NetZero Pathfinders

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Methodology Report

About NetZero Pathfinders

NetZero Pathfinders is a public resource that provides concrete, actionable policy insights for achieving a de-carbonized economy. Pathfinders leverages the capabilities of Bloomberg LP including BloombergNEF, Bloomberg Philanthropies and numerous partner organizations to make the methodology and policy solutions available via its web portal, www.bloomberg.com/netzeropathfinders. The initiative aims to serve municipal, regional, national and international policy makers, financiers, business leaders and others. Pathfinders illuminates paths to net zero by:

1. **Identifying the specific challenges de-carbonization efforts must address.** These represent the pillars of net-zero strategies, major emitting sectors of the economy and key stakeholder groups in the race to zero.

2. **Highlighting solutions effective today.** Without immediate action, the world could reach 1.5 degrees Celsius above pre-industrial levels as soon as 2028. Policy and other measures that work now therefore are critical. Pathfinders outlines actionable solutions to put the world on track for success this decade while laying the foundation for de-carbonizing harder-to-abate sectors post-2030.

3. **Telling success stories.** Through trial and error, governments and others have for more than four decades been testing potential decarbonization solutions. Pathfinders profiles field-tested measures that have been implemented internationally, nationally, and locally and their results. Pathfinders case studies can serve as inspiration for others formulating their own net-zero strategies.

This report aims to summarize Pathfinders' methodology and serve as a basic resource for policy makers and other key stakeholders to use on when designing decarbonization strategies. Further examples and details can be found on the Pathfinders web portal, which includes a best-practices library.

Since there is no single path to decarbonization and solutions can vary widely by sector or jurisdiction, the NetZero Pathfinders platform is structured as a flexible and ongoing framework that can continually evolve. We encourage engagement from all stakeholders and invite further examples of progress in the race to zero. To learn more or to share your successes, please contact us at pathfinders@bloomberg.net.

Pillars of net-zero strategies

1. Accelerate deployment of mature climate solutions

Thanks to extraordinary progress achieved over the past decade, zero-CO_2 emitting technologies exist that are lower cost to operate than their fossil-fueled rivals. The list includes wind and solar power projects in most of the world and electrified vehicles in a small but growing number of nations. Yet these climate-friendly technologies do not always flourish, in part due to policies that explicitly protect incumbents.

2. Support the development of new climate solutions

The current suite of cost-competitive zero-carbon technologies – wind, solar, batteries and electrified transport, among others – is poised to cut emissions meaningfully over coming decades. But to zero out emissions entirely, more technologies will be required to provide around-the-clock, zero-carbon power, decarbonize industrial processes, cut emissions associated with livestock production and meet other challenges.

3. Manage the transition or phase-out of carbon-intensive activities

Despite the immediate threat posed by climate change, national governments continue to subsidize the burning of fossil fuels or underwrite their extraction through state-owned companies. While this clearly must cease, scaling back subsidies that artificially cap consumer gasoline and electricity prices can be politically challenging. Nonetheless, policy makers and others have found innovative ways to phase out fossil-fuel supports.

4. Create appropriate climate transition governance structures

The scope of the climate crisis is forcing smart policy makers to take a multidecadal view of the problem. But policies are only as good as the frameworks that exist to implement and enforce them. Policy makers must recognize that to attract investment in low-carbon technologies – and enjoy the associated economic benefits – they must construct governance structures that are durable and long-lasting.

Four pillars of net-0 strategies

1 Accelerate deployment of mature climate solutions

2 Support the development of new climate solutions

3 Manage the transition or phase-out of carbon-intensive activities

4 Create appropriate climate transition governance structures

Stakeholders of the race to zero

Government	Sectors | Industries	Finance	Civil society
National	Energy	Institutional investors	Education
Regions | States Provinces	Materials and Buildings	Asset managers	Acceptance | Culture
Cities	Transport	Banks	Welfare | Inclusion
Regulators	Agriculture	Rating Agencies, Index providers, Insurances	Ownership
International		Public and development banks	Philanthropy

Source: BloombergNEF, NetZero Pathfinders

NetZero Pathfinders

November 2022

Solutions for the race to net-zero

Pillar 1
Accelerate deployment of mature climate solutions

Emitting sectors and industries				Finance	Civil Society
Energy	Materials and Industry	Transport	Agriculture		
Speed construction of clean power plants	Embed goal of a 'circular economy' in all appropriate decision-making	Speed deployment of EVs and charging infrastructure for road transport	Implement sustainable management systems	Replicate proven private investment models in more mature markets	Support public acceptance and understanding of clean alternatives
Accelerate build-out of current energy storage technologies	Speed use of bioplastics in consumer and business products	Boost walking, micro mobility and public transportation	Encourage sustainable food consumption	Accelerate public investment in less mature markets	Make clean solutions easy to choose
Proliferate heat pumps and other clean technologies to buildings	Establish and enforce industrial energy efficiency standards		Support targeted fertilizer usage and use of low-carbon products		
Promote efficiency retrofits for homes and commercial buildings					

Pillar 2
Support development of new climate solutions

Emitting sectors and industries				Finance	Civil Society
Energy	Materials and Industry	Transport	Agriculture		
Support the deployment of low-carbon hydrogen			Trial low-emitting agriculture machinery and vehicles	Leverage finance for less profitable low-carbon solutions	Stimulate appetite for new low-carbon alternatives
Support development of new end uses for hydrogen					
Support carbon capture, utilization and storage projects			Support research and development of alternative proteins	Accelerate finance for research and development	
	Promote use of lower-carbon fuels in hard-to-abate-sectors				
	Support development of new sustainable materials	Support electrification of hard-to-abate vehicles	Back technologies that cut emissions from livestock and crops production		
	Electrify industrial processes				

Source: BloombergNEF, NetZero Pathfinders

NetZero Pathfinders

November 2022

Solutions for the race to net-zero

Pillar 3
Manage the transition or phase-out of carbon-intensive activities

Emitting sectors and industries

Energy | Materials and Industry | Transport | Agriculture

All emitting sectors (Energy, Materials and Industry, Transport, Agriculture):
- Integrate environmental considerations into trade policies
- Implement carbon-pricing mechanisms
- Create emissions standards and regulations

Energy, Materials and Industry, Transport:
- End fossil-fuel subsidies and discourage fossil fuel use

Energy:
- Phase out high emitting power plants
- Phase out high emitting heating sources

Materials and Industry:
- Ensure sustainable mining

Transport:
- Phase out internal combustion engine vehicles

Finance
- Leverage private financial products to help industries transition
- End financing of high-emitting sources
- Leverage public funds to support a just transition of communities

Civil Society
- Manage the impact of the transition on jobs and businesses
- Train workers for a lower-carbon economy

Pillar 4
Create appropriate climate transition governance structures

Emitting sectors and industries

Energy | Materials and Industry | Transport | Agriculture

All emitting sectors (Energy, Materials and Industry, Transport, Agriculture):
- Establish independent bodies focused on climate goals and projects
- Ensure continuity of climate goals and projects
- Enhance cross-government and cross-stakeholder coordination
- Encourage and enforce corporate climate commitments

Finance
- Align financial institutions' portfolios with climate targets
- Encourage climate-related financial disclosures

Civil Society
- Push for binding goals that include concrete CO_2 reduction targets
- Drive social development and equality across the value chain

Source: BloombergNEF, NetZero Pathfinders

Net zero solutions

The sheer magnitude of climate change can make it difficult to discern how best to address the problem. The good news is that effective solutions have been tested and proven already in cities, states and nations around the globe. Many of these are now ready to be implemented in other contexts and at far greater scale. This report breaks the climate challenge down into the four pillars of net-zero strategies and describes crucial solutions to address these challenges.

The pillars of net-zero strategy are relevant for all major emitting sectors of the economy and key stakeholder groups in the race to zero. They encompass:

1. Accelerating deployment of mature climate solutions
2. Supporting the development of new climate solutions
3. Managing the transition or phase-out of carbon-intensive activities
4. Creating appropriate climate transition governance structures

Thanks to extraordinary progress achieved over the past decade, zero-CO2 emitting technologies now exist that are lower cost than their fossil-fueled rivals. The list includes wind and solar power projects in most of the world and electrified vehicles in a small but growing number of nations. Yet these climate-friendly technologies do not always flourish, in part due to policies that explicitly protect incumbents.

While the current suite of cost-competitive zero-carbon technologies – wind, solar, batteries and electrified transport, among others – is poised to cut emissions meaningfully over coming decades, more will be needed to zero out emissions entirely. Technologies will be required to provide around-the-clock, zero-carbon power, to decarbonize industrial processes, to cut emissions associated with livestock production and to meet other challenges.

Despite the immediate threat posed by climate change, national governments continue to subsidize the burning of fossil fuels or underwrite their extraction through state-owned companies. While this clearly must cease, phasing out high-emitting sources and scaling back subsidies that artificially cap consumer gasoline and electricity prices can be politically challenging. This will also require a transformation of the corporations, utilities, and communities that have historically relied on the operation of these technologies and bