Partners Capital and the Clean Air Task Force Workshop: *Bringing the Energy Transition Down to Earth*

14th September 2022

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Introduction

On the 14th of September 2022, Partners Capital partnered with the Clean Air Task Force ("CATF") to host a workshop lunch titled "Bringing the Energy Transition Down to Earth" at the National Science Museum in London.

The goal of the workshop was to identify opportunities, challenge current narratives around the energy transition, and facilitate knowledge sharing and debate amongst investors, philanthropists, and non-government organisations involved in the energy transition. The speakers were asked to deliver an update on where the energy transition is today and delve into the practical challenges of scaling current and emerging solutions from an investment and policy perspective.

We heard from Armond Cohen (President and Founder, CATF), Stan Miranda (Founder and Chairman, Partners Capital), Steve Brick (Senior Advisor, CATF), Julian Critchlow (Advisory Partner, Bain & Company), and Lily Odarno (Director, CATF). The range of perspectives provided by the speakers led to healthy discussion and debate which was moderated by Oliver Morton (Senior Editor On Energy and Environment, The Economist).

Our Speakers

Armond Cohen, President and Founder, Clean Air Task Force

Armond Cohen is President of Clean Air Task Force, which he has led since its formation in 1996. In addition to leading CATF, Armond is directly involved in CATF research and advocacy on system requirements to decarbonise global energy systems, and nuclear energy. Prior to his work with CATF, Armond founded and led the Conservation Law Foundation's Energy Project starting in 1983. He is a member of the Keystone Center Energy Board, board member of the Nuclear Innovation Alliance, and former Board Chair of the Electric Power Research Institute Advisory Council. Armond is an honors graduate of Harvard Law School and Brown University.

Stan Miranda, Founder and Chairman, Partners Capital

Stan founded Partners Capital in 2001 and is Chairman of the firm's Board of Directors. He was previously the Chief Executive Officer from 2001 until June 2020 and also held the Chief Investment Officer position until 2016. He is a member of the firm's Global Investment Committee and has been the senior advisor to the Private Equity asset class team since the firm's founding. Previously, Stan was a Co-Founder and Managing Director of Evolution Global Partners, a Kleiner Perkins & TPG affiliated venture capital firm; Director of Bain & Company and member of its Worldwide Executive Committee (Chairman in 1997-98); member of Bain & Company's Private Equity Practice and Private Equity Investment Committee member; and Certified Public Accountant. Stan holds an MBA from Harvard.

Julian Critchlow Advisory Partner, Bain & Company

Julian is an Advisory Partner with Bain & Company working with clients to navigate the Energy & Carbon Transition. Formerly Julian was the UK Director General, Energy Transformation and Clean Growth at the Department of Business, Energy & Industrial Strategy. Prior to joining the UK civil service, Julian Critchlow was a Director in the London office of Bain & Company and head of Bain's Global Utilities & Alternative Energy Practice. He is a non-executive director of Nyobolt, a Cambridge based technology company pioneering fast charging energy storage systems. Julian was on the National Board of Employment for Excluded Group initiative of Business in The Community and Vice Chairman of the Channel Swimming & Piloting Federation.

Steve Brick, Senior Advisor to the Clean Air Task Force

Steve Brick is an independent consultant and has worked for more than forty years at the intersection of energy and environmental policy; his expertise includes utility regulatory policy, energy economics, energy technology assessment and air pollution control policy and economics. He is a Senior Advisor to the Clean Air Task Force. Steve is also currently an adjunct faculty member at the Kellogg School of Management, Northwestern University, where he teaches on energy, development, and climate change. Previously he served as Research Director at the Energy Center of Wisconsin, responsible for a wide range of studies on energy efficiency, renewable energy and on the environmental impacts of energy systems. He received his BA and MS from the University of Wisconsin-Madison.

Lily Odarno, Director, Energy and Climate Innovation, Africa, Clean Air Task Force

Lily Odarno is the Director of CATF's Energy and Climate Innovation Program, Africa. She leads CATF's effort to address the dual need of expanding affordable energy in developing economies and building a global decarbonised energy system. Her work focuses on development-centric energy transition pathways, utility markets, and technology innovation for low-carbon energy development in Africa. Lily joins CATF from the World Resources Institute where she led the establishment of the Institute's Energy Access Initiative in East Africa. She later led policy engagement and the uptake of data and analytic tools for integrated energy planning, in partnership with government energy agencies, ministries, private and civil society organisations across the region. Prior to that, Lily worked with the Center for Energy and Environmental Policy and the UNEP DTU Partnership, where she conducted research in West Africa under the former Clean Energy Development Program.

