Green finance in China: achieving sustainability through finance

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Executive summary

In recent years, China has made ambitious commitments to tackling climate change, including targets to reach peak carbon emissions by 2030, as part of the Paris accord agreed in 2015. China will require US$6.4 – 19.4 trillion of green investment to reach these targets.

Green bond issuances have played an important part in raising capital for these investment needs. However, data on the use of proceeds is not yet sufficiently comprehensive to establish whether green bonds provide finance that is more effective or additional to traditional sources of finance. In *Economic impacts of green finance,* we examine the data gaps in determining the effectiveness and additionality of green bonds and set out how green bonds can become more robust sources of capital for China's low-carbon transition.

In this paper, we explore whether and how green finance can go beyond financing assets that are consistent with sustainability goals to finance the assets and fulfill investment needs required to transform sectors or the economy to a more sustainable model. In this respect, the context in which an investment is made, and in particular its role in building assets and activities critical to accelerating the development of a sustainable sector or industry model, determines whether the investment is green at a transformational level. Thus, to explore this deeper version of green finance we have assessed the possible transformation needs of multiple sectors, including power, chemicals, steel and coking coal in the context of two provinces – Sichuan and Shanxi – which have very different industrial bases and power supply profiles.

In Shanxi province we found that the most significant impediment to sustainability is the importance of coal, and coal related industries, to its economy. As much as 20% of provincial revenues come directly from coal mining, while related industries, support services and multiplier effects could push the dependency of Shanxi on coal to 60-80%. Without transformation models and strategies that address the ramping down and replacement of coal as the mainstay of the province's economy, Shanxi will never be able to achieve either environmental or economic sustainability, and could thus provide a significant political barrier to the national level goals for sustainability.

In Sichuan province, ample hydroelectric resources mean the province produces relatively low levels of carbon emissions, and from a climate change perspective it is relatively sustainable compared with most Chinese provinces. However, here we found that market design, system planning, and transmission systems at the national level reduce the ability of Sichuan to use its resources to contribute to higher levels of sustainability elsewhere in China.

In both cases, green investment and infrastructure needs are slightly less obvious when viewed through the lens of a sustainability led transformation. In the Shanxi case, for instance, a transition needs to support the province as it closes, transforms, and replaces coal assets within the economy, eg, by using some of them in a less carbon intensive, more flexible role alongside renewables, developing carbon capture systems to extend the life of some assets more sustainably while buying time to achieve a full transition, or by developing new sectors of the economy that can support workers. The critical question is what role a "deeper" green type of finance could play in these types of transformations.

With a new approach, we ask whether "deep green" finance can enable and accelerate these transformations and how. We have not found a single formula or process for deep green finance in China or elsewhere. Since the transformations that are needed will vary widely by industry, geography, resources, starting point, and competitive environment, we strongly suspect that there is no single formula, suggesting that a menu of approaches might be needed.

However, based on the needs of Shanxi and Sichuan, we propose four tests to determine whether finance is deep green finance:

1. It must help to overcome barriers to an industrial, sectoral, or economic transition that lead to near permanent and nearly complete sustainability;
2. It needs to work closely with all parties to the transition – policymakers, technology providers, project developers, workers – to align interests and minimize the cost and risk of the transition;
3. It should extend beyond bonds to the entire capital structure to address the range of financial needs and issues of the transition that can be resolved through finance;
4. It will need different principles of measurement and verification that are likely to be idiosyncratic and transition specific.

Recommendations

These four tests lead to related recommendations that suggest how we might create a green finance system focused on the transformations. Effective green finance, with the monitoring, reporting and verification standards described in the earlier papers, can provide a foundation for policymakers and investors can build transformational, deeper green finance. However, deep green finance initiatives will require additional steps to ensure that finance is effective in facilitating the transition, including developing:

1. A sector or economy level sustainability transition strategy.
2. An investment plan for assets and other financing needs.
3. A policy/market/finance framework that links policy development with finance needs.
4. Blended finance concepts for green equity, green bonds, and other types of green finance that optimize the policy/finance framework.
5. Monitoring, reporting, and verification standards specifically tailored to transformational green finance.
6. Strategic monitoring and adjustment of financing needs as the transformation develops and takes shape.

These ideas have been developed with extensive engagement with stakeholders from China Energy, China's National Institute for Clean and Low Carbon Energy (NICE), Shanxi Development and Reform Commission (Shanxi DRC), China Development Bank, People's Bank of China (PBOC), and Tsinghua University. In a global context, we have also been engaging on climate transition risk issues, in particular with the Network for Greening the Financial System, which counts the PBOC among one of its most active and influential early members. We believe that the future of green finance and its contribution to a highly sustainable future economy in China and globally, rests with further development of these deeper green finance concepts and methodologies.

1. Introduction

In the three companion papers to this work we have focused on whether green finance in China is redirecting finance towards more environmentally friendly investments. The results are inconclusive, mainly because the monitoring, reporting, and verification (MRV) systems and standards are not robust enough to track accurately the use and impact of the funds. For example, we found that 51% of green bond issuance did not specify the use of proceeds.[1] The lack of adequate MRV limits the assessment of the additionality of the proceeds to anecdotal evidence. That is, we cannot determine whether the green finance has made a real difference in the size and number of sustainable projects, except through the observation of a few example green bond issuances.

In this paper we go one step further, exploring how we might determine whether, and how, green finance might accelerate long-term systemic improvements in sustainability across entire industries or economies within China. We start with the premise that to encourage improvements to systemwide sustainability, what we call "deep green" finance would need to address one or both of two potential barriers by providing:

1. Finance to facilitate the transformation of the system itself. A collection of sustainable projects might not lead to a more sustainable system, particularly where integration of these projects creates rising costs or unsustainable side effects. In many cases, only a limited number of "sustainable" projects can be integrated into the existing market structure before the integration capacity is exhausted. At this point, the structure itself may need to change to incorporate new technologies, markets, supporting infrastructure, or regulations.
2. Finance and risk management to coordinate retirement of the existing, less sustainable system with expansion of the new sustainable system. Barriers to closing existing, but unsustainable assets, may be a greater impediment to sustainable systems than the financing needs of new sustainable assets. While the new assets slow the growth of environmental degradation, the existing assets may continue to pollute. Unfortunately, closing existing assets may lead to job losses, lost tax revenues, lost value to investors, and damage to the economy, all of which can create political and financial barriers to closure and improved sustainability. Further, a failure to coordinate the increase in production from sustainable supplies with the decrease from existing sources may cause shortages, gluts or other distortions, with knock on economic impacts that could undermine investment in improved sustainability.

