thus greater efficiencies. The focus is now on developing advanced ultrasupercritical (AUSC) power plants which will nudge efficiencies past 45% towards 50% (LHV). Integrated gasification combined cycle (IGCC) plants produce power from both the heat of gasification of coal and from combustion of the syngas produced. IGCC systems are expensive to build and, although they offer the potential for cost-effective carbon capture and utilisation or storage (CCUS), their advantage over USC and AUSC plants relies heavily on the monetisation of this advantage. The handful of full-scale IGCC projects in Japan and China will likely determine the feasibility of this technology in practice. Next-stage development will see the syngas from IGCC used in a fuel cell (IGFC).

Combustion systems which use O_2 rather than air for combustion (oxycombustion) offer advantages for CCUS since the flue gas, once scrubbed, is relatively pure CO_2. However, like IGCC, the extra expense of this approach is only economically sensible if there is remuneration through carbon credits or CO_2 sales. Supercritical CO_2 systems (sCO_2) take advantage of the fluid dynamics of sCO_2 to operate turbines more efficiently than steam. This sCO_2 can be in closed, indirect, cycles, or the sCO_2 could be produced from cleaned oxyfuel combustion gases. The Allam Cycle is an sCO_2 system currently being tested in Texas on gas, which could lift the efficiency of combustion systems by several per cent whilst also producing a clean CO_2 flue gas. The high efficiency, small size and simple layout of sCO_2 power cycles coupled with other technology attributes could result in potentially large reductions in capital and fuel costs, and decreased greenhouse gas emissions. The sCO_2 cycle therefore facilitates CCUS but requires there to be a demand for it.

Polygeneration systems can produce either chemicals or electricity from gasified coal or can produce both simultaneously. In practice, the extra expense and complexity of these plants can be off-putting to investors who are likely to focus on whichever product will give the most revenue in the shortest period. Hybrid systems, such as plants which use solar power to preheat intake water for coal plants, are technically feasible. The challenge is to make them practical and affordable and this is likely to be case-specific.

Many of the technologies discussed will benefit from developments in advanced materials and in materials handling (production, fabrication and welding). A new supply chain of components will need to be created to allow these systems to be rolled out in any quantity. All these systems will require further support and funding to ensure they make it to the peak of the development curve (*see* figure above).

Critical factors for success

The sheer scale of advanced coal-based projects may make banks and insurance agencies reluctant to be involved in their finance. As the number of advanced coal plants grows, however, this investment risk will reduce as the uncertainties are resolved and the knowledge and experience increase. There are several factors which could create the impetus needed to move some of these systems from development into deployment:

- emission standards which promote investment in ultra-clean baseload power systems;
- CO_2 credits or other financial advantages for systems which facilitate commercial carbon capture; and
- financial rewards for providing clean, flexible baseload power as a back-up to intermittent renewable energy systems.

Coal could offer almost zero emission power in the future but, to achieve this goal, significant investment is required to carry innovative new technologies from theory into practice.

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: Technology readiness of advanced coal-based power generation systems by Dr Lesley Sloss, CCC/292, ISBN 978-92-9029-615-7, 113 pp, February 2019.