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Acting on Climate Change: Technology and Financing Options

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Combating climate change demands urgent action from multiple stakeholders. This dialogue therefore brought together speakers from academia, industry, start-ups and government organisations. Owing to the global nature of the climate actions required, this discussion involved participants from across Europe, North America and China – countries and regions that a major role in the global climate system. The aim was to go beyond discussions on international targets, and actually focus on how to achieve these targets. Accordingly, the dialogue centred on new technologies, financing mechanisms and carbon markets, and brought together the collective wisdom of all participants in a cross-border dialogue. The lively discussion provided inspiration for new action plans and continued dialogue.

Current Trends and Future Targets:

In order to achieve the conditions of the Paris Treaty or the Glasgow COP 26 objectives and limit global warming to well below 2°C, and ideally 1.5°C, a zero-carbon economy has to be achieved by mid-century. The effects of climate change are more evident than ever before with extreme weather conditions seen all throughout the US, Europe and China this year. The recent floods in Pakistan bring to light, once again, the multi-fold effect of climate change on socio-economic development. Currently, Europe and the US have set targets to achieve net zero by 2050, and China has targets for 2060. This requires several technological innovations, along with increased funding and immediate global resolutions on carbon pricing. In the past 15 years, dramatic progress has been made in technologies and their cost of deployment has dropped significantly. The cost of wind and solar have both hugely reduced. Last year in Saudi Arabia the cost of solar PV was only $10 per megawatt hour or only ¢1 per kilowatt hour. This is a drastic decrease compared to what was $300 per megawatt hour about 10 to 15 years ago. In the UK, five years ago offshore wind costs were about £150 per megawatt hour. Today, the latest auction was only £37 per megawatt hour. Battery technologies have also seen a dramatic growth with a drastic fall in costs from $1000 per megawatt only ten years ago. This progress is due to a combination of fundamental technological advancements and better understanding of battery chemistry, and continuous efforts and improvement to scaling-up production and due to economies of scale. These reasons also contribute to the reduction in costs of electrolysers, and consequently the cost of green hydrogen. The cost of green hydrogen is anticipated to fall rapidly in the next ten years from around $10 a kilogram today to $5 a kilogram in the 2020s and to down to $1 a kilogram by 2050.

These developments have now enabled a stronger drive to decarbonise the electricity system. With it being clear that solar and wind are the cheapest ways to produce electricity, the focus at the UK Energy Transitions Commission (ETC), for example, is now on overcoming challenges to balance supply and demands in the power system across the year. Hydrogen is increasingly seen as a solution to long duration energy storage. There are also a range of intermediate storage technologies and many other possible storage options such as liquid air, compressed air, flow batteries, and various forms of heat storage. Decarbonised electricity makes it possible to electrify the economy significantly. Many sectors such as passenger road transport are heading towards total electrification. In the last five years, even the electrification of heavy-duty road transport has become increasingly more possible. Four months ago, at Gothenburg in Sweden, Volvo Trucks successfully tested a 40 ton, 16m long electric truck which is already being mass produced. Similarly, the other major Swedish truck manufacturer Scania also has recent trucks that are fully electrified.

In addition to these technological innovations, it is evident from market adoption trends that electric vehicles are increasingly becoming the popular choice. Compared with 2020, sales nearly doubled in 2021 to 6.6 million (a sales share of nearly 9%), bringing the total number of electric cars on roads globally to 16.5 million.[1] The IEA estimate that 13% of new cars sold in 2022 were electric. However, this is only a small percentage of the global stock of more than 1 billion passenger vehicles. There are several challenges associated with electric vehicles adoption that need technological and market solutions. Electric vehicles have a higher upfront cost but a lower maintenance price and lower cost per mile. However, these benefits could potentially be nullified by higher time costs from refuelling and higher disposal costs. At the same time, while it is encouraging to see engineering and technological breakthroughs making medium- and heavy-duty electric vehicles implementable at scale, it is important to calculate the impact of large-scale deployment of heavy-duty electric vehicles on the grid. Therefore,

[1] IEA, 2022. https://www.iea.org/reports/electric-vehicles

engineering and technological progress in electric vehicles should be combined with energy grid optimisation efforts at every level.

As a whole, the transportation sector contributes to about 30% of the total emissions. Other sectors such as steel, cement, chemical manufacturing, aviation, and shipping contribute to a larger chunk but are harder to electrify. For the past five years the ETC directed their efforts to analyse these sectors and published the Mission Possible Report. This report set out the optimistic view that it is technologically and economically feasible to achieve net zero even in these sectors by 2050. In the past five years the confidence and attitude towards achieving net zero have also dramatically changed. For example, in the aviation industry there has been progress from CORSIA committing to just 50% reduction in aviation emissions, to a very wide coalition of airlines, aircraft manufacturers and airports today working towards a 95% reduction in emissions by 2050. In fact, this week the International Aviation Transport Association (IATA) has issued a recommendation to ICAO, the global aviation regulator, to adopt a net zero by 2050 target. Furthermore, technologies such as hydrogen direct reduction and using ammonia in ship engines aid in achieving net zero in the steel and shipping industry respectively.

Overall, there are four main technologies to help achieve net zero targets - direct, electrification, hydrogen, bioenergy through sustainable use of bioresources, and carbon capture and storage. Among these, hydrogen and electricity will play the most important role in the future. It is expected that the total usage of hydrogen will grow from 100 million tons today to 800 million tons in 2050 with major usage in the shipping industry for power storage and in steel production. This would lead to an increase in the demand for electricity growing from today's value of 27,000 terawatt hours to as much as 95,000 to 130,000 terawatt hours. A significant portion of this, about 25,000 to 40,000 terawatt hours, will be used to produce hydrogen from electrolysis, ammonia, and synthetic fuel. Different countries across the world are already building electricity systems to accommodate these changes, with China clearly standing out in these efforts. China is currently building wind and solar at the pace required to meet these lofty future requirements.