Executive Summary – Stan Miranda: Insights from the Partners Capital and Clean Air Task Force Workshop

We went into this event knowing that the energy transition is the single largest investment opportunity facing investors for the coming decade. Although it is a 28-year journey to net zero by 2050, the date most often cited in sovereign and corporate net zero plans, what happens between now and 2030 is what will most profoundly define the degree of success for global decarbonisation. I also believe that the best decarbonisation-related investment opportunities will present themselves in this period to 2030 as well.

I went into the workshop hoping to gain more certainty around the many areas of uncertainty surrounding the energy transition, including the pace of renewable energy penetration given land, transmission infrastructure, political and storage constraints. I was hoping to hear of technological and economic breakthroughs for green hydrogen and carbon capture and I was hoping to hear how electric vehicles would overcome raw materials bottlenecks and that the pace of charging station rollout had increased dramatically. Whilst I heard a lot that was new and learned a great deal, most of what I heard broadened the fan of potential outcomes for each brick in the decarbonisation pathway and implied more uncertainty, not less.

During the speeches and discussion, we heard from many in the room that this extreme level of risk and uncertainty pointed to diverse pathways pursuing multiple avenues to decarbonisation. Opinions included: do not rely only on wind and solar; bioenergy will be key; nuclear should play a key role; no one storage technology should be relied on; and we will need to lean on multiple storage technologies across the full range of discharge and time-shifting functionality. In addition to the broad array of opinions, we agreed that the transition pathway should not be beholden to a narrow range of suppliers selling raw materials, commodity inputs, or equipment. At the moment, China dominates many of these industries and what we have learned from recent geopolitical events is that we must diversify sources of supply and strive for greater self-sufficiency. This is not currently obvious from many of the most relied upon energy transition plans. What the workshop made clear was that policy makers, NGOs, philanthropic organisations and the corporate world should continue to put in motion plans for multiple, simultaneous pathways and hedge our bets.

Unfortunately, multiple uncertain pathways are a disaster for investors. It implies that some investments will work but that many will not and that, similar to "Cleantech 1.0", many investors will be left with capital losses for prolonged periods of time. During "Cleantech 1.0" returns were negative from 2005-15, a scenario that all investors looking at the energy transition want to avoid. Today, there are large investors writing large checks, but how long will this last if the returns don't stack up? The uncertainty caused by multiple uncertain pathways is also bad for attracting the required capital from the right sources. Starting with the technological breakthroughs needed, we are not seeing leading Silicon Valley venture capitalists take on this challenge. Their focus continues to be on the cloud, cyber, blockchain, fintech, biotech rather than climate-tech investments. Infrastructure investors are investing heavily in the energy transition space, but in some cases these investments are not the "government bond-like" investments that they typically deliver to their pension fund clients and can be much riskier. Utilities are signing off-take contracts with the infrastructure developers to get the renewables platforms built. At the moment infrastructure may be an attractive investment, but the risk of further renewables development without adequate storage may result in persistent periods of oversupply to the grid and this will make them more reluctant. My conclusion from the workshop was that not enough of the energy transition is on the right side of a tipping point. Others in the room do not agree with this conclusion. But, from our perspective, the facts do not prove tipping points have been reached.

What could push many nascent developments over the tipping point would be creating a cost to emitting carbon for all net emitters, i.e., introducing a global carbon tax and a revenue stream for all carbon reducers or sinks. These two elements would have to be connected through an efficient market. If all emitters had to pay the cost of offsetting their carbon emissions, overnight we would see clarity on which bricks in the energy pathway would have the greatest momentum. Carbon capture would gain huge capital inflows, driving technology investment up and cost curves down. Support for nuclear would likely return. Transmission networks would get built. Imposing a cost on all carbon emitters of course has a cost, and as we stated in our Partners Capital Energy Transition Investment Framework, households ultimately pay it. But that usefully gets at the core of the problem. It is our behaviour that will ultimately drive the greatest change.

