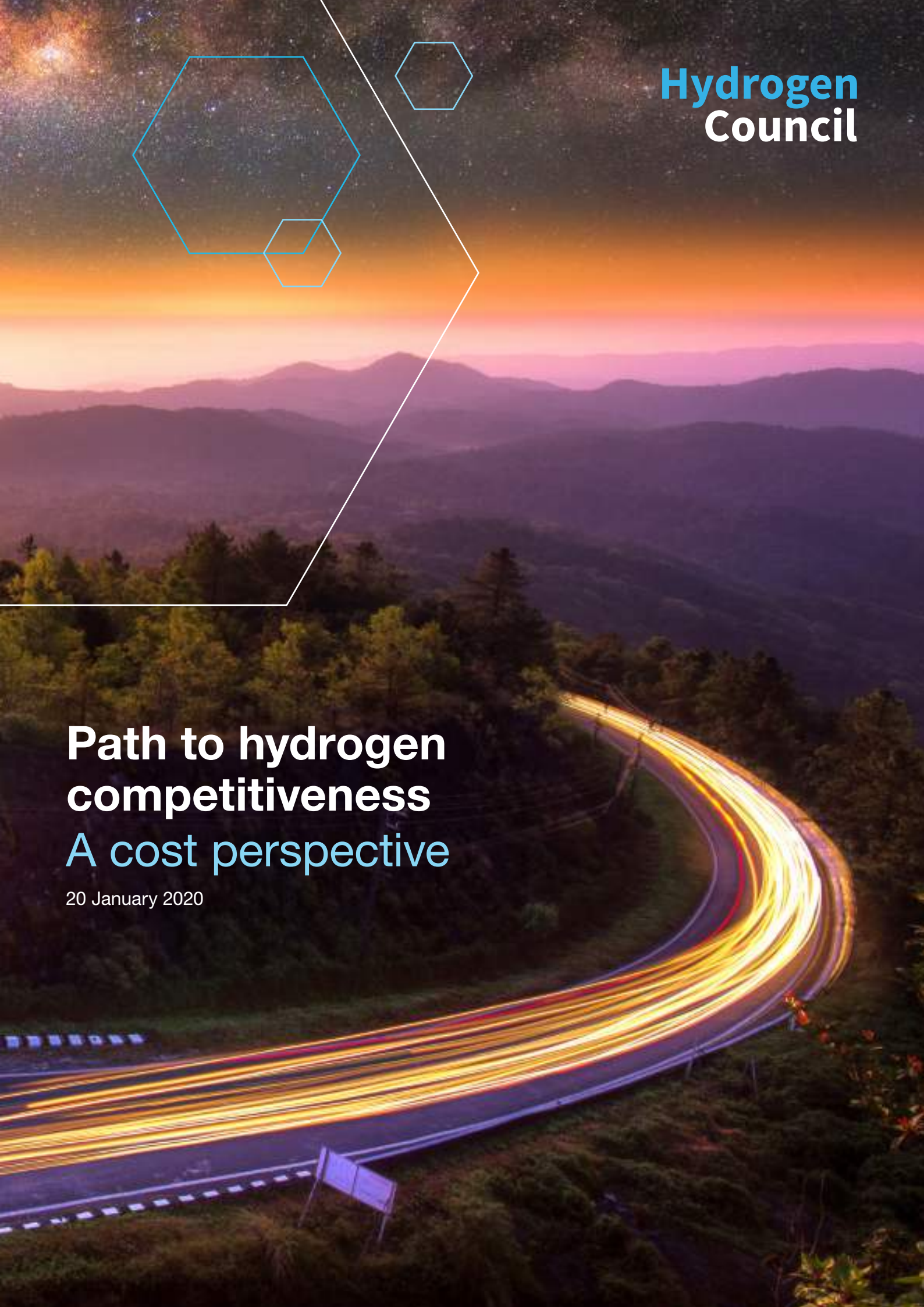

Hydrogen Council

Path to hydrogen competitiveness

A cost perspective

20 January 2020

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Contents

Executive summary

A path to hydrogen cost competitiveness

As public pressure is rising to limit global warming to 1.5 degrees Celsius, global leaders are grappling with how to best take on this unprecedented challenge. Full decarbonisation requires a multidimensional strategy, which has spurred renewed interest in hydrogen. Governments are recognising hydrogen's ability to decarbonise sectors that are otherwise impossible or difficult to abate – such as intensive personal or collective transport, freight logistics, industrial heating and industry feedstock – and its role in energy security. Meanwhile, industry leaders across the automotive, chemicals, oil and gas, and heating sectors look to low-carbon hydrogen as a serious alternative to reach their increasingly substantial sustainability objectives.

