INTERNATIONAL ENERGY AGENCY
COAL INDUSTRY ADVISORY BOARD

CIAB

45th PLENARY MEETING

DISCUSSION SESSION REPORT

IEA Coal Industry Advisory Board Plenary Meeting
IEA Offices
Paris
29th – 30th November 2023

CIAB PLENARY DISCUSSION SESSIONS

November 29th & 30th 2023

The *Coal Industry Advisory Board* (CIAB) is a group of high-level executives from coal-related enterprises, established by the International Energy Agency Governing Board in July 1979 to provide advice to the IEA from an industry perspective on matters relating to coal. The CIAB Plenary meeting is held annually and is one of the mechanisms in which CIAB Members provide information and advice to the IEA on relevant energy and coal-related topics. The meeting includes a series of discussion sessions with presentations from external and member speakers on topics of relevance to the industry and a wider audience. This report covers the three discussion sessions discussed at the CIAB's 45th Plenary meeting.

DISCUSSION SESSION AGENDA

"Discussion Session 1: Managing the Energy Transition & Maintaining Grid Stability
Chaired by Mr Dennis Hesseling, Head of Gas & Power Markets Division, IEA

- Maintaining Grid Stability & Resiliency – A US Perspective – *Commissioner James Danly, US Federal Energy Regulatory Commission (FERC)*
- Electricity Security & Resiliency in Europe (A German Case Study) – *Professor Dr Marc Bettzuge, Professor of Economics, Energy & Sustainability. Director of the Institute of Energy Economics, University of Cologne.*
- **IEA Perspectives on Electricity Security & Resiliency** – *Dr Pablo Hevia-Koch, Head of Renewable Integration & Secure Electricity Unit, IEA.*

Discussion

"Discussion session 2: Addressing the Demand for Critical Minerals
Chaired by Mr Julian Beere, Executive Head of Strategy, Business Development, Bulks & Other Minerals, AngloAmerican

- **IEA Perspectives on Critical Minerals, Feedback from September Summit –** *Mr K.C. Michaels, Lawyer, Office of Legal Counsel & Mr Eric Buisson, Critical Minerals Analyst, IEA*
- **Critical Mineral Supply Demand Perspective –** *Ms Rebecca Gordon, Chief Executive Officer, CRU Consulting.*
- **Understanding the Magnitude of Renewable Energy to Meet Demand & Associated Impact –** *Mr Rohitesh Dhawan, President & CEO, International Council on Mining & Metals (ICMM).*

Discussion

"Discussion session 3: The Need for Coal & CCUS in the Clean Energy Transition
Chaired by Mr Hitoshi Murayama, Executive Counsellor, Chairman Emeritus and Mr Akira Yabumoto, Executive Senior Advisor of Global Energy Markets & Policies, J-Power

- **IEA Update on CCUS –** *Ms Mathilde Fajardy, Energy Analyst, IEA*
- **Coal & CCUS Can Deliver, An Update from Boundary Dam** – *Ms Zuri Epp, Project Manager, Generation Asset Management, SaskPower.*
- **China Energy Update on CCUS -** *Dr Xu Dong, Director, Carbon Neutralisation Research Centre of the New Energy Institute, China Energy.*
- **Update on China Huaneng Long Dong CCUS Project –** *Dr Lianbo Liu, Director, GHG Reduction & Clean Fuel Department, China Huaneng Group Energy Research Institute.*

Discussion

Introduction & Overview

The aim of the discussion sessions is to engage the IEA Secretariat, CIAB Members and invited guests, in a discussion concerning major issues affecting the coal industry. This covers its role in effective mitigation of greenhouse gas (GHG) emissions today and in the future as well as the provision of secure low CO_2 energy. This was especially so following recent IPPC reports concerning the more urgent need to address GHG emissions and global Net-Zero objectives.

The three discussion sessions were focussed on:

1. Managing the Energy Transition & Maintaining Grid Stability
2. Addressing Demand for Critical Minerals.
3. The Need for Coal & CCUS in the Clean Energy Transition.

The first discussion session included a US perspective on grid stability and resiliency followed by a European perspective with specific focus on Germany after which there was an IEA perspective on electricity security and resilience. There are serious challenges emerging associated with increased deployment and dominance of variable renewable energy (VRE) technologies on grid systems centred around stable supply-demand management as firm dispatchable power capacity, used to support and underpin VRE deployment, is being decommissioned.

The second discussion session opened with an IEA perspective on critical minerals and feedback from the IEA hosted summit in September followed by a review of supply demand perspectives. The focus then moved to understanding the magnitude of renewable energy to meet demand and the associated impact. It is clear given the drive for VRE technologies, significant strain will be placed on limited critical mineral resource with associated impact on supply and price. Timely development and permitting of new resource need to be addressed as well as a more balanced approach to the energy transition.

The third discussion session focused on the reality of CCUS with an iEA update, an update from Boundary Dam as well the China Energy & China Huaneng CCS projects. It is clear CCS is a viable technology to substantially reduce CO_2 emissions from coal with significance increase in interest reflected in global project development status. In essence it is not so much fossil fuels but the associated emissions.

DISCUSSION SESSION 1: Managing the Energy Transition & Maintaining Grid Stability

Chair - Mr Dennis Hesseling, Head of Gas & Power Markets Division, IEA

Mr. Dennis Hesseling, in his opening comments referred to the importance of maintaining grid stability and security during the clean energy transition. He then proceeded to introduce each speaker in turn and would chair the later discussion session.

Maintaining Grid Stability & Resiliency, a US Perspective

Commissioner James Danly, US Federal Energy Regulatory Commission (FERC)

Commissioner Danly openined by explaining FERC's jurisdiction including power system services, transmission, gas and oil pipelines as well as reliability standards to ensure reliability of supply etc. FERC is fuel neutral and takes no position on preferred power generation resource. However, that is changing due to the impacts and challenges now being experienced, especially concerning stability, with an increased share of variable renewable energy (VRE) on the system.

Resource adequacy is a key area of importance for FERC. There are now large problems in having reserve when needed that will ensure stability. Current problems concern regions with a wholesale market environment and associated investment drivers with inadequate revenues associated with some suppliers with associated consequential impact.

There is impact on capacity markets with depression of capacity pricing impacting those generators with a higher cost base resulting in premature plant retirements with associated impact on capacity margins. This is being further compounded by intermittent resources and loss of system inertia. There are now measures underway to establish new tariff mechanisms that better value reserve capacity. The view in the US is some areas will see the rapid phase out of coal however, the reality is if renewables and just-in-time-gas is not reliable then reliance increases on other resources such as hydro and nuclear. So, the hope the rapid onset of renewables will offset fossil is becoming more and more unrealistic.

A key challenge has been the establishment of markets that appropriately reflect the value of MWs across the asset base with the fault of the

past being to value all MW capacity in the same manner.

Battery technology capability at utility scale is still extremely expensive and wider scale availability is still a rolling 10 years away so, firm dispatchable responsive capacity still needs to be delivered by coal and gas. However, there are challenges associated with new gas plant and associated infrastructure, mainly concerning the permitting of the power plant as well as permitting of any associated gas network needs.

In many respects, power markets send mixed messages. Such markets do not compensate for firm fuel contracts key to underpinning fuel supply contracts to key dispatchable assets (such as gas) needed to provided key system support such as balancing, stability and inertia. There is also a gap between aspirational policies and legislators implementing the mechanisms to deliver on policy goals. So, the coal fleet is likely to remain as is for the foreseeable future to meet dispatchable needs.

The outsourcing of fuel resource could have significant implications from a security of supply perspective so, in the US, coal will continue given US coal supplies. Commissioner Danly would advise other countries to review their respective energy and associated fuel mix to ensure appropriate management of risk with respect to fuel outsourcing.

In emerging countries, coal will remain a key energy resource for at least the medium term because there is simply not the infrastructure in place.