The concept of a global carbon pricing market is entirely possible if a critical mass of Paris Accords' signatories could agree on the parameters of such a system. Many countries already tax portions of their economy on their carbon emissions but there are too many highly inefficient emissions trading systems (ETS) that can see value wiped out or catapulted as the scope of these ETS schemes change. Prices paid to carbon offset purveyors (i.e., tree planters) are disconnected from these marketplaces with gaps between the price per tonne of carbon varying from $3 for some voluntary offsets to $120 for some ETS prices. Global carbon prices or developing internationally accepted carbon border adjustment mechanisms are not at the top of the policy priority list, but this could well be the most powerful catalyst for adding clarity to the future energy pathway. This clarity would unlock huge investment capital. At present, the development of a global carbon price or internationally recognised carbon borders seems a long way off.

So where does this leave us from an investment perspective? We will steer clear of most infrastructure investments but will invest in the services and component products that are sold into the infrastructure builders and we will invest in the technologies that appear to be breaking through. Many of these technologies are being financed and built in partnership with national governments who are helping to get the scale needed to reduce seriously steep cost curves to foster penetration. There are a handful of exceptional private and public equity asset managers who are deep experts in these two areas and will continue to lead the pack.

In the meantime, we at Partners Capital will continue to dig deeper into the research and will continue to speak with more true insiders to refine our energy transition investment thesis. As part of our impact investing strategy at Partners Capital, we will continue to look for insight into which energy transition technologies will be most successful and make selective investments where we see a good match between risk and reward. Such opportunities do exist today, but there are just not enough of them.

Speaker Summaries: Bringing the Energy Transition Down to Earth

Armond Cohen introduced the purpose of the workshop; to challenge current narratives around the energy transition, which are often built around deterministic modelling – what needs to happen, rather than what is most likely to happen. Armond hoped that attendees would develop a deeper appreciation of the complex nature of the energy transition, and the need to factor human behaviour into policy and investment decision-making. Armond concluded by saying that as the energy transition is unlikely to be linear, and that a broad diversity of approaches will be required to take the energy transition from theory to practice.

Stan Miranda covered the enormous investment opportunity presented by the energy transition. Using the International Renewable Energy Agency's (IRENA) framework, Stan broke down the 37 gigatonnes of CO2 abatement that is required to limit temperature increases to 1.5°C. Stan critically evaluated the six technological themes (bricks) that IRENA's framework identifies as drivers of the energy transition including renewables, electrification, energy efficiency, hydrogen, carbon capture and storage, and bioenergy with carbon capture and storage (BECCS). Stan asked attendees to consider: 1) the most likely path of the global energy transition; 2) their confidence in the ability of emerging and current technologies to deliver the CO2 abatement needed; 3) whether the abatement potential of certain technologies was being overstated; 4) what policy changes were required to facilitate the energy transition; and 5) the investment implications of the energy transition.

Julian Critchlow spoke of his experience developing the UK's net zero strategy and covered the challenges of developing a policy that is both specific at a national and local level. Julian underscored the risks that the energy transition poses to global economies, but also framed it as an unprecedented opportunity that could lead to enormous economic development in the UK, as well as delivering emissions reduction. Julian stressed the importance of governments carrying out long-term planning as it related to the energy transition as there are unexpected challenges everywhere. One example Julian gave highlighted the need for the UK Treasury to plan a replacement for the £28B of fuel duty tax income currently paid by internal combustion engine cars given electric vehicles do not pay this tax.

Steve Brick summarised and challenged a series of mindsets and issues that he believes are impeding the energy transition's progress. The first mindset that Steve challenged was that of technological exclusivity, the idea that new technology alone can solve the energy transition. Steve focused, in particular, on challenging the notion that the current technologies that we have for wind and solar will be sufficient when combined with battery storage. The second mindset he questioned was the idea that money is no object when it comes to the energy transition. Often, he said, it is assumed that any solutions replacing current high-emission technologies will be accepted. More specifically, Steve pushed attendees to start thinking about the downstream impacts of the energy transition and touched on consumer behaviour. Consumers are not likely to support or vote for technologies and policies that increase the cost of their current lifestyle. Steve highlighted that many energy transition models and frameworks do not correctly account for human behaviour. The reluctance of individuals to live next to large-scale power generation (both fossil and renewable) or large-scale transmission infrastructure is an issue in densely populated countries. Steve gave examples of certain areas in Europe where consumers have already indicated (through voting) that they will not tolerate any further change to the natural landscape on account of renewable energy. Steve concluded by pushing attendees to start thinking about the energy transition with a systems-based approach that considers the technological, geographical and human elements of the energy transition.

Lily Odarno spoke about the idea of a just energy transition from the perspective of developing economies, which will be a consequential actor in the energy transition. Lily highlighted that there were shortcomings in the 2050 net zero frameworks and models used by OECD experts. These models and frameworks often assume that developing countries will quickly leap-frog to new, lower carbon technologies such as distributed wind and solar. In an African context, assuming that countries will leap-frog to these technologies is fundamentally at odds with the expectations and development goals of African governments. African governments aim to drive up manufacturing so that it becomes a substantial part of GDP and believe that 60% of the total African population will be based in urban areas by 2060. Fuelling such large urban populations with manufacturing-based economies will require much more than distributed wind and solar. In conclusion, Lily stated the need for OECD countries to be realistic about where the energy transition is heading in the context of the Global South rather than where they would like it to go. Africa has almost 600M people without access to modern electricity services and, absent breakthrough energy technologies, it will lean on its considerable fossil fuel reserves to address this issue.

Following on from these formal comments, Economist Editor Oliver Morton moderated discussion across the full group of attendees. The discussions went particularly deep in the six important areas of the energy transition with a summary of the key points made below. There were two sides generally taken to each of these debatable areas, but we have asserted which arguments seems to carry the most weight in our opinion. We are sure that many others in the room would not agree with our conclusions. As promised to the participants, we will not attribute any comments to any one individual.

Six Key Takeaways from the Workshop

1. **Net zero targets and the energy transition are breathtakingly ambitious in a historical context and in absolute terms.**

Workshop participants felt that there had been a sudden increase in interest and efforts to realise the energy transition in the last three years. Since there has been general scientific and popular agreement around the dangers of climate change for at least 10 years, they asked what had suddenly changed to galvanise action? The consensus at the workshop was that the IPCC's 2021-22 sixth assessment report had been a key driver of popular alarm. Combined with COP 26 hosted in the UK in 2021, the report spurred many companies, governments, and endowments into action and resulted in the setting of net zero targets ranging from before 2040 to 2080. As a reminder, the IPCC's sixth assessment report concluded that greenhouse gas emissions need to peak by 2025 to limit future global warming to 1.5°C above pre-industrial levels and avoid the worst impacts of climate change. This is the preferred scenario of the Paris Agreement.

Prior to targeting net zero, emissions reduction targets were often structured as a percentage reduction from a defined base level (i.e., "we will reduce CO2 emissions by 40% by 2030 based on 1990 levels"). In the case of many developed countries, these targets were largely achievable without completely overhauling their energy mix, transmission infrastructure, or relying on the development of nascent, emerging technology. But, most if not all of these need to occur to achieve net zero. In that sense, the level of uncertainty around the technologies needed to achieve net zero targets and the scope of the emissions reduction required is what makes net zero target setting so unusual and so ambitious in a historical context.

Sovereign leaders and corporate management clearly understand that net zero means getting to a point at which their net contribution of CO2 into the atmosphere is equal to the amount of CO2 taken out of it. Achieving this goal will require massive scaling of both proven and nascent technologies so that they can replace fossil fuel power generation. There was considerable doubt expressed in the room as to whether the necessary changes in consumption patterns needed would occur such that economies become more environmentally sustainable ("circular").

The workshop consensus was that, in absolute terms, the energy transition is one of the biggest megatrends in recent human history. Some participants framed it as the next industrial revolution because of the scale of the economic changes required. The changes required across energy generation, transport and consumption present an enormous investment opportunity, but the uncertainty caused by reliance on emerging technology and the lack of established winners and losers within these technology markets makes investing in this megatrend highly risky.

2. **Short term material cost rises will not negate long term cost-curve improvements or render learning curves redundant, but they do add to uncertainty around energy transition pathways.**

One participant highlighted that despite the scale of the energy transition challenge, there is a case for optimism. It took approximately 80 years to develop first terra watt (TW) of wind turbine generation capacity which was completed in 2017. The next TW of wind turbine generation capacity will be completed later this year in 2022. With each doubling of the units of volume in any industrial undertaking (think semiconductors and Moore's Law), academics usually point to a ~30% decrease in the unit cost (i.e., this is the slope of the cost curve against cumulative volume of production). If this doubling continues, wind power in particular will see significant relative cost improvement and will contribute much more meaningfully to the 37 GtC02 abatement required to get to net zero by 2050. But this concept applies to all aspects of the energy transition (e.g., EVs, charging stations, batteries, hydrogen electrolysers, carbon capture, and so on).

Another participant used the example of the decline in utility-scale solar costs as a case for optimism. They argued that this provided a good example of how solar (in conjunction with other renewable energy sources) could replace fossil fuel generation. The costs of utility scale photovoltaic (PV) systems have declined c.80% since 2010 and in some countries, this has made the price of solar electricity competitive with or cheaper than fossil fuels. If this pattern continues, more countries will implement scale solar power.

Both participants stressed that their learning curve and cost curve examples provided evidence of improvements in technology being non-linear. They added that new technologies often face resistance until certain tipping points, after which they become widely adopted (the so-called S-curve of technology adoption). This creates a positive feedback loop of further investment, improvement and results in even wider adoption.

Electric vehicle adoption was presented as another case for optimism. In 2021, 10% of global new car sales were electric. So far in 2022, 13% of global new car sales have been electric. In the UK, 33% of new car sales are electric. For this participant, this all pointed to cost-curve improvements (i.e., electric vehicles becoming more affordable) and imminent broader adoption.

This optimism, however, did not go unchallenged. It was argued that the declining costs of renewables and electric vehicles was being eroded by the current price inflation of raw materials. Raw inputs for solar panels and wind turbines spanning steel, copper and aluminium all increased 50%-80% in 2021 alone, negating much of the cost improvements of recent years. Whilst this set-back was acknowledged, the general opinion at the workshop was that this was likely to be a temporary challenge to the continuing trend of cost and efficiency improvements. However, this point did highlight how increases in input costs further widen the confidence ranges around: 1) implementation timelines for broader renewable energy adoption, and 2) return on investment.

3. **The current energy crisis in Europe may place the investment in the European energy transition on hold over the near term.**

On the back of the war in Ukraine, the question of resource and energy security has posed an unprecedented challenge to European countries. At the workshop, there were a range of opinions as to how this crisis would impact the energy transition in Europe.

Some participants felt that the crisis may result in the development of new energy security policies and accelerate the European energy transition. These participants felt that countries would look to wean themselves off Russian natural gas as quickly as they could. They believed that the crisis may usher in new level of collaboration amongst the European countries. The outcome of the crisis could be an urgent push to roll out non-fossil fuel dependent energy production but at the moment, it is unclear whether this collaboration will materialise.

Others felt that in the short term, the energy crisis-driven spending solutions which are being implemented by European governments places energy transition plans in jeopardy. To protect consumers from energy price shocks, European countries are implementing rescue packages for businesses as well as separate support packages for consumers. Germany has pledged €67B to support struggling energy companies and Finland and Sweden have agreed to provide €33B of support to their energy producers as well. However, according to Norwegian oil and gas producer Equinor, the support needs to go much further. Equinor estimates that €1.5T of support is needed to support energy companies across the European block just to compensate for additional collateral payments, which are required as a result of energy price volatility. Participants argued that that as these types of policies are rolled out across Europe, the total cost will mean that Europe's share of the c.$6T per annum investment required to realise the 2050 energy transition may well be put on hold.

Another participant highlighted that there was an additional complication caused by the spending. Once Europe is looking back on this current energy crisis, the amount of additional spending by governments (on top of the COVID 19 related debt pile) may mean that the energy transition will have to operate in a more capital starved environment than previously projected as governments will have less capital to deploy. In practical terms, this may mean that the level of required return for risky projects will have to be even higher than it was previously.

4. **A global carbon price is needed to de-risk energy transition investments but requires a critical political mass to become a reality. This is not likely in the near term.**

At present, energy transition investors are faced with multiple uncertain and geographically complicated energy transition pathways. From an investment perspective, the spread of outcomes is huge. The corollary is that for larger-scale projects such as infrastructure, a huge amount of risk must be shouldered by very patient capital.

