INTERNATIONAL ENERGY AGENCY
COAL INDUSTRY ADVISORY BOARD

CIAB

46th PLENARY MEETING

DISCUSSION SESSION REPORT

IEA Coal Industry Advisory Board Plenary Meeting
IEA Offices
Paris
6th – 7th November 2024

CIAB PLENARY DISCUSSION SESSIONS

November 6th 2024

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 46th Plenary meeting.

DISCUSSION SESSION AGENDA

Discussion Session 1: The Importance of CCUS in the Clean Energy Transition
Chaired by Mr Hitoshi Murayama, Executive Counsellor, Chairman Emeritus supported by Mr Akira Yabumoto, Executive Officer, Global Energy Markets & Policies, J-Power.

- *IEA Energy Technology Update – Dr Uwe Remme, Head of Hydrogen & Alternative Fuels Unit, IEA.*
- *China Energy Update on China's CCUS Policy, CCUS Collaboration & CCUS Projects – Mr ZHU Jiangtao, Executive VP, Guodian Power Development Co., Ltd, Deputy Executive Director, National Coal-Based CCUS Technology R & D Centre.*
- *An update from China Huaneng on Longdong – Dr LIU Lianbo, Director GHG Reduction & Clean Fuel Dept, China Huaneng Group Energy Research Institute.*
- *Global Status of CCUS with Special Focus on Coal-Based Industries – Ms Ellina Levina, Head of Public Affairs, GCCSI.*

Discussion

Discussion session 2: Maintaining Grid Stability & Resiliency During the Energy Transition
Chaired by Ms Neva Espinoza, SVP, Energy Supply & Low Carbon Resources, Chief Generation Officer, EPRI.

- *IEA Update on Electricity Security – Dr Jacques Warichet, Power System Analyst, Renewable Integration & Secure Electricity (RISE) Unit, IEA.*
- *Electricity Security & Ongoing Challenges to be Addressed - Mike Caravaggio, Director Thermal Generation & Hydro Fleet.*
- *Managing Ongoing Challenges in Maintaining Grid Stability & Resiliency During the Energy Transition – Mr Camilo Serna, SVP Strategy & External Engagement, NERC.*
- *Optimal Grid Mix in 2050 for a Diverse Generation Portfolio – A Japan Case Study – Mr Andy Boston, Director, Red Vector Ltd & Dr Geoff Bongers, Executive Consultant, Gamma Energy Technology.*

Discussion

Discussion session 3: Management of Critical Minerals Supply & Demand
Chaired by Mr Tae-Yoon Kim, Head of Energy Minerals Analysis Unit, IEA.

- *IEA Critical Minerals Update (Recycling & Traceability) – Mr Shobhan Dhir, Critical Minerals Analyst IEA.*
- *Western Supply Challenges for Critical Minerals - A Cobalt Example – Mr Wayde Yeoman, Executive General Manager – Commercial, Jervois.*
- *Management of Critical Raw Materials - The Example of Copper – Joint overview by Freeport-McMoRan & Atlantic Copper – Mr Javier Targhetta, President Atlantic Copper and SVP Sales & Marketing, Freeport McMoRan.*

Discussion

Introduction & Overview

The aim of the discussion sessions is to engage the IEA Secretariat, CIAB Members and invited guests, in 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. It also covers review of critical minerals given wider context and associated relevance in the clean energy transition to the mining sector.

The three discussion sessions were focussed on:

1. The Importance of CCUS in the Clean Energy Transition.
2. Maintaining Grid Stability & Resiliency During the Energy Transition.
3. Management of Critical Minerals Supply & Demand.

The first session reviewed the continued importance and relevance of CCUS in delivering CO_2 emissions reduction and supporting energy security needs. The session commenced with an IEA energy technology update focusing on investment, technology and industrial strategy as well as the role of CCUS and associated scenario update. Reference was also made to growing momentum in CCUS and policy needs. There followed an update on China's CCUS policy, CCUS collaboration and various CCUS projects including two major CCUS projects, managed by China Huaneng and China Energy. The session closed with a global CCUS status update by the GCCSI focusing on coal-based industries.

The second session concerned the importance of maintaining grid stability and resiliency during the energy transition with updates from the IEA as well as a review of electricity security and ongoing challenges to be addressed with increased reliance on VRE and reduction in dispatchable capacity. A perspective on an optimal grid mix in 2050 was also discussed.

The third session opened with an IEA update on critical minerals followed by an overview of western supply challenges citing the example of cobalt as well as management of critical raw materials citing the example of copper. With continued focus on renewable energy deployment, significant strain will be placed on limited and constrained critical mineral resource impacting supply, price and energy security. Timely development and permitting of new resource must be addressed as well as a more balanced approach to the energy transition.

DISCUSSION SESSION 1: The Importance of CCUS in the Clean Energy Transition.

Chair - Mr Hitoshi Murayama, Executive Counsellor, Chairman Emeritus supported by Mr Akira Yabumoto, Executive Officer, Global Energy Markets & Policies, J-Power

Mr. Hitoshi Murayama, in his opening comments referred to the importance of CCUS in supporting energy security and grid stability as well as CO_2 reduction. He referred to increased momentum in CCUS and a CCS related law recently passed in Japan focused on ramping up CCS by 2030. He spoke of the various projects to be started in Japan by 2030 and the importance of international transportation of CO_2 in Asia. He made the point an all technologies approach is needed to address decarbonisation.

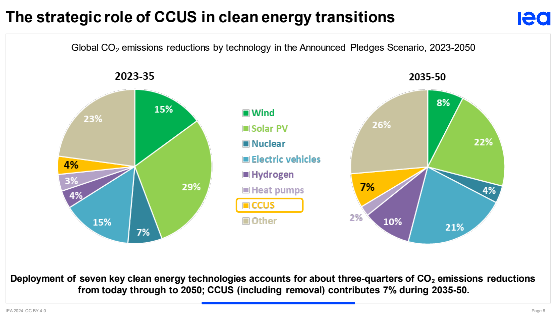
IEA Energy Technology Update

Dr Uwe Remme, Head of Hydrogen & Alternative Fuels Unit, IEA

Dr Remme spoke of the boom in investment associated with clean technology manufacturing. However, the current manufacturing base is highly concentrated geographically, with China accounting for around 70% of the global manufacturing output value associated with six key clean technologies. In certain component areas China accounts for 97% so, China remains the world's clean technology powerhouse. The value of China's clean technology exports in 2035 is projected to be roughly equivalent to the projected 2024 oil export revenue of Saudi Arabia and the UAE combined.

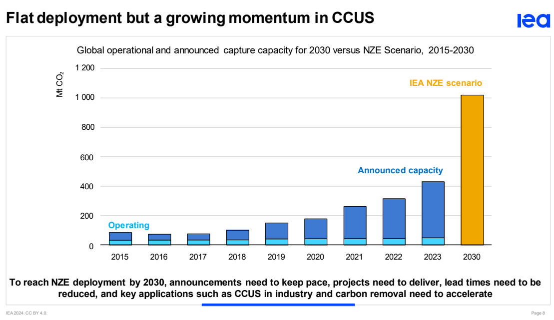
Associated shipping routes are mainly from China and SE Asia with potential choke points being the Strait of Malacca through which 50% of technology trade and 30% of coal trade passes. The Strait of Hormuz is another potential choke point through which 20% of oil passes. Such choke points represent areas of potential supply risk that need to be managed.

Dr Remme spoke next about the strategic role of CCUS in the clean energy transition with CCUS anticipated to account for 4% of global CO_2 emissions reductions between 2023 and 2035 then, 7% between 2035 and 2050 on an APS basis.



With respect to the updated IEA scenarios, CCUS could play a major role in emissions reduction concerning the power and industry sectors. By 2030 CCUS could account for 40bnt of CO_2 captured and by 2050 could account for 300bnt.

Whilst deployment of CCUS remains relatively flat, there is growing momentum.



However, to reach NZE deployment by 2030, announcements need to keep pace, projects need to deliver, lead times need to be reduced and application of CCUS in industry needs to accelerate.

The application of CCUS needs to expand to new sectors such as Hydrogen, DAC and Natural Gas. There needs to be focus on regional distribution of CO_2 across both emerging and developed economies.

New policy momentum is supporting investment in CCUS worldwide with successful execution of announced CO_2 capture, utilisation and storage projects would boost investment by a factor of 10 by 2025, with strong growth in power and infrastructure.

Permitting remains a major hurdle and the associated timelines along with project lead times need to be addressed. Dr Remme summed up stating it is time for CCUS to deliver.