While it is now clear which technologies could help to achieve net zero in different energy sectors, there is a range of developments required at different stages for these technologies. Some technologies such as next generation batteries require progress in research and development. In some others, efforts need to be made to translate the technology from the pilot scale to the commercial stage. For example, SSAB's plant in northern Sweden produced 100 grams of steel in hydrogen. This is a pilot scale plant that needs to be scaled-up to a commercial market. The same is true for bio- and synthetic- jet fuel.

Apart from innovations in energy technologies, major improvements in the agriculture sector are crucial. The agriculture sector is responsible for 25% of all emissions in the world, with meat production being a major contributor. Speakers warned that if the current level of meat consumption continues, with meat being produced from ruminant animals and driving deforestation, a catastrophic climate change is inevitable. This reaffirmed the importance of synthetic biology in meat production. Estimates suggest that the total amount of new investment required in technology investments is about $ 4 trillion per annum across the world, offset by a reduction in investment in the fossil fuel sector of about $ 0.5 trillion per annum. It is important that these investments are not concentrated only in developed countries. Investments in developing countries at all income levels are crucial to combat climate change. Here a key role is played by multilateral development banks of climate finance, along with international coordination. This is seen in many issues across the world including issues related to China's huge investments in the Belt and Road program.

In sum, it is evident that there is a need for exponential engineering and technological advancements to further existing technologies. Simultaneously, innovating new processes to help achieve net zero targets is essential. The role played by emerging technologies in the present and future needs to be carefully analysed to help draft policies that encourage technological progress and early adoption. Technological progress also needs to be accompanied by international coordination and discussion on the potential role of broader carbon adjustments. In specific sectors where there is international trade involved it is important to have a coordinated approach to carbon pricing which accelerates technological innovations to achieve net zero.

Potential Contributions of Emerging Technologies

Advanced Battery Technologies:

Current battery technologies are too expensive for universal mass adoption. There has been a lot of progress in reducing costs recently, particularly in China, but there are also massive sustainability issues. At present, there is no battery technology that can compete with pumped hydropower for electricity storage. While there is a significant drop in battery prices at the moment, current technologies are close to their fundamental limits. As regards sustainability, large-scale giga-factories require essentially all the cobalt produced from the Democratic Republic of Congo, in particular. Similarly, the consequences of lithium mining associated with water in Chile, Bolivia and Argentina raise serious concerns. A sustainable push on the other hand is the move toward higher levels of nickel in electric vehicles. To address safety issues in batteries, several start-ups and larger companies are developing solid state batteries which do not use liquid electrolytes and use ceramic separators. To date, however, they have only been able to produce battery packs of very small size. The next step, therefore, is to raise efforts to produce solid state batteries in large factories at scale. But perfecting the necessary ceramic separator at this scale is a massive challenge.

Looking beyond lithium, China and several countries in Europe already have various limithim-replacement programmes in place. However, the energy density of these technologies is not high. In principle, this can be overcome by using cobalt. There are other paradigm shifting technologies such as lithium air batteries, lithium sulphur batteries and magnesium-based batteries. The Technology Readiness Level (TRL) of these, however, is still low. Likewise, redox flow batteries provide an opportunity to decouple energy and power but they still cost the same as lithium ion batteries. Despite these obstacles, several start-ups and companies are making serious strides in advancing battery technologies. For example, one such start-up focuses on fast charging. Fast charging could be truly advantageous as it would mean heavy batteries are no longer required for long-distance transport. It also has applications in robotics where fast charging is valuable.

To be able to use batteries and fuel cells for meeting 2050 net zero goals, progress in fundamental science along with increased investments is required. Using computational and experimental tools to study and control meta-stable battery materials is essential. Additionally, it is important to develop strategies for grid technologies that not only focus on cheaper alternatives in the near future, such as sodium ion or redox flow batteries, but can accommodate sustainable battery technology in the long run.

In line with these considerations, several questions were raised about long-term strategies for adopting electric vehicles and more broadly, about transportation strategies for the future when it is not fully clear in the present which is the most efficient option. It is important to note that efforts made to move away from lithium to different elements have the potential to create the same problems faced with lithium sourcing. Long-term planning in collaboration with expert geologists to identify sustainable elements is currently missing. Selecting new elements for battery applications purely based on chemical viability is a narrow approach that is not ideal. Scoping new energy materials should be a multi-pronged effort taking into consideration the combined economic, environmental, and energy efficiency factors.

Hydrogen Technology:

Hydrogen is often viewed as the wonder fuel that can easily replace natural gas. However, this expectation is not fully realistic today. As of 2021, about 98% of hydrogen was produced from steam methane reforming. This so called “brown hydrogen” is a major cause of climate change, referred to by some as the “climate killer”. When the carbon dioxide released during this process is captured and stored, this is called blue hydrogen. Green hydrogen refers to hydrogen produced from water electrolysis using renewable energy sources. This is an emerging technology that is key in the future for usage of hydrogen as transport fuel or for on-site applications.

The very high mass energy density of hydrogen (120 MJ/kg) is extremely attractive. One kilogram of hydrogen has about three times the energy of one kilogram of diesel. However, the low volumetric density of hydrogen causes serious storage issues. For example, one kilogram of hydrogen occupies 11,000 litres at standard temperature and pressure. Essentially, hydrogen needs to be compressed using high amounts of energy and at very low temperatures (as low as -235°C). But it is also highly flammable, explosive and reactive. Recently, the US Department of Energy has developed criteria for using hydrogen in small vehicle transport. The requirement is that the hydrogen storage material stores at least 6.5 weight percent hydrogen. However, due to the various fundamental problems with hydrogen and the challenges with storage and transportation, the adoption and development of hydrogen powered small vehicle transport is questionable.

