AFRY THINKPIECE: IMPLICATIONS OF CHINA'S PROPOSED 2060 CARBON NEUTRALITY

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IMPLICATIONS OF CHINA'S PROPOSED 2060 CARBON NEUTRALITY

AFRY Management Consulting's China team reacts to China's recently announced 2060 carbon neutrality ambition:

- We set the scene by discussing the announcements, China's emissions and energy situation, before
- examining potential implications for three sectors that account for over 90% of domestic carbon emissions: electricity, industry and transport; and finally, we draw some initial conclusions for global energy markets focussing on fossil fuels and the implications for future cost trajectories of key low-carbon technologies.

Key messages

China currently emits close to 10Gt of CO_2 (almost 1/3 of the global total). Its fossil-fuel based economy is expanding and is expected to continue to do so, the country is undergoing rapid urbanisation, and domestic demand for energy-consuming goods and services are growing as income levels rise. Achieving carbon neutrality by 2060 while maintaining this growth is a monumental task.

Meeting the target is likely to require a robust acceleration of existing decarbonisation measures and the adoption of a range of new ones. Actions will need to be scaled up soon and sharply.

- Peaking emissions in 2030 will leave 30 years to achieve carbon neutrality. This will require reducing, sequestering or offsetting approximately 300Mt of carbon dioxide each year between 2030 and 2060 – (almost) the equivalent of decarbonising France annually
- Three sectors of the economy, namely electricity, industry and transport make up over 90% of emissions. Emissions are driven by the use of coal, oil and natural gas which together make up 86% of primary energy consumption. These sectors and fuels will be significantly disrupted
- The electricity sector, almost 50% of emissions, may need to undergo almost total decarbonisation.
    - We anticipate the deployment of over 2000GW of new wind and solar capacity by 2050, primarily displacing coal. This level of deployment may to be enhanced with scaled-up policy ambition aiming to meet the target (to be outlined, perhaps in initial forms, in the upcoming 14th Five Year Plan)
    - According to our current modelling, emissions in the sector could fall by over 60% by 2050 over 2020 levels (Central Scenario), suggesting the need for direct policy action to accelerate emissions reductions for the remaining 40% in order to reach net-zero by 2060

- Approximately 600-700GW of coal capacity could fall out of the system by 2050 due to plants retiring and project economics, though some new gas plants are likely to be deployed. A breakthrough in CCS[1] will be needed to abate approximately 600GW of coal and gas generators in the decade to 2060 - or these will have to be encouraged offline by new market mechanisms, or mandated to close
- This very intermittent future system will require huge investment in flexibility and balancing – for existing thermal plants, and of course batteries and possibly hydrogen particularly as of the 2030s when firm thermal capacity begins to fall off the system
- Nascent markets will similarly experience the impacts of intermittency and low-marginal cost generation – with important considerations for investors in China's renewable energy projects
- Natural gas may be challenged to play a significant role as a transition fuel, or source of flexibility, due to high costs – with important consequences for LNG[2] importers
- New electricity market designs, already under development, will need to be structured such that they enable the transition while limiting costs to consumers and government

- Accounting for over 30% of emissions, China's industrial sector will also need to undergo deep decarbonisation.
  - Current programmes to electrify the sector - boilers, kilns and other processes - are likely to be accelerated
  - Fuel substitution (coal to gas or eventually hydrogen) may also accelerate, though careful consideration will have to be given to the use of gas due to its high costs
  - Energy efficiency programmes for industry will be strengthened
  - CCS for certain industrial processes will likely be necessary
- In the transport sector, which drives approximately 10% of emissions, efforts are likely to build on existing programmes which initially aimed to reduce China's 60% reliance on imported oil.
  - A potential ban on passenger ICE[3] sales by 2035-3040, proposed in 2017, may need to be brought back into focus

[1] Carbon capture and storage

[2] Liquefied natural gas

[3] Internal combustion engine

- Expected scaled targets for EV deployment will require expanded investments in charging stations and the continuation of some targeted subsidies across the EV value chain
- Decarbonising trucking, shipping and possibly aviation will require overcoming bottlenecks facing the hydrogen industry – in particular transportation infrastructure, but also addressing the cost competitiveness of green hydrogen

- Globally, China accounts for over 50% of global coal, 14% of oil and 8% of gas demand – what happens to demand in China for the fuels has global implications
  - The measures described in this report would signal an eventual retreat from global commodity markets. This could begin before, or after the 2030 peak emissions target – impacting on commodity prices and long-term contract negotiations. Decades-long investment decisions in coal, oil and gas assets and markets globally will now need to consider China's decarbonisation pathways. Key will be to understand the timing and trajectory of China's shift in these markets
- The massive supply chain investments China will have to make in wind, solar PV, batteries and possibly also hydrogen production (electrolysers, methane reformers, or pyrolysis) will drive the costs of these technologies down – creating new opportunities for the global energy transition as clean tech costs are reduced. Investors and governments worldwide will need to re-consider strategies in order to account for long-term cost trajectories

What was announced?