Questions

Ms Tania Constable asked about how CCUS costs are captured, she also asked when the addressing senior IEA staff is the message being conveyed concerning coal and the role of CCUS. Dr Remme confirmed costs are obtained from ongoing projects and the project database. He also mentioned the IEA are in talks with various governments with CCUS offered as an option when informing country ministers.

China Energy Update on China's CCUS Policy, CCUS Collaboration & CCUS Projects

Mr Zhu Jiangtao, Executive VP, Guodian Power Development Co., Ltd, Deputy Executive Director, National Coal-Based CCUS Technology R & D Centre

Mr Zhu spoke of China's CCUS industry development. He talked through China's dual carbon approach based on CO_2 emissions peak before 2030 and carbon neutrality before 2060 with CCUS a recognised key technology to delivering coal power decarbonisation. Mr Zhu also spoke of the Sunnylands Agreement and the commitment of the US and China to both advancing at least 5 large-scale CCUS cooperation projects by 2030 covering both the industrial and energy sectors.

Mr Zhu provided some background to China Energy and to GD Power commenting that 71.6GW of its thermal power base is focused on decarbonisation technologies. He spoke of GD Power's R & D activities and associated focus on CCUS covering the full R & D value-chain. Mr Zhu commented on some of the major achievements since 2005 with over 100 CCUS demonstration projects either in operation or under planning, transitioning from small and medium to large scale across China. These included China Huaneng's Longdong 1.5Mt/a project, PetroChina's Xinjiang Oilfield 2Mt/a project and China Energy's Jinjie Company 4Mt/a project. He also referred to several CCS/CCUS cluster projects.

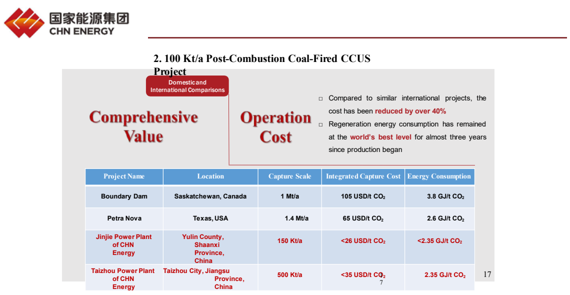
With respect to China's CCUS policies, China has introduced 70+ CCUS-related policies covering plans, standards, roadmaps, and more diverse technologies. There is also focus on accelerating CCUS technology support by local governments.

In the policy context, this helps facilitate the action-plan for low-carbon transformation of coal-fired power.

Mr Zhu spoke of the China-US Sunnylands Agreement and associated progress timeline from May to September 2024 and continuing into the future. Within the context of the Sunnylands Agreement there is the CCUS project cooperation plan, the circular economy forum and the China-US climate liaison mechanism including technology sharing.

Putting China Energy CCUS innovation into practice, Mr Zhu provided an overview of CCUS R & D from CO_2 capture through CO_2 utilisation and sequestration. MR Zhu talked through four major project examples:

1. 100kt/a Post-Combustion Coal-Fired CCUS Project. China's first full-process demonstration project with associated construction time reduced to 439 days. Operation costs have been reduced by over 40% and regeneration energy consumption regularly achieving world's best standards.



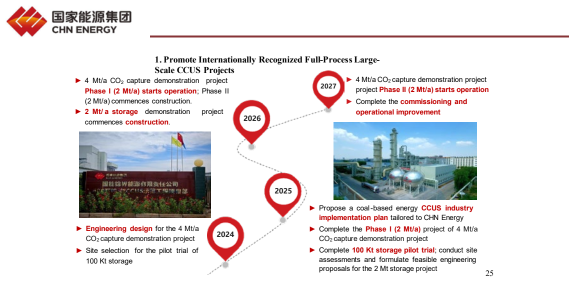
2. CO_2 Mineralisation Utilisation Engineering Demonstration, China's first industrial verification unit for CO_2 chemical looping mineralisation utilisation. The project also achieved long-term stable carbon sequestration and was listed as one of the top 30 & 60 projects respectively in the Carbon X Program and XPrize Carbon Removal. This was also China's first 10kt coal-fired power CO_2 mineralised solid waste curing concrete process successfully producing a first batch of fly ash bricks. This is another method of facilitating permanent storage of CO_2

3. 100Kt Coal-to Chemicals CO_2 Capture & Saline Acquifer Storage Project. The world's first 100Kt coal-to-liquids high-concentration CO_2 capture & saline aquifer storage demonstration project.

4. Ningxia 3Mt/a CCUS Demonstration Project, Phase I. This is currently one of the largest low-carbon demonstration projects in China in planning, to be completed in 3 phases.

Mr Zhu referred to several major scientific and technical breakthroughs in CCUS optimisation achieved to date including optimal CO_2 capture, the economical utilisation of CO_2, expansion of storage scale and the wider policy planning improvements.

In terms of future activities, China Energy is focused on promoting internationally recognised full-process large-scale CCUS projects. He talked through key activities in 2024, 2025, 2026 and 2027.



The strategic focus is on energy security, energy revolution and the dual carbon goals.

Questions

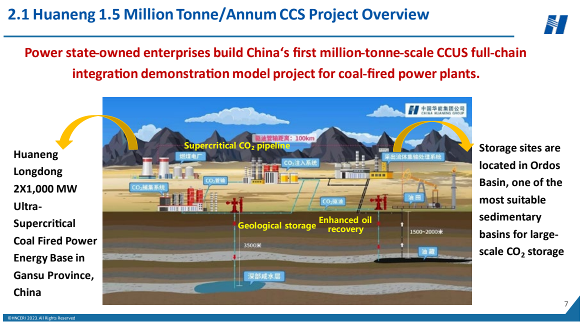
Mr Mick Buffier asked, in percentage terms, how much reduction on an energy consumption per ton of CO_2 basis is being achieved and how much cost reduction as well as how much more reduction can be achieved. In response Mr Zhu commented around an 8% reduction in energy consumption was achieved at Jinjie. In terms of cost, the first priority is not to lose money on electricity production, he could not put a figure on future cost reduction.

An Update From China Huaneng on Longdong

Dr Liu Hanming, China Huaneng

Dr Liu opened providing an overview of the CERI CCUS development and deployment timeline from 2006 to 2024/25. He then went on to focus on the current 1.5mt CCS Longdong project.

He provided an overview covering the CCUS full-chain integration demonstration project with coal-fired power plant focus.



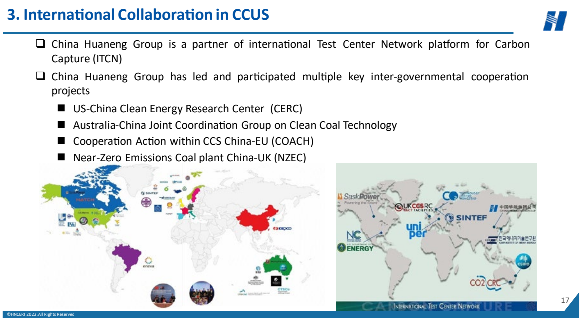
Dr Liu described the current construction phase and associated progress to date with construction currently in advanced stages. He then provided an update on the status of major equipment and associated component installation. Assembly and factory testing is basically completed with delivery already underway. Construction will be finalised by the end of 2024 with commissioning due to start in early 2025.

With respect to China's first multi-axis centrifugal compressor, selection and preliminary design is complete to meet supercritical CO_2 requirements. There will be 2 x 750kt units.

Dr Liu talked through various photographs illustrating progress concerning internal packing as well as on-site installation of various containers and columns all of which illustrated ongoing progress. He then provided an update on the pipeline transportation project covering the 110km to the oil field to facilitate EOR with pipeline commissioning due in December 2025.

With respect to the dedicated geological storage environmental background monitoring has been conducted continuously for two years. The injection well being close to the power plant is sensitive to surface deformation so, there is ground deformation monitoring being undertaken with associated accuracies in millimetres.

In conclusion, Dr Liu summarised China Huaneng's international collaboration concerning CCUS listing the various collaborative organisations with which they're engaged.



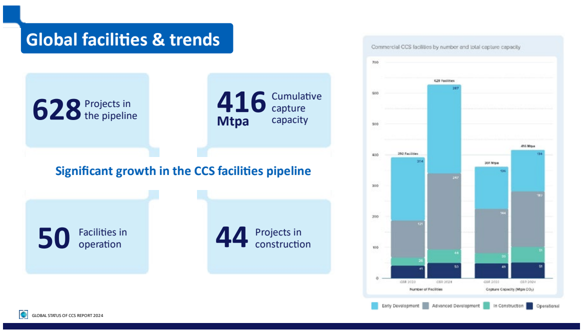
Questions

Mr Mick Buffier asked what levels of reduction in energy, solvent use and operational cost do China Huaneng envisage. Dr Liu commented on one of the main differences with Boundary Dam and Petra-Nova concerned coal cost which is cheaper in China. Also construction speed is higher resulting in associated cost reduction. He further commented, through technology innovation $35/t CO_2 is now being targeted which China Huaneng has already achieved with room for further improvement.