Another drawback of hydrogen is the high cost. In 2021, it cost between $10 and $12 per kilogram to produce. To make hydrogen competitive with natural gas, however, the cost would have to be brought down to $1 to $2 per kilogram. This requires a massive increase in technology and scale. However, using electrolysers to produce hydrogen is highly inefficient. From basic calculations, it can be seen that the energy required for producing hydrogen is 142 MJ/kg. But the mass density of hydrogen is only 120 MJ/kg. Therefore, a large amount of energy input is required to obtain a lower output. Therefore, the electrolysis of water to produce hydrogen will always use more energy as this energy conversion process can never be made 100% efficient. This is due to several factors such as overpotential, thermal energy loss and the use of heating in the case of the electrolysis of pure water. Electrolyser efficiency is currently around 80% and electrolysers will undoubtedly become more efficient, but there will always be losses. Therefore, converting hard-won renewable electrical energy into hydrogen for mass-energy supply is not the best option and it is more efficient to directly use the electricity. These concerns are also the reason why most commentators currently believer hydrogen is an unlikely solution to power passenger vehicles.

It is also important to note that very large amounts of renewable energy would be required to produce hydrogen at scale. Some reports estimate that 20 times the current offshore wind per year than in the previous 20 years needs to be generated for the next 30 years. Further, hydrogen embrittlement of steel pipes and welding causes huge issues while transporting hydrogen. Therefore, at the present it is attractive to utilise hydrogen locally and create local hubs for the production and usage of hydrogen. There are also other state- of-the-art methods to produce hydrogen such as a solid-state method, which uses a series of semiconductors in a multi junction. In terms of storage, apart from ammonia there are many other high energy molecules that can be used as storage. But the major issue here is the reversibility of the storage as this is a major thermodynamic and chemical problem.

On the upside, however, hydrogen is a good alternative for some applications which could be used for high-power heating applications such as steel, cement, glass etc. However, the main question remains about how hydrogen should be transported - by mass-grid supply or by localised regional hubs. Regional hubs minimise the immediate costs and potential problems with piped transport by having the industrial units close to the source of renewable energy and hydrogen production. It is now widely accepted that the latter model is the most logical one. Essentially, there are two main factors that determine the development of hydrogen fuel: First, the loss encountered during its production using electrolysers, and second, the unit price of renewable hydrogen compared to natural gas. At or around parity with natural gas, however, the use of hydrogen in mass supply becomes viable (regardless of the energy loss). To overcome losses from electrolysers, many efforts are also made to use nuclear energy for the generation of hydrogen. Several recent technologies such as the rock cavern storage, which is the storage of hydrogen under very high levels of compression in Sweden, have shown that there are possibilities to overcome some of the hurdles pertaining to hydrogen. But a large question mark still hovers over the economic feasibility of these technologies.

Industrial Hydrogen Production:

While several advances at the lab-scale have been made in hydrogen technologies, the prospects for large-scale hydrogen production have not been overly promising. Hydrogen is widely considered as the energy of the future. But this is not a recent concept and in fact, the same sentiments around hydrogen have been echoed for several decades now. The concept of hydrogen powered vehicles was formalised even prior to the wider ideological conception of electrical vehicles. This raises questions about what has been limiting large-scale hydrogen adoption and why hydrogen is still the energy of the future and not the present. Fundamentally, in many ways this is an industrial engineering question and not completely a basic science hurdle.

Engineering efforts in the industrial production of hydrogen using renewable energy is the need of the hour. One very promising initiative leading the way in industrial production of hydrogen is seen in Spain. This initiative in the last two years has led to the formation of a hub of 30 companies covering all stages of the hydrogen value chain. This includes various upstream, midstream, and downstream companies including several solar developers, and electrolyser and engineering companies. This initiative was ranked the largest green hydrogen project in the world with an aim of producing 3.6 million tons of hydrogen in Europe by 2030. This hub also aims at bringing down the cost of hydrogen to only €2.5 per kilogram - 75% cheaper than the current price of natural gas in Europe. With these targets, this hub has €12 billion worth of contracts in place. There are four main factors playing a huge role in reaching these targets. These include capturing solar energy through large scale installations of PV of 500 to 1000 MW up to 25,000 MW across the Mediterranean (with no connection to the power grid as this would drive up the cost), combined location with electrolysis, scaling up electrolysis and standardising the process. This hub is a joint venture between the developer, H2 Energy, the gas transmission company of Spain, Enagás, and two major off-takers - ArcelorMittal, the world's largest steel company, and Fertiberia, southern Europe's largest fertiliser company. This initiative has already signed the first EPC contract. This comprises of 9.5 GW of solar and 7.4 GW of electrolysers producing hydrogen from the end of 2025. The construction of this is scheduled to start in 2024 to deliver through pipelines of 1000 km. These pipelines have already been studied and tested to deliver the first batch of 330,000 tons of hydrogen annually to sites in northern Spain. These would be used by electrolyser direct reduced iron steel, ArcelorMittal to produce 2.3 million tons of green steel, and to produce 1 million tons of fertiliser by Fertiberia.

This hub would also be launching, along with Spain’s largest bus company, 1,000 green fuel cell buses by 2025 with a TCO lower than hydrogen. In addition, the coal fire plant in La Rioja is going to be converted to a hydrogen generation plant with 2470 carbon power. This project is scheduled to be presented at COP 27 on November 14th with the president of Mauritania, the president of the African Union, and the president of the European Investment Bank with an aim of producing 100 million tons from Africa to meet demands in Europe and Africa.

Overall, hydrogen technologies have come a long way and such industrial advances in large-scale deployment paint an optimistic future for hydrogen. These industrial hubs producing hydrogen at large-scales truly pave the way for ensuring hydrogen is adopted as the energy of the present. It is also promising to see progress made in the recent years in decarbonizing the steel manufacturing industry with the demand for metallurgical coal, coke and coal expected to fall by 85% or 90% by 2050. This is due to novel technologies being employed, most of which use hydrogen in one fashion or another.

Independent Renewable Energy Systems:

It is evident that major progress has been made in battery and hydrogen energy technologies. How to effectively integrate these energy technologies into energy grids and how the energy distribution would occur are now the bigger questions to look at. The energy grids in existence in several regions are not suitable to handle the direct integration of new energy production technologies. In particular, while wind and solar energy prices are cheaper than ever before, the demand and supply imbalances in the grid prevent their wider adoption. Digital resources and AI can help to manage these imbalances. But these technologies are not yet fully ready for practical implementation. Currently high voltage transmission lines are used, and these take five to ten years to build. This would significantly slow down the energy transition. An interesting alternative is net zero industrial parks embedded with independent renewable energy systems. These would allow us to build heavy-load industries that are 100% renewable energy based. This has already been tried in Ordos, the largest coal producing city in the world. Here, the world's first national industrial park has been built. The important hurdle faced here was the issue of long-term storage. An interesting solution to tackle long-term storage is Ammonia. It has the potential to be used as the output of an industrial park and at the same time serve as seasonal storage. In order to produce ammonia cheaply and efficiently, hydrogen electrolysers and alternative catalysts and production methods to the Haber-Bosch process that would allow ammonia production at ambient temperature and pressure are required. Once ammonia is produced, subsequently, it can be converted back to large amounts of energy by two different methods. These are ammonia turbines and ammonia fuel cell batteries. Both of these methods are good alternatives that allow separate power generation and energy storage. However, to make these technologies commercially viable, huge investments to fuel deep technological breakthroughs in ammonia-production, power generation and storage are required.

Some speakers expressed strong hopes for net zero industrial parks and suggested these might become the "new steam engine" for the green industrial revolution. Net zero industrial parks indeed integrate renewable energy production with renewable energy consumption through the advanced independent energy system.

A Case Study: Tackling Carbon emissions in China

Clearly, a study of the practical implementation of emerging technologies discussed so far is important. While all of these technologies have the potential to produce significant amounts of renewable energy independently, the optimised combined implementation of more than one emerging technology in a local region is not straightforward. In this sense, it is beneficial to study the recent advances in China. China is the largest contributor to carbon emissions globally. While it is indeed true that per capita emissions of China are lower than many other countries, it is still undeniable that China's efforts to reach net zero targets will have significant impacts on the global carbon emission levels.

Last year, the Energy Foundation of China and the International Energy Agency launched a report on China's technological map toward zero emissions by 2050. The core technological factors highlighted were the power sector and the electrification of different sectors. These roadmaps have been translated into practice in many parts of China as can be seen in Inner Mongolia, for example. Inner Mongolia contributes to 25% of China's coal production. But at the same time, it possesses huge potential for immediate transition to renewable energy. And efforts have been made by the Energy Foundation of China by integrating different technologies. As a part of the national scheme of green stimulus for green recovery, several PV power generation equipment have been installed in this region. In addition, over 158 PV projects are in the bidding process. A combination of different technologies is employed here. High voltage transmission technologies are used to directly circulate current to transmit green power from Mongolia to more energy intensive regions such as in Beijing municipality, Chengdu, Shanghai and Hangzhou provinces. In the last couple of years, engineering projects have been able to successfully transmit energy between Shanghai and Lu'an in northwest China, about 1000 km apart. In the next 4 to 5 years, plans are made to invest more capital in this grid transmission project to transmit renewable electricity to the eastern part of China.

China has also been focusing on high energy storage technologies. Currently efforts are being made to retrofit existing reservoirs for energy storage. More engineering efforts have also been made in chemical energy storage technologies such as batteries. Early concepts and discussions on virtual power plants, especially based on IT and voltage signals, are considered too. In the last year, there has been rapid development and acceleration down the learning curve of offshore wind power in China, especially in Iguanodon, Kiangsu, and Shandong. In the coming years, it is expected that the costs of offshore wind will decline rapidly along with low transmission costs as these regions are in close proximity to energy intensive areas.

These recent advancements in green energy technologies and planning in China could provide lessons for other countries and provide examples of local models that might be adapted for different environments.

Synthetic Biology:

In order to advance efforts to produce valuable chemicals sustainably, another interesting approach is synthetic biology. It has enormous potential as a platform technology, but one that is still at an early stage when it comes to its wide-scale commercial applications outside the laboratory. Synthetic biology is the design, engineering and re-engineering of biologically based parts, devices, and systems. Synthetic biology, along with synthetic engineering which involves advances in DNA sequencing, informatics, DNA assembly and genome construction, have made it possible to achieve a wide selection of chemical processes using these technologies.

The chemical industry enables the production of crucial molecules and materials including complex therapeutics, painkillers, vaccines, packaging materials, furniture materials that we rely on every day, and personal care items, all of which are derived from fossil fuels. The chemical industry is the only sector whose reliance on fossil fuels is still increasing. Microbes are nature’s chemists that could alternatively be used to produce valuable chemicals from sustainable feedstocks. Microbes can fix carbon dioxide and produce bulk chemicals. They can also produce hydrogen. Other examples include the production of adipic acid which is a precursor of nylon. Annually, 2.7 million tons of adipic acid is produced from benzene. This is responsible for 8% to 10% of global emissions. Instead, synthetic biology can be used to produce adipic acid from lignin waste, of which 70 million tons are generated every year. Synthetic biology can also be used to turn PET into vanillin. The precursor molecules in the formation of vanillin are even more valuable as they are a starting material for pharmaceuticals, different materials and cosmetics. Certain bacteria are also capable of recycling metal and are used to selectively recover metals from lithium battery leaks. Other bacteria can help concrete to self-heal. Meanwhile, genes from spiders have been added to yeast which allows it to brew up silk. There are many more examples where synthetic biology and engineering is a key platform technology. The American government has made major investments in synthetic biology and has announced drafts of technical roadmaps in recent years. Recently, the American President had also signed an executive order for the national biotechnology and bio-manufacturing initiative.

Overall, it was argued that the tools of synthetic biology definitely have the potential to replace conventional methods in chemical production. However, it is yet not fully certain if it is an economically and commercially viable method for large-scale production of chemicals. Production at large-scale necessitates industrial engineering of bioreactors that have high efficiency and durability. However, a lot of the cutting-edge advancements in synthetic biology-driven production still remain at smaller scale.

Beyond Technological Innovations:

Going beyond renewable energy innovations and production, the consensus of the dialogue was that it is important to focus on concerns associated with the transmission, distribution, storage and consumption of the renewable energy produced. For example, in the context of China, solar prices are extremely cheap at roughly about $2 per kWh. Wind energy is also cheap at about $4-5 per kWh. However, the difficulties in transmission and storage prevent immediate large-scale adoption. In China, efforts are made in Shanghai to convert hydro power stations into power storage facilities. Shanghai is the major power exporting province in China. But to effectively utilise the cheap energy produced it is important to rebuild power grids with smart decentralised distribution systems. Distributed systems help to address the imbalances of power supply and consumption. Such decentralised systems are the focus of several companies currently.

Energy transmission internationally is also a new challenge. There are projects in place to develop wind and solar energy in Morocco, for example, and transmit the energy to the UK via undersea cables. These efforts highlight the importance of interconnecting geographies across the world to effectively balance the renewable energy system. Focus on consumer demands is another important aspect that determines the adoption of novel renewable energy innovations. Regulations from different government bodies are also key in this aspect. These need to not only focus on the current technological advancements but also give room and incentive for future developments. For example, the regulations in the landmark Inflation Reduction Act by the US government focuses heavily on existing battery technologies such as lithium-ion batteries. This maybe a missed opportunity as there is not much scope to encourage alternative minerals and technologies. Early on NMC batteries had equal amounts of nickel, magnesium, and cobalt. But due to concerns about the source of cobalt, latest versions of the battery have a 9:0.5:0.5 ratio of the elements. However, this has now reached the stage where nickel would be the limiting factor in the next 10 years. Therefore, regulations need to be framed carefully to be able to accommodate such rapid changes in technologies and resource bottlenecks. In this regard, several managerial issues along with concerns about transmission, storage and safety are also seen in the green hydrogen plants. Once again, the case study of China can be used to understand the importance of distribution and storage in green hydrogen plants. There are currently multiple green hydrogen projects in place with one already functioning in Yingshan. However, it has been learned that to effectively transfer the energy produced, extensive efforts must be made to continuously balance the demand and supply gaps.

Financing Action on Climate Change

The financing of climate change mitigation is the flip side of the ongoing technological development that must be considered in order to reach the Paris Agreement targets and country specific UN Nationally Defined Contribution (NDC) targets, for without sufficient financing, technology will not be developed and deployed. In 2009, at COP15, developed countries pledged to give $100bn annually by 2020 to developing countries, this target has yet to be met. In 2022, at COP27 in Egypt, a new attempt at global climate finance, focused on adaptation (loss and damage) was agreed, although with little detail on the specific.

Further work has been taking place to advance the use of voluntary carbon markets, under Article 6 of the Paris Agreement, however the progress made at COP27 has been widely criticised by NGO and other environmental groups for the lack of safeguards and concerns over indigenous rights and food security. Overall, this shows that much more work and ongoing dialogue is needed to develop effective climate financing mechanisms. The UK and China, as centres of finance, banking and global development have the opportunity to play a key role in this both in the private and public domains. The subsequent discussion highlighted some of the ongoing work, barriers, and opportunities for financing climate mitigation across the two countries and further afield.

Private Sector Finance Initiatives

As already mentioned, private and voluntary carbon markets are insufficiently governed under Article 6 of the Paris Agreement, peer to peer, or other forms of climate finance are broadly uncovered and much more work is needed to harmonise and scale up the sector. The session began with a high-level focus on how more private finance can be brought in to finance the green transition and the international coordination that is required, out of this, three challenges were highlighted that various coordination bodies are currently working on.

The first international challenge is to harmonise the taxonomy around the green transition, the variety of different definitions currently in play provides a great deal of confusion to those operating in the market and slows down financing operations who need to take time to understand them. While progress has been made on this, including the creation of the Common Ground Taxonomy between the EU and China, several other countries, including the US and Japan do not want a single taxonomy. The second challenge is the need to reach consensus on global disclosure standards. This work is underway and was taken up by the G20 in 2021, however challenges remain, especially with small- and medium sized enterprises (SMEs) that do not want to accept International Sustainability Standards Board (ISSB) standards. Many SME argue that it is both too costly to implement and they lack the capabilities required to do so. This requirement for internationally agreed disclosure standards was also paired with the need for greater incentives for low carbon projects that aren't financially viable in their early stages, even when their environmental benefits are well understood. Examples of incentives include inclusion with a carbon market (where they can sell credits) or subsidisation and tax exemptions. However, both pricing and non-pricing mechanisms should be considered to provide incentive (particularly in the short term) to drive private sector finance into the green economy.

The final and most expansive challenge discussed is the variety and diverse demands for green financial products from the private sector that need to be met. This includes long term financing, through the green bond market, supply chain financing and financing options for SMEs wishing to move their operations onto a sustainable, low-carbon basis. This last point was highlighted as particularly critical given how much of the global economy is underpinned by SMEs. Financing for supply chains and SMEs has a lot of synergistic potential as these same SMEs often form parts of supply chains for larger organisations that have greater access to green finance. The challenge of 'who pays and access to finance' was raised by a representative from a SME, a further challenge they noted was the choice of technology. Where technological development within a sector is occurring at pace there is a concern about choosing the 'right' technology or waiting to see which technology becomes dominant, factors which can delay implementation and deployment.

It was concluded that many of these problems feed into one another, resulting in the difficulties that SMEs face with disclosure create bottlenecks for companies wishing to expand their private investment in this space. Solutions to these problems, such as improved information systems, public portals or public provisions for reporting environmental, social, and governance (ESG) credentials, are being developed but will require time to be rolled out at scale.

In response to these challenges, three specific examples of solutions by the private finance sector were discussed: efforts to bring greater transparency, innovation to open new asset classes and developing coalitions to problem solve (particularly around bottlenecks in the market).

Greater transparency

In the six years since the first green bond was launched in 2015, the market has grown to over $1 trillion, this is about 45% green bonds (which have a specific greening activity linked to them) and 55% sustainability linked instruments (which typically have some sustainable target associated with it, such as emissions reduction. Greater use of these different types of classification and taxonomy would allow greater certainty about the outcome of issuing these bonds.

New asset classes

Greater use of taxonomy and identification of areas in need of greater financing to support the green transition have allowed for private finance to open up new types of asset classes to directly support their development. New infrastructure required for a sustainable transition along with new forms of financial intervention to meet these capital needs are being developed.

Coalition building

There is a broad recognition, stemming out of COP26, that the finance sector toolkit currently focused on risk needs to be retooled to look at emissions alignment. A lack of knowledge about the technologies and tools required to drive down the emissions curve is resulting in new coalitions and dialogue to develop this knowledge, particularly in the industrial sectors. The efforts underway here, it was revealed, have also led some private finance groups to develop targets for emissions reduction within a specific portfolio or sector. Some of the challenges associated with this, including a lack of data (which was emphasised as an issue by multiple participants) and the geopolitical challenges that emerge are also driving a need for greater coalition building in this space to push it forward. These coalitions should include groups within the finance sector and externally, working with expert groups and others within the decarbonisation space to fill in knowledge gaps.

While the discussion touched on some of the key challenges and solutions associated with developing private capital financing of climate mitigation, it was also observed that these solutions failed to recognise some of the inherent challenges associated with a dependence on the private sector for funding problems characterised by market failure (i.e., carbon externalities), excessive consumption and monopolistic behaviour. Since the Paris Agreement in 2015, the World Bank alone has given nearly $15 billion to finance fossil fuel projects, and an analysis of the world's 60 largest banks have given almost $4 trillion in fossil fuel financing. Greater and ongoing discussion and global discourse is needed across all levels to acknowledge these issues and discuss the phase down of both the use and fossil fuels both to reduce emissions and provide space (and capital) to the expansion of green financing.

The role of international organisations

International organisations, including financing bodies and banks, and also standards and trade bodies, are seen as the bedrock upon which rigorous and expansive global climate financing can be built. In the fiscal year 2022, the World Bank delivered almost $32billion in climate financing, up almost 20% on the previous year. This shows the rapid scale and expansion of financing by international organisations. However, as is widely recognised (particularly by the UN and at COP27) more is needed if we are going to ween the global economy off fossil fuels and transition at the scale required.

Many of the same concerns, particularly around standards and disclosure were also expressed during the discussion on the role of international organisations. Parties involved in these discussions must expand beyond multilateral development banks (MDBs) to include a wide range of international organisations including those responsible for setting standards. Alongside this, many of the public-private partnership platforms present during COP26 also need to be included. Within these international organisations, universal standards and disclosure requirements are seen as the most important infrastructure required to finance a green transition.

More explicitly, within these organisations, their role is generally seen as being to leverage private finance into the market. However, the budgets of the MDBs are currently too small to leverage the amount of capital required. To provide 10% financing of the $3.5 trillion required, for example, $350 billion of investment by MDBs is needed, significantly beyond the current $80 billion financing capacity of the MDBs today. As part of this ability to leverage private finance, MDBs also have a responsibility to ensure that private finance and capacity building activities are focused on the emerging countries who need them the most (and also have the least access to them) to ensure they develop alongside making the green transition. Scaling up these MDBs alongside rethinking their development objectives to sit alongside a new green transition agenda is likely to require some fundamental changes to have these organisations are structured.

In addition to scaling up the amount of resources that can be invested in the green transition, more work and international coordination is required for global risk management. This expanded understanding of global risk needs to take into account typical forms of risk alongside the risks associated with climate change and the knock-on risk that could have on financial stability. Concerns were also raised about the risk of corruption when scaling up the amount of climate finance available, and also the risk of greenwashing, both in the form of funds allocation that is not “sufficiently green” but also ignoring the required action to bring down emissions (not just expand clean energy), through removing investment from “dirty” activities. There was broad consensus, however, that these risks can be mitigated through greater guidance, governance and cooperation between international organisation (including the IMF who play an important role in risk management) as well as national governments

Finally, the disconnect between the level of concern amongst climate scientists and the lack of market response in terms of asset price decline and volatility attributable to climate change, was raised. This disconnect raises several questions first around why we are not seeing such volatility in the market, second, what will happen if/when we begin to see this climatic turbulence spill into the global financial markets, and third, will the international organisations have the skills and capacity to respond?