Questions

Mr Dennis Hesseling asked about the revenue mechanism for coal power generators to which Commissioner Danly responded, current market mechanisms facilitate adequate revenue however there is downward pressure on prices, so a sustainable and appropriate market mechanism is a key challenge to be addressed.

Mr Roger Miesen asked whether capacity markets were working well or not, to which Commissioner Danly responded, the US has different market structures which can be assessed in terms of effectiveness. In one region, the market mechanisms are undermining resource availability.

Mr Mick Buffier commented, the existence of problems is recognised but associated issues and challenges don't seem to penetrate at global policy level. Therefore, how best to get such matters discussed at international levels? In response Commissioner Danly commented such matters are discussed in the US across various US utility regulators but do not seem to reach policy level. At some point in time there is likely to be a major incident and, it seems, until there is a real crisis, the basic premiss on how the system works will not be reviewed. Without market mechanisms having the correct attributes there is going to be a problem. It comes down to fairly simple principles of engineering and physics.

Electricity Security & Resiliency in Europe – Insights from Germany

Professor Dr Marc Bettzuge, University of Cologne

Professor Bettzuge provided some background concerning the pathway to climate neutrality in Germany and various studies undertaken looking out to 2045. From an energy perspective fossil fuel consumption will reduce by 35% by 2030 compared with 2018, with only 18% of final energy consumption from oil and gas by 2045 with associated supply made up mainly of bio or synthetic fuels. By 2030, 31% of final energy in 2030 is related to electricity increasing to 50% by 2045, making electricity the most important energy carrier from a final energy perspective. This all results in a predicted outcome of the aggregated final energy demand reducing by around 41% between 2018 and 2045.

With respect to hydrogen >20% by volume admixture will be allowed into the natural gas grid. It is predicted there will be around 38TWh of hydrogen demand in 2030, predominantly from industry and by 2045, 15% of final energy is predicted to be hydrogen, making it the second most important energy carrier from a final energy perspective.

Focusing on electricity power generation and supply from a German pathway to climate neutrality perspective, there is predicted to be an increase of 60% in gas generation by 2030 compared with 2019 with 130TWh of hydrogen used to generate electricity and heat by 2045. In addition, there will be 70% biomethane in remaining non-hydrogen gas power plants by 2045. This all means Germany will be reliant on imported hydrogen to meet its needs.

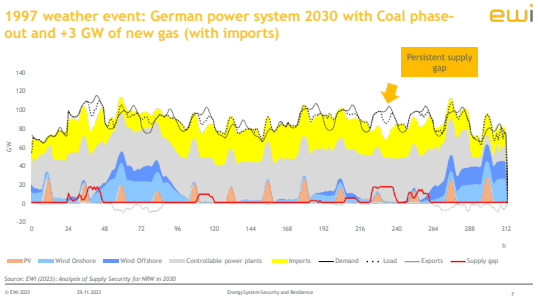
With respect to renewables 68% of electricity will be supplied by VRE by 2030, 85% by 2045 with 55% of electricity supplied by wind by 2045. To

support Germany's electricity supply management, 41TWh of trade, mainly imports and mostly from France, the Netherlands and Norther Europe will be required by 2030 with a 7TWh net export position forecast by 2050.

Over the mid-term there will be an increase in volatility of power generation supply which will coincide with a reduction in dispatchable capacity forecast to reduce by 61% by 2030 compared with 2019. It is anticipated 10GW of battery storage will be added by 2030 but this will have little beneficial impact for security of supply over prolonged periods of darkness and low wind.

The increased reliance on VRE will lead to greater dependence on, as well as exposure to, the weather and weather phenomena. Professor Bettzuge cited the challenges experienced during January 1997 when there was less VRE on the German system. During this time generation from VRE was minimal due to prolonged low solar radiation and prolonged low wind speeds which created supply challenges in the German grid system.

Taking the 1997 incident and projecting forward to 2030, considering the significant reduction in dispatchable capacity, Professor Bettzuge offered a prediction of what could happen in a similar weather event assuming no import support.

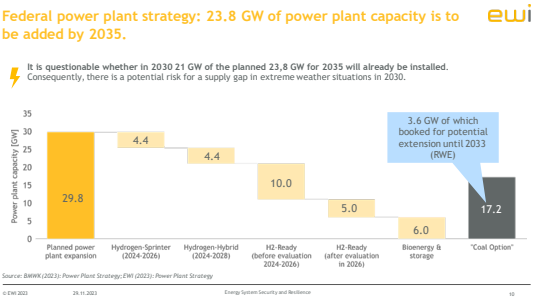


It is clear, Germany is no longer self-reliant in terms of electricity supply with notable shortfalls highlighted. Battery storage may help address brief shortfall periods however, supply challenges would continue up to 24hrs in duration or longer.

Therefore, Germany will be reliant on imports, mainly from France however, that, in turn, will be reliant on associated nuclear capacity availabilities as well as reliability of an aging asset base.

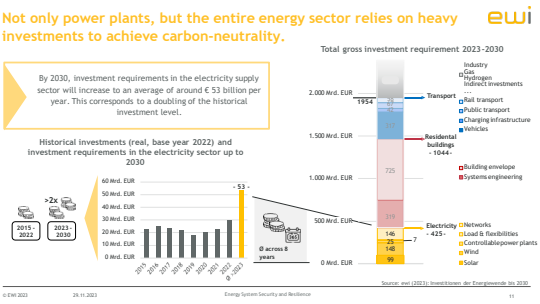
Stress testing of electricity supply demand management in Germany has identified at least a 20GW shortfall. To help address this, renewable energy capacity installation objectives have been increased however, stress testing has suggested this is likely to have minimal impact during a prolonged adverse weather event.

A Federal power plant strategy has been developed and is being implemented to address the addition of 23.8GW of power plant capacity by 2035.



However, it is questionable as to whether such an installation target can be met therefore the risk of gaps in supply in 2030 remain. So, the strategy calls for new gas power plant to by H_2-ready and existing coal plants may need to remain market available to guarantee supply with 3.6GW of plant ear-marked for life extension to 2033. The German Government is currently investigating how to best incentivise such a strategy.

In Germany, there too is grid congestion mainly in a north-south direction so, when incentivising power plant capacity, location is key with generating assets needing to be located in the right area.



The magnitude of investment to deliver on the Federal power plant strategy is significant and will need to increase to around 50bn Euros per year by 2030 which is equivalent around double current levels. Key questions remain in terms of how will such funding be met, who will fund, where will associated equity come from and how is such significant investment increase going to be managed? Meanwhile, electricity prices are set to remain high, around double 2020 levels on

the most optimistic basis but likely to be between 2 & 5 times higher.

Questions

Mr Dennis Hesseling commented on the decline in dispatchable power capacity and increased reliance on imports.

Dr Pablo Hevia-Koch commented on the demand expectations in 2030 which is partly driven by increased use of electric vehicles, and increased use of electricity in heating such as use of heat pumps. The increase is notable when taking in context with the 1997 weather event.

Mr Mike Garwood asked about the projected aggregated final energy demand reduction in the 2018 to 2045 projection of around 41% presented by Professor Bettzuge.

Professor Bettzuge responded concerning the reduction on an aggregated basis assumes demand from industry remains flat and factors in assumptions around improved energy efficiency associated with the wider switch to electricity. It also assumes significant retrofit of insulation to buildings, associated reduction in oil and gas needs but also assumes a flat economic situation.

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IEA Perspectives on Electricity Security & Resiliency

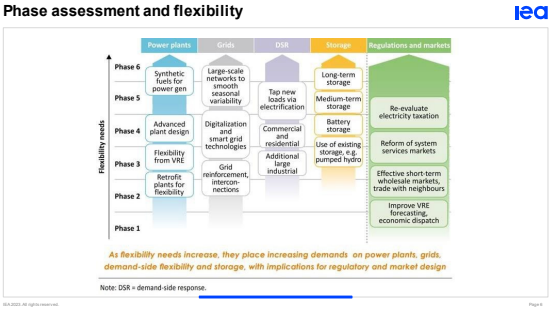
Dr Pablo Hevia-Koch, IEA

Dr Hevia-Koch opened by referring to the recent reconvening by the IEA of the Electricity Security Advisory Board (ESAB) attended by 60 electricity regulators, market participants, policy makers, consultants and academics. There were high-level representatives from the US, Japan and Australia.