The Hydrogen Council's previous report, 'Hydrogen Scaling Up', showed the critical role hydrogen could play in global industrial decarbonisation. Since then, technological advances and early demonstration projects have significantly lowered the cost of many hydrogen applications. Yet despite rapid improvements in recent years and a clear prospect for further cost reduction, the competitiveness trajectory and required investments to reach the scale at which hydrogen is competitive remain unclear to many.

This report provides an evidence base on the path to cost competitiveness for 40 hydrogen technologies used in 35 applications. For policymakers, such a perspective provides firm ground on which to base financial and non-financial support that will unlock the economic value of hydrogen and to develop adequate policy frameworks. For decision-makers in industry, it brings a holistic picture of whole value chain cost dynamics and interactions, allowing them to put their own efforts into a broader perspective.

Scaling up hydrogen value chain to unlock further cost reductions

Our findings suggest that scale-up will be the biggest driver of cost reduction, notably in the production and distribution of hydrogen and the manufacturing of system components. This will deliver significant cost reductions before any additional impact from technological breakthroughs is considered. For instance, at a manufacturing scale of approximately 0.6 million vehicles per year, the total cost of ownership (TCO)[1] per vehicle will fall by about 45 per cent versus today. 30 percentage points of this cost drop is attributed to manufacturing scale up, 5 percentage points to the fall in low-carbon and/or renewable hydrogen production costs and 10 percentage points to the scale-up of hydrogen refuelling infrastructure deployment.

90 per cent of cost reduction for non-transport applications are from scaling up the supply chain

On average, the cost of hydrogen supplied comprises more than 70 per cent of the TCO for non-transport applications. Delivered low-carbon hydrogen costs are expected to drop sharply over the next decade and will account for up to 90 per cent of the total drop in TCOs from 2020 to 2030 across applications with shorter supply chains. Lower production and distribution costs will both contribute to lowered delivered hydrogen costs.

The cost of low-carbon and/or renewable hydrogen production will fall drastically by up to 60 per cent over the coming decade. This can be attributed to the falling costs of renewable electricity generation, scaling up of electrolyser manufacturing, and development of lower-cost carbon storage facilities.

[1] TCO defines the total costs incurred by a customer over the lifetime of using an application, including capital, operating, and financing costs.

Secondly, distribution costs will drop significantly with higher utilisation of distribution system infrastructure. For instance, with improvements in scale and utilisation, the cost of a single trucking journey of 300 km will drop by 40 per cent. Usage of existing pipeline networks may further slice these costs given sufficient utilisation. Countries with limited gas or renewable electricity sources seeking to increase use of low-cost hydrogen will benefit from lower international shipping costs, making it a viable alternative to local production.

Up to 70 per cent of cost reductions for transport applications are from manufacturing scale-up of end-use equipment

Scaling up manufacturing is another way to reduce costs for many hydrogen applications where costs of end-use equipment comprises a large component of TCO (e.g. fuel cells and tanks in transportation). Large-scale industrialisation of components and vehicle integration, together with lower-cost hydrogen fuel, will halve vehicle TCO in the early stages of scale-up for these and similar applications. The scale in manufacturing of equipment will account for up to 70 per cent of this reduction.

A competitive low-carbon option across 22 applications by 2030

A hydrogen production and distribution system at scale will unlock hydrogen's competitiveness in many applications sooner than previously anticipated. This analysis focused on 35 representative use cases and shows that in 22 of these the TCO will reach parity with other low-carbon alternatives by 2030. These 22 hydrogen applications are material: in total they comprise roughly 15 per cent of global energy consumption. This does not imply that hydrogen will satisfy all this energy demand by 2030, but it does showcase that hydrogen will have a significant role to play as a clean energy vector in the future energy mix. Some examples of applications that become competitive are:

- Commercial vehicles, trains, and long-range transport applications will compete with low-carbon alternatives by 2030 due to lower equipment and refuelling costs.
- Hydrogen boilers will be a competitive low-carbon building heating alternative, especially for existing buildings currently served by natural gas networks.
- In industrial heating, hydrogen will be the only viable option to decarbonise in some cases.
- Hydrogen will play an increasingly systemic role in balancing the power system as hydrogen production costs drop and demand rises.
- Low-carbon and renewable hydrogen will become competitive with grey hydrogen used for industry feedstock today as costs fall and carbon prices rise.