Global Status of CCUS with Special Focus on Coal-Based Industries.

Ms Ellina Levina, Head of Public Affairs, GCCSI

Ms Levina informed the Plenary of the GCCSI Status Report published in recent weeks with focus on the importance of collaboration, which the GCCSI considers as key. She also referred to a significant increase in project development, but that challenges remain, mainly concerning investment cost, community concerns (social acceptance) as well as regulatory barriers.



Once projects currently under construction come on line CO_2 capture capacity is on track to double to >100Mtpa.

Sustained and strengthened policy support continues to drive global CCS deployment with various multilateral initiatives as well as new and strengthening CCS legal frameworks, especially across the US, Europe, the Middle East, Southeast Asia and Brazil. However, to facilitate and support the significant increase in CCUS deployment needed, project derisking remains key to CCS investment. Whilst policy-improved financing prospects will help this is partially offset by several factors such as cost inflation, high interest rates, permitting challenges as well as political uncertainty.

That said, there are some potential tailwinds for CCS such as:

1. The continued need for reliable baseload and dispatchable power capacity
2. Demand for high-quality carbon credits
3. Increasing multilateral development bank support
4. Momentum in equity investments and M&As.

In addition, there is recognition of the value CCS can offer in hard to abate areas such as industry also, CCS is seen as a versatile technology option.

The US still leads on CCS projects through Federal funding and strong policy support such as the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act.

CCS progress continues in Canada which has 7 operational facilities with 5 under construction. CCS legislation in Brazil is considered a milestone for South America where successful CCS operations continue at the Santos Basin ore-salt reservoirs.

CCS is progressing in Asia Pacific where there is 1 operational facility and 4 under construction. Standalone CCS legislation has been released in Indonesia, Japan, South Korea, Western Australia and expected by the end of 2024 in Malaysia.

Transboundary CO_2 transport and storage is being discussed in Australia, Japan, Singapore, South Korea, Indonesia and Malaysia. In India, the potential for CCS remains strong where there are four interministerial CCUS taskforces.

In China, CCUS is forging ahead with CCUS prominent in climate policies and plans to reduce emissions from coal-fired power plants based on a 3-pronged approach – CCS, co-firing green ammonia and co-firing biomass. Central Government in China is leading international collaboration some of which already touched earlier.

Ms Levina summarised several key CCS related projects in China, much of which has been covered by earlier presenters. However, in summary, there are 7 operational projects with a further 5 under construction.

Across Europe and in the UK there are 5 operational facilities and 10 under construction with CCS a key focus in climate and industrial policy agendas and where roadmaps for CCS deployment set to facilitate significant progress.

Across Europe, the number of transport and storage facilities in development has doubled in a year.

Across the Middle East and Africa there has been a shift in focus to CCS with 3 operational facilities and 6 under construction in the region. CCS policy in the region is advancing rapidly with carbon markets being established to support deployment. In addition, collaboration is at the fore of development. Identification of storage sites is progressing in Egypt, a CCUS pilot well has been drilled in South Africa, a small DAC project launched in Kenya with further opportunities being developed in South Africa.

In summing up, Ms Levina made the point, to help address what is a global problem, CCS deployment needs to be on a global basis which needs global collaboration. This would need to include international collaboration platforms, Government level bilateral agreements, public-private partnerships as well as private sector cooperation and engagement.

Questions & Discussion

During respective presentations, five minutes was allocated to address any immediate questions raised and such questions have been reported above. Fifteen minutes was then allocated for wider questions and discussion covering all discussion session presentations.

Mr Nikolaus Valerius asked of Ms Levina in the context of CO_2 capture and CO_2 markets what sort of market arrangements are needed and how might they develop. In response ***Ms Levina*** stated CCS needs to be integrated into carbon markets and a mechanism for negative emissions (credits etc) will also be needed. Market expansion is also needed and associated market rules across respective regions need to be compatible to account for the likes of storage and monitoring of CO_2. There are discussions already ongoing in some countries with respect to storage and Article 6 in the UNCCS will be key. Ms Levina commented Germany has gone from rejecting CCS to embracing the technology along with associated project and market development however, currently it is only in the context of CCS for gas.

Ms Veronika Shime asked what stage the majority of projects are i.e. pre-planning, pre-permitting, post permitting etc and what are the associated risks depending on project phase.

She also asked how many are coal-based and what is the timeline for the 50 + 44 to get to where they are? ***Ms Levina*** confirmed the number of projects at different stages is growing but nowhere near implementation with associated progress very slow. Many are at the pre-FEED and FEED stage so, it is uncertain how many of these projects will be realised so, it is important to understand the associated issues and address accordingly. In terms of coal, 9 of the US projects are coal with 15 in China however, it is not anticipated there will be much by way of coal + CCUS in the power sector, it will mainly be steel and cement with respect to coal applications.

Ms Levina further commented it can take at least 6 years for project agreement to proceed to plant operation citing the Northern Lights example (including permit receipt time). In Europe, permitting approval typically takes around 18-months and it is planned to shorten this to 9 months.

Mr Mark McCallum asked about the trans-boundary movement of CO_2 such as across Europe and Asia Pacific and what is the most pragmatic way of addressing associated agreements suggesting the Denmark/Norway arrangement seemed a good approach. Ms Levina referred to the London Protocol which governs the movement of CO_2 however, not many countries have ratified the London Protocol. Some countries are not members or parties of the London Protocol but will be required to follow a similar approach. She was not sure if there was any way round this with the GCCSI seeing the need for trans-boundary movement so, associated timescales need to be accelerated.

There being no further questions and discussion Mr Murayama summed up the session and thanked all for their participation engagement making the point about how important it is the importance of CCS is shared with the IEA Secretariat.

DISCUSSION SESSION 2
Maintaining Grid Stability

Chair – Ms Neva Espinoza, SVP, Energy Supply & Low Carbon Resources, Chief Generation Officer, EPRI.

Ms Espinoza expressed appreciation for the first discussion session and the associated importance of CCUS given 80% of global energy use is fossil fuel based. Even in the context of shifting from a fuels to minerals economy, fuels and fossil fuels remain key. She commented, in 5 years 90% of the global economy will be under a decarbonisation plan compared with around 10% currently. Ms Espinoza spoke of the continued importance of energy security as well as resiliency and a need to balance priorities so, all options should remain on the table to better facilitate and manage the energy transition. She commented trained workforce, social impact, resource etc vary world-wide with various impact.

Ms Espinoza referred to the three pillars that influence good energy management –

1. Energy supply which is currently being undermined.
2. Energy demand which is continually increasing.
3. Weather patterns with associated global impact.

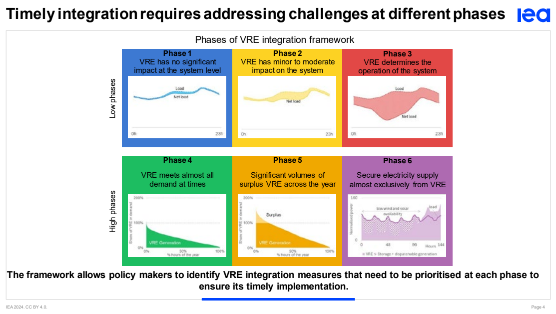
Issues concerning energy demand can be managed accordingly but this is becoming more of a struggle with associated downward negative impact. Energy demand is now significantly higher driven by factors such as data centre demand growth so, there is associated upward pressure. With respect to the weather it depends on location as well as time of day related impact and associated impacts on infrastructure so, weather patterns and associated impact needs to be better understood and managed.

IEA Update on Electricity Security.
Dr Jacques Warichet, Power System Analyst, RISE Unit, IEA.

Dr Warichet opened with an overview of how solar PV and wind are set to grow further looking out to 2030. He commented that what is needed under APS is currently on track. However, focus is needed on a range of measures including appropriate integration of renewables and management of flexibility. He cited countries such as Denmark who are considered to have integrated well.

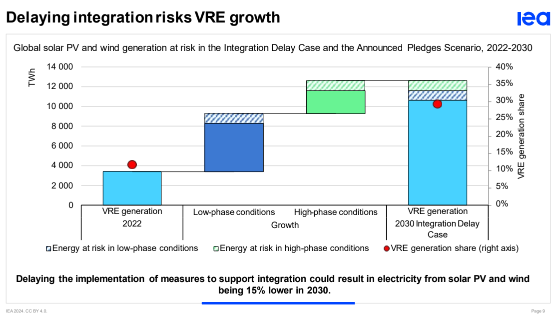
VRE resource needs to be integrated as deployed, there are concerns over symptoms associated with integration challenges, such as grid congestion and negative prices which are sending cautionary signals to investors in solar and wind.

