Repowering coal plants for a sustainable future

How the legacy machinery at coal power plants could be brought back to life using advanced heat sources

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To avoid catastrophic climate impacts to people and our planet we must apply our most innovative strategies to the toughest-to-decarbonise parts of the economy, which include aviation, shipping and the single largest emitter of carbon emissions, coal-fired power plants.

As of 2022, the world has more than two terawatts (TWe) of coal-fired electric power plants, adding almost one-third of global net annual CO_2 emissions. Coal is plentiful and coal-fired power plant construction and operation is well understood and growing. Additionally, coal plants provide reliable energy and wealth generation in their communities, which makes closing coal plants difficult.

Moreover, since more than half of global coal plants are less than 14 years old, it is unrealistic to expect such young assets to simply retire, especially considering growing energy demand and supply shortages. Coal's virtues, ironically, make it a historically neglected area of the climate challenge and now the single biggest problem we face – but flip it around and tackling coal-fired generation could present the single biggest decarbonization opportunity on the planet.

The Repowering Coal Initiative, led by TerraPraxis with partners, Bryden Wood, MIT, Microsoft and University at Buffalo, is developing transformative design and construction solutions aimed at retrofitting existing coal-fired power plants with new advanced (reactor) heat sources, while still retaining the substantial societal and economic value of the existing power plant infrastructure. The process focuses on efficiency and cost-effectiveness as the means to overcome deployment barriers and replace coal with nuclear power sources, creating a viable path to sustainable, reliable energy for those economies still reliant on coal-fired power.

TICKING TIMECLOCK

Current strategies for increasing energy generation often involve developing new generation sites, particularly when building renewable generation such as solar and wind. These new locations must be 'plugged in' to deliver energy from the site to the consumer, a dynamic that typically requires installing new grid connections and transmission lines.

In the US, Princeton University's Net Zero America Report found that even a 'low renewables' scenario would require the grid to double or triple in size – and building new grid transmission capacity is notoriously challenging. So, any strategy that depends on significant new transmission includes additional challenges, often to an extent that approaches unrealistic. If, instead, the US coal-fired power plants were reconfigured, or 'repowered', with new advanced heat sources, the amount of new transmission required would be reduced by 40 percent.

This approach has the potential to radically de-risk our transition to net zero and presents a significant decarbonisation opportunity. The goal is to replace the coal-fired boiler while retaining the rest of the plant – which includes the steam turbine, generator and existing grid connections and transmission. The retained plant components continue their

Taking the DfMA approach

Design for Manufacture and Assembly (DfMA) brings the principles and benefits of manufacturing to construction. It is part of the industrialised construction revolution and adds value at every stage of the design and build process by identifying opportunities for standardisation of components and processes.

For this project, Bryden Wood is standardising and customising heat transfer and storage systems to allow small nuclear systems to 'plug in' to existing coal plant infrastructure delivering a capital cost saving of 28-35% (compared to a new nuclear plant) and without major reworking of the existing energy grid. A new, component-based building system has been developed to optimize all stages of the project, the structural components for which can be mass produced and assembled on-site by non-nuclear specialists.

New digital infrastructure will enable design knowledge to be embedded in the building systems and design tools so that all stakeholders can share progress and results in real time across all projects.

Algorithmic design tools are being developed to assess coal plant viability for AMR replacement; create initial concepts using a design configurator in just days; and produce detailed design outputs for manufacturing.

"The tools we are creating mean we will have a huge number of plants poised to convert to clean energy as soon as the reactors are ready. This readiness is only possible with adaptable and universal design," says Martin Wood, co-founder of Bryden Wood.

DfMA solutions have been used to good effect by a wide range of different types of companies including major contractors, government departments, big industry and tech-start ups, resulting in significant reductions in construction time, carbon and cost by increasing productivity and efficiency.

Repowering coal is the biggest carbon abatement opportunity on the planet"

operation, delivering clear and significant economic and logistical advantages.

This can only be effective if it is done efficiently — in the same way that SMRs will make nuclear cost effective through a move from a traditional *project-based* construction approach to a *product-based* manufacturing approach. To achieve this, the group is developing a standardised, scalable building system, with a view to configuring the design to be able to meet any kind of site or plant requirements while also accommodating a range of different heat sources.

This is being achieved using a highly automated design, along with a design for manufacture and assembly (DfMA) approach. New algorithmic design tools are being created that can assess coal plant viability for boiler replacement, generate initial concepts using a design configurator in just days and go on to produce detailed design outputs for manufacturing. This strategy is intended to deliver low project costs and achieve the rates of deployment and scale necessary to fully decarbonise the two terawatts of coal otherwise projected to still be in operation worldwide by 2050.

WHY REPOWERING COAL?

If the world is to reach net zero in time, this really is a necessary strategy. While the UK has just three coal-fired power plants left, coal is the source of reliable electricity for millions of citizens worldwide. According to Statista, China still runs 1,100 stations, India 285 and even the US has 240. Then there are other countries in Asia and the whole of Africa.

In July, BP released its annual Statistical Review of World Energy. The report shows, yet again, that electricity is the world's most important and fastest-growing form of energy, with global electricity generation growing by a record 1,577 terawatt-hours, an increase of 6.2% over 2020. For perspective, last year's increase in electricity production was greater than the electricity output of France, Germany and Britain combined.

Despite growth in renewables, coal-fired generation continued its dominance of the electricity sector in 2021, accounting for 51% of the increase in global electricity generation. Coal's share in the global generation mix increased slightly to 36%, while wind and solar combined reached 10.2% of power generation. Although China and India accounted for over 70% of the growth in coal demand in 2021, both Europe and North America showed an increase in coal consumption in 2021 after nearly 10 years of back-to-back declines.

And of course, crucially, carbon dioxide emissions from energy use, industrial processes, flaring and methane (in carbon dioxide equivalent) rose 5.7% in 2021 to 39.0 GtCO2e, with carbon dioxide emissions from energy rising 5.9% to 33.9 GtCO2, close to 2019 levels. It is clear to see that we have a continually increasing need for the benefits of energy — just without the emissions.

In the US, Canada and Europe, entire communities are economically reliant on coal plants and shutting them down would cause substantial unemployment and hardship. In the United States alone there are 260 gigawatts of operating coal. Repowering existing coal power plants using advanced heat sources presents a key political opportunity to garner bipartisan support for climate action in a way that maintains jobs, socio-economic benefits and tax revenues.

In addition, as mentioned previously, most of the existing global coal fleet is just 14 years old, representing a trillion dollars of unrecovered capital. The prospect of the retirement of that fleet is highly unattractive for most of those owners and investors – yet clearly, to achieve net zero they cannot continue if they are powered by coal.

If they are repowered with advanced heat sources instead, however, not only will their owners and investors continue to benefit from the original outlays, the plants will likely run at a much higher capacity factor than they do today and at lower cost, making them even more profitable. There will also be the potential to add other value driving services, such as atmospheric carbon removal, as well as hydrogen production with the cooling towers. All of this work would turn these communities into clean energy hubs that will operate for decades to come.

RISING REQUIREMENT

Post-pandemic, coal usage is surging to its highest ever level. In the UK, we still have two gigawatts of coal in operation and because the global recovery is an energy intensive process, places like China, Asia and Africa are burning coal to stimulate economic advance. In Europe, meanwhile, the Russian gas restrictions have meant countries like Germany are ramping up coal production to fill the gap.

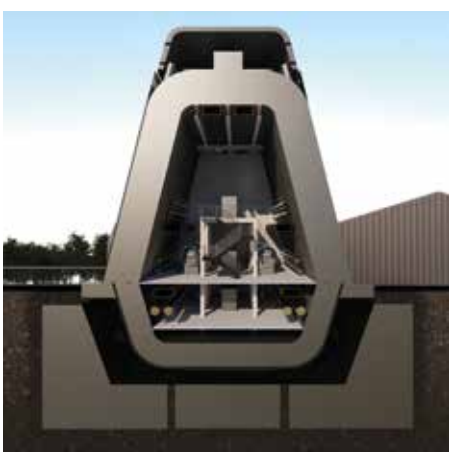
In April, China announced it will increase coal output by 300 million tons this year. In May, India said it aims to increase domestic

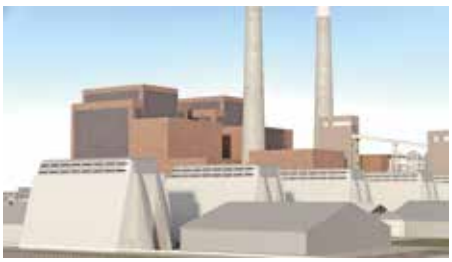
coal production by more than 400 million tons by the end of next year. According to the Energy Information Administration, burning a ton of coal releases about two tons of carbon dioxide. Thus, the 700 million tons per year of new coal consumption in China and India will result in 1.4 billion tons of extra carbon dioxide emissions. BP says that is about the same volume of emission reductions achieved in the US between 2005 and 2020.