Green finance as currently structured and measured often focuses more narrowly on whether the specific investment is environmentally friendly, rather than whether the investment will lead to greater economywide sustainability. And with good reason. If, as our work shows, it is difficult to determine what a green bond financed or whether that project financed delivered additional sustainability, then determining whether the finance had an impact on the larger system is even more difficult.

[1] The state and effectiveness of the green bond market in China, Climate Policy Initiative, June 2020, https://climatepolicyinitiative.org/wp-content/uploads/2020/06/The-State-and-Effectiveness-of-the-Green-Bond-Market-in-China.pdf

Nevertheless, the ultimate objective of green finance is to improve overall sustainability, so as we develop a perspective on green finance in China we need to explore what might be needed to make this further step towards deep green finance. To this end, we explore what might be needed for green finance to contribute to unlocking or encouraging the structural changes needed to transform industries and economies in China to high levels of sustainability, and how we might go about encouraging deep green finance.

As yet, we have found no established formula or process for deep green finance, either in China or elsewhere. Indeed, since the transformations that are needed will vary widely by industry, geography, resources, starting point, and competitive environment, we strongly suspect that there is no single formula, suggesting that a menu of approaches might be needed. For this paper we have looked at two different provincial energy systems – in Sichuan and Shanxi provinces – to identify key issues in those two systems that could require green finance, or other policy change, to unlock transformations to higher levels of sustainability. In each province, as well as at the national level, we have met with, interviewed, and developed workshops with energy companies and miners, development and reform commissions, financial institutions, investors, and academics, to identify potentially important industrial transformations and the related financing issues or questions. From these two short cases studies we draw initial lessons around the potential for "deeper green" finance in China. As a starting point we will begin with a summary of the mainstream green finance issues from the first papers, to provide a context for comparison.

a. Background: Measuring and tracking green finance and additionality in China

The key elements of evaluating the basic impact of green finance, as laid out in the first three papers, focuses on two main elements:

1. Whether the green labelled finance flows to projects or activities that are verifiably green or sustainable.
2. Whether there is sustainability value to the green label. That is, whether the finance is additional to the finance available if the label did not exist or whether the labelling and green finance market encouraged development of more sustainable projects, or projects that were more sustainable.

Charting the flow of green labelled investment to specific projects or activities is less straightforward than it might first appear. Green bonds may go to a company or a portfolio of investments and thus get intermingled with investments that are less "green" and capital may be shuffled through a company in ways that make tracking difficult.

Meanwhile, the first test of additionality is whether the financial flows encourage greater sustainability or merely replace investments that would have been made anyway with other sources of funding. In other words, we need to test whether the project or activity either proceeded or expanded because the finance was available. That is, investments encourage greater sustainability when they either:

- Provide access to capital markets and investment for sustainable activities that would not have had access to capital markets without green finance, or
- Reduce the relative cost of financing more sustainable investments – and in so doing encourage more sustainability by reducing the relative cost of sustainability activities.

Our analysis suggests that the results are mixed on both points of tracking verifiability and additionality. The results suggest that green finance is still in its early phases and lacks the data, standards, reporting and verification needed to ensure, or even properly assess how much of green finance in China flows fully to sustainable activities and is additional.

While the findings imply that more thinking, effort and monitoring needs to be directed towards data reporting, verification, and additionality assessment, while we are developing the green finance playbook, it is important to understand whether there is an opportunity to achieve transformational sustainability.

b. Sustainability as an economywide transition and “deep green” finance

Sustainability is a systems concept that is difficult to narrow down to targeted investments in specific assets. For example, it is not clear that adding electric vehicles to a transport system is sustainable when the addition leads to more coal-fired generation. Even adding renewable energy to an electricity system may not increase sustainability if the availability of cheap energy only encourages more energy use and does not reduce systemwide carbon emissions. More importantly, and often even more subtly, achieving full or high degrees of sustainability often requires wholesale changes in industry structure, value chains, and market mechanisms. For instance, electricity markets that have relied on the flexibility of coal-fired powerplants to increase or decrease output in response to changing demand, can integrate moderate amounts of renewable energy capacity before running out of capacity to adjust to consumer demand, as renewable energy is often dependent on sunshine or wind to generate electricity and is therefore less able to respond to demand. As the coal plants retire, the problem could get worse, unless the system changes to encourage behavioural, technological, and financial changes such as demand response, battery storage, or incentives to balance the supply mix to reduce flexibility needs. In other words, improving sustainability solely through a collection of sustainable projects could be self-limiting without the structural change needed to keep integration costs low and facilitate the retirement of the old assets.

From this perspective, achieving deep green finance first requires an understanding of the path and endpoint to greater sustainability for either an industry, or preferably, an economy as a whole. Thus, we need to answer four questions in developing deep green finance:

1. What would or could a sustainable industry or economy look like and what would be the potential or likely pathway to sustainability?
2. What are the barriers and potential catalysts to that sustainability vision?
3. How can finance help overcome barriers or activate catalysts?
4. How can progress be measured and what metrics could be used to guide finance along the deeper green path?

The path and sustainability objective will depend on circumstances on the ground, which is why we are using the Shanxi and Sichuan energy systems as examples to demonstrate the wide range of potential paths. Barriers and catalysts can be technological, behavioural, financial or political. In theory, green finance could contribute to all four. Finance can help reduce the cost of technological innovation including support for research and development or accelerated deployment of emerging technologies. Finance can also provide incentives that catalyse behavioural change. It can reduce the cost of capital and bring finance to projects that would otherwise not be financed (as in basic green finance) and help create new businesses, or organizational structures that are better suited to the transition. And lower costs can encourage policy change.

On the barriers side, the work of CPI Energy Finance over the last 10 years highlights the intersection of finance and politics and the centrality of financial risk. With the declining cost of renewable energy, and developments in electric vehicles, batteries, and other low carbon technologies, our analysis suggests that low carbon energy systems would be lower in total cost – once operating costs, investment and the cost of finance are appropriately considered – than the current fossil fuel-based regime. With costs continuing to fall, low carbon energy stems are increasingly more attractive. As we will suggest below, the advent of sustainable energy being lower cost than less sustainable energy should make low carbon energy the default options, and therefore calls into the question the difference between green finance and mainstream finance, leaving only the distinction between mainstream finance and finance that perpetuates environmentally unsustainable businesses, assets, or practices.