He summed up some of the outcomes from ESAB 2023 which included advancing work on electricity security and how to maintain security during the energy transition. ESAB participants also requested the IEA take a more active role in shaping debate around electricity identifying key areas such as market design, grids, integration of increased VRE, data alignment and collection. Participants see extreme weather events, the changing generation mix and barriers to grid investment as some of the areas of major risk and threat to security.

Electricity security and VRE integration are two sides of the same coin. It is essential to plan ahead with respect to system integration, assess the common challenges faced across various countries dealing with VRE installation from minimal share major share and managing variable output such as that associated with seasonal impacts.

Various regions have demonstrated successful integration of VRE but as higher levels of VRE are installed with associated reliance, the flexibility of power systems must continue to expand.



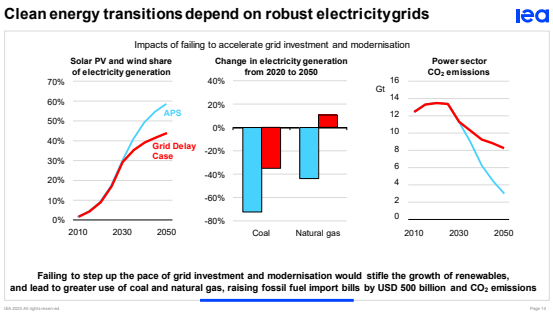
Adopting a phase approach is essential to addressing and managing what needs to go hand-in-hand to support technology transition. This should cover the complete spectrum from power plants through grids, demand side response (DSR_ management, storage as well as regulatory and market aspects.

The IEA recently published its grids report, “Electricity Grids and Secure Transitions” which should be reviewed.

The nature of electricity systems is changing. Demand is set to more than double by 2050 compared to 2010 with significant changes in demand profiles such as associated with increased deployment of EVs. Also, wind and solar PV are reshaping electricity supply and set to represent 80% of new capacity additions by 2030. However, there are increasing concerns regarding grid congestion and bottlenecks with 1500GW of capacity (mainly wind and solar) globally in an advanced stage of deployment but delayed due to grid constraints. Grid investment has been stagnant with less investment across emerging economies which is of even greater concern. So, there is a global grid capacity challenge that needs to be addressed.

Over the next two decades, 80 million km of grid network need to be added or replaced which equates to total grid network length that exists today. Grid investment needs to double by 2030 in step with renewables however, this raises concerns around materials supply and associated supply chain management. Materials demand especially with respect to copper and aluminium will increase significantly under APS.

An additional challenge concerns the excessively long lead times associated with planning and consent. Electricity grid development is complex, involves many stakeholders and can take many years, which requires advance planning and decision making to support electrification and timely deployment of renewables.



The clean energy transition depends on robust and secure electricity grid networks. Failing to step up the pace of grid investment and associated modernisation will impact renewables deployment and resulted in prolonged use of coal and natural gas. The associated knock on effect could increased fossil fuel import bills by around $500bn and associated increase in CO_2 emissions.

Dr Hevia-Koch, in conclusion summed up the call to action based on the following six points:

1. Bring planning up to date.
2. Unlock investment.
3. Address barriers.
4. Secure supply chains.
5. Leverage legislation.
6. Develop a skilled workforce.

Questions

Mr Roger Miesen asked whether there should be greater emphasis on other technologies other than VRE. Dr Hevia-Koch stated IEA scenarios include other technologies such as batteries and CCS however, economic growth and access to distribution are key issue. The main drivers to support grid investment are economic and access related.

Questions & Discussion

During respective presentations, five minutes was allocated to address any immediate questions raised. Fifteen minutes was allocated for wider questions and discussion across the three presenters.

Mr Brian Ricketts raised the question about demand destruction in Germany with new government powers concerning demand reduction forcing owners and users of EVs and heat pumps to use less.

In responses ***Professor Bettzuge*** stated the German Regulator has facilitated change with proposed rulings for grid operators to intervene on supply to EVs and heat pumps to limit consumption and help manage supply to other more critical areas. He referred to the security of supply gap commenting the new German Regulator rule does not change much. Demand flexibility has to be factored in however, betting and relying on demand flexibility to help manage a 1997 weather phenomena scenario is optimistic especially when dealing with multi-day periods.

Mr Akira Yabumoto in the context of impact on total system and the need for significant investment asked how much is transmission and how much is distribution related. ***Dr Hevia-Koch*** stated $600bn is needed by 2030 extending out to 2040 across the system. The impact of grid reliability is estimated at $100bn.

Mr Mick Buffier asked what cost the consumer is likely to see in the electricity price they pay. ***Dr Hevia-Koch*** stated the recent IEA study looked at the status and evolution of tariffs, but he did not have the information to hand to answer the question directly.

Commissioner Danly mentioned the importance of locational pricing. In the US they have abandoned the one-price fundamental premiss with price signals being confused by incentives. The change to location pricing will help illustrate investment due to lack of price signals.

Professor Bettzuge referred to disruptive policy scenarios. A central planner/modeller will look at what investment will deliver on objectives. However, that is a tall order because no one planner or modeller can address investment needs, it requires a coordinated approach. The key matter to address is governance and who takes what decisions and what is the relevant authority to coordinate. His view is the current

liberalised energy market environment is unlikely to facilitate the coordinated approach needed.

Dr Hevia Koch emphasised the importance of market designs which are key to helping facilitate ongoing grid security, resiliency and reliability. He also stressed the importance of taking appropriate advantage of all technology options with appropriate remuneration across the complete energy mix and generation asset base.

DISCUSSION SESSION 2
Addressing the Demand for Critical Minerals

Chair – Mr Julian Beere, Executive Head of Strategy, Business Development, Bulks & Other Minerals, AngloAmerican.

Mr Julian Beere provided some brief introduction to the discussion session mentioning the recent joint workshop held with the IEA in June which helped support the September IEA Summit on critical minerals. He referred to key areas of importance, concern and support required such as supply, ESG etc raised and requested by IEA Senior Analyst Mr Tae-Yoon Kim, currently leading the IEA program and associated activities in this area. Mr Beere then proceeded to introduce each speaker in turn and would chair the later discussion session.

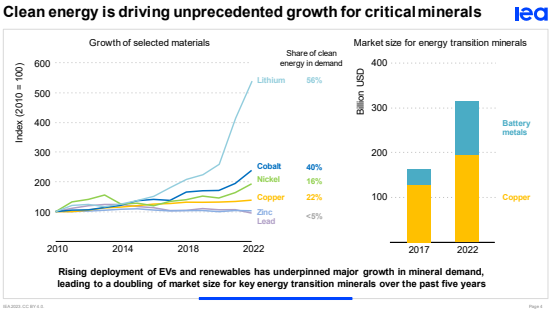
IEA Perspectives on Critical Minerals & Feedback from the September Summit.

Mr K.C. Michaels & Mr Eric Buisson, IEA

Mr Michaels and Mr Buisson provided an update on the Critical Minerals & Clean Energy Summit hosted by the IEA in September. They summarised the six key takeaways from the meeting as follows:

1. Accelerate progress towards diversified minerals supplies - Participants emphasised the importance of developing new projects in diverse geographical regions, especially in processing and refining sectors.
2. Unlock the power of technology and recycling – There is a clear need to expand research, development and deployment concerning supply technologies and ensure utilisation of all potential sources of recycled materials.
3. Promote transparency in the markets - Participants called for efforts to improve price transparency and expand supply chain due diligence and traceability practices.
4. Enhance the availability of reliable information - Need to strengthen market monitoring and explore international data-sharing mechanisms to enable stakeholders to gauge risks and identify bottlenecks.
5. Create incentives for sustainable and responsible practices - Enhance regulatory protections and embed environmental and social considerations in investment decisions to reward good performance.
6. Foster international collaboration - Improve coordination and collaboration among governments, industry, civil society and international organisations, including supply security.