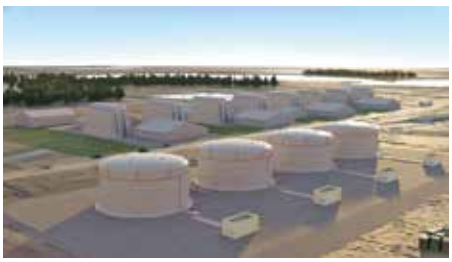
The truth is that we do not really know what trajectory we are on with regards to the potential temperature increase. The International Energy Agency modelling predicts 1.8 degrees, but that figure makes the assumption that all current commitments – on deforestation, methane emission reductions and the updated nationally determined contributions (NDCs) – will be met. Realistically, that is highly unlikely.

Furthermore, the 1.8 degrees figure does not include any meaningful increase in global energy access – yet there are currently four billion people in the world who lack access to enough electricity and 850 million people who lack access to any electricity at all. Some projections, such as by BP, suggest that the latter figure could rise to three billion people by 2050, which, given the profound harm to people and the environment that a lack of access to energy causes, we must hope does not happen. However, if in the best case – that global access to energy increases – we must ask where all this needed energy is going to come from.

Analysis suggests that even if everyone on Earth had access to just a median level of electricity (about 4,000 kilowatt hours compared to the average 15,000 kilowatt hours in the US), we would need to triple our global energy infrastructure. Yes, triple it. Surely, then, it is vital that we also start taking our rising energy demand into account and building it into our climate mitigation strategies.







SUSTAINABLE TRANSITION

Considering these global challenges, and the short timeline to achieve them, it is important that we figure out how to repurpose as much infrastructure as possible, because this offers a route to a rapid, low-cost transition to zero-emissions fossil fuel alternatives at a scale relevant to the markets being addressed. We urgently need clean energy solutions that will not require big behavioural changes, or huge investment in associated infrastructure.

This means both a shift to DfMA as well as solutions design that can address the cultural blockers and lower the barrier to entry. The transition to cleaner technologies and fuel sources needs to become an irresistible, straightforward decision for investors, which means making them more profitable and working with the grain of human behaviour.

In the case of repowering coal power plants, the existing workforce is likely to be very interested in the prospect of another 60 years of highly profitable plant operation, but without the pollution and emissions. Approaching our decarbonisation challenges in this way means we are more likely to succeed, and we will do so faster. That is hugely important because we only have 28 years left to achieve this transition globally.

Now we are standing at the cusp of a huge opportunity for the nuclear industry, with a whole new avenue of potential. Nuclear energy's ability to make both heat and power means we can really start to dig into these tough to decarbonize sectors of industrial heat, domestic heating, desalination, fuels and repowering coal. What a lot of new technologies really need is lots of clean heat and power. Once we achieve that, the domino effect will unlock other elements.

It is also important to remember that the challenge of turning the climate crisis around rests solely on the shoulders of our working generation. Although future timescales can sometimes feel abstract, 2050 really is not far away and our net zero deadline is looming. In fact, half of the emissions in the atmosphere today were emitted in the last 30 years – despite the alarm bells ringing about climate change during these past three decades.

FUNDING THE CHANGE

One of the greatest challenges is finance, because there is still a lot of prejudice against nuclear power in this area. The World Bank, for example, has not yet changed its policy to allow finance for nuclear projects. In addition, even though the science is clear that nuclear is the lowest carbon and most sustainable energy source available, the European sustainable finance taxonomy remained in a state of consideration for years about whether it should qualify as 'green'.

Fortunately, in July, the European Union voted to reject an objection to nuclear energy being included in the Taxonomy delegated act, which could mean the beginning of the end at last to the uncertainty driven by anti-nuclear dogma. Despite the recent public and political shifts in favour of nuclear energy, the urgency related to the climate crisis will only continue to increase and we must be ready to act and put the right strategies into place globally.

We need to rapidly deliver on licensing, siting, public acceptability, supply chain strategies and more. All these elements need to be designed and ready to go as soon as the world is ready for them. The opportunity will soon be here. If we look back at the last 20 years, we see that large sectors like retail, e-commerce and entertainment have all undergone huge, fundamental shifts as a result of rapid technological adoption. Embracing advanced heat solutions as part of our climate crisis toolkit presents a similarly transformative opportunity.

In another 20 years, we need to be able to look back at today and feel confident that the decisions we made brought the climate crisis under control. For that to be the case, it is essential we work together, bringing all our individual talents, insights, and capabilities to the task. Repowering coal is the biggest carbon abatement opportunity on the planet – and through collaboration we can make it a reality.