Despite the lower costs that make many sustainable energy projects mainstream, green finance has a role in overcoming the financial risks that come from the transition of the current energy system to a low carbon system. A transition to a lower carbon energy industry, or cement, steel, transport, or tourist industry, will involve significant structural changes to the industries and the economy. As these changes in structure shift value from one group to another, say from resources owners to manufacturers, or from miners to renewable energy installers, some previously valuable assets, market positions, or skills will lose value. Banks and investors, and the entire financial system, will face risk as assets that previously supported investment and credit no longer have sufficient value to support the debt burden. This risk lies in countries that lose export revenues, jobs, taxes and royalties from fossil fuel and other higher carbon exports, from investors and companies that lose significant shareholder value based on existing and future production from higher carbon resources, workers who lose their livelihoods as jobs disappear. Our work has indicated that if left unmanaged, these risks could undermine credit ratings, pension funds, government finances, financial stability, and economic growth.[2] This risk, and the uncertainty around the impact as it could spread through the economy, may be the greatest impediment to sustainability.

From that perspective, green investments may be significantly less transformational if they serve to further entrench structures and practices that prevent higher levels of sustainability, or if they delay needed structural change. On the other hand, investments that encourage structural change and transition may provide significant sustainability impact, even if the assets being invested in might not at first sense seem sustainable at all.

This risk, along with the requirements for a deeper green transition as highlighted in the four questions above, varies region by region. Our analysis of two very different provinces in China shows the differences between the transitions within China and begin to show the challenges of defining and measuring deep green finance.

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[2] Understanding the impact of a low carbon transition in South Africa, Climate Policy Initiative, March 2019: https://climatepolicyinitiative.org/publication/understanding-the-impact-of-a-low-carbon-transition-on-south-africa/

2. Shanxi province

a. Background

Shanxi is a relatively poor province about 500 km to the west of Beijing – GDP per capita is about two-thirds that of the Chinese average – with an economy almost entirely dependent on coal. Over recent years, ownership of coal mining has shifted from national companies to provincially owned companies. Companies owned by Shanxi province now account for about 80% of coal production, increasing the impact of coal on Shanxi fiscal revenues and its budget. Direct revenues to the Shanxi provincial budget from coal mining may be as much as one-fifth of GDP, while employment in mining and industries that support coal mining or are dependent on coal as an input could raise the dependency to 60%-80%. In 2017, over 75% of total industrial revenues in Shanxi were accounted for either directly by coal mining and fuel processing (47%), or electricity, steel, non-ferrous metals and chemicals where coal was the primary input (29%). As of 2014, coal mining directly accounted for 870,000 jobs in Shanxi and indirectly contributed many more.

While Shanxi is dependent on coal, China is dependent on Shanxi coal. The province produces around one-quarter of China's coal, or about one-eighth of all coal produced globally. Shanxi is also home to about one-third of China's coal reserves. By contrast, with around 37 million inhabitants, Shanxi has less than 3% of China's population.

Historically, China has sought to develop and improve the economies of the western provinces to reduce income inequality and the political pressure that inequality can cause. While developing coal resources in Shanxi has been an important part of these efforts, China has sought to industrialise Shanxi, first through developing industries, such as power generation, steel and chemicals, where access to inexpensive coal could provide a competitive advantage, but more recently into unrelated industries including high-end manufacturing, aviation, and technology. The Shanxi development plan includes these industries and five others as priorities for development.

Recognition of Shanxi's overdependence on coal has been an important rationale for diversification of its economy. Coal prices, for example, have had a disproportionate impact on the economy and the provincial budget. There is also recognition of the need to transition away from coal and the local environmental impact of coal. Shanxi has above-average wind and solar resources and has now installed 20GW of wind and solar power, just shy of 20% of Shanxi's total generating capacity. Shanxi has about 5% of China's total wind generation capacity. Shanxi's capital, Taiyuan, was also one of the first cities in the world to switch its entire taxi fleet to electric vehicles, with several EV manufacturers operating factories and other facilities there. The city has been listed as one of the top 20 cities in the world for EVs. Meanwhile, Shanxi has sought to close some of its less efficient coal mines, and has reduced coal mining slightly since 2015, but dependence remains very high.

b. Sustainability in Shanxi within the wider context of China

Unsurprisingly given the importance of coal, Shanxi's carbon emissions per capita ranked second among Chinese provinces, after only Inner Mongolia, despite having GDP per capita well below the Chinese average. The strong push into renewables and electrification may have helped slightly, but the issue is not one of provincial energy needs, but of carbon intensive exports to other parts of China. In fact, carbon emissions outside of Shanxi, from the use of its exported products (scope 3 emissions), are significantly higher than emissions within the province, while even the internal emissions are mainly produced for exported products.

More specifically, Shanxi ships much more than half of the coal produced to other provinces in China for power generation and steel-making. A large share of the remaining coal is used in powerplants to generate electricity that is exported to other provinces.

Shanxi also has a large steel industry, based around coal, that supplies steel used across China. More significantly, Shanxi is the major producer of metallurgical coal in China, producing about one-third of all coke produced in China, feeding steel mills across the country. This figure is particularly impressive since many integrated steel plants combine coke and steel production on one site. Thus, the coke trade in China is dominated by Shanxi, which produces most of the coke that is traded in China rather than produced on site. About 10-15% of Shanxi's coal production is used to produce coke in the province. Coke production represents around one-fifth of CO2 emissions from traditional integrated Basic Oxygen Furnace (BOF) steel making. Thus, Shanxi effectively imports 20% of steelmaking CO2 emissions for the coke it produces (for scope 1 emissions), while the coking coal Shanxi exports adds four times more CO2 emissions than is accounted for in Shanxi's provincial emissions (that is, scope 3 emissions).

Additionally, Shanxi has also used its coal resources as feedstock to the chemicals industry. Using coal as a feedstock is usually many times more carbon intensive than using oil or gas. Once again, these chemicals are primarily shipped to other Chinese provinces.