In 9 of the 35 use cases we studied, low-carbon or renewable hydrogen solutions will also be competitive with conventional options by 2030. For example, this is the case for heavy-duty trucks, coaches with long range requirements, and forklifts.

Conclusion and recommendations

Scaling up existing hydrogen technologies will deliver competitive low-carbon solutions across a wide range of applications by 2030 and may even offer competitive low-carbon alternatives to conventional fuels in some segments. Yet, to reach this scale, there is a need for investment, policy alignment, and demand creation.

Need for investment: approximately USD 70 billion required to become competitive

Realising this ambitious vision for hydrogen's role in the future of energy is far from automatic and requires investment above and beyond current commitments. Specifically, the gap between the costs of hydrogen technologies and their lowest cost low-carbon alternative will require funding in order to bring hydrogen to scale and, consequently, cost parity. We have identified several areas where investment until 2030 would make the biggest difference:

- In production, achieving competitive renewable hydrogen from electrolysis requires the deployment of aggregated 70 GW of electrolyser capacity, with an implied cumulative funding gap with grey production of USD 20 billion. Beyond 2030, after reaching economic competitiveness, the cost of renewable hydrogen will further decrease. To initiate the implementation of low-carbon hydrogen from natural gas reforming with carbon capture and storage (CCS), we estimate USD 6 billion is required to fund the additional production costs versus grey hydrogen until 2030, assuming the usage of existing reservoirs.
- In transport, the refuelling and distribution networks required and the cost differential for fuel cells and hydrogen tanks compared with low-carbon alternatives imply an additional required investment of USD 30 billion to cover the economic gap.
- In heating for buildings and industry, financing the cost difference between hydrogen and natural gas and investments to build or repurpose the first gas pipeline networks for hydrogen will amount to USD 17 billion by 2030.

While these figures are sizable, they pale in comparison to global spending on energy. Together they account for less than 5 per cent of annual global energy spend and are on par with the support provided to renewables in Germany of nearly USD 30 billion in 2019. Industry is prepared to invest, but clarity of policy direction to support hydrogen's adoption will accelerate progress. It is all the more critical to act now, as accelerated scale-up will lead to economic deficits to be remedied.

Need for policy alignment: level playing field to accelerate scale-up

Enabling regulations from governments will accelerate industry investments that will ultimately lead to scale. We see six ways in which governments can level the playing field:

- **National strategies.** Governments have a role to play a role in setting national targets, as they have done already through 18 hydrogen roadmaps developed across the globe.
- **Coordination.** Governments are well positioned as neutral conveners of industry stakeholders to mediate potential local investment opportunities.
- **Regulation.** Governments can help remove barriers that may exist to invest in the hydrogen economy today, e.g. by facilitating the process to obtain permits for new refuelling stations and developing internationally consistent regulation to limit market specifities.
- **Standardisation.** Governments can also support industry to coordinate national and international standards, e.g. around pressure levels and safety.
- **Infrastructure.** Governments can choose to invest in the deployment of new infrastructure and re-use, where relevant, of existing networks (e.g. natural gas networks).
- **Incentives.** Finally, governments could decide to apply incentives, e.g. tax breaks or subsidies to encourage the initial acceleration of hydrogen.

Need for market creation: five enablers to establish a market

Even with the right enabling investments and policy support, the choices made at critical inflection points along hydrogen's development will serve to either nurture or suppress the industry's growth. We see five levers through which stakeholders can create demand and establish a market. Together, these can enable hydrogen solutions to reach cost competitiveness in the near future:

- **Reduce market uncertainty.** Stakeholders can look to renewables for inspiration: the creation of long-term offtake agreements removed market risk from installation projects, leaving only technical risk. Another example is facilitating a shift to end-to-end zero-emission fleet logistics solutions that serve captive, recurring demand.
- **Focus on scaling applications and technologies that create the biggest 'improvement-for-investment'.** Critical tipping points – after which costs fall sharply – appear throughout our analyses. For example, scaling fuel cell production from 10,000 to 200,000 units can reduce unit costs by as much as 45 per cent, irrespective of any major technological breakthroughs, and can impact multiple end-use cases. Scaling up to 70 GW of electrolysis will lead to electrolyser costs of less than USD 400 per kW.
- **Seek complementarity in hydrogen solutions.** The development of certain hydrogen solutions can create a virtuous cycle that makes other hydrogen applications viable. For example, leveraging hydrogen infrastructure around airports for on-site refuelling of buses, airport heating, local industry feedstock and potentially in the future, airplane refuelling, will reduce the costs of each individual application.
- **Prioritise increasing utilisation rates in distribution networks.** Moving from 20 to 80 per cent utilisation rates in distribution and refuelling networks can slash distribution costs by up to 70 per cent, which could, for instance, reduce the costs of hydrogen-based home heating by 20 per cent. This will require deploying a minimal threshold of infrastructure to ensure the network serves user demand.
- **Invest in low-carbon and renewable hydrogen production.** Low-cost hydrogen is among the top three cost reductions for every hydrogen application and will be the single most important factor in accelerating the hydrogen economy alongside the created additional demand.