On Tuesday President Xi reiterated China's Paris Agreement INDC[4] commitment to peak emissions by 2030, and then announced for the first time a new target to achieve 'carbon neutrality' by 2060.

The announcement comes as an ambition, falling short of putting forward a hard or legislated target. However, the (Chinese) phrasing "diligently strive to achieve carbon neutrality by 2060" suggests a relatively high level of ambition compared to other potential formulations.

More details, including some indications relating to the mechanisms to be put in place, are expected in China's forthcoming INDC (now expected to be scaled-up) as well as to bolster targets for 2025 in the upcoming 14th Five Year Plan.

[4] Intended Nationally Determined Contribution

Is ‘carbon neutral’ the same as ‘zero-carbon’?

No, but rather it can be understood as ‘net-zero’ in the European context. While no official domestic definition of ‘carbon neutral’ has been put forward by the Chinese government (neither has the eventual accounting methodology to be applied), it is broadly accepted to refer to achieving net-zero carbon emissions by balancing economy-wide emissions with carbon sequestration and carbon offsetting.

This vision for future decarbonisation allows for some emissions to occur where fully decarbonising some sectors is currently seen as technically impossible or too costly within the expected timeframe – for example aviation, shipping and some industrial processes.

When considering how to achieve carbon neutrality, it is usual to highlight three avenues:

- Reducing emissions, in particular in electricity, industry and transport sectors by deploying low-carbon or renewable electricity generation, electrifying industrial processes and modes of transportation
- Offsetting carbon emissions, for example by reducing emissions elsewhere in order to counterbalance for local emissions, or across sectors
- Carbon sequestration, in which carbon emissions are captured from industrial, power or other processes that emit carbon and are then stored (possibly in a carbon sink) in order to prevent its entry into the atmosphere. Combining sequestration with some processes, such as the burning of biomass for heat or electricity production, can result in net removals from the atmosphere, as can afforestation or the capture and storage of carbon directly from the air

In broad terms, these strategies are already underway, proposed, or under research and consideration in China.

What’s the story of China’s carbon emissions?

Reaching almost 10Gt in 2019, China currently accounts for just under a third of global carbon emissions. Economy-wide emissions have grown 20 times in just over 50 years as the country’s economic expansion accelerated over this period and was fuelled primarily by coal, a locally abundant and therefore cheap source of energy.

Two sectors, power and industry, together account for more than 80% of emissions. This reflects their sectors’ position in primary energy consumption and their continued reliance on coal for energy. Efforts to achieve carbon neutrality in 2060 will need to focus on these two sectors as a priority.

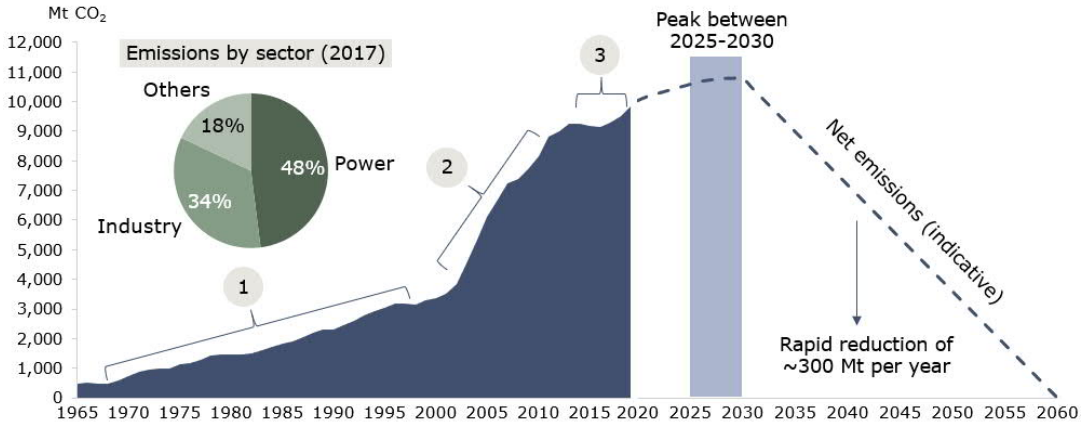
As shown in Exhibit 1 below China's emissions trajectory have experienced a number of phases:

1. Rising steadily as 'Reform and Opening' since 1978 gradually opened up the economy
2. Sharp increases from the early 2000s to the early 2010s after China's accession to the WTO[5] and waves of FDI[6] drove economic expansion
3. A slowdown from 2013 as a transition of growth drivers to less energy-intensive services got underway

Moving forward to achieve the target carbon emissions will need to trace a steep decline in just 30 years – following the target peak of carbon emissions in or around 2030.

Current domestic projections estimate emissions to peak near to current levels between 2025 and 2030 at around 10-11.5 Gt. Achieving carbon neutrality thirty years later will therefore mean reducing net emissions by approximately 300 Mt per year, or roughly equivalent to decarbonising France every year.

Exhibit 1 – Historical evolution of carbon emissions



Source: BP Statistical Review of World Energy, CEADs, AFRY analysis

Which fossil fuels underlie these emissions?

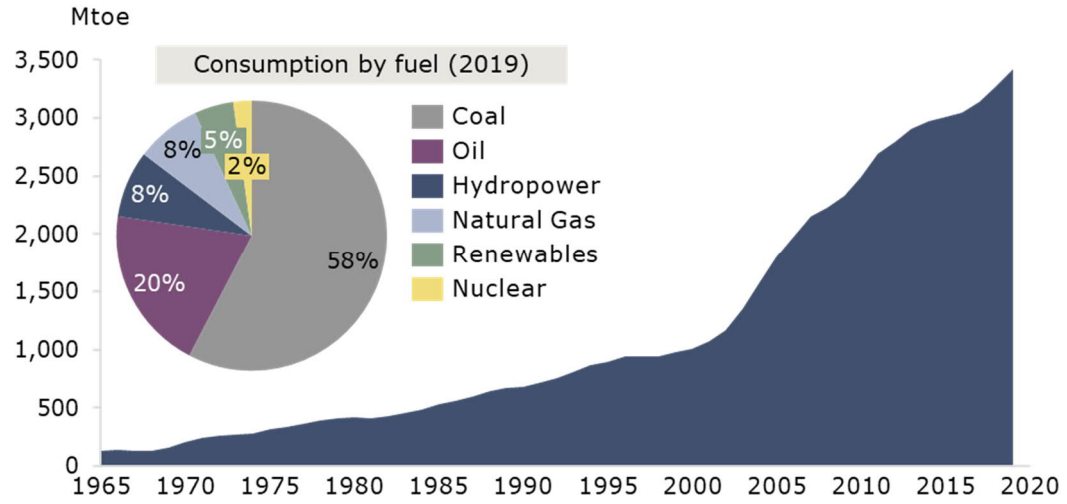
As elsewhere, China's economic expansion has been driven by the consumption carbon-intensive fossil fuels, and as such the emissions trajectory shown in Exhibit 1 above is very similar to the evolution of energy consumption shown in Exhibit 2.

By 2019, economy-wide primary energy consumption stood at 3,384 Mtoe, having expanded 25 times relative to half a century ago.

[5] World Trade Organisation

[6] Foreign Direct Investment

Exhibit 2 – China's primary energy consumption



Mtoe: million tonnes of oil equivalent. Source: bp Statistical Review of World Energy

Three main fossil fuels exist in China's primary energy mix – coal, oil and natural gas.

Coal is the traditional backbone of China's energy supply (accounting for 58% of primary energy consumption) – used widely for power and heat generation, as well as many industrial processes essential to the economy. With an approximate emissions content of 3.8tCO_2/toe, it will also likely to be primary target of emissions reduction measures taken to meet the 2060 target.

Oil makes up 20% of China's primary energy consumption, used mainly in chemical, transport and manufacturing sectors, and with a carbon content of 3tCO_2/toe is a potent source of emissions. Reducing oil's role in China's energy mix will therefore be core to meeting the target, but is also an energy security priority – driven by China's lack of oil resources and approximately 60% import dependency for this fuel.