They reported clean energy transition in taking place at a faster pace than expected with momentum continuing through 2023 and likely beyond. This has been supported by strong investment in manufacturing capacity, faster than in 2022. The clean energy transition is driving demand for critical minerals with associated pressures on supply management.



Meeting climate goal objectives means further likely rapid growth throughout the decade with associated demand for critical minerals increasing more than three-fold looking out to 2030.

The IEA has created an interactive critical minerals data explorer which provides full access to the demand projections under various energy scenarios and technology evolution trends. The associated link is as follows:

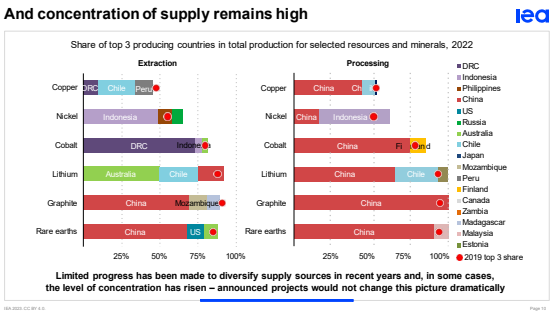
https://www.iea.org/data-and-statistics/data-tools/critical-minerals-data-explorer

There are in effect three supply-side challenge related questions that need to be adequately answered and addressed:

1. Can future supplies keep up with the rapid pace of demand growth in climate-driven scenarios?
2. Can those supplies come from diversified sources?
3. Can those volumes be supplied from clean and responsible sources?

There is an increase in critical mineral supply, with investment in 2022 30% higher than 2021.

Announced projects are matching announced climate ambitions. The host of newly announced projects, if implemented as planned, would be sufficient to meet countries' clean energy ambitions for some minerals, but the adequacy of future supply is far from assured.



However, supply concentrations remain high with associated risk given the limited spread of supply sources. Announced projects would not dramatically change this situation. Unlocking new refining capabilities will significantly reduce bottlenecks and increase supply chain resilience.

There is an upcoming IEA report on sustainable and responsible mineral supply chains which will highlight the importance of mitigating the risks mining presents, to minimise harm to people and the environment, alongside efforts to reduce demand and increase circularity. Failure to address such risks could result in the following:

1. Discourage **investment** by increasing the cost of capital, diminishing returns and create liability.
2. Deter potential downstream buyers.
3. Increase the likelihood of conflicts with local communities and other stakeholders.
4. Cause acute supply disruptions.

The combined effect may result in hindering the scale-up of clean energy technologies and limit climate management progress.

The IEA has suggested five key recommendations for policy makers:

1. Ensure legal and regulatory protections for the environment, workers, Indigenous Peoples and communities, supported by sufficient means of implementation and enforcement regimes.
2. Channel public spending to encourage the development of better practices and to incentivise good performance.
3. Strengthen the collection and reporting of granular and standardised data to enable benchmarking and progress tracking across the industry and throughout the supply chain.
4. Ensure companies improve transparency throughout the supply chain, including through enhancing traceability, undertaking due diligence and reporting publicly on risks and mitigation actions.
5. Support the development of initiatives that help companies demonstrate that their operations are sustainable and responsible while ensuring cross-compatibility and interoperability.

There are several upcoming IEA publications. In December 'Sustainable and Responsible Critical Minerals Supply Chains: Guidance for Policy Makers' and 'Critical Minerals Policy Tracker 2023' will be published. In 2024, 'Critical Minerals Market Outlook 2024' and a special report on recycling will be published.

Questions

Dr Andrew Minchener asked whether the iEA were setting up a mammoth task and questioned whether they were approaching critical minerals the right way. In response ***Mr Michaels*** stated the need to be clear on where the IEA has capability and a good track record. The IEA should not be a standard setting organisation however, it should be kept in mind, member governments are looking to the IEA for support.

Ms Veronika Shime commented she was pleased to see the IEA looking more intently at critical minerals and stated the CIAB would be happy to be a resource of support given its membership includes most of the leading players

in the mining and supply of critical minerals. So, given challenging timelines, the CIAB is keen to be involved in helping expedite supply. She stated ESG and traceability is essential and suggested initial focus should be on mature well established sectors first to lead the way and set an example. She also stated that all relevant countries are responsible for developing their own critical minerals resource and not leave to others. Added to critical minerals Ms Shime highlighted the importance of steel making coal and the criticality of metallurgical coal needs to be recognised given associated increased demand for steel.

Critical Minerals Supply Demand Perspectives

Ms Rebecca Gordon, CRU Consulting

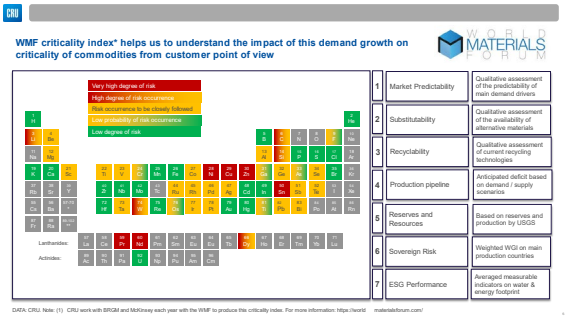
Ms Gordon opened by referring to global needs and mining stakeholder wants in the context of critical minerals supply. The world needs acceleration of geopolitically resilient supply quickly and in an environmentally and socially responsible manner. Mining stakeholders want reliably profitable businesses that provide future returns whilst ensuring environmental and social responsibility.

There are several areas of mismatch such as good understanding of availability and location of resources. Demand uncertainty and associated difficulties in forecasting demand undermine investment cases, there are major policy and regulatory challenges to be addressed especially with respect to developing new mining projects and bringing on stream in a timely manner. There are geopolitical issues that also need understood and managed. CRU uses the World Bank Political Stability Index in its assessments.

Demand for key critical minerals is being driven by renewable energy technologies and increase in e-mobility related transportation with associated demand increase projections to 2028 compared with 2020 levels summarised as follows:

1. Lithium up from 57% to 90%
2. Cobalt up from 30% to 58%
3. Nickel up from 9% to 31%
4. Aluminium up from 5% to 14%
5. Copper up from 2% to 7%
6. Phosphate rock up from 0.2% to 2%
7. Steal plate up from 2% to 5%

The material requirements associated with decarbonisation of power and transport increase almost three-fold from around 25Mt in 2020 to 70Mt in 2040 with the largest percentage of associated materials being iron ore, followed by aluminium, copper, lithium, nickel, phosphate rock, cobalt and vanadium.
Looking at lithium, nickel, phosphate rock, cobalt and vanadium in the context of battery technology whilst associated metals are of lower volume in the bigger materials picture, they are associated with fastest rate of demand growth with a 1,256% increase in 2040 compared with 2020.



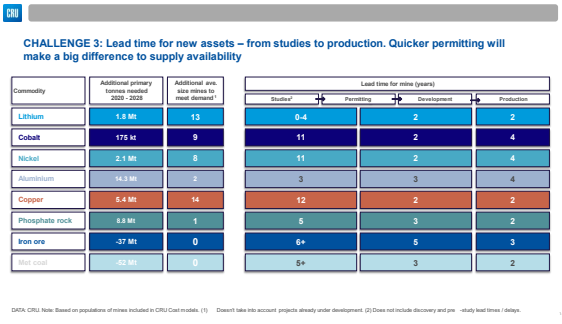
The World Materials Forum (WMF) has produced a minerals criticality index which helps understand the impact of demand growth on criticality of commodities from the customer point of view. It also lists some of the challenges and risks associated with critical minerals supply such as market predictability, consumer behaviour as well as others such as sovereign risk and associated risk to supply which have significant impact as highlighted by some current and recent geopolitical challenges. The index can be used on a dynamic basis as business environments change and so can be amended and updated accordingly.

Even those commodities with a low overall criticality rating will face structural change as the decarbonising value chain shifts demand to higher quality material. An example is the demand for iron ore however, iron covers various elements within a range of risk. High silica steel is also an example of potential constraint.

Ms Gordon presented three country/region focused case studies concerning copper to illustrate areas of associated risk exposure. In the case of Japan, it has no copper reserves therefore risk resides in procuring concentrate from the seaborne market with high geopolitical exposure to Japanese consumers being key. With respect to the US, copper supply is the key risk to associated energy transition with uncertainty of supply considered a high risk factor although investment in secondary supply is starting. In the case of Europe, lack of copper reserves and high geopolitical exposure are key challenges for copper consumers.

There are four key challenges that need to be addressed.

1. How to prioritise power availability and should criticality be a factor. Many critical industries are power hungry and need uninterrupted supplies of power, which can be a major challenge in some countries.
2. Local ESG challenges often do not align with long term climate goals. In essence, each jurisdiction may not feel so strongly about ESG related matters and may dilute. Mining and processing is often emissions and/or waste intense and can contribute significantly to regional emissions levels.
3. The excessive lead times from initial resource find, feasibility studies to production associated with new assets. The quicker permitting will make a big difference to supply availability.



4. A robust regulatory environment is needed. Speed is critical and the role of government is help keep things simple. An appropriate policy framework is needed.

Questions

Mr Julian Beere commented on his liking of the criticality index and considered it useful matrix given its dynamic characteristic.

Ms Veronika Shime referred to the extraction of cobalt from areas such as the Democratic Republic of Congo (DRC) and suggested countries and associated companies extracting minerals from such regions should look to develop their own domestic resource where possible. She commented on the occurrence of market manipulation by certain actors citing an example in the US where the permit to extract was recently obtained but it became economical for resource production due to market manipulation in cobalt pricing through others flooding the market with associated price depression. Also international trade policy does not include appropriate protections for international investors so geopolitical risk takes on greater significance.

Mr Sadamori referring to the criticality index asked whether the semi red colouring of the carbon box referred to graphite. In response ***Ms Gordon*** confirmed it was and commented on the importance of understanding the different qualities of carbon. Carbon products (bi products of oil refining) are needed in smelting with some being more difficult and costly to obtain.

Mr Brian Ricketts raised a question for Mr Randall Atkins of Ramaco concerning many Eurocoal members who wished to diversify and so was keen to understand how this had been achieved by Ramaco. In response ***Mr Atkins*** commented on the fact that alternative uses of coal had been around for 100 years or more so, they looked at alternative uses of thermal coal. They began a review of coal use with the US DOE including products such as graphene, carbon fibre etc. The US National Laboratories analysed carbon samples extracted from a Ramaco resource and found a significant deposit of rare earth elements and critical minerals. So, he would encourage other coal asset and resource owners to also review the alternative uses of coal.

Mr Michael in the context of the criticality framework, ESG and geopolitical risks asked whether there were areas not covered by CRU that they would like to review. In response, ***Ms Gordon*** commented the criticality framework is quite simplistic at present. She had found a paper that looked at water and power consumption so had focused on these two areas for now. Other factors will be reviewed as data and information becomes available so, it is very much work in progress at the moment.

Understanding the Magnitude of Renewable Energy to Meet Demand & Associated Impact

Mr Rohitesh Dhawan, ICMM

Mr Dhawan started off with a critical minerals reality check based on the following eight points:

1. By 2040, 60 mines the size of AngloAmerican's Quellaveco mine, which took ~20 years to develop, will be required.
2. On average, a sizeable mine takes 17 years from discovery to first production because of typically around 5000 permitting obligations.

3. ICMM's 25 member companies account for a third of the global industry across 650 sites. However, there are 25,000 mining companies operating 30,000 mine sites globally.
4. The market cap of ~2000 listed mining companies is less than the market cap of Apple, and many other tech firms.
5. **T**echnology, materials efficiency and improved recycling can reduce the amount of primary material needed by 20–60% for most materials.
6. There are ~5000 active projects associated with Energy Transition Minerals, approximately 50% are on / near indigenous land.
7. Mining is the #1 most dangerous sector for human rights defenders and the highest number of environmental conflicts (22% of all reported conflicts).
8. Mining is ranked the lowest of all sectors (below oil & gas) in fulfilling responsibilities to society and the score in 2023 is amongst the lowest it has been for 20 years.

The point also made is several of the reality checks listed are of the mining industry's making. Quellaveco is the best example of a mining project involving local communities and meeting other ESG requirements. With respect to ICMM member countries these already achieve high ESG standards however on a global basis this is 25 member companies out of around 25,000 in operation.

Having offered a reality check, Mr Dhawan suggested several reasons for how this has come about:

1. Global mining Capex averaged ~$100 billion in the last decade (including coal and iron ore) yet, ~$70 bn capex is needed annually to 2030 just to prevent bottlenecks to achieving net zero.
2. Global exploration spend in 2022 was $14 bn, the highest in 10 years but less than the $20 bn in 2012 and nowhere near enough to meet demand needs. Half of the 2022 spend concerned gold and gold does not support the clean energy transition.
3. Nimbysim has gone bananas i.e. build absolutely nothing, absolutely nowhere, anytime soon.
4. In the past 50 years, 63 major tailings dam failures have been reported worldwide.
5. Metal mining has affected 164,400 km of floodplains and 480,700 km of river channels, 23 million people live on The speedmining affected floodplains.
6. There are an estimated 50,000 not-fully rehabilitated mine sites in Australia alone.

Having suggested how the industry got here, Mr Dhawan offered some suggestions on how to get there and address demand needs through a sustainable and responsible supply of critical minerals.

1. Permitting reform without lowering standards.
2. Harmonisation of voluntary standards with multi-stakeholder governance to help facilitate responsible mining.
3. Investors not having their cake and eating it too therefore properly supporting the industry.
4. Sharing power and influence so 'others tell our story for us'.
5. Some kind of truth & reconciliation process to deal with the legacy of mining.

Questions

Ms Sithole in the context of the reality check and mining being ranked the lowest of all sectors mentioned how communities do not always connect the benefits such as implementation of key infrastructure e.g. roads etc which whilst meets mining extraction needs also improves the local environment in a way some governments are unable to. She recognised there is a trust deficit to be addressed but expressed uncertainty as to whether the mining industry is ready to step up and be honest about mining impacts.

Mr Dhawan suggested if the mining sector is becoming a provider of last resort in implementing and installing infrastructure, this will not be a sustainable siruation. There needs to be a partnership between industry and government. If this does not happen there is a risk investors will walk away because certain regions just become too challenging due to lack of infrastructure so, it is essential industry and government work together.

Mr Beere made the point that some of the political risk includes some of the softer elements.

Mr Michaels suggested political risk is one that is difficult to quantify.

Questions & Discussion

During respective presentations, five minutes was allocated to address any immediate questions raised. Fifteen minutes was allocated for wider questions and discussion across the three presenters.

Mr Mick Buffier expressed surprise at Mr Michaels and Mr Buisson concerning mining company rating and performance related comments in their presentation. He stated major mining companies are fulfilling compliance responsibilities concerning rules and regulations. He recommended they talk with Mr Dhawan concerning company rating with major listed companies heavily monitored. He suggested there is no need to reinvent the wheel when rating information and the associated management process already exists.

Mr Julian Beere struggled to reconcile the IEA statement that copper supply related investment was on a par with need. That is not his understanding from his position within the industry. In response ***Mr Buisson*** agreed copper has been an area where there has been least ramp up in production capability compared with other minerals where ramp up has been better.

Mr Dhawan also reflecting on the IEA presentation struggled with reconciling the statements around announced projects. It will be challenging to better quantify announced projects given the huge amount of uncertainty associated with project delivery.

Mr Bindemann also expressed concern about the statement in the IEA presentation concerning announced projects matching announced climate ambitions and the optimism expressed during the presentation. He suggested there is a significant difference between a project being announced and being delivered and whilst there was an element of qualification in the associated slide, he expressed concern that the press and politicians latch onto the headline statement which is extremely misleading.

Mr Buisson commented on the three IEA scenarios and related supply/demand needs around each scenario and it is a question of supply-demand capability to meet relevant scenarios.

Ms Gordon made a similar point concerning the announced projects statement and associated dangers. There needs to be a breakdown of announced projects to understand associated status so, where are they on the project lifecycle so the context of such statements is understood and managed. There also needs to be clarity around some of the key materials e.g. when referring to Nickel there are significant differences in demand for say nickel metals as opposed to nickel chemicals so, clarity of message is essential.

Mr Michaels and Mr Buisson expressed appreciation for the feedback and comment which they noted and took on board.

Mr Nowak made the point that whilst the focus of the discussion session had been predominantly on the supply of critical minerals, associated processing also needs to be considered. He therefore asked whether the mine timelines talked of also included processing of critical minerals.

Ms Gordon in response to the question raised by Mr Nowak, stated the processing side tends to come on line in a much shorter time frame and can typically ramp up output in a 6-18 month timeframe. She also commented on cost curves being driven by policy with cost curves being fairly flat with stronger strategy and policy and become skewed based on associated investment risk.

Mr Dhawan suggested the current challenges are harder to quantify. He further suggested one of the most valuable commodities may be social trust which needs to be addressed to help accelerate supply.

Ms Ersoy referring to Mr Dhawan's suggested approach concerning 'how to get there' referred to UN related standards for reliable investment data as well as proposed EU standards all of which could help facilitate the 'getting there'.

Mr Beere in response commented it is as much about implementation as it is about the actual industry standards.

DISCUSSION SESSION 3
The Need for Coal & CCUS in the Clean Energy Transition

Chair – Mr Hitoshi Murayama, Executive Counsellor, Chairman Emeritus & Mr Akira Yabumoto, Executive Senior Advisor of Global Energy Markets & Policies, J-Power.

Mr Murayama opened by commenting on the importance of CCUS in the context of net-zero and its associated importance to the energy transition as a whole. There is growing momentum around CCUS with the GCCSI

reporting around 361Mt CO_2/yr of projects with 200 projects announced since 2022.

The speed of CCUS and associated interest is encouraging although it seems the IEA still do not view it as a viable net-zero technology. There is criticism that CCUS is extending the use of fossil fuels however, such energy resource is needed to maintain energy stability and security whilst at the same time supporting reduction of CO_2. If the focus is purely on CO_2 reduction, then coal + CCUS should be considered a viable transition approach. It will help support earlier achievement of low carbon energy.

The IEA agrees the increased dominance of VRE needs flexible and firm dispatchable power so increased deployment of CCUS in power generation could offer significant contribution. In Japan there is work on CCUS legislation which the Government is looking to introduce given it is key to supporting decarbonisation of the power sector.

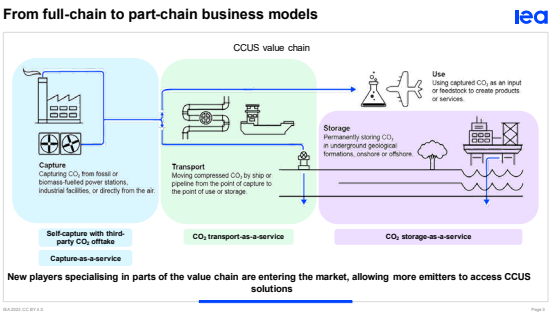
In February 2023 a CCUS joint venture with the oil sector was established in Japan with the aim of commencing CCUS operations by 2030. He reiterated the importance of the CIAB and the ability to share the industry perspectives and associated insights with the IEA and support the IEA accordingly. He concluded his discussion session introductory remarks suggesting learning from the past helps prepare for the future.

Dr Timur Gul, Chief Technology Officer offer some comments before the start of Ms Fajardy's presentation. He mentioned a new IEA report on CCUS and policy models. He also referred to the vital importance of CCUS and a view that it is the only viable option for industry to meet 2050 objectives along with other options such as BECCS. However, he expressed caution and the need to manage expectations and understand the delivery limitations concerning CCUS. In essence real world project delivery is key to meeting levels of expectation.

IEA Update on CCUS

Dr Mathilde Fajardy, IEA

Dr Fajardy commented on flat deployment but a growing in momentum in CCUS. Whilst announced capacity has notably increased in the past 3 years, there has been little change in operational capacity over the last 7 years. To meet the IEA NZE scenario will require announcements to keep pace, projects to deliver, reduction in lead times and acceleration of key applications. The levels of operational capture by 2030 are around 1bnt CO_2 50% of which is industry and fossil power related. To put into context around 20MtCO_2 was captured in 2022. Also the current project pipeline is around a third of what is needed by 2030.



In the past, projects have been on a full value chain basis so capture – storage however there is increasing focus and interest in part chain business models which is considered a positive development. So there are new players specialising in parts of the value chain entering the market and allowing more emitters to access CCUS solutions.

Existing policies are inadequate to facilitate the scale up of CCUS. Cost reduction and legal frameworks have helped many CCUS projects however, with less than 20% of captured CO_2 injected in dedicated storage, CCUS cannot be scaled up especially in areas key to achieving NZE. Carbon management strategies are being implemented which illustrates the need for a wider range of tools to address CCUS deployment.

Ms Fajardy reviewed four key challenges along with a commensurate suite of policy tools:

1. Economic viability – Carbon price has limited impact based on current average price so cost reduction measures are needed such as tax credits, incentives etc to better support learning by doing. Increased demand for low carbon products will also help along with support for revenue generation.
2. Reduction of lead times – with less than 7 years to 2030 lead times need to be addressed. Government support is needed via policy e.g. to reduce permitting timelines. Data sharing can also help accelerate project delivery times. Also, key is addressing social acceptability which requires public engagement early in the project life cycle.
3. Bridging the innovation gap – Many projects are at demonstration stage or below so more investment is needed to

accelerate technology readiness and facilitate wider spread application. Policy is again needed to support.

4. Tackle new project complexities – Manage cross border sharing of infrastructure and better coordinate the associated value chain. Infrastructure deployment is key along with the location of plant to storage sites. Various policy tools are needed to address many of the challenges.

Questions

Mr Garwood asked whether there had been any comparison undertaken by the IEA between support and incentivisation for renewables and CCUS to understand if there is a level playing field. In response ***Dr Fajardy*** and ***Dr Gul*** confirmed to the best of their knowledge no such comparison or assessment had been undertaken.

Mr Miesen referred to four CCS projects he had knowledge of, two of which gas related and two of which BECCS. He commented project lead times as such in terms of build etc were not so much an issue. The issue is regulation, policy and associated support systems which are very unclear, certainly in Europe. He added there is also no price mechanism for negative emissions or, at best, it's very limited therefore, not much of an incentive. In addition, there is inadequate development of storage which is a further delaying factor.

Dr Fajardy commented the EU has a key role in addressing various barriers across member countries. She referred to countries such as Denmark that have support packages but something more consistent is required across the EU. In follow up ***Mr Miesen*** stated current EU timelines and lack of clarity are too late for 2030 however ***Dr Fajardy*** referred to the EU 2030 objectives and suggested Denmark is an example of what can be done.

Mr Buffier, in the context of Dr Fajardy's slide concerning the third of the three challenges she spoke of, highlighted the need for CCUS especially with respect to the use of coal in cement, steel and power. Following up on Mr Garwood's earlier question concerning incentives, Mr Buffier made that point that the message concerning how CCUS can contribute to net-zero needs better communicating. Coal is not going to go away soon, and the IEA has a key role to play here.