Dr Warichet stated timely integration requires addressing challenges at different phases and he talked through the various phases of a VRE integration framework with associated categorisation helping advise policy makers on prioritisation.

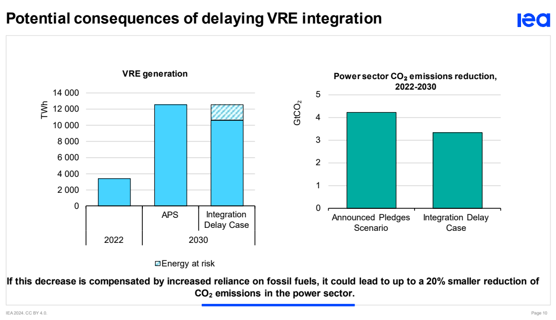


Most power systems in the world are considered to be currently in the low phases, 1-3. However, more systems will be at higher phases by 2030. Some are already at high phases due to associated wind penetration, but more systems will be at high phases by 2030 driven by solar PV penetration.

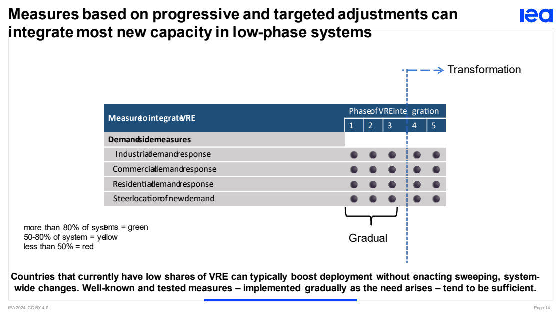
According to Dr Warichet, VRE generation in 2030 needs to grow almost 4x that of 2022 levels with global growth in VRE to meet APS 2030 delivering 4.2Gt of CO_2 emissions reduction. He commented most VRE growth occurs in low phase conditions with 64% in low phase and 36% in high phase. He further commented delaying integration risks VRE growth potentially resulting in electricity from solar PV and wind being 15% lower in 2030.



The potential consequences of delaying VRE integration could be increased reliance on fossil fuels which could result in a 20% smaller reduction of CO_2 emissions in the power sector.



Dr Warichet stated that widely adopted VRE integration measures are often straightforward with associated practice commonly involving modifications to existing assets or operational management to increase flexibility. Measures based on progressive and targeted adjustments can integrate most new capacity in low-phase systems.

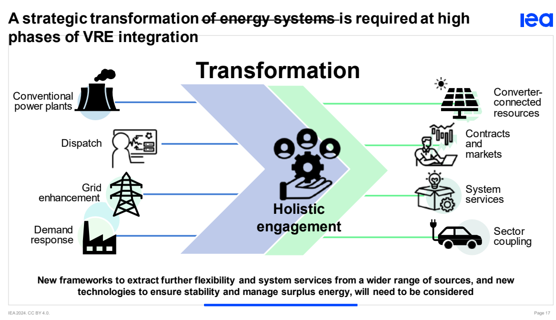


Countries with high VRE share solutions and challenges with greater focus on stability and flexibility. With respect to high phases, a portfolio of technologies will need to be deployed such as:

1. Pumped Storage Hydro
2. Interconnectors
3. Synchronous Condensers
4. Static Synchronous Condensers
5. Electrolysis
6. Battery Storage (with Grid-forming)
7. Bi-directional EV Charging

Most technological solutions needed to address stability and flexibility are mature or nearing maturity however, their successful rollout relies on appropriate policy and regulatory action.

In essence a strategic transformation of energy systems is required in the case of high-phase VRE integration.



In summing up, Dr Warichet listed 6 key policy actions needed to accelerate effective VRE integration:

1. Assess the system's preparedness for VRE integration.
2. Ensure secure grid operation with clear requirements from VRE.
3. Unlock flexibility from the existing power system.
4. Design incentives to garner flexibility and systems services.
5. Accelerate technology integration and innovation.
6. Adopt a holistic approach.

Questions

Mr Nikolaus Valerius raised the point that with increased share of renewables, investment in grids plays a major role. He asked, to keep cost affordable how is this factored in? ***Dr Warichet*** confirmed the IEA had not undertaken a full investigation into financing. He recognised grid costs are increasing and energy storage will require further investment. He commented, total system cost is predicted to decline over time based on work undertaken by the World Energy Investment (WEI) team. In addition, energy efficiency and improvement in demand-side management will help manage costs.

Mr Mick Buffier asked how wind droughts are taking into account in the IEA's modelling. He commented in a Phase 6 scenario almost the whole grid is VRE based with some backup capacity. He suggested, evidence to date suggest this is very expensive. He cited California with the highest VRE concentration in the US, Germany and the Australian NEM. He therefore asked where the evidence is to suggest associated cost is coming down. ***Dr Warichet***, in response confirmed several weather years had been modelled and that wind drought is dealt with through back up generation which can deal with seasonal variability. He suggested such generation will be used less so, associated capacity needs must be balanced.

In terms of system cost, this is still at the early stage of modelling. With respect to an integrated global model, this is still in the early stages of transition and needs more evidence to support the view that costs will reduce.

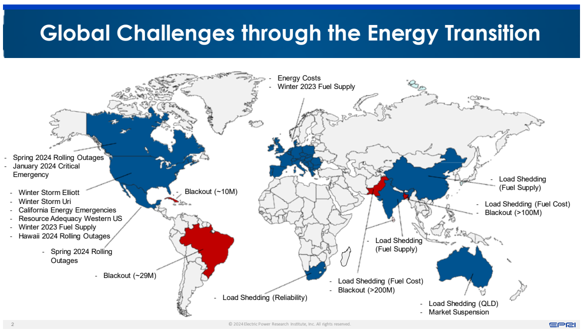
Electricity Security & Ongoing Challenges to be Addressed.

Mr Mike Caravaggio, Director Thermal Generation & Hydro Fleet.

Mr Caravaggio opened, commenting on the previous presentation which seemed to be predominantly based on modelling output so, he will look to offer a perspective of what is now in reality being experienced.

He commented on real challenges being experienced maintaining ongoing reliability of electricity supply on a 365/24/7 basis and cited recent grid failure issues and associated blackouts in Cuba.

Mr Caravaggio summarised some of the challenges faced on a global scale over the past year or so during the energy transition citing various weather related events, rolling outages, load-shedding, winter fuel supply issues etc.



There are differences in approaches associated with managing security of supply with oil based on an inventory (90 day) approach and natural gas based on pipelines, LNG terminals and storage. In the case of electricity, security of supply is often measured and managed on a minutes basis especially on marginal days. Electricity supply can be lost in a matter of minutes with the risk of grid collapse in bad times.

Typical examples are the Critical Emergency Alert issued as Alberta's power grid was put under strain in temperatures of -40°C, with only 36% and 3% of solar and wind capacity respectively, able to generate and contribute to meet demand requirements. In essence the installed VRE capacity did not deliver.

With respect to ERCOT and winter storm Uri, the grid was 4 minutes away from collapse and blackout. In this case 2% and 0% of wind and solar capacity respectively offered any contribution to meet system demand need.

Secure and reliable electricity supply is needed 100% of the time.

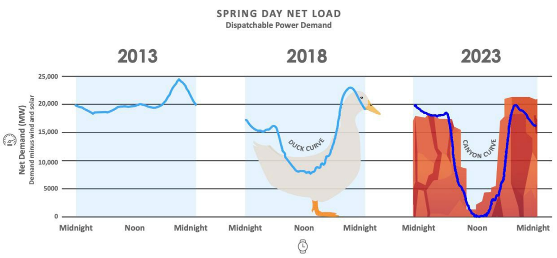
Problems are now being experienced during non-peak demand times with shortage of supply due to needs to manage generation plant maintenance. So, a combination of power capacity on outage as well as low wind and solar output can result in rolling outages and load shedding to manage demand and grid integrity.

This is illustrated through NERC assessments highlighting regional reliability concerns with many US regions at elevated and/or high risk. Added to this AI is driving a third wave of data centre power demand growth with associated impact on maintaining ongoing supply management.

Taking the example of ERCOT again and energy output vs capacity, whilst there has been significant growth in system capacity mainly VRE related, associated output can still be minimal during certain days and depending on time of year etc.