Natural gas makes up 8% of the primary energy mix, and is mainly a fuel in industrial processes (currently being promoted to replace coal), heat and power generation and residential consumption for cooking and heat. A much cleaner fuel in terms of its carbon content (2.3 tCO_2/toe) natural gas may be considered as a transition fuel from coal as China decarbonises, but it may struggle to achieve this position due to China's 30% import dependency on the fuel and its high costs relative to renewables.

Non-fossil fuels – primarily hydropower, but also nuclear and renewables account for 17% of the primary energy mix. Rapid growth in these sources of energy are expected as fossil fuels fall out of the mix.

What could the new target imply for the key sectors driving energy consumption?

In this thinkpiece we focus on three key sectors responsible for more than 90% of China's carbon emissions – electricity, industry and transport. We consider at a high level some of the likely future initiatives and implications for these sectors following the announcement of the carbon neutrality target.

Electricity

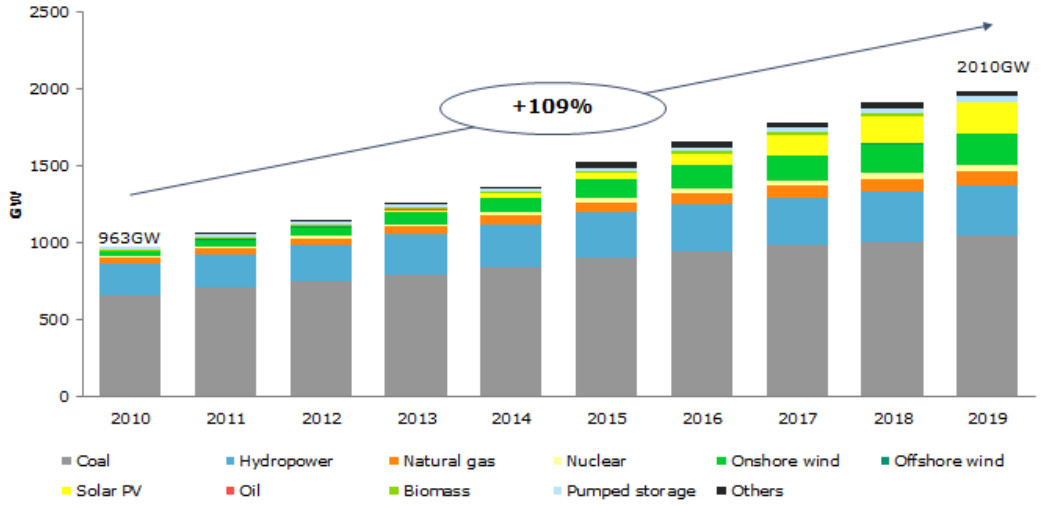
Achieving carbon neutrality by 2060 would require the almost complete decarbonisation of China's electricity sector, currently responsible for almost 50% of carbon emissions on its own.

This will require aggressive policies to support decarbonisation by deploying more low-carbon, investing in and scaling new technologies and putting in place the market arrangements that would enable these investments to take place while limiting the costs of the transition to consumers and the government.

With over 7000TWh of demand China's electricity sector is the largest in the world, representing approximately 12 times the scale of Germany. A generation fleet of over 2000GW meets this demand, composed primarily of thermal coal units, accounting for over 60% of output. CCGTs, almost entirely combined with heat loads, have been deployed at comparatively moderate levels (primarily due to high fuel costs) with 87GW on the system by the end of 2019. China's oil generation has mostly already been closed due to current emissions standards and restrictions.

The past decade though has also seen the world's largest expansion of intermittent renewables take place in China generation, with over 400GW of wind and solar PV brought forward financial incentives, falling technology costs and a range of targets outlined in government plans (including a 31% non-fossil fuel generation target by 2020, rising to 50% by 2030).

Exhibit 3 - 10-year evolution of generation capacity by type



Sources: NEA, NBS

As is the case globally, the decarbonisation of the sector is therefore already underway though a long road lies ahead to achieve almost complete carbon neutrality by 2060.