Government planning versus market competition

The state and the market are often seen as either being in tension, or alternatively, as the two key, yet distinct mechanisms for development. However, as we have seen in the context of international organisations funding climate development they are inextricably linked. MDBs are funded by state governments and yet see themselves as providing leverage for private finance into a system or economy. State financing is particularly valuable where it is able to take on risk typically not considered viable by the market or offer insurance where others are unwilling to do so. That being said, it was noted that it is important that the state does not become subservient to the market, socialising the risk associated with decarbonisation while the reward remains privatised. This is important, both in the case of developed states funding global decarbonisation, and for developing states that need to build private wealth while also ensuring that wealth is not extracted or captured by private finance in way that would disrupt wider economic development.

Nevertheless, it was agreed that to view government planning and the market competition as opposites was very misleading because there is no way forward other than for the government to work with the market in response to climate change. Historically, the vast majority of government planning for climate change (at the international coordination level) has happened during the COP negotiations. Given this fact, there was a sense within government that the climate issue was being dealt with “over there” and had become siloed.

The separation between climate policy and the political, economic and financial systems have made it very hard to produce the finance needed to meet our climate targets. Bringing financial institutions into the conversation was a significant element of the COP26 negotiations and managed to revitalise the target made in Paris for $100 billion in climate investment which had been missed and is now on track to be met in 2023, alongside further successes in funding allocated for climate adaptation.

This past lack of funding has been attributed to the missing presence of economic and finance ministers and central bankers in conversations previously dominated by environment ministers who have no control over spending, the success of COP26 was largely a result of bringing these players to the table. Alongside, there has also been success in bringing new sectors to the table, particularly nature, land use and agriculture.

By expanding out the conversation around net zero to include more people, the COP negotiations have also allowed more people to come on board to bring about net zero, such as finance and asset managers. We now have 90% of the world economy and over $100 trillion under asset management committed to net zero. However, the large expansion in funding for clean energy and technology has not triggered a withdrawal of funding from fossil fuels that is also required. Many large financial institutions who are driving green investment continue to fund and underwrite investment in fossil fuels, which continues to fuel the climate breakdown. One partial solution to this would be a more expansive discussion around disclosure and risk to account for the risk of the asset to wider environmental considerations, not just the existing process of measuring the risk to the asset.

The ongoing energy and geopolitical crises have also played a role in accelerating some of the trends we began to see during COP26. The (UK) government in its COP presidency has had some success in bringing finance ministers to the table to make climate finance commitments, however there is still work to be done to leverage this in the private markets to bring about the full scale of climate funding required. This is particularly evident in the climate adaptation and mitigation cases where £250 has been allocated, but this is only a fraction of the adaptation plan of a single country that will need to adapt to a warmed planet.

Beyond the negotiations at the international summits, there is much that the nation state can do to push a faster transition, both in terms of policy and rhetoric used around climate action. With the re-emergence of the state as global actors, the rhetoric of national security or competition can be very effective in spurring advancements in these areas, however we need to be careful that they don't get out of hand and can become destructive. The potential and concerns around these new approaches and geopolitical rivalry can be evidenced in the latest climate policy developments. Many of the recent legislative successes in the US have seen strong anti-China, protectionist elements (including the Inflation Reduction Act; IRA). While this puts large amounts of money into clean energy it also makes it harder to garner international cooperation and sets us down a ‘rocky-road’ pathway as outlined by the IPCC.

Despite these potential concerns, it was noted that the diplomatic power of climate change had never been greater, and climate action currently has the power to open doors and bring people to the table in a way that other geopolitical issues do not. This recognises that there will be massive shifts in the global economy as a result of the green transition and we need to start thinking about how we are going to meet these changes (as international organisations, states or peoples).

The Role of Carbon Markets

National and regional initiatives: towards a global carbon market

The role and governance of private markets have already been touched on as they play a critical role in scaling private financing. Government-led carbon markets (typically referred to as an ETS - emissions trading scheme) are much more established and thoroughly regulated, although not always successful. The role of carbon markets was noted at the outset of the discussion, with the caveat in the opening remarks that carbon pricing could not provide the sole answer to the energy transition. In many sectors we have seen that a carbon price is (or would be) insufficient to produce the desired change, and that subsidies and regulation are typically more effective. However, in energy intensive industries carbon pricing can have some positive impact when paired with other supportive measures. Furthermore, these energy intensive sectors, such as aviation, shipping, and chemicals, are very internationalised sectors, making the imposition of a consistent carbon price even harder.

This session covered a broad range of issues around the introduction (and scaling) of carbon markets. Ranging from more foundational questions of whether trading schemes, which have become the preferred method of setting a carbon price, are in fact the most optimal form, to the conditions, both within the market itself and the wider economy, that are necessary to support carbon markets of various forms.

The impact of the ongoing war in Ukraine and the impact on energy prices loomed over the entire discussion. The volatility of carbon markets to global shocks such as these and the destabilising effect that is has on the price (and therefore the decarbonisation incentive) led to the suggestion that maybe a carbon price imposed through taxation may be a better way of aligning the long- and short-term decarbonisation incentives (another key function of the market). Moreover, the decision to fix limits on the quantity of emissions and not their price within the market, with resulting price volatility, highlights why we shouldn't be reliant on these mechanisms to fund the green transition. We need to recognise that the transition will require more capital than could be provided through these markets and that they are unlikely to provide sufficiently stable price signals for investment and infrastructure decisions to be made of the back of them.

The remainder of the discussion centred on the requirements for markets (in all forms) to be successful and overcome some of the challenges previously highlighted. Three key elements were raised and discussed: the need to increase the size and scope of markets, increased cross border collaboration, and strong rules to govern market behaviour.