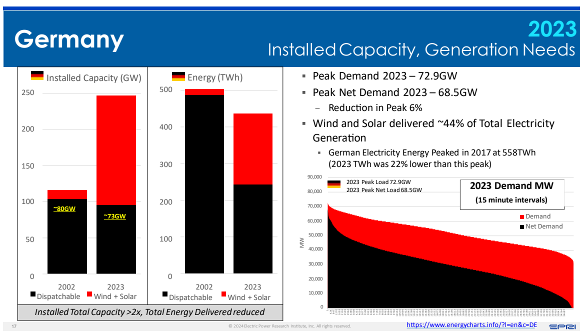
Every two months, ERCOT project the system is not going to work normally with the associated likelihood of load-shedding.

Taking the California CAISO example, what used to be a ‘duck’ curve is now a ‘canyon’ curve due to seasonal mismatch.



Even though more battery storage exists in California, there can still be too much solar in the Spring resulting in around 20-25% of associated energy needing to be curtailed so, additional storage is needed.

Taking the example of Germany, wind and solar delivered ~44% of total electricity generation.



However, even with more wind and solar on the system, it is not delivering 2002 energy demand levels let alone 2017 with 2023 generation 22% lower than the 2017 peak.

When analysing further, in a given hour 150GW of installed wind and solar capacity delivered an actual output to the system of 4GW.

With respect to decarbonisation, Germany and the US have similar CO_2 intentions however the price of power in Germany is higher than in the US.

In terms of the actions needed these centre around finding viable decarbonisation pathways so:

1. Development of zero emitting load following dispatchable resources on a 24/7/365 basis.
2. Integration of solutions across industries including large load flexibility.
3. Mechanisms to keep existing dispatchable generation capacity viable.

In conclusion, Mr Caravaggio made the following points:

1. Flexible operation & plant age impacts dispatchable generation capacity with ways needed to minimise and manage associated impact especially in terms of managing marginal days where the situation can become critical.
2. Seasonality aspects need to be better understood, appreciated and managed. This is important in defining and managing marginal days.
3. When considering hourly dispatch variable generation can increasingly drive the need for flexible generation with associated financial implications for best matching technologies.
4. In the context of capacity and energy, reliability requires capacity to cover marginal days.

Questions

Ms Veronika Shime commented in the 20-teens the talk was about energy poverty and access to electricity. Today, it seems we are going backwards and did not think there would be talk about the US in the context of reliable access to electricity. ***Mr Caravaggio*** agreed and commented on the lesson learned from Storm Uri and the need to keep learning and ensure affordability is considered as much as net-Zero.

Mr Dennis Hessling asked about the electricity price difference between Germany and the US and whether associated taxation had been taken into account. ***Mr Caravaggio*** confirmed taxation elements are included but differences could be skewed a little due to respective gas prices concerning the US and Germany, with prices a little lower in the US.

Mr Mick Buffier referred to the previous presentation by Dr Warichet and emphasis on dependence on wind and solar. He felt something did not add up if there is no access to or availability of dispatchable capacity. How can reliance on wind and solar result in a stable grid when taking into account sever weather events such as Storm Uri and the recent situation in Alberta. In response, ***Mr Caravaggio*** commented if there is interconnection with neighbours who can support demand needs then increased VRE may be more manageable but if everyone is heading in the same direction then that could become challenging given lower solar in winter along with periods of wind drought in the same season. He felt it would be difficult to manage high VRE penetration without commensurate dispatchable capacity to support.

Managing Ongoing Challenges in Maintaining Grid Stability & Resiliency During the Energy Transition.

Mr Camilo Serna, SVP Strategy & External Engagement, NERC.

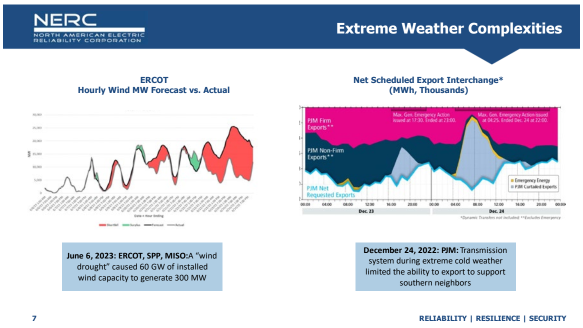
Mr Serna started by providing some background and context to NERC and the ERO (Electricity Reliability Organisation) Enterprise and summarised key program areas of focus. These concern the importance of balancing competing goals such as affordability, reliability and environmental responsibility along with increased electrification with NERC specifically focused on reliability. The NERC approach concerns the need to understand, quantify and mitigate risks.

He referred to what is considered a hyper complex risk environment with a rapidly changing resource mix, extreme weather-related complexities, accelerating demand growth and an evolving threat landscape all of which occurring at the same time.

With the rapidly changing resource mix available margins are getting tighter with capacity in the North American system decreasing by 4% on a peak comparison basis. There are ongoing interconnection queue issues with 2TW of capacity queued mostly solar and wind related with associated reliability challenges.

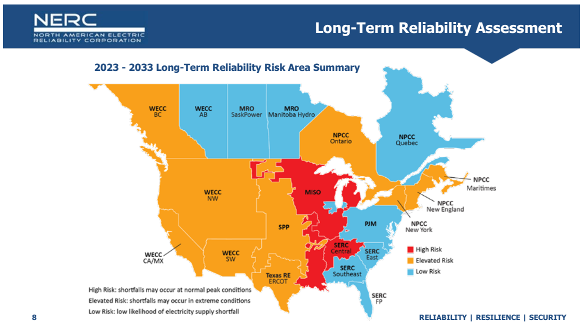
Demand growth in 2018/19 was around 0.5% and is now at 1.5% and could increase to 2.5-3.0% and even 4.0% due to growth in AI and associated data centre demand needs. The electricity system also needs to cope with weather patterns it was not designed for.

It is now important to plan for wind and solar drought events.



Storm Elliott illustrated how dependent on the gas system Texas is with weather patterns covering wider areas over longer duration and more severe therefore, weather complexities need to be planned for.

From 2023, most of the US is in an elevated or high-risk category.



With high meaning associated regions could experience outages under normal conditions and elevated meaning outages are likely in more extreme incidents with associated analysis based on fact not just assessment.

What is needed are informed policy makers who will look at the data and what is needed to ensure reliability of supply. Deployment of new resource also needs to be ensured. Reliability of energy supply is needed not just capacity that can meet the needs of key services such as frequency, load ramping and voltage support with a technology mix required to address associated needs.

There also needs to be a change concerning scenario planning with focus on resilience moving away from 1-in-10 related statistics.

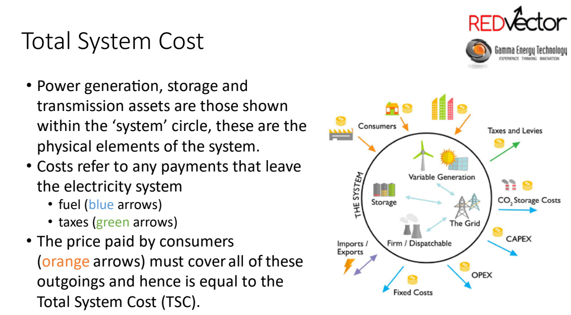
Transmission improvements are also needed to better integrate regions and associated flexibility capability. There is a need to balance energy supply such as if gas say meets 40% of demand needs then it is essential to ensure commensurate gas supply is available when needed.

Integration of data centres is also needed to help support overall system reliability. Whilst significant improvements have been delivered, industry collaboration is key, as well as research and the involvement of Government agencies.

Optimal Grid Mix in 2050 for a Diverse Generation Portfolio – A Japan Case Study.

Mr Andy Boston, Director Red Vector Ltd & Dr Geoff Bongers, Executive Consultant, Gamma Energy Technology.

Mr Boston referred to recent Australian NEM modelling he had been part of and comparison with recent work relating to Japan. He also referred to the release of the associated IEAGHG publication later in 2024 or early 2025.



He spoke about total system cost and the associated importance especially in the context of modelling because total system cost includes other relevant system costs such as taxes and levies. In comparison, the previously favoured approach based on LCOE is a pet hate of Mr Boston's because it is too limited and too simplistic. His emphasis will be on $/MWhr of demand.

Modelling is a spectrum varying from a broad modelling approach to a more detailed approach with MEGS sitting in between. MEGS (Modelling Energy & Grid Services) looks at thousands of different scenarios and associated impact on total system cost as well as level of decarbonisation achieved.