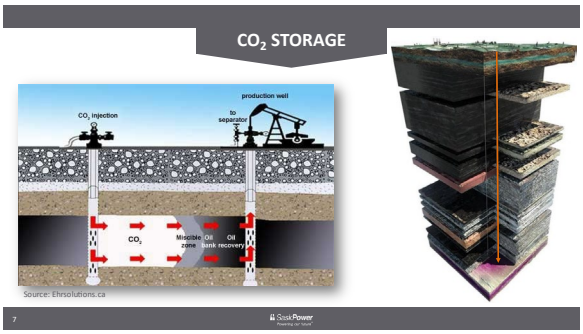
Dr Fajardy agreed CCUS has a role to play especially in addressing the abatement of younger coal assets. She stated by 2050 here will be 90% renewable deployment by which time coal will emit around 2% of global CO_2. She also made the point that in the context of cement production two thirds of associated emissions are process related and not directly due to combustion so the value of CCUS needs to be kept in context. In follow up ***Mr Buffier*** suggested it needs to be understood that 90% renewables cannot deliver and underpin grid stability as was discussed in some detail during the first discussion session so, in that context, coal is likely to continue to play a major role in some key global regions.

Mr Sadamori stated coal with CCUS still has a significant role to play and that needs to be recognised.

Coal & CCUS Can Deliver – An Update From Boundary Dam, Key Learnings

Ms Zuri Epp, SaskPower

Ms Epp provided some introduction and background to the Boundary Dam CCS project, designed to remove 1Mt/yr CO_2 on a 90% capture basis with operational experience demonstrated the design capture rate is often being exceeded. She talked through the capture process and the amines used (DC & DS amines)



The majority of CO_2 is sold to an off taker 80km away for EOR with the remaining CO_2 stored in the Aquistore Well, deposited into the Deadwood formation. Adjacent to the well is a PTRC Observation used for research purposes across the globe.

Major issues experienced during operation include flyash & Biofouling. Flyash ingress has impacted on heat exchangers, packing, amine degradation and foaming. In the event of a precipitator cell failure flyash ingress greatly increases.

The Amine Filtration Unit installed, has been plagued with a series of operational challenges and been out of service since 2015. Numerous studies are underway to rectify the filtration issue. Due to a very poor filtration system, flyash builds up on the heat exchangers in the SO_2 process. To combat the derate caused by this, SaskPower has added spares and installed an ultrasonic bath where the heat exchangers are cleaned on a regular cycle, all while CCS remains online. This has helped minimize the potential outages and derate situations.

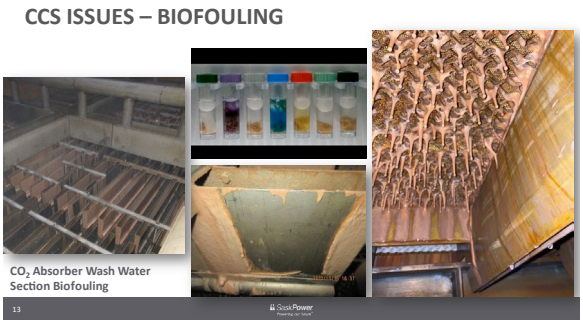
A significant amount of flyash also accumulates in the packing, perforated stainless steel plates used to create a surface for the flue and amine to interact. Prybars are often used to remove the packing solidified into the vessel. Packing is now replaced more frequently to maintain efficient performance of CCS.

The first large scale packing replacement project for both the SO_2 and CO_2 absorbers (not all beds) was completed in 2021 during a planned outage. This was critical path of the outage and required extensive planning and 24hr shifts to complete. The next packing replacement is planned for 2025.

Flyash can lead to amine degradation and foaming. The DC amine is used to capture the CO_2 from the flue gas and is very valuable. It is high in cost and directly impacts how much CO_2 can be captured. However, amine degrades at a higher rate than anticipated, based on operational experience. The thermal reclaimer originally installed proved to be undersized and was upgraded in 2021.

An iron removal trial is currently underway with the thinking that low iron levels decrease the rate of degradation. There is data to support this, and SaskPower continue to run this trial at even lower iron and degradation levels.

Foaming occurs because of degradation and contamination. Foaming is currently controlled by redundant activated carbon vessels and antifoam. There have been many studies to find the right balance between antifoam and activated carbon. The activated carbon also leaches iron into the system, which accelerates degradation. After changing the type of antifoam used, the plant now changes three activated carbon vessels every six months, previously it was two vessels every three weeks.



Biofouling has become an issue in recent years, particularly in the top of the CO_2 absorber tower, which is open to the environment. Shocking the bed with caustic while offline, opening the absorber doors to dry it out, mechanical cleans, and circulating DC amine has mixed success in resolving the issue.

Work is underway to DNA sequence the biologicals and develop a solution to improve differential pressures across the bed. Recently most success has been experienced with an offline caustic clean of the bed which has nearly reset the differential pressure levels. SaskPower are also working on a shock dose regime to control the biofouling however, generally, biofouling does not affect daily production.

In terms of key learnings, Ms Epp divided these into two categories concerning both power plant reliability and CCS reliability.

Power plant reliability is critical, without it there is no CCS operation so, focus has been on the following:

- Ensuring maintenance is planned well in advance.
- Prioritisation of operational risks so that they are addressed during planned outages opportunities.
- Continuous operational improvements such as proactive sootblowing to avoid a plant derate to address fouling and slagging.

In terms of CCS operational reliability Improvements, these have included the following:

- Add redundancy to avoid plant outages to allow for cleaning of key components such as heat exchangers.
- Address fouling to avoid outages such as adding demister sprays to keep flyash from fouling the SO2 absorber demisters
- Understanding the metallurgy to avoid outages due to leaks such as the caustic line and acid plant.

In terms of CCS reliability, despite unforeseen setbacks in 2021 due to a compressor motor failure and the start of 2022 with cooler leaks, reliability is higher than ever. Both failure incidents were due to manufacturing, not the CCS technology. Key performance headlines are as follows:

- Reliability for 2023 is 87%, above the 75% target.
- CCS has captured over five million tons as of February 2023 and has also exceeded the goal of capturing 800,000 tons within one year.
- The plant maintenance schedule is a two-week outage every six months and one major outage every five years.

The next major is scheduled for the spring of 2025 when the BD3 generator and turbine will undergo a major overhaul, compressor rebuilt, and SO2 and CO2 absorber packing replaced.

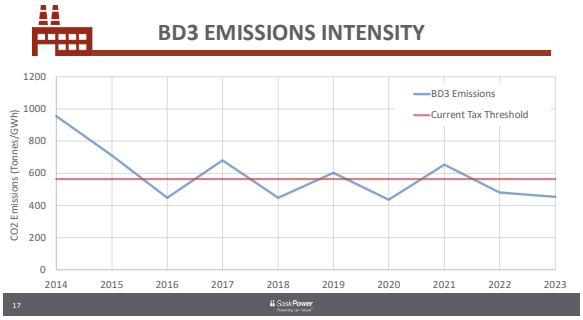
In terms of key learnings, these can be summed up in terms of reduced cost of operations and overall emissions.

Reduce Cost of Operation

- Reduced chemical costs e.g. addressing the degradation rate, success with iron removal, keep DS amine health in good standing to minimize use of caustic.
- Improved flyash management through keeping the electrostatic precipitator cells in good working order and having a flyash removal filtration system.
- Retain amine cleaning in house as outsourcing is expensive. Good success in installing an ultrasonic bath to clean heat exchangers. All chemical cleans are also managed and undertaken in house.

Overall Emissions

- Derate the host power unit when capable to match the capture rate, however, this dependent on there being no grid constraints.
- Align host power unit and CCS outages to minimize emissions. Before CCS would take more frequent outages than the host power unit, but that has been corrected.
- Address the biological issues and foaming to increase the capture rate.



With respect to power plant emissions intensity, average daily CO_2 capture rate when CCS is online has improved over time and contributes to lowering the overall emissions of the facility.

By comparison, other 300MW units emit approximately 900 tons/GWh. In January, Boundary Dam Unit3 with CCS was dispatched after hydro but before natural gas. With rising natural gas prices, BD3/CCS have proved to be a very valuable and unique asset to SaskPower.