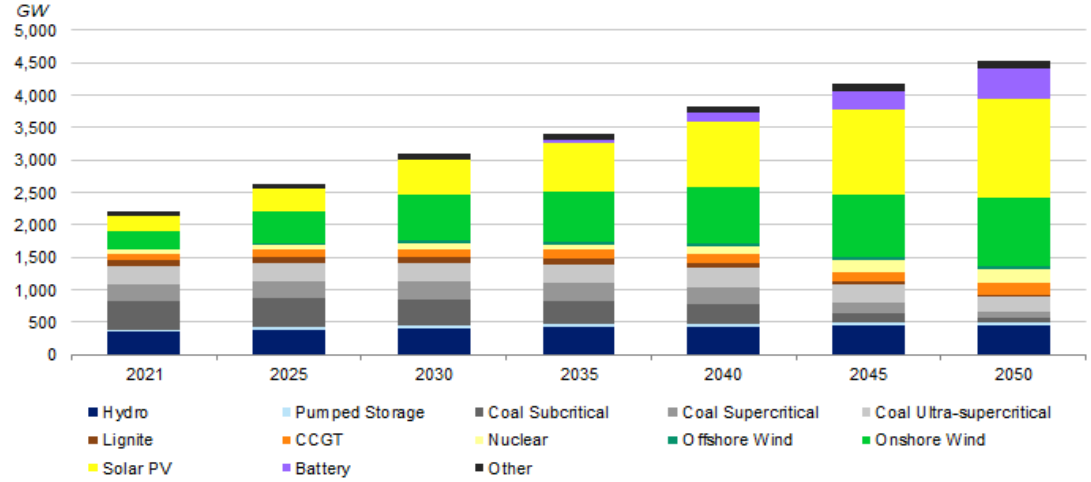
Based on our China BID3 electricity market model's Central Scenario, we anticipate decarbonisation to progress rapidly in the electricity sector – with more than 2000GW of new wind and solar PV to be brought forward by 2050.

Both wind and solar PV are already competitive on a levelised cost basis with new coal plants in some locations across the country. As wind and solar PV deployment progresses with continued government support and due to falling costs (we project wind and solar LCOEs to fall a further 20-30% by 2050) the economic lifetime (as opposed to the technical lifetime) of many of China's coal plants could already be shortened due to market forces. If government policy were to accelerate this deployment further technology cost reduction due to the scale of investment is likely to accelerate this trend.

Nevertheless, we still expect almost 400GW of coal units (primarily ultra-supercritical) on the system by 2050, as well as almost 200GW of CCGTs[7]. This leaves 600GW of fossil-fuel generation capacity to be replaced or abated in the decade out to 2060 (or earlier), or approximately 13% of the generation fleet.

[7] Combined cycle gas turbine

Exhibit 4 - AFRY 2050 capacity projection (Central Scenario)



Source: AFRY Analysis

Our model suggests that emissions from China's electricity sector could fall 60% by 2050 relative to current levels. The complication is therefore how to remove or abate the next 40%. Clearly, accelerated action will be needed across a range of policy and market solutions. These could include:

- Massive investment into more onshore and offshore wind, utility and distributed PV, as well as other renewable energy sources including hydropower (where we anticipate some new capacity deployment, though constrained by a lack of unutilised waterways)
- An expansion in investments in new nuclear capacities, though these are likely to be regionally limited due to water resource availability
- Scaled investment in the renewable energy supply chain across expanded manufacturing capacity as well as R&D to bring down technology costs and increase the output of domestically manufactured WTGs[8] and PV modules (deciding on these investments now nominally becomes easier based on a 40-year expectation of up-scaled demand for these technologies)
- A drive (likely to be led by fossil-fuel companies) to achieve a breakthrough in CCS technology to abate emissions from thermal units, or the closure of the remaining thermal fleet by 2060, though opportunities may be limited by adequate geology
- Also a necessary breakthrough (in CCS) to enable the adoption of hydrogen in electricity, currently produced in China primarily using coal (rather than gas with SMR[9] in the European context), or rapid investment in R&D for and scaled up deployment of electrolysis to reduce the technology costs and enable 'green' hydrogen to play a role in electricity generation/balancing