Thus, Shanxi's sustainability and carbon emissions are intricately interweaved with energy, power, steel, and chemical industry policy across China, yet most decisions that affect the industry are made in Beijing or elsewhere in China and not Shanxi itself. Shanxi is significantly exposed to the risk of changes to sustainability policies, but mostly those policies that are decided at the national level and in provinces outside of Shanxi that consume their coal, coke, chemicals, and power. The precarious economic dependency of Shanxi on coal is not lost on Beijing, with its goals to reduce inequality between regions in China and the aim to develop the economies of provinces such as Shanxi. In fact, it is possible that concern about the fate of provinces like Shanxi is an important obstacle to improving sustainability and lowering carbon emissions for all of China.

c. Transformational sustainability in Shanxi

Traditional green finance for energy efficiency, electrification, or renewable energy, may have an impact on the margin, but more efficiency and clean energy will have comparatively little impact on sustainability if all it does is allow more exports of emissions and emission intensive products. Transformational green finance must address the structural dependency of Shanxi on highly carbon-intensive industries. Specifically, we must ask:

1. How can carbon intensive industries such as mining and steel be replaced or made more sustainable?
2. If these industries are to be replaced, what strategic lever can Shanxi use when its industrial and economic leverage has so far been based almost entirely on access to inexpensive coal?

3. How much time does Shanxi have to make the transition, and how can that transition be made effectively?
4. What support does Shanxi need and how does that support and transition needs fit within the wider Chinese context?

With its plan to develop eight industries in Shanxi to diversify from coal, Shanxi and China have a first cut at the answer to the question 1, although it is likely that the path will be difficult, time-consuming, and require more than these eight industries. It is possible that support in developing one of these non-coal industries could have more green “leverage” than traditional green investments, but that is uncertain and will be difficult to prove. We did, however, identify options in the energy system that could buy time for the transition in Shanxi and increase the speed and sustainability of the transition.

1. Repurposing coal-fired powerplants to provide flexibility and backup services.
2. Developing carbon capture and sequestration (CCS) for power generation.
3. Developing CCS for industries including coking, steel, and chemicals.

Each of these have benefits, but also questions.

I.REPURPOSING COAL FIRED POWERPLANTS FOR FLEXIBILITY AND BACKUP

The path to sustainable energy in China, as elsewhere, lies with low carbon electricity, with renewable energy, and maybe nuclear power, providing a major share. Renewable energy has variable output that depends on wind, sunshine, or rainfall, while nuclear power is less flexible than thermal generation in its output. Thus, China, like other countries, will need to develop tools, such as energy storage and batteries and more effective demand management, to balance supply and demand across the day and year. With the cost of renewable energy having fallen below the cost of coal-fired power in most circumstances, the most significant barriers to a sustainable energy industry may emerge from the speed at which renewable energy and flexibility resources can be scaled up, and the transition costs involved in shutting down coal fired powerplants and coal mines.

One path to easing the transition is to use the flexibility of existing coal-fired generation to support the build out of renewable energy while batteries, demand management and other flexibility tools are developed. Since flexibility services such as reserves, daily and seasonal load shifting, are increasing in value, existing powerplants can in this way maintain value, even as they generate less energy and therefore produce less greenhouse gas emissions. Clearly, a plant that is used 20% of the time to produce valuable support services produces less CO_2 than a plant operating 80% of the time producing baseload power.

There are at least four ways that powerplants can provide more flexibility:

- Lowering minimum operating levels. Thermal powerplants have a threshold operating level below which operation is unstable. Since plants take some time – often hours or days – to shut down and restart, which can also be costly, plants are typically forced to run at minimum operating levels overnight or when there is excess solar or wind generation during the day to ensure that these plants can be available when the capacity is needed. The result is that coal plants often operate even while wind and solar energy is being curtailed. Lowering minimum operating thresholds from 70% of full capacity to 30%, more than doubles the amount of flexibility the plant can offer and reduces coal generation and renewable energy curtailment.

- Seasonal operation. Where renewable energy output is seasonal – as we will see in the case of Sichuan below – a second option is to run the powerplants only during seasons where renewable energy is not available, to allow smoothing across the year.
- Increase ramp rate. When the sun sets and PV output declines, lights and other source of demand may also increase, causing very rapid increases in load that needs to be met from other sources. One important flexibility need is the ability to increase output quickly – that is, ramping. Thermal powerplants provide ramping, but there is a limit to what a plant can provide. Investment and upgrading can increase the amount of ramping provided by each plant, sometimes reducing the number of plants that need to be kept online to meet the ramping need (sometimes plants are kept online to meet ramping rather than peak, further increasing the minimum operating constraint).
- Two-shift operation. The most controversial upgrade is to enable two-shifting of powerplants. Here, startup and shutdown times are decreased, and startup costs lowered – through enhanced control systems, and steam bypass systems and other investments – to enable plants to shut down and start up on the same day, for instance, to shut down completely overnight when demand falls or in the daytime when there is enough solar energy. While two-shift operation has been successful at relatively low costs in some places, there is resistance from operators over the operating risk and cost of the investments.

Each of these four options requires some investment, may require research, and likely requires new sets of incentives, which we will discuss below in the potentially transformational role of green finance. Transmission and interprovincial transfers will also need to be adjusted to enable the flexibility delivered to balance renewables across China, as is needed to provide maximum value.

From a transition perspective, increasing flexibility extends the value of powerplants, reducing the resistance that comes from the lost value, while increasing the amount of renewable energy that can be integrated into the system and reducing carbon emissions. However, coal consumption itself would fall, leaving the economic disruption to coal-mining dependent regions in place. In the case of Shanxi, powerplants represent only a small portion of the value and employment loss that provides resistance to the transition.