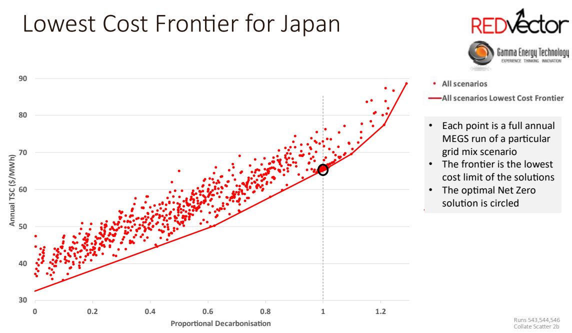
It considers factors such as:

1. Energy must balance (run on a two-hourly basis.
2. It works on a certain amount of reserve and demand/frequency response.
3. It addresses adequacy of inertia and maintaining frequency.
4. It adds up reliable capacity and adequacy to meet peak demand. In this case solar gets a zero factor because it is not reliable for guaranteed electricity at times of peak demand. Wind is factored at around 2-3% of capacity.

Mr Boston next provided an introductory overview of the Japanese electricity system covering both transmission and generation. Transmission comprises nine weakly interconnected regions five of which are interconnected by less than 25% of peak demand. Also, the interconnection between two synchronous regions is very limited.

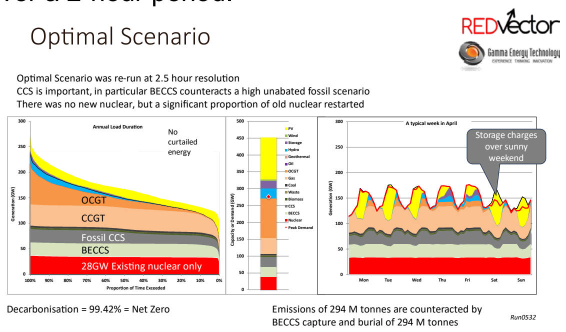
Generation is currently dominated by imported fossil generation at 71% however, renewables delivers around 22% of energy with nuclear making a comeback following the restart of 12 reactors.

Mr Boston talked through what he referred to as the lowest cost frontier for Japan outlining the volume of scenarios assessed and associated outcomes looking to ensure the whole portfolio has adequate firm capacity to meet demand. Various capacity mixes were assessed across the scenarios.



On the associated graph, the value of '1' on the horizontal scale represented a completely decarbonised system with '>1' a situation where CO_2 is being removed from the atmosphere. The graph is always the same shape no matter the systems modelled. The optimal Net Zero solution is that circled on the graph.

The next step is to take what is considered the optimal scenario and re-run at a higher resolution over a 2-hour period.



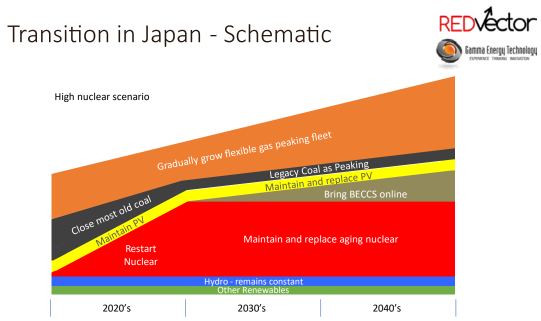
The optimal scenario includes some unabated fossil but this is covered by BECCS to compensate. There is not much by way of renewables due to little wind although there is some solar PV. There is around 130GW of solar PV but not much by way of generated output. There is no new nuclear but does include a significant portion of old restarted nuclear.

A high nuclear optimal scenario was run at a higher 2.5-hour resolution which included 38GW of existing capacity plus 22GW of new nuclear. In essence new nuclear pushes out fossil CCS, but there remains significant unabated fossil coupled with BECCS to offset emissions. This is only slightly more costly with a TSC which is $3/MWh higher than the low nuclear scenario.

Mr Boston then looked at some of the constraints on the system. He looked at the value of renewables. In the case of wind, adding offshore wind increased the cost of all scenarios by around $8-10/MWh. In 100+ scenarios created that included the cheapest offshore wind (fixed foundation), offshore wind was clearly uneconomic. With respect to onshore wind there was insufficient land resource for significant onshore capacity. With respect to solar PV, this was economic in some cases.

The next option considered was on a what if CCS, BECCS or nuclear was unavailable. The modelling output demonstrated taking away nuclear significantly increases costs for all high decarbonisation scenarios. The TSC on a Net Zero basis increases by around $10/MWh, fossil CCS availability is cost neutral and not having BECCS makes costs much higher for all scenarios.

In summary, to get to the lowest cost scenario for Japan, key is restarting nuclear and shutting down old coal. BECCS should be introduced from 2030 with coal retained on a peaking basis. In addition, maintain and replace aging nuclear capacity.



There remain some outstanding questions that need to be addressed which are:

1. What are the restrictions on sustainable biomass and how would that affect solutions?
2. At what imported cost does hydrogen make sense for Japan?
3. Can ammonia be used to store energy in Japan?
4. What are the constraints and real costs of CCS for Japan and how would that affect nuclear?

Questions

Mr Kasai asked why Japan was selected. He made the point CCS in Japan is not easy and whilst CO_2 capture is possible, storage will be a struggle. In response ***Mr Boston*** commented on time spent modelling the Australian NEM, his familiarity with the European power systems as well as parts of the US so, wanted to look at other different systems with different challenges. With respect to Japan there is renewed interest in nuclear, there is limited land for effective renewable integration and whilst he recognised some of the CO_2 storage issues, he assumed storage would be dealt with elsewhere such as Malaysia. So, transportation of CO_2 will be key.

Mr Paul Flynn asked about the economics in the context of BECCS vs Fossil with CCS and how was this assessed in terms of biomass vs coal. In response ***Mr Boston*** looked at the biomass supply chain taking Drax in the UK as an example and assumed similar associated costs for Japan. Assuming similar costs associated modelling was positive however, it would be a case of determining whether the biomass option is sustainable and realistic. In addition, there is an assumption the CCS costs used in modelling are accurate also, biomass offsets some CO_2 which helps in the modelling context.

Mr Mark McCallum asked if data based on the China experience is used whether that affects the modelling outcomes. Also what if the existing nuclear fleet is excluded and the focus is on new build nuclear? From an Australian perspective new nuclear would need to be considered given there is no nuclear in the country. ***Mr Boston*** commented lower CO_2 capture costs will encourage more CCS however, with respect to biomass, there is less sensitivity with respect to capture cost.

Dr Hans Wilhelm Schiffer asked whether there had been any comparison with IEA modelling work and associated analysis undertaken because there seem to be areas of contradiction and a gap. ***Mr Boston*** stated he is aware what he has undertaken is different to the IEA modelling. He was not sure if the IEA had taken into full account constraints concerning renewable energy deployment and associated additional system costs to integrate. It is also important to pay attention to local constraints depending on the country and associated network system.

Ms Neva Espinoza commented on how it is possible to get very different results from modelling depending on inputs, assumptions, constraints as well as the outcome sought.

Mr Carlos Fernandez Alvarez asked where the cost data came from. ***Mr Boston*** confirmed the use of Lazards but looked at the input assumptions associated with their LCOE related figures. Where data was not available, he consulted other sources including a leading Tokyo based consultancy to understand local wind and solar performance.

Mr Earl Melamed asked about the load growth prediction and nuclear fleet restart. He commented Kansai Electric did not believe many nuclear restarts will be possible whereas the analysis undertaken by Mr Boston suggests all nuclear plant will be restarted with associated impact on coal-power. ***Mr Boston*** confirmed he'd looked at several nuclear nuclear scenarios and with respect to the lower TSC scenario, the assumption made was that 75% would be restarted. There were other scenarios based on a 100% restart and no nuclear at all. So scenarios investigated have covered from no nuclear to 100% restart to some restart and some new nuclear.

Dr Jacques Warichet commented that countries are turning to electrification more and more and this discussion session has highlighted the need for and importance of electricity security so, associated policy action is needed to address this. Electrification and associated end use needs to consider efficiency as well as system flexibility. He sees a role for solar PV to support peak demand during daytime hours.

Given the length of question and discussion following Mr Boston's presentation there was no time for wider discussion. Ms Espinoza summed commenting on the need to broaden strategic think around the future electricity system and not be so focused on renewables. In terms of the global energy mix, 80% is still fossil based and 20% of final energy is electricity generation and supply related.

She suggested focus on predominantly one approach to decarbonisation is impacting reliability and security of the grid and therefore electricity supply. Also do not just focus on decarbonising electricity, focus should also be placed on decarbonising the economy.

DISCUSSION SESSION 3
Management of Critical Minerals Supply & Demand

Chair – Mr Tae-Yoon Kim, Head of Energy Minerals Analysis Unit, IEA.

Mr Tae-Yoon Kim referred to the expansion of critical minerals related activities in the IEA including associated data and policy analysis as well as security of supply. He expressed his appreciation to the CIAB for the support given over the past couple of years in this area. He plans to share the output of associated IEA activities including the IEA's Critical Minerals Outlook 2024 publication which discusses short to medium term risks, geo-political matters as well as supply-demand challenges.

IEA Critical Minerals Update (Recycling & Traceability)

Ms Amrita Dasgupta, Critical Minerals Analyst, IEA

Ms Dasgupta referred to a special report on recycling of critical minerals, policy recommendations, market status etc, to be issued by the IEA on the 18th November.

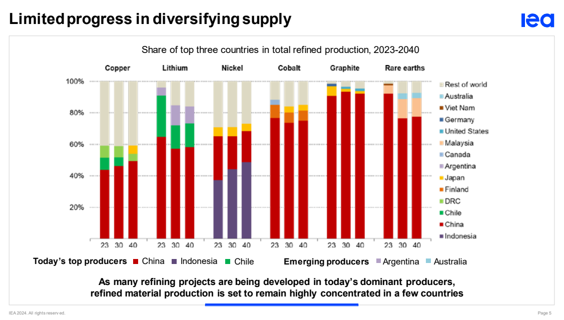
She spoke of the global perspectives and outlook for critical minerals, the central role of critical minerals and associated value chain.

The key message from 2023 is the falling prices of critical minerals with battery materials experiencing particularly sharp reductions. Whilst demand has remained high supply growth has outpaced demand with associated over-capacity mainly in China resulting in price reductions/corrections following a period of significant increase.

Critical minerals are becoming a growing share of end-user technologies.

There is a mixed picture concerning the future balance between supply and demand. Expected supply from announced projects is within range of projected 2035 requirements under APS to reach associated national and global climate goals, with major exceptions being copper and lithium.

With respect to improving diversity of supply, little progress has been made.



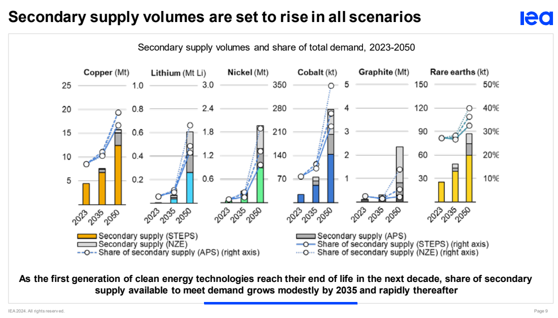
The share of top producing nations has generally increased since 2020. As many refining projects are being developed by dominant producers, refined material production is set to remain highly concentrated across a few countries.

Government incentives to help support and facilitate supply chain diversification are increasing with domestic manufacturing incentives now making up 10% of total government spending allocated since 2020.

To help address some of the supply-demand challenges it is vital to step up efforts on recycling, innovation and behavioural change. Recycling rates increase substantially with growing policy attention and the increase in battery recycling. Without the uptake of recycling and reuse, mining capital requirements would need to be 30% higher. Recycling of copper could reduce primary supply by ~30% with nickel around 15%.

Ms Dasgupta then focused on the IEA special report on recycling of critical minerals, to be issued on 18th November and summarised some of the key points.

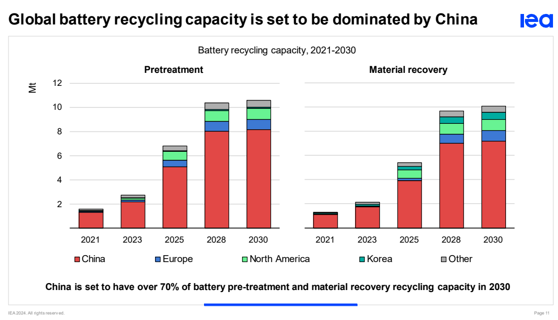
Secondary supply volumes are set to rise across all scenarios.



The picture is set to change rapidly as wind turbines, batteries etc reach end of operational life by 2030 so the secondary share of the market may reach more than 30% by 2050 for many critical minerals.

Efforts to improve collection rates will matter e.g., if collection rates reach 90%, then supply of lithium and nickel could contribute over 25% of demand in 2050 and in the case of cobalt could near 35%.

With respect to recycling of battery capacity there has been a 50% year-on-year rate of growth.



Recycling capacity is set to be dominated by China which is set to have >70% of battery pre-treatment and material recovery recycling capacity by 2030. This means there is a need to ship for material recovery which does not help with respect to diversification and security of supply.

Recovering minerals from mine waste is becoming more viable with extraction of copper from tailings becoming more economically attractive. Today in Chile, there are 100 tailings sites with ore grades that exceed primary production, totalling 2Mt of contained copper.

To address the challenges being experienced today and likely tomorrow, Ms Dasgupta summarised the following recommendations:

1. Develop detailed long-term roadmaps.
2. Harmonise waste management & recycling policies to develop efficient secondary markets.
3. Strengthen domestic infrastructure with incentives and mandates.
4. Encourage traceability, standards and certifications to boost consumption of recycled materials.
5. Provide targeted financial support for technology innovation, R & D and workforce training.
6. Strengthen recycling systems in emerging and developing economies.
7. Tackle data and information gaps.
8. Embrace a holistic approach beyond recycling.
9. Tackle environmental, social and governance (ESG) issues for recyclers.

Questions

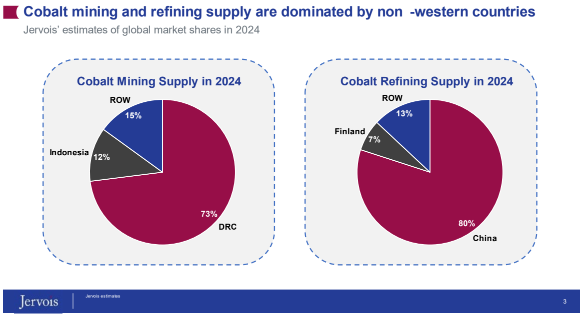
Ms Veronika Shime commented on the projected increase in electricity demand and asked whether the critical minerals team work with other IEA teams. With respect to increased demand for electricity etc and the wider energy picture supply-demand matters go hand-in-hand. ***Ms Dasgupta*** commented the WEO team have 100 personnel and the critical minerals team works closely with other sectors in the IEA such as those involved with power modelling. With respect to feed back loops and impact on electricity demand, ESG etc, more work is needed in this area. She mentioned future work concerning the influence of AI and associated data centre demand and so, will be working with the IEA power team in that regard.

Mr Tristan Stanley asked how the economics and associated cost and prices associated with recycled materials compared with primary. What trends are being noted and how competitive could recycling be? ***Ms Dasgupta*** recognised a key issue is the economic viability of recycling and while critical minerals prices have reduced, they are still high. She commented that the IEA advocates government support for recycling projects because otherwise they may not be profitable but are key from an ESG perspective and need support e.g., recycling requires less water usage with associated reduced GHG implications.

Western Supply Challenges for Critical Minerals – A Cobalt Example.

Mr Wayde Yeoman, Executive General Manager, Commercial, Jervois.

Mr Yeoman commented on how cobalt used to be considered a minor metal but now considered a critical mineral given its role in battery technology with demand projections outstripping supply. In essence 70% of cobalt consumption is driven by EV battery demand.



Cobalt mining and refining supply are dominated by non-wester countries, predominantly China. Chinese refining capacity has more than doubled since 2017 with capacity in the ROW reduced during the same time period.

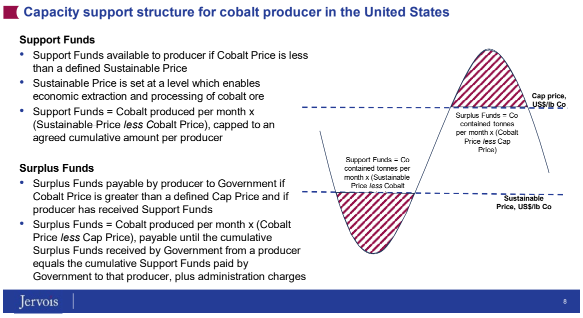
Mr Yeoman talked through some of the Western supply challenges associated with critical minerals which are linked to extreme market concentration with current global supply chains dominated by China. To reduce supply chain risk, western governments have stated policy goals to support development of independent supply chains for these materials to meet growing demand.

In essence China made a centralised, strategic and purposeful decision over a decade ago that certain key future technologies would underpin its future with associated significant State support. Added to this western supply costs are often higher than non-western suppliers.

Investment in critical minerals is challenging due to ongoing price volatility and, in the case of cobalt, historically low prices. Without continued and increased action and support from western governments, it will not be possible to build necessary supply chains in the West. The associated cost of western supply chains compared to non-west has created challenges for policy and investment decision makers. However, government support can help induce support from industry and lenders.