[8] Wind Turbine Generators

[9] Steam Methane Reforming

- Investment in the physical sources of flexibility that will enable the transition to a more intermittent system such as thermal plant flexibility: batteries for short-term balancing, hydrogen for seasonal balancing particularly in the 2030s as firm capacity begins to fall out of the system as well as limited new investment into pumped storage
- A move away from the current system of capacity and generation planning, which is inflexible and poorly adapted to a future heavily intermittent system. And therefore the implementation of markets that allow trading across multiple timeframes and up to (close to) real-time, engage the demand side, are integrated across provinces (enabled by effective transmission investment) to allow for inter-provincial balancing, effectively reflect network congestion with effective zoning or nodal pricing, and that procure response and reserve in a range of (including short) timeframes from a wide range of resources
- As these markets are implemented, wholesale prices will be impacted by a system increasingly dominated by low marginal cost generation, with important implications for investors in future projects
- Reforming renewable support schemes will be required to balance the need for new renewable deployment with the costs of the transition to consumers. This is likely to translate into the continuation of existing plans to retire the renewable energy FiT[10], the possible introduction of a 'green electricity certificate', but also potential consideration of mechanisms that would expose renewables to future balancing costs (important as intermittency in the system grows) and reduce the costs of deployment, such as auctions for contracts for difference or similar mechanisms
- Importantly as well, will be the implementation of a national carbon market (which has already been proposed for this year), initially not to incentivise a transition from coal to gas as in the European context (the coal-gas fuel cost delta is so large that a Chinese carbon price would have to be unrealistically high to achieve this), but rather aid in identifying (and accelerating) which older or less efficient coal units should be retired first

Industry

Over 30% of China's carbon emissions are attributable to industrial activities (excluding the electricity industry). In order to achieve carbon neutrality in 2060, industrial sectors such as iron and steel, cement, aluminium, chemicals, petroleum refining, paper, glass and other manufacturing sectors will have to undergo deep decarbonisation with investments in energy efficiency improvements, recycling, direct-use fuel substitution and electrification.

[10] Feed-in-Tariff

The use of fossil fuels, and associated carbon emissions, in industry stem primarily from direct use of coal for heat provision, on-site electricity production or in industrial processes. Therefore the some implications of the new target for China's industrial sector could include:

- Accelerated electrification of boilers and kilns (with parallel investment in low-carbon technologies in the electricity sector), a process which is already underway but agnostic to the source of electricity being used – mechanisms are now more likely to be put in place to prove low-carbon or renewable electricity consumption (such as the green electricity certificate mentioned above)
- More ambitious energy efficiency standards, building on those outlined in recent policy announcements – reducing demand for electricity and heat in the sector
- The extension of the proposed national carbon market to the industrial sector (the carbon market is currently planned to only cover thermal coal generators in its potential early implementation phase)
- Fuel switching from coal to gas or hydrogen (for example in steel production), though as mentioned separately this will require significant investment in enabling low carbon hydrogen production and its associated transportation infrastructure
- Increased R&D into CCS applications for industrial sectors that cannot be decarbonised in other ways

Transport

The transport sector is responsible for approximately 10% of China's carbon emissions. More ambitious implementation of existing initiatives to deploy electric and fuel-cell vehicles will be needed to reduce emissions in this sector, along with significant investment in charging infrastructure, and investment in R&D to unlock the potential to decarbonise challenging segments such as trucking, shipping and aviation (or potentially also bio-fuels applications).

China has over 250 million privately-owned vehicles on the road today (with industry projections for approximately 500 million vehicles by 2050[11]), almost 4000 airplanes in the skies (13% of the global total), and almost 9% of the world's shipping tonnage in its waters.

Electrification of the transport sector has already started, though focussed on passenger vehicles. By mid-2019 China already had 3.4 million 'New Energy Vehicles' (NEVs, a term used to capture BEVs, PHEV

[11] CNPC, China Energy Outlook 2050

and FCVs[12]) in circulation, a small proportion of the total fleet but a world-leading number.

The sustained growth in electric and hybrid vehicles since the mid-2010s has been driven by government targets for deployment, falling battery costs as manufacturing capacities have ramped up, as well as subsidies for OEMs[13], charging stations and vehicle buyers.

Similarly, targets have been brought forward for hydrogen fuel-cell vehicles and subsidies have followed for OEMs, fuelling stations and buyers as well.

The policy impetus to deploy EVs and FCVs has been historically driven by urban air pollution concerns and energy security (China is dependent on imports for 60% of its oil consumption), but this will now have to shift also towards decarbonisation of the wider energy system. Implications of the new target could include:

- Renewed consideration of a ban on the sale of ICEs, which has been under consideration since 2017. Timeframes previously discussed ranged from the mid-2030s to 2040 (already announced locally for Hainan province last year)
- Raised ambition on NEV targets, in particular for EVs and FCVs with, by extension, continued support schemes across the value chain (though with their gradual removal expected as the technologies become more cost competitive)
- Significant investment into hydrogen production (which makes up over 50% of the fuel's delivered cost today), to enable cost reduction and scaled up consumption in transport
- Domestic hydrogen is produced mainly as a bi-product of industrial processes and by using coal (which at approximately 8-10 RMB/kg is considerably cheaper than the 30-40 RMB/kg cost for producing hydrogen from renewables with electrolysis). Government and industry action will therefore have to shift to unlocking abated hydrogen production from coal, or reducing the costs of low carbon hydrogen production technologies in order to decarbonise trucking, shipping and possibly also aviation segments
- Investment into hydrogen transportation itself will also be fundamental. The domestic hydrogen market is highly location-specific, centred around industrial clusters and (as elsewhere) lacking the transportation infrastructure or long-range (cryogenic) trucking technology to allow the fuel to transit the country – and thus enabling the expanded use of hydrogen in transport. Investments in R&D and new infrastructure will be needed

[12] Battery Electric Vehicle, Plug-in Hybrid Electric Vehicle, Fuel-Cell Vehicle

[13] Original Equipment Manufacturers

What are some of the potential implications for the global energy sector?

With over primary energy demand growth expanding by over 3000Mtoe in half a century, China's position in global energy markets has been one of an insatiable source of demand growth.

This apparently obvious equation is now much more likely to change. As discussed above, China will have to take robust action in all major energy consuming sectors to replace fossil fuels with cleaner alternatives – signalling a potential retreat from global coal, oil and gas markets.

In addition, as the scale of investment and deployment in renewable energy, batteries and hydrogen in electricity, industry and transport needed to achieve carbon neutrality by 2060 is likely to deliver further material cost reduction and scale to these technologies, creating new opportunities for decarbonisation globally.

Position in global energy markets

As we show in Exhibit 5 below, China accounts for over half of global coal demand. Imports are only a small fraction (8% in 2019) of total consumption, though global suppliers have established long-term export relationships with Chinese consumers, and made investment decisions accordingly.

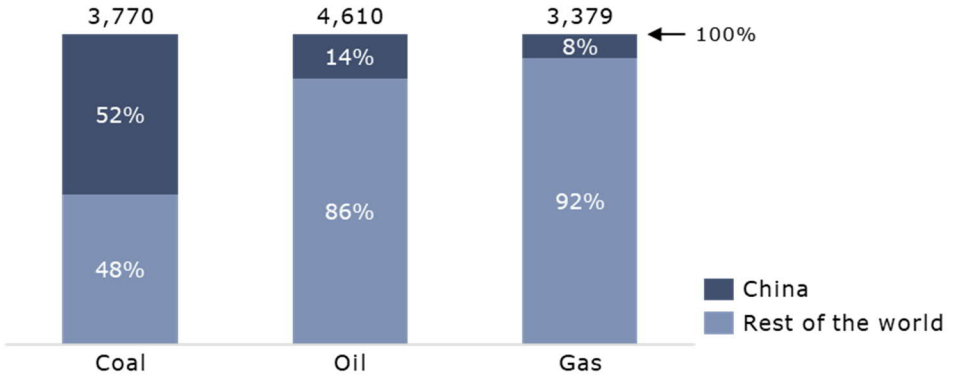
Shifts in Chinese domestic coal demand is the most prominent single factor impacting global coal prices today. Therefore a future with reduced Chinese coal demand will impact significantly on spot coal prices and the renegotiations of long-term coal supply contracts. Consequently this will impact on the investment decisions these suppliers will make in maintaining or expanding coal production.

China accounts for almost 15% of global oil demand with over 60% of domestic consumption imported via global markets. Similarly, in particular with the electrification of transport, China's demand for oil products will begin to ebb – further strengthening expectations for lower oil prices in the long-term.

Accounting for 8% of global gas demand, but with only limited local gas reserves, China has grown to become the second largest importer of LNG. Similarly, global production or transportation investment decisions

(made on decades-long horizons) will increasingly have to account for China's shift to carbon neutrality over the next four decades.