Carbon markets only cover approximately 23% of global emissions today which is insufficient to have a global impact of emissions reduction. However, there are developments in emerging markets engaging with carbon markets, as well as ongoing institutional discussions about if/how scope 2 and 3 emissions could be brought into a market mechanism, which would dramatically increase the coverage and have an impact on emission. One way to achieve this is to have greater cross border collaboration and a multilateral approach to both ETS' and voluntary carbon credit schemes. It was concluded that existing multilateral organisations have a vital role in helping to scale these schemes, particularly voluntary ones, and a vested interest in doing so in order to meet their own climate targets. The challenges with achieving such international coordination were widely commented on and echoed the need for strong rules to support the expanded markets. Learning from existing markets, such as the bond market, highlights the need for stronger market governance, particularly around transparency and market liquidity, with the potential of new technology such as blockchain providing an answer to some of these challenges. Many of these reforms would stabilise the market and support its growth and would be a significant benefit to both issuers and borrowers of carbon credits, across all of the carbon markets.

Reflecting on the initial caveat about the capacity of carbon markets, the session concluded by drawing out some of the challenges associated with a single carbon price and specifically the non-fungibility between emission reduction and negative emissions. Despite the benefits of larger more stable markets, speakers highlighted the need for potentially smaller markets (such as one dedicated to negative emissions), where inclusion in a single market might create unwarranted incentives. Despite the limitations of carbon markets, it was agreed that it would be an omission to discuss how climate technology and mitigation are financed without explicitly touching on the various forms and types of carbon market that exist, and their continued development should be pursued.

It was also noted that it is worth reflecting on the changing nature of geopolitical alignment and the future that international carbon markets play in this. As one speaker noted, the attendees were inherently multilateralist in their predisposition and outlook, a view somewhat at odds with the increasing de-globalisation and regionalisation we are currently seeing. While increased discussion and collaboration across borders is a worthy goal, the actions of many global players, not just Russia, with rising authoritarian tendencies in a number of countries globally necessitates a discussion about what ongoing multilateralism and shared markets means in this context.

These forms of discussion and their fruits may help to mitigate the rising illiberal tide we see globally and therefore their importance cannot be underplayed; however, their exact role and ability within a wider, changing geopolitical landscape is an area for future continued dialogue.

Conclusion

The scale of action required to meet the climate crisis is unprecedented, both in the movement of capital and technology. By bringing together politicians, academic and business leaders, the event was able to share the strong desire and appetite for greater and faster action and understand the various actions that the different players are undertaking to scale these requirements.

Among other innovations, this dialogue brought to light some of the cutting-edge advancements made in battery and hydrogen energy technologies. These two fields have shown huge potential to produce and store renewable energy effectively. Moving forward, extensive discussions were held that put the onus on addressing industrial engineering questions that determine the actual practical implementation of the cutting-edge battery and hydrogen technologies. The fundamental roadblocks in both these technologies are the high cost and questionable economic feasibility at the current stage. While this of course demands further research and development, it is important to not look at these technologies in isolation. Energy distribution is a big challenge that is often missed in the renewable energy technologies discussions. It is evident that existing grid technologies are not built to accommodate the direct integration of large-scale battery and hydrogen energy technologies, Therefore, it is important to look at emerging energy technologies within the framework of grid level distribution. Energy hubs that achieve efficient energy usage by creating localised energy production and consumption are promising alternatives to high voltage long distance transmission. Such distributed energy systems have the potential to function effectively in isolation. This reduces the power-supply gap and removes the toll on the power grids significantly. Overall, discussion of such practical large-scale implementation issues in this dialogue highlighted the importance of looking at present day implementation of emerging technologies, going beyond recent advancements as promises of the future.

In the area of synthetic biology, meanwhile, it was concluded that these tools definitely have the potential to replace conventional methods in chemical production. The challenge is to overcome the barriers to deployment at economically and commercially scale to replace the production of chemicals and related products currently using fossil fuels and highly energy-intensive existing technologies.

The financing and technological solutions to the energy crisis are necessarily symbiotic. The discussions that took place highlighted that collaboration and innovation is required across both to produce the solutions required. Moreover, while the discussion focused on the large-scale changes and solutions that people are working on, it was clear that a societal wide transformation was required and that no actors could be excluded. This includes the difficult discussions about what activities will not be permitted going forward such as fossil fuel extraction, and smaller players such as SMEs being brought onboard who may not have the time or resources to make the necessary sustainability changes themselves.

The dialogue contained significant discussion about the need for transparency and parity that can be brought about through regulation and international agreement. However, it is important to go further, to ensure that the state (in its various international manifestations) has the power to constrain and bound the excesses of the market and private industry. As highlighted at COP27, developments in the voluntary carbon market may see the rights of indigenous peoples put at risk or the food security of developing nations risked for the carbon offsets and biofuels for the flights of richest nations. Significant changes in capital flows are required, away from the financing of fossil fuels (which still occurs) and towards the green transition. As was briefly highlighted during the session, ensuring that current dirty activities are descaled and defunded is just as critical as scaling up technologies discussed here, greater and ongoing dialogue between these parties is needed in how to achieve this.

Finally, the discussions around technology and financing both highlighted in detail the need for multilateral cross border engagement to unlock greater action. However, growing geopolitical tensions create roadblocks to achieving this. The ‘rocky road’ scenario, as this is called by the IPCC, will make greater collaboration on these issues increasingly challenging and likely slow any eventual reduction in emissions. Nevertheless, there was universal demand, across the transcontinental collection of experts brought together for this discussion for such action and increased multilateral collaboration to continue between the organisations and companies present.