Hydrogen is already scaling up and considerable investments are being made globally. It will provide an important low-carbon option across a wide range of sectors. However, hydrogen's development still requires suitable financial, infrastructural and policy support to allow it to achieve a wide deployment and scale-up through commercial projects. Given the urgency of the global decarbonisation challenge, society must capitalise on hydrogen's advantages now. The hydrogen industry can help enable the energy transition to a net-zero world, and this report clearly identifies the cost trajectories of its many applications, presenting numerous opportunities.

A **comprehensive cost perspective** on hydrogen applications and technologies

35 applications

40+ hydrogen technologies

Modelled in detail to develop the pathway to hydrogen competitiveness

Introduction and methodology

Hydrogen is accelerating

Policy and economic forces are converging to create unprecedented momentum in the hydrogen sector, paving the way for rapid deployment of and investment in hydrogen technologies. A growing number of societal actors – from youth activists to scientists to concerned consumers – are pushing for stronger policy action to more drastically limit carbon emissions. Climate change requires urgent attention: if we continue to emit CO_2 at current levels, we have only ten years remaining in the global carbon budget before we breach the 1.5-degree Celsius threshold, emphasising the need for immediate action.

Governments are responding with increasingly ambitious decarbonisation targets. At the time of the 2019 UN Climate Summit, 66 countries had announced their intent to meet net-zero carbon emissions targets by 2050. In the EU, regulation includes potential fines for failure to meet targets, and a Green Deal was recently announced to support the net-zero emissions target. In the US, 25 states formed the bipartisan United States Climate Alliance with a collective commitment to reduce greenhouse gas (GHG) emissions by at least 26 to 28 per cent below 2005 levels by 2025.[2] China has made considerable progress towards its climate policy goals of reaching peak emissions by 2030 and meeting its target of 20 per cent of primary energy demand from non-fossil fuel sources with continued investment in sustainable technologies.[3]

Unlike previous eras in hydrogen's development, the renewed attention on hydrogen is strengthened by a realisation that the use of hydrogen will be critical if we are to meet the climate objectives. Governments are recognising hydrogen's ability to decarbonise sectors that are otherwise impossible or difficult to abate – such as logistics, industrial heating and industry feedstock – and its role in energy security. Meanwhile, industry leaders across the automotive, chemicals, oil and gas and heating sectors look to low-carbon and renewable hydrogen as a serious alternative to reach their increasingly robust sustainability objectives.

This renewed attention also comes as the key cost drivers of clean hydrogen have seen a sharp improvement. For instance, electrolysis fed with renewable electricity – the most common production method to produce 'renewable hydrogen' – has become 60 per cent more affordable as low-carbon and renewable electricity prices have dropped and electrolysis capex has fallen. The cost of solar and wind power, the largest driver of renewable hydrogen production costs, has seen an 80 per cent decrease over the past decade. Recent subsidy-free offshore wind auctions in Europe and bids close to or below USD 20 per megawatt hour (MWh) for solar photovoltaics (PV) and onshore wind plants have been seen. This downward cost trajectory for renewables should continue, with 14 times more solar capacity projected to become available in 2030 than was previously estimated. At the same time, electrolysis capacity has also started to accelerate, with at least 55 times more capacity expected by 2025 versus 2015, which will result in a similar cost drop in electrolysis capex.

Building on this momentum, governments have implemented a growing number of tangible policies promoting hydrogen. To date, 18 governments, whose economies account for 70 per cent of global GDP, have developed detailed strategies for deploying hydrogen energy solutions. This includes recent announcements from the coalition of governments forming the Energy Ministerial to target the global deployment of 10 million fuel cell electric vehicles (FCEVs) by 2030 – a fourfold increase of the target over the last two years – and projects across China, Japan, the US, and South Korea to build 10,000 hydrogen refuelling stations by 2030.

[2] US Climate Alliance (2019).
[3] Qi, Y., Stern, N., He, J., Lu, J., King, D., Liu, T., Wu, T. (2018).