Exhibit 5 – China's share in global energy consumption



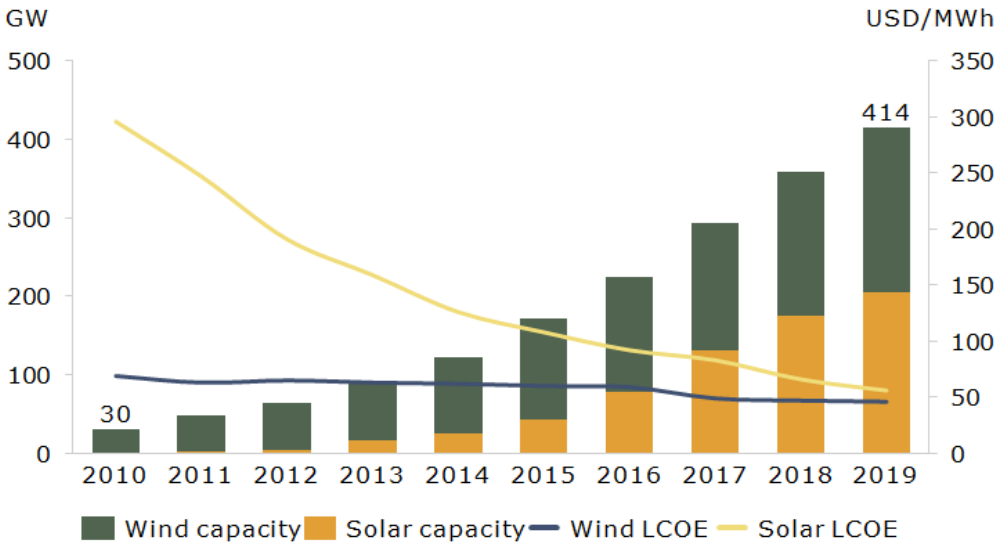
Unit: Mtoe. Source: bp Statistical Review of World Energy

Technology cost reduction

Domestically the costs of renewable energy in the Chinese market have come down dramatically over the past decade.

As shown in Exhibit 6 below, the LCOEs[14] of domestic wind and solar PV have come down by approximately 40% and 80% respectively. This has taken place against the backdrop of over 400GW of capacity additions over the same period.

Exhibit 6 - Historical wind and solar PV capacity and LCOE



Source: AFRY Analysis

[14] Levelised cost of energy

In AFRY's own BID3 China electricity market model, we project over 2000GW of new wind and solar PV capacity to be brought onto the system by 2050. This figure may even be higher under an aggressive policy agenda to reach carbon neutrality by 2060.

As this happens, the system will become more intermittent. Balancing requirements are likely to require significant deployment of batteries, and possibly hydrogen also.

New supply chain investments will be needed in production capacity and also in R&D. As the supply chain ramps up to meet demand across these key technologies, costs are likely to fall further due to the economies of scale achieved by expanded production.

In AFRY's own projections, by 2050 we expect (with variations between provinces) wind LCOEs to fall a further 20-30%, solar PV to come down by approximately 40%, and 2 hour and 4 hour battery costs to approximately halve.

The domestic expansion in manufacturing capacities and associated technology cost reduction will likely be necessary for China to achieve its 2060 ambition, but in parallel will represent an opportunity for decarbonisation in other locations as Chinese OEMs export locally manufactured technologies globally – evidenced already by China's current role in global solar PV module markets and associated impact on prices.

Concluding reactions

The announcement has global implications. It is a strong demonstration of how seriously China takes the threat of climate change, and how the country is positioning itself to bolster its leadership role in the green economy.

China has set itself a mammoth task. Many of the measures described in this note will need to be strengthened where they exist already, or adopted soon. Timing will be crucial, with only 30 years (after a peak 2030) to reach net-zero emissions by 2060.

Whether it is possible remains to be seen, but setting such an ambitious target will surely be important in the global fight against the potential impacts of climate change.

Understanding the trajectory moving forward will be essential for energy companies and investors, energy consumers, as well as governments, around the world in determining strategies for both domestic and Chinese markets.

OUR CHINA TEAM

AFRY Management Consulting's China team is based in Beijing. We specialise in quantitative economic analysis of Chinese electricity and gas markets.

Our China team builds on AFRY's recognised global expertise and analytics in the Chinese market, advising domestic and international clients including investors, utilities, industry and government.

We offer transaction support (due diligence), market studies, strategy advisory as well as electricity and gas market design services. We also support our clients to adapt to China's new market designs with a suite of services across risk management, trading and hedging.

Our analysis in China is underpinned by AFRY Management Consulting global suite of analytical tools, including our local BID3 China electricity market model.

Our China model:

- covers all Chinese provinces;
- features a plant-by-plant database of the entire electricity system;
- considers all interconnection;
- runs an hourly optimization for 2021-2050;
- integrates multiple years of hourly weather data with a 50 km^2 resolution, allowing us to capture the effects of intermittent generation;
- integrates outputs from AFRY's own global gas and coal models which also cover China;
- runs AFRY's internationally recognised and internally consistent High, Central and Low scenarios, producing independent and bankable projections.

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