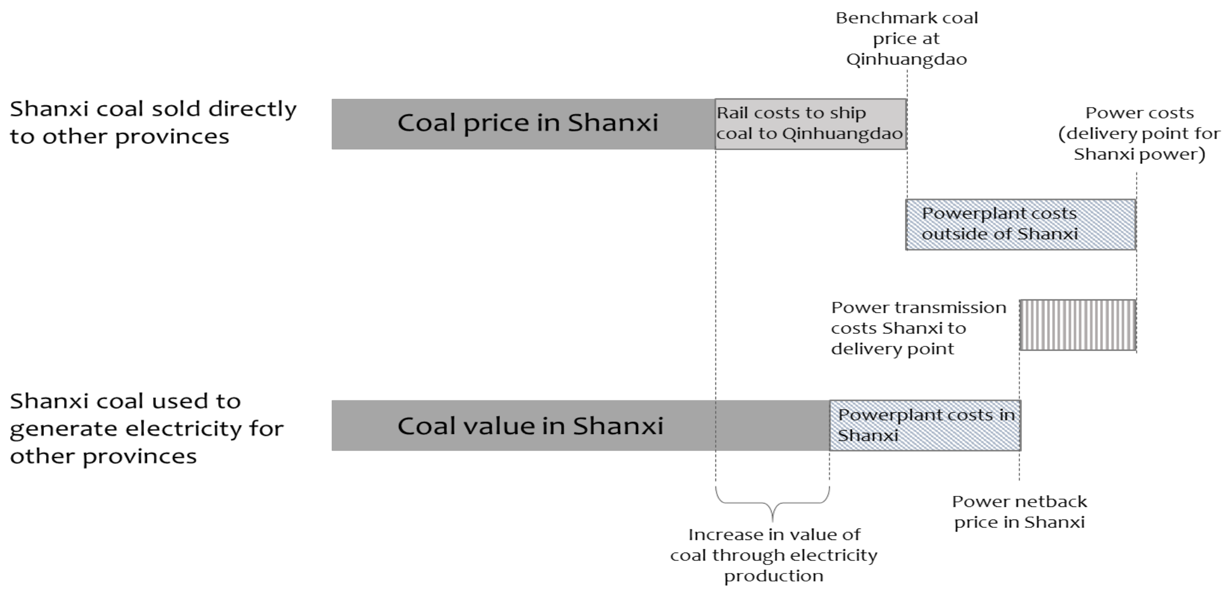
II. DEVELOPING CARBON CAPTURE AND SEQUESTRATION (CCS) FOR POWER GENERATION.

Ten or 15 years ago, CCS for power generation was widely regarded as one of the potential silver bullets for decarbonizing electricity. Today, the price per kWh of renewable energy has fallen below that of electricity from new coal-fired powerplants and is sometimes below even the variable and fuel cost of existing coal. Adding capitally intensive CCS equipment which also decreases the efficiency of the powerplants will only make uncompetitive coal less competitive. The argument that baseload power from thermal plants is needed has likewise been undercut by other technological developments including the declining cost of batteries. Finally, the argument that coal is needed to provide flexibility in the transition – as described above – holds merit, but also undercuts CCS, as the lower load factors of coal used for flexibility effectively increase the impact of CCS on cost as the capital costs of the CCS equipment are amortised over fewer kWh.

In the case of Shanxi and China, those arguments miss two crucial points; the value of CCS in reducing the transition impact on regions such as Shanxi and how the coal resources itself is valued and priced.

As in Figure 1, the price of coal in Shanxi province is effectively set by netting off the rail transport cost to ship the coal to Qinhuangdao port where coal in China is benchmarked. The price at Qinhuangdao is linked to global seaborne coal prices. The value of the coal resource in Shanxi is thus the benchmark price less the transport cost less the mining capital costs and fixed and variable mining costs.

Figure 2: Improving the value of Shanxi coal through power generation



Where the coal is used in Shanxi for power generation, the benchmark price becomes power generation elsewhere in China, which is likely to be the coal price at that location plus the powerplant capital, fixed and operating costs. Against this benchmark we subtract plant costs in Shanxi (which may be slightly lower than that in the other province) and add transmission costs. So there may be added value in Shanxi if transmission costs are lower than rail transport costs. This differential, and the relative cost advantage due to land costs and labour costs in Shanxi, justifies building of power plants in Shanxi for export to other parts of China.

Adding CCS costs increases the capital, fixed and operating costs. Crucially, where the cost of CCS is less than the current value of the coal resource, adding CCS reduces the value of the coal resource, but maintains the value of the jobs and infrastructure in place to mine the coal. In cases like Shanxi, where the scale of employment is very large and there are not yet enough alternative jobs to replace the nearly one million jobs in mining, there can be significant value in maintaining employment that otherwise would produce much less value or need to be relocated. In other words, a case could be made to develop CCS in Shanxi as a method of decarbonizing the provincial system while providing 30 years or more of additional time to develop alternative industries and sources of employment during the transition. This pattern is likely to hold only in countries with high employment in coal mining and large low carbon transition requirements. That is, China – and specifically Shanxi and Inner Mongolia – and potentially India.

III. DEVELOPING CARBON CAPTURE AND SEQUESTRATION (CCS) FOR INDUSTRIES INCLUDING COKING, STEEL, AND CHEMICALS.

The case for CCS in industry is distinct from power in some important ways. Most importantly, in many industries CCS may be one of the most competitive ways to decarbonize the industry in question. Issues around flexibility and load factor of plants become less important. The issues are specific to each industry. For Shanxi the important industries are steel, coke and chemicals.

Chemicals is interesting in that coal is a lower cost feedstock compared to oil, and security of supply is assured by domestic coal rather than imported oil. However, coal has a significantly higher carbon footprint than oil for chemicals production, which increases the cost advantages of oil, when carbon costs are fully accounted. However, depending on the process used to convert coal into chemicals, we understand that the cost of CCS for coal derived chemicals could be lower than for oil derived chemicals, due to the higher concentration of CO2 in the coal plant exhaust stream. Thus, if chemical production from oil is also required to capture its carbon emissions, a step that is necessary to achieve the UNFCCC objectives for greenhouse gas mitigation, then coal might be penalised less by CCS costs compared to oil-based chemicals in China, depending on an array of cost factors. Significantly more study is needed on the cost and competitiveness of coal to chemicals CCS, including an evaluation of residual emissions, but there may be the potential to maintain the chemicals industry more sustainably in Shanxi with CCS.

Steel currently has three competing and complementary paths to decarbonization. The first is material substitution, decreased use of steel, and increased recycling. This path, which depends on policy nearly entirely outside of Shanxi, would reduce primary steel production, and thus demand for coking coal and coke which are used mainly in primary steel, but not in steel recycling. CCS will provide no protection for Shanxi against the reduced demand for coking coal that will result.

The second two paths regard the production of the primary steel itself. One involves replacing coke – and therefore coking coal – with hydrogen as the reducing agent to convert iron ore to iron, the most carbon intensive part of steel production, with the resulting exhaust becoming H2O rather than CO2. The other involves capturing CO2 emissions from the current steel production process through CCS. The economics of the hydrogen path are improving as the cost of producing it falls, but the CCS path continues to look competitive in many circumstances. Here, the same arguments of the value of coal and employment discussed in CCS for power might continue to hold.

Coke feeds into primary steel-making as the reducing agent for iron ore as described above. Converting coking coal to coke accounts for about 20% of total emissions from steel production. Shanxi converts much of its coking coal to coke before shipping the coke to steelmakers. While capturing CO2 from the coking process might be relatively straightforward, as the CO2 concentrations from coking are relatively high, putting CCS on coking is only sustainable if the blast furnaces and basic oxygen furnaces of the downstream primary steel makers also fit CCS to their plants. In fact, one of the issues with CCS for steel is the multitude of CO2 sources that needs to be captured and aggregated to achieve low carbon goals, which raises the cost and increases the carbon footprint relative to the direct reduction of iron with hydrogen path. Thus, CCS for coking can only be deemed sustainable if it is part of a nationwide campaign or CCS supply chain cluster.

d. A vision for transformational sustainability in Shanxi

Transition in Shanxi must address the tension between supporting the economy and a sustainability transition when the main source of income and economic viability, coal, is inherently not sustainable. One potential solution is to improve the sustainability of coal during the transition to allow more time for the province to diversify and build new sources of income and prosperity. The main avenues include reducing the carbon footprint of coal through CCS in power and industry, while also converting the power fleet to enable greater uptake of zero carbon generation in Shanxi and outside. With this vision, a crucial question is what role can or should green finance play in enabling this transition.

3. Sichuan province

a. Background

Sichuan province provides a stark contrast to Shanxi. With mid-level GDP per capita compared with other Chinese provinces, and a relatively large population with a diversified economy including manufacturing, agriculture, minerals, Sichuan has the lowest CO2 emissions per capita of any Chinese province. Sichuan's total electricity demand is very similar to that of Shanxi, despite having double the population and a GDP per capita 20% higher. While lower energy demand contributes to lower emissions per capita, Sichuan's abundant hydro resources are the main factor behind lower emissions. Eighty percent of Sichuan's generation capacity is hydroelectric, with coal accounting for most of the rest. Sichuan has relatively poor wind and solar resources and has land constraints that have limited build out of renewables compared to provinces like Shanxi. Sichuan has plans to expand hydroelectric capacity with some reports suggesting that Sichuan could have one-quarter of China's hydroelectric capacity by 2030.

b. Sustainability in Sichuan within the wider context of China

Like all regions in China and elsewhere, Sichuan has energy industry sustainability opportunities in energy efficiency, transport, and to a lesser extent in renewable energy and decarbonization. Like Shanxi, however, the most transformational opportunity lies in relations to other provinces and the rest of China.

Hydroelectric production in Sichuan is highly seasonal. Although there is storage capacity that enables shifting of output over the year, most of the production falls during the rainy parts of the year. During these months, Sichuan produces more electricity than it needs, exporting excess when it can, while during drier months Sichuan uses its coal powerplants and imports to balance its needs. Unfortunately, Sichuan is unable to export all of its excess production. Meanwhile, coal plants in Sichuan spend long stretches of the year where they do not generate at all. Most Chinese powerplants still get paid on the basis of a fixed tariff per unit of output. The tariff has been structured so that powerplants recover their fixed costs for the first annual tranche of generation – it has typically been set at 5,500 hours per year – after which they recover only variable costs. While this system has been set to encourage higher availability of the power plants, in the case of Sichuan – and others as coal plants move towards becoming backup suppliers – where output is constrained by residual demand after hydro and other renewable energy generation, powerplants will struggle to recover their costs if they cannot reach the annual generation targets. The Chinese have experimented with different tariffication systems, but the incentives are not yet aligned with transition goals.

We further understand that part of the reason that Sichuan cannot export all its excess energy may not reflect transmission constraints, but rather these incentives in the electricity tariffication system. Neighbouring provinces, which also have hydro generation and therefore will have similar seasonality problems as Sichuan, may choose not to accept excess generation from Sichuan, either because of their own hydro generation or because doing so would reduce the capacity factor of their coal fired power fleet, and therefore make those plants loss making. Further afield in other parts of the country, wind and solar generation may also be curtailed at different times of the year, because the electricity system is not flexible enough to absorb the additional variable energy supply. Sichuan's hydro power could easily supply flexibility to balance more renewable energy. Long distance HVDC transmission lines are in place, but markets, incentives, and even the system analysis and management tools, do not seem to be in place to optimize the dispatch of energy and flexibility across the country. The result is that the hydro power in Sichuan is substantially undervalued, wind and solar will become increasingly more expensive to integrate into the system as a result, and additional coal fired generation will continue to replace carbon free energy from hydro, wind and solar, because the mechanisms to optimize the system and the incentives to provinces to do so are not in place.

c. Transformational sustainability in Sichuan

Basic green finance for energy efficiency, renewable energy, including wind, solar and additional hydro, low carbon transport, are among measures that could provide incremental sustainability benefits in Sichuan. Deeper green finance involves systemic change that will engender transformational sustainability benefits that would otherwise be constrained by the current structure, either because benefits are limited by provincial borders, or by the technology, incentives and operating practices employed. In the context of Sichuan, there are likely to include:

1. Further transmission expansion
2. Measurement, metering, and planning systems at the interprovince level that will allow development of flexibility markets and incentives to optimize production and flexibility.
3. Enhancements to the hydroelectric capacity that enables additional delivery of flexibility to where it is needed
4. Development of provincial and national level incentives and markets to manage balancing of hydro, wind, solar, and other energy sources.

While programmes to address these types of issues are underway and being tested in China, it is unclear whether the objectives are aligned with sustainability or objectives related to lowering the cost of achieving these integration or carbon savings benefits.

4. Implications for "deep green" finance

The needs of the Shanxi and Sichuan energy systems show how achieving a sustainability transition is often complex, with differing solutions applying to the same industry in different locations. Significantly, the contrast between Shanxi and Sichuan show how circumstances affect the ease or difficulty of the transition. In Sichuan, the abundance of hydro and the relatively green system makes the transition far easier than in Shanxi, with its heavy dependence on coal and the resulting need for management of both the winding up and winding down of elements of the transition. Despite the differences, both transformations are enmeshed in a national transition and will require coordination with national efforts at market reform and energy transition.