During the workshop it was put forward that global "polluter pays" mechanisms (carbon taxes) should be developed and combined with payments for those sequestering carbon out of the atmosphere. The establishment of an efficient market linking the two would also be needed and allow price discovery. The participant felt that the huge disparity between the $150 per tonne price of some governmental emissions trading systems vs. the $3 per tonne price of some voluntary offset programmes also needed to be addressed. It was argued that a common carbon price needs to be applied between compliance and voluntary carbon markets, and that the scope of compliance carbon markets needed to be increased. If this were to happen, capital would naturally flow to developing more emissions reducing solutions and it would also incentivise companies to move to new, less-polluting fuels and technologies quicker. In 2021, the container shipping giant Maersk argued exactly this point and called for a $150 per tonne price on shipping fuel. The firm said that this was price required to push the industry – which accounts for c.3% of global emissions annually – into greener alternatives.

The challenge to implementing a carbon tax or a carbon border adjustment mechanism is that the policies require a huge amount of political momentum. Some participants in the workshop were optimistic about the chances of carbon taxes being implemented more broadly, soon. They believed that if a critical mass of Paris Agreement signatories were to push towards implementing carbon taxes and a carbon border adjustment mechanism, there was a fighting chance that they could gain approval from the World Trade Organisation (WTO) for such exceptions. They believed that getting approval from the WTO was the only plausible solution that would allow countries to implement carbon border adjustment taxes without encouraging international tariff wars.

A final criticism put towards carbon taxes or carbon borders was that it they are both very OECD-centric solutions. Essentially, the world's largest historical emitters are seeking to restrict emissions elsewhere in the world whilst maintaining their own competitiveness. On that basis a carbon tax was not likely to be politically feasible for the Global South in the near term.

5. **Rather than a "technology first" approach, the energy transition must be approached with a holistic, systems approach. Due consideration of human behaviour, supply chains, tax revenues, geography, and other consequences of the transition are essential for successful decision-making for policy makers and investors.**

Many of the most widely cited energy plans out to 2050 or other end points, piece together a linear logical set of discrete contributors that all add up to a reduction of carbon emissions from their present levels (c.37Gts) down to zero. There is rarely a scenario laid out with one or more bricks in the decarbonisation waterfall, failing. The discussion laid out the various aspects that may not be realised and for this reason, several participants highlighted the need to invest heavily in multiple technologies, hoping that enough succeed to achieve our goal.

In addition, we heard from one participant on the "feedback loops" that we need to consider in such plans or the "system effects". The example used was that of petrol station infrastructure being cut in half as electric vehicles continue to penetrate. Gasoline retailing is a huge industry with significant employment, tax revenue and property valuation consequences as it goes out of existence. Employment, property costs, raw material costs and tax revenues are just a few of the hundreds of consequences, intentional and unintentional, of the energy transition. These are not always in the plans but clearly need to be as part of a just transition.

During the workshop participants were encouraged to consider the challenges posed by human behaviour. Both "not in my backyard" responses to new infrastructure projects, and the fact that the energy transition must deliver price parity to current solutions, present large barriers to success. It was argued that consumers have a threshold at which they will not accept any additional change to the natural environment and that they also have a price that they are not willing to pay for electricity and heating. These two human behaviour points must be factored into any decisions about whether a technology, or policy is likely to be a success. Focussing on a technology-centric approach to policy or investment increases the risk of failure.

Alongside the considerations of human behaviour, participants were also pushed to consider the challenges posed by supply chains. Models often assume that technology will be the driving force of the energy transition: if a new technology can generate cheap, safe power, then it will be successful. However, what is often missing in evaluations of the scalability of technologies is: 1) whether the entire supply chain is scalable, 2) the resource cost of the technology and 3) where these resources are located. These stumbling blocks must be considered, alongside human factors, to evaluate whether a technology is truly scalable. The example used was that it is often assumed that solar power will be one of the key technologies for the energy transition (alongside wind). The general argument being that once solar power is scaled appropriately and combined with battery storage, solar power will be able to provide a large proportion of the electricity required globally (particularly as solar power costs are assumed to continuously decline). The challenge, however, is that not all the costs decline at the same rate over time and some costs may not decrease further at all. Recent commodity price shocks have led to increasing costs of raw materials and the situation in Europe has highlighted the challenges of resource dependency and how this can dramatically increase prices over a short period of time. Price shocks aside, current solar technology is also constrained by geographic area and one participant argued that as more land is converted to solar, the price for purchasing new land may increase, not decrease.