Ms Epp, in summing up made the following points:

- BD3/CCS is the first full scale carbon capture plant on a coal fired power station.
- There have been many trials and errors, but all in all, production has improved from 2200tpd to 2800tpd.
- Over 800,000 tons CO_2 has been captured in a calendar year and in total over 5,000,000 tons have been captured.
- Reliability is the best it has ever been.
- Cost/ton is drastically decreasing since startup. Costs are well below carbon tax limits and are continuing to decline. SaskPower gains revenue from the sale of flyash, sulfuric acid, and CO2.
- CCS is serving to offset overall emissions at SaskPower and is a valuable asset to the fleet.

Questions

Mr Earl Melamed commented he understood the total capital cost of the plant was around

CAN$1.2bn and carbon tax currently at $65/t is set to increase to $170/t.

Mr Wang asked about energy reduction rate and solvent development to which ***Ms Epp*** commented optimised operation had helped reduce energy consumption. She could not answer about solvent development but mentioned amine circulation helped with solvent management.

China Energy CCS Project Update

Dr Xu Dong, China Energy

Dr Xu Dong provided a progress update concerning large-scale carbon capture projects in China. Since the introduction of the 'Carbon Neutrality' targets, China has significantly expanded its capture demonstration project status transitioning from medium to large scale, million-ton-level demonstrations across multiple industries including electricity, chemicals, steel cement and building materials.

Respective project status ranges from five projects commissioned during 2021, 2022 and 2023 to four under construction. He commented that most of China Energy's related CO_2 emissions are associated with thermal coal which will be a main area of focus for them as they seek to align with China's objective of carbon neutrality by 2060.

China's large scale carbon capture projects are also evolving swiftly towards full-process, integration and regional clusters, with particular focus and associated developments in the Pearl River and Yangtze River Deltas, with some projects scaled to a capacity of ten million tons. Many of these projects concern oil and petrochemical companies and associated industry.

In terms of China Energy's progress concerning large scale carbon capture project, Jinjie which is a 150,000t/a coal-fired demonstration plant commenced operation in June 2021 and, at the time was China's largest full process post-combustion CO_2 capture-EOR/storage demonstration project. It has a capture rate of >90%, produces CO_2 purity >99.95% with a CO_2 capture heat consumption of 2.35GJ/tCO_2. It has also completed 700 days safe and stable operation with all associated CO_2 used for EOR.

China Energy's Taizhou plant is a 500,000t/yr coal-power CCS project, the largest full scale CCUS demonstration project in Asia to date. Construction started in March 2022 and commercial operation commenced in June 2023 so, a 15-month construction and commissioning phase. To date >100,000 tons of liquid CO_2 has been produced.

In terms of the progress associated with large scale CCS demonstration, the China Energy projects are demonstrating continuous improvement through learning by doing. Compared with other similar projects around the world they have significantly reduced the total cost associated with CO_2 with both the Jinjie and Taizhou plants operating around $35/t$CO_2$. In addition, both plants are operating with around 10% less energy consumption. Both plants are also operated with an automatic control system based on a one-button start-stop process.

China Energy is also planning a 1000MW coal-fired power unit with full carbon capture project, projected to capture around 4mt/yr.

Coal is so important to energy security and grid stability in China therefore, coal is a longer-term energy resource.

Questions

There were no questions following the presentation and in the interest of time it was decided to proceed to the next presentation and pick up any questions in the later discussion time allocated.

Update on China Huaneng 1.5mt/yr CCS Project

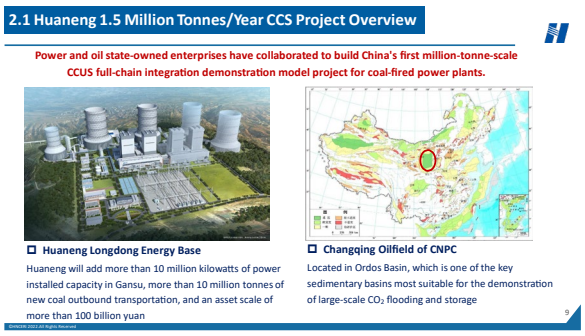
Dr Liu Lianbo, China Huaneng

Dr Liu provided some background to the Huaneng Clena Energy Research Institute (CERI) and their involvement in CCUS development and deployment since 2006 and looking out to 2024/25. He then moved on to the update of the 1.5mt/yr CCS project providing some background and overview.

Project approval was received in February 2022, feasibility studies were undertaken later in the year and completed in 2023 with associated construction due to be completed by the end of 2024, an extremely ambitious timescale which is on track to be met.

This will be the world's largest post combustion CO_2 capture plant with the host 2x1,000MW supercritical units part of a 10GW energy hub

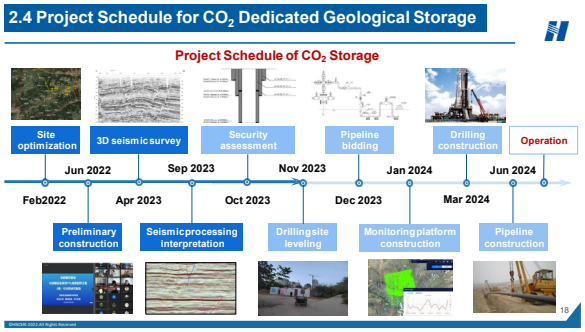
including 8GW of renewable generation. It will use Next Gen CO_2 capture technology and is anticipated to operate at a cost of <$35/t



Power and state-owned oil enterprises have collaborated to construct China's first million-tonne-scale CCUS full-chain integration demonstration model project associated with coal-fired power plants.

China Huaneng has developed new technology process and design, with specific focus around the absorber, heat exchanger, desorber and CO_2 compressor, to significantly reduce CO_2 capture costs. They have also developed a new generation of packing and improved packing design to reduce pressure drop and separation efficiency.

Some of the major equipment associated with the project includes China's first multi-axis centrifugal CO_2 compressor to meet supercritical pipeline transmission requirements.



There is dedicated geological storage associated with the project located 300m away injecting to a depth of 3,500m. Site optimisation, preliminary construction works, seismic surveys and security assessment works have all been completed.

A significant amount of investigative work has been undertaken concerning storage. It is essential to implement geological storage of CO_2 in saline aquifers in China, which can accommodate around 98% of China's CO_2 storage capacity.

In terms of storage monitoring and verification, this is addressed through trihdral corner reflectors plus interfrometric synthetic aperture radar (InSAR). Since March, China Huaneng have collected a total of 13 datasets using a COSMO-SkyMed radar system. In addition, and given the well site is close to local communities, atmosphere-soil-subsurface water monitoring is undertaken using sensors installed around the injection well with samples collected on an automatic basis every 5 minutes and uploaded to an on-line monitoring website.

In essence the Huaneng Zhengning 1.5Mtpa carbon capture and storage project, part of the Longdong Energy Base, will be the first million tonne scale project to demonstrate flexible CCS to support increased penetration of VRE on the China electricity grid.

Questions

There were no questions following the presentation and in the interest of time it was decided to proceed to the next presentation and pick up any questions in the later discussion time allocated.

Questions & Discussion

There was some brief discussion concerning the magnitude of the two Chinese CCS projects as well as the impressive project timescales. There was a feeling, these projects along with others such as Boundary Dam could help shift the dial in terms of the attitude and what, until now, has been slow progress concerning interest in CCS and recognition of the significant contribution that could be made in the context of the net-zero agenda.

In closing the discussion session Mr Murayama, commented on the three excellent CCS project examples presented and their associated operation. He commented on them being practical examples of projects which will be of significant value demonstrating a route to decarbonisation that needs to be better communicated. This feeds into the important role of the CIAB in terms of demonstrating what can be done.

Coal Industry Advisory Board

For more information about the IEA Coal Industry Advisory Board, please refer to www.iea.org/ciab, or contact Carlos Fernández Alvarez at the IEA (Carlos.Fernández@iea.org)

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