Together, Shanxi and Sichuan show how a range of activities, each with their own funding requirements, need to be integrated to achieve a deep and sustainable transition.

Table 1: Example funding needs for a deep transition in Shanxi and Sichuan provinces

Transformation/ Activity	Shanxi/Sichuan examples	Barrier to overcome	Potential finance need
Research and development – New technology development and piloting	• CCS for power • CCS for industry • Powerplant flexibility enhancements	• *Technological* • *Financial* (inherent risk in technology development)	R&D funding – *De-risking, blended finance, R&D support?*
Technology deployment and scale up - Manufacturing	• Factories to support equipment build (as below)	•*Financial* (investing in scale ahead of demand)	Facility and supply chain investment for manufacturers – *Credit/Equity?*
Technology deployment and scale up – Equipment	• Renewable energy • Energy storage (battery deployment and cost reduction) • Plant flexibility upgrades • Metering and control systems for incentives, real time and locational pricing, etc	•*Financial* (Large scale roll out of multiple technologies)	Project and corporate finance for energy companies – *Project finance? Corporate finance to energy companies?*
Supporting infrastructure	• Transmission • Information systems for control and integration	•*Financial* (low cost finance to reduce infrastructure cost) •*Political* (aligning infrastructure plans with transition needs) •*Political* (setting up pricing to reduce finance costs)	Infrastructure finance – Credit (Provincial or infrastructure companies)? Bridge financing?
Regulation, markets, concept development, and facilitating assets	• Enhanced energy markets and pricing systems • Analysis, deployment, and integration of transition options • Incentives and planning for optimization of powerplants, transmission, and dispatch	•*Behavioural* (creating new behaviours) •*Political* (overcoming inertia and incumbent interests) •*Technological* (developing new models and related tools and infrastructure)	Development and market restructuring funds – *Restructuring funds? Technological assistance?*
Risk management and phase out of existing assets/system	• Transition risk management for Shanxi province level revenues, retirement and repurposing of existing assets	•*Financial* (Maintaining economic growth despite phase out of industries; de-risking the transition) •*Political* (building a long-term plan and sticking to it against opposition)	Transition funding to smooth transition phase outs – *Insurance? Hedging? Long term transition assistance/credit?*
Retraining and personnel development	• Retraining of coal miners and development of renewable energy and storage installers, systems operators, etc	•*Behavioural* (building new skills and behaviours) •*Political* (overcoming entrenched practices)	Transition funding – *Structural loans and retraining loans?*

Each of these activities requires different types of funding, with different risks and counterparties, within different parts of the capital structure. In this way, deep green finance is likely to extend well beyond the confines of green bonds. But a critical question is when is finance transformational as opposed to basic green finance. Based on the needs of Shanxi and Sichuan, we propose four tests:

1. Deep green finance must help to overcome barriers to an industrial, sectoral, or economic transition that lead to near permanent and nearly complete sustainability

   Before finance can be labelled transformational, we need to understand what the transition is, what needs to be done, and what role finance can play in making the sector or industry as sustainable as possible. The plan should include both the sustainable end state, as well as the transition path needed to get to that end state. Both the end state and the transition are likely to have major funding needs that could benefit from green finance markets and concepts.

   Table 1 shows the types of activities and roles for finance that might be applicable in either Shanxi or Sichuan provinces. However, these are just illustrative, a long-term transition strategy needs to be in place to make sure that the finance and investment are heading in the right direction.

2. Deep green finance needs to work closely with all parties to the transition – policymakers, technology providers, project developers, workers – to align interests and minimize the cost and risk of the transition

   Finance cannot solve all sustainability issues. Generally, finance needs to support policy, although arguably policy needs to support finance as well. The objective should be to choose the combination of policy that sources the right type of finance at the most efficient cost, by allocating risks to those parties (investors, government, consumers, etc) best placed to bear the risk.[3] Above all else, deep green finance, or any type of green finance, should not just be a tool that fixes inefficient policy.

   Take the example of renewable energy in Shanxi province. We have not been able to assess specific projects and the related tariffs for wind or solar generators in Shanxi, however, we have seen that with relatively good wind and solar regimes, as Shanxi has, renewable energy should be less expensive per unit of energy than coal generated power, given pricing structures that reflect costs and risks and appropriate financing costs. Thus, one would expect that renewable energy should be the default for all new build technology and financing renewable energy would be the standard, mainstream financing opportunity in electricity generation. Thus, the difference between green finance and finance begins to blur, except that financing more carbon intensive generation would clearly not be green.

   However, markets, incentives, industry structure and policy all complicate the picture. First, in China, as elsewhere, tariffs do not always reflect the underlying cost or value of the energy produced. Thus, just because renewable energy might in abstract now be less expensive, the tariff offered might be less attractive than for less sustainable energy.

[3] Financing clean power: a risk-based approach, Climate Policy Initiative, 2017

Second, the markets and industry structure might impose risks on renewable energy that make it more expensive to finance than it should be. For example, a lack of incentives for demand flexibility or storage could increase the risk that renewable energy will be curtailed. If the tariff is set such that renewable energy generation is not compensated when output is curtailed, the risks to financers, who now have less certainty around how much they will generate each year and therefore how much they will be paid, increases markedly. Our analysis in Germany a few years back suggested that without increases in flexibility and/or changes to the curtailment impact on revenues, that curtailment risk could increase the cost per kWh of renewable energy by 50%. [4]

If policy or market and tariff design that create difficulties that green finance resolves, is it green finance if the only result is to correct for deficiencies in regulation, incentives and market design? Here we may run the risk of perpetuating poor policy by papering the defects over with green finance. Interestingly, in China there are also mechanisms that work in reverse. We hear that benefits of investing in renewable energy unrelated to energy costs – such as access to land or de facto reservation of capacity to build more renewables in future rounds – may add value to the projects and make them more attractive and easier to finance.

Policymakers and financers may not be the only parties that need to coordinate, as technology providers, among others might also need to be involved to optimise finance and its impact.