An additional consideration is that if a country plans to become reliant on solar, they will also need to rely on energy storage systems. As such, investors and policy makers need to apply the same supply chain and land use considerations to battery storage technology to any analysis that they are conducting on the scaling of solar power. Technologies cannot be considered on a standalone basis: there are stumbling blocks at each node in their supply chains and the supply-chains of supporting technologies must also be considered.

Geography must also be taken into account for successful investment and policy decision making. Both economic development and natural resources availability will play a key role in the energy transition pathways of individual countries. Current OECD frameworks and targets assume that the developing economies will leap-frog to distributed wind and solar. Unfortunately, this presumption does not match with the economic growth ambitious and development goals of these countries. Absent any near-term breakthrough technology development, fossil fuel rich African nations will harness their natural gas reserves to bring people out of energy poverty. Not acknowledging that developing economies are likely to harness their available resources to help themselves, and assuming that they will import technology manufactured from developed economies is dangerous for three reasons: 1) it underestimates the emissions that will be generated by consequential developing economies between now and 2050, 2) it encourages unrealistic estimates of how quickly certain countries can decarbonise, and 3) it encourages investors to assume higher global penetration rates of renewable energy than are realistic, which increases investment risk.

6. **Due to the skills required to effectively evaluate new technologies and energy transition risk, investments in the energy transition should be viewed similarly to industrial venture capital.**

Energy transition investment opportunities sit in a unique position. There is the potential for huge total addressable markets to develop but uncertainty around transition pathways makes it difficult to identify winners and losers. The core question that investors need to address is whether or not – factoring in potential human, supply chain and geographical factors – the technology that they are investing in will be able to compete with fossil fuel generation within the next 8 years to 2030. If not, the next questions they need to answer are: what needs to be true for this technology to be competitive and when is this change going to be realised? So far, very few investment managers are able to answer these questions confidently and master the energy transition opportunity set. This level of uncertainty means that the investment opportunities for the energy transition have a risk return profile similar to industrial venture capital. This means that investors need to be ready for long-term payoffs and high failure rates. With the true cost of capital being so uncertain for long term projects, investment managers will need to be able to navigate an environment where there is trillions of dollars of potentially mispriced capital. The consensus in the room was that the challenge of understanding the cost of capital for energy transition investments is likely to persist until there is a solution for pricing the carbon that is emitted or sequestered from the atmosphere.

Conclusion

We did not take time in the meeting to summarise conclusions, but we have taken the liberty in the Executive Summary to do so. The energy transition remains far from being on track and for many countries a 2080 target may be more realistic than 2050. To have a chance of achieving net zero by 2050, the pathways will need to be more specific in defining the full set of consequences of what is being added and what is being taken away to achieve the transition. In some cases, the consequences of reductions in fossil fuels from the economic system can increase the challenges for their long-term replacement (using the examples of decreasing hydrocarbon tax revenues, and higher costs of raw materials for wind, solar, batteries, and EVs). Individual countries will all need to rely on different mixes of existing and new technologies to achieve their net zero targets and energy transition goals. In many cases this invalidates "one-size fits all" models and frameworks which are guiding many of us.

A great number of critical developments needed to support the energy transition remain outstanding. New technologies need to be developed across all of the decarbonisation bricks of renewables, electrification, energy efficiency, hydrogen, carbon capture and storage, and bioenergy with carbon capture and storage, and their efficacy needs to be proven at scale. On the policy side, regulation needs to push towards broad application of carbon taxation, with taxation at the borders from exporting nations who are not taxing carbon inside their countries.

Despite these challenges, there is also a case for optimism. Wind, solar, batteries and electric vehicles continue to cost less and are being adopted more widely. There is also a huge amount of popular and political momentum behind reaching net zero and the scale of the energy transition presents investors with a huge investment opportunity set. Those investors with the deepest insights into the most likely path of the global energy transition, will see the most opportunity.

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