Commodity risk is a key risk to the reliable supply of metals and for critical minerals with limited non-western supply, price volatility risks are multiplied. Critical minerals can also be weaponised with forced low pricing blocking development projects which rely on market price mechanisms. Conventional solutions for price volatility management are not readily or practically available for critical minerals.

One proposed solution by the US government is the concept of a capped price stability mechanism for cobalt.



The difficulty is in the establishment of capacity support schemes and establishing an associated support fund as well as commensurate payment mechanisms.

Mr Yeoman summarised the western critical minerals supply challenges from a cobalt example perspective as follows:

1. Non-western investment in mining supply has created an over-supply situation where low prices make it difficult to make a business case for higher cost western projects.

2. Western investors require business stability and certainty of demand / offtake before committing.

3. EV supply chains in western jurisdictions not yet developed.

   It is difficult to make an investment decision on a United States project for example when there are not yet any United States based customers (even if projects are under evaluation / development).

4. United States foreign entity of concern ("FEOC") regulations are having a significant cobalt market impact

5. Other policies arguably less successful due to high costs associated with new western operations.

   Government funding structures not aligned with realities of today's critical minerals businesses

Questions

A member of IEA staff attending the meeting shared agreement with the key economic challenges and referred to the importance of cobalt in the defence and aerospace sectors. Whilst there are support mechanisms such as price floor and the US IRA, they are not working in practice so, what else is needed? ***Mr Yeoman*** referred to the suspension of a Jervois mine due to the market price falling below viability price when the mine was developed which at the time was $30/ton. In addition the expectation that demand for EVs would accelerate in the West has not materialised partly because production in the west has not ramped up accordingly. FBOC has helped with respect to some supply from Finland.

Ms Kate du Preez asked whether increased costs include ESG and industry regulation. ***Mr Yeoman*** agreed western suppliers have to deal with higher ESG costs but that is considered part of normal operation. ESG costs are small comparatively on an overall higher cost basis hence the need for financial support.

Management of Critical Raw Materials – The Example of Copper – Joint Overview by Freeport-McMoRan & Atlantic Copper.

Mr Javier Targhetta, President Atlantic Copper & SVP Sales & Marketing, Freeport McMoRan.

Mr Targhetta commented on copper being the oldest metal known to Man and the significant demand for copper over the past 100 years mainly driven by the electricity industry however, sustainability of supply is a concern.

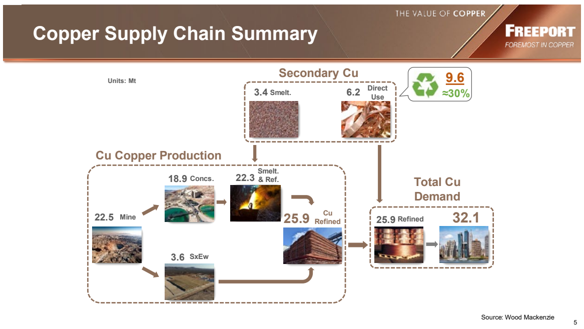
In terms of supply/demand drivers, 70% of the global population is projected to be in cities with more than 600 million households. There is the growth in raw materials in general however, the intensity of use is declining thanks to technology innovation and end-use efficiency.

Mr Targhetta talked through the growth of raw materials demand illustrating the typical range of raw critical minerals required for EV vehicles compared with ICE vehicles and the range of raw materials required for the average smartphone culminating in the need for 70tons of ore per smart phone. To produce <1% copper requires 300,000 tonnes of ore to be ground and milled with associated waste implications. In one day 1Mt of earth is extracted to produce 300,000tons of ore and <1% copper.

Copper is an essential metal for the electrification and decarbonisation of the world's economy and copper has been declared as a strategic material by the world's major powers.

China is investing in South Africa and South America in particular in Peru. Copper usage in China has increased 10-fold compared to 2000.

Currently the supply demand relationship for copper is well balanced with 2/3 from mines and 1/3 via recycling.



In terms of recycled copper, 1/3 is refined and smelted in copper production with 2/3 sent for direct use with less energy intensity impact. The various byproducts associated with copper production can also have a value.

Over the next 10 years a supply gap may evolve however it depends on the increase in EV uptake, urbanisation etc. Three sectors – electric mobility, renewables and urbanisation will account for 70% of copper demand by 2030.

The view of Mr Targhetta is there will enough copper for years to come, it will come down to how much will be mined and associated costs. He commented there is a lot of secondary copper stock via what he termed the urban mine so, households, vehicles as well as landfill sites however, how resource can be extracted from the urban mine requires further thought.

Copper mining supply related challenges include the general steep increase in CAPEX and OPEX costs since 2020. Older assets are producing lower grade copper in lower quantities. Also, smaller mine projects and permitting timelines are a challenge along with raw materials supply chain requirements and the importance of responsible mining (ESG). There is the social and political uncertainty in major copper mining districts such as the African Copper Belt, Chile, Peru etc that need to be managed on top of the associated remote location of operation challenges such as workforce, community impact etc.

Secondary copper resource will not be enough to meet demand needs. Less than 50% of scrap material is extracted copper also when the cost of raw copper goes up, more copper scrap appears and vice versa. Which adds risk to a recycling business given the cost associated with the extraction process.

In conclusion, Mr Targhetta's view is it is reasonable to think that a balanced copper market should be a likely future scenario. Recycled copper is a good complimentary resource but can never replace primary copper supply to meet current and anticipated future demand.

Questions

Mr Tae-Yoon Kim asked what the reason for Mr Targhetta's view on supply demand was given supply demand imbalances occurring. ***Mr Targhetta*** referred to increased focus worldwide on copper extraction from waste (not tailings) which will help bolster supply.

Ms Alexandra Heggarty with respect to extracting copper from waste, asked whether Freeport had looked at this from existing sites. ***Mr Targhetta*** clarified that tailings and general waste such as limestone is used for back-filling mines. What is being looked at and used is low grade material previously considered uneconomical to process. Given price increases and technological advancement product is now being extracted.

Mr Murayama commented on discussion two years ago concerning copper at which time it was the view supply will not meet demand. This view seems to have changed so, what has led to such a change of view? Is it due to increased recycling or other factors? ***Mr Targhetta*** stated it is not so much that recycling is helping to bridge the gap, it is possibly more related to some previous wrong assumptions e.g., 10 years ago Chinese GDP growth prediction was double digit resulting in a possible 8% demand increase in copper. This prediction has not materialised resulting in reduced demand increase. Also, the growth in EV demand has been lower than predicted so, demand has not been as strong or not grown as forecasted.

Questions & Discussion

Ms Amrita Dasgupta asked Mr Targhetta and Mr Yeoman what they considered to be the key challenges in the policy environment and how did they see the interaction with key government and policy makers. ***Mr Targhetta*** suggested it varies depending on which part of the world and which country with some being more favourable toward and some less or against mining activities. In general there is increasing understanding that production of metals is essential. There are however contradictions e.g, in the EU decarbonisation and competitive industry should co-exist in Europe however, the EU ETS tends to punish rather than help. Most CO_2 emissions are more a byproduct of activities so, technology needs to be developed to help decarbonise such as CCS and electrification. This is costly and punishing is not an effective approach.

Mr Yeoman referred to concentration of supply creating tensions and risks with government drive to facilitate catch-up, the challenge is how. Different countries are looking at different mechanisms and approaches, some of which compete and do not work in harmony. It would be helpful if all stakeholders involved in the energy transition would work together. Big swings in pricing can have an impact especially a niche critical mineral such as cobalt.

Ms Veronika Shime commented it took Jervois 20 years to secure permitting of the Idaho mine which, if it had been shorter would have reduced the pressure and risk associated with ROI so, there is a need to look at policy pressure along with supply chain. In response ***Mr Yeoman*** agreed and would support expediting permitting because of associated investment costs. ***Mr Targhetta*** added the CRMA recommends reducing permitting timescales not to exceed 27 months and it would help greatly if member governments adopted this recommendation.

Mr Paul Baruya commented on the view of financial institutions on renewables etc and that there was less financial institution based mining expertise impacting on associated understanding of value, importance and impact. ***Mr Yeoman*** added, what is new to financial institutions is price volatility with such volatility a blocker to investment. However, government support can help smooth out volatility effects and incentivise investment. ***Mr Targhetta*** agreed, in addition, addressing country related risk is critical along with managing ESG needs

In closing the discussion session Mr Tae-Yoon Kim highlighted some of the key points raised during the session and thanked everyone for their engagement and participation.

Mr Earl Melamed offered some final comments referring to it taking 17 years to get a mine project online when taking into account time associated with consultation, securing investment and permitting. He also commented that one major mining company predicts a 10Mt shortfall in copper supply by 2035.

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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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