Research and development pilot testing or technology deployment are two important financing needs in the transitions in China. Favourable financing, such as that brought about by green finance, can reduce the effective cost of a demonstration project. However, the value of pilot tests lies in the knowledge gained from the project. Typically, this value is recovered in future projects, rather than the demonstration plant. Thus, financing would be difficult unless a clear mechanism is established to monetise the value of the knowledge for the demonstration investor. Typically, the mechanism lies with some form of policy intervention.

In technology deployment, the situation is more nuanced. While an industry is being developed, as was the case with solar PV a few years ago, the cost of that product might be higher than incumbent competing products, but falling fast. The benefit of subsidizing deployment lies in the belief that increased deployment will lead to learning by doing and economies of scale that will bring down the cost of the new product to the point where it is competitive, as was the case with renewable energy. In that case, the price for the new product might be set higher than the competing incumbent technology, with the increment to the tariff effectively paying for the learning that drives down long-term costs. Here, once again, it is a policy decision to transfer of some of that value to the early projects. The twist is that some of this value falls to the developer-investor, while some lies with the public good.

The final case for green finance is one that so far has been less explored, the role of finance in smoothing out the path for the losers in the transition. Numerous options for finance present themselves, including hedging of downside risk, securitization of write-

[4] Policy and investment in German renewable energy, Climate Policy Initiative, 2016

downs of regulated assets, transition assistance for countries and regions needing to invest in industries or infrastructure to replace the jobs and revenues associated with the high carbon industry or assets to be phased out. While the impact of this finance might be more transformational and thus in some ways more green than actual sustainability projects, there is not yet the nomenclature or effectiveness measurement available to classify or account for this type of green investment.

In any of these cases, the role of green finance should be to enable an effective transition with efficient and fair policymaking, bringing the appropriate finance, whether that is debt or equity or another form of finance or risk management, to the project to achieve the system transformation desired. Clearly, as each of these examples show, the truly transformational green finance can only occur when policy, markets, and finance are all aligned.

3. Deep green finance should extend beyond bonds to the entire capital structure to address the range of financial needs and issues of the transition that can be resolved through finance
Bond markets are most effective when dealing with relatively low risk projects, backed by government or corporate balance sheets or predictable and secure cash flows. Equity markets are better at financing riskier and less certain projects, while a host of other options, and blends of options, can address different mixes of risk, predictability and timing. As we see from Table 1, only a subset of those activities offer cash flows most appropriate to bond holders. The option is thus to either enact policy or market structures that guarantee cash flows or transfer risks in a way that makes bond financing feasible, or to explore different capital structures to address the risk. The partnerships described above, with the potential for government finance, multilateral development banks, commercial banks, and corporates all participating in the financing, leaves room for creative green financing approaches to optimize the use of finance, policy, and other levers.
4. Deep green finance will need different principles of measurement and verification that are likely to be idiosyncratic and transition specific

Taking each of these areas back to Shanxi and Sichuan and each of the categories of investment needed for the transition shows how most of the greenest potential investments fall into the less defined categories of investment. Critical questions remain on how to separate the impact of policy from investment that either lowers the cost of capital or makes more funds available. While the potential role of green finance remains important, the paramount requirement of deep green finance seems to be to work within a structure that leads towards a vision of the transition and a continuous improvement of the incentives that lead to that transition.

While our research has shown that even today's basic green finance lacks effective MRV to ensure that green finance is useful and productive, the analysis of the needs of a deeper transition in Shanxi and Sichuan demonstrates how much further we can, and need to, proceed to tap the full potential of green finance. A central indication is that for the deepest of green finance, standardised measurement may be impossible. Thus, deep green may not be a mass market financial product. However, with strong policy and financial market buy in and cooperation, there is a potential to drive truly transformational change.

5. Recommendations

Effective green finance, with the monitoring, reporting and verification standards described in the earlier papers, can provide a foundation for policymakers and investors to build transformational, deeper green finance. However, deep green finance initiatives will require additional steps to ensure that finance is effective at facilitating the transition, including the development of:

1. A sector or economy level sustainability transition strategy that outlines the measures needed for its transformation. As in the Sichuan and Shanxi examples above, the strategy must identify the paths for achieving sustainability, establish how various technology and policy options fit into that strategy, identify the potential barriers to implementing the strategy, and suggest solutions that help overcome these barriers.
2. An investment plan for assets and other financing needs that identifies which assets and activities will need to be developed built to implement the transition strategy (again, as in Table 1).
3. A policy/market/finance framework that links policy development with finance needs. In particular, this interface needs to address allocation of various types of risks to achieve the most efficient and effective transition. For example, policy, taxation, and market design can transfer risks between investors, government and consumers, such as energy price risk, cost risk, project completion risk, demand risk, or weather risk. Policy can also create its own policy risk. Transferring these risks to investors will increase financing costs, as investors need to cover the costs of managing these risks. Increased financing costs could pay for themselves if the investor/developer can manage these risks at a relatively low cost compared to the cost of consumers, or the government bearing these risks. Significantly, the risks and the ability to manage those risks are likely to shift over the course of the transition, with technology risk in early phases of a transition gradually being replaced by operating, execution and market risks.
4. Blended finance concepts for green equity, green bonds, and other types of green finance that optimize the policy/finance framework. While the transition strategy and framework will effectively allocate various risks to investors, consumers, or government, the capital structure can further enhance the financial efficiency of green investment and further reduce costs. By allocating portions of the green finance to more risk-tolerant green equity investors and other portions to more risk averse green bond investors, while allocating other elements of risk and finance to governmental or quasi-governmental financial institutions such as development banks, deep green finance can optimize the capital structure in the same manner that development finance optimizes capital structures more generally.
5. Monitoring, reporting, and verification standards specifically tailored to transformational green finance. In addition to the standard green finance MRV requirements that will focus on use of funds and additionality, MRV for deep green finance will need to develop separate measures that show how investments are consistent with the transformation strategy and accelerate the transformation strategy.

6. Strategic monitoring and adjustment of financing needs as the transformation develops and takes shape. Unlike standard green finance, the definition of what is transformational is likely to change over time as the sectoral transformation itself evolves. In the first instance, finance needs will evolve, for instance where early stage technology development finance might be replaced by deployment finance. Further, strategies themselves will evolve as technology changes, or as markets evolve. New technology discoveries or changes in consumer behaviour or needs are likely to impact what will be needed by the transition. The strategy will need to react to these changes, and the green finance and MRV will need to adapt as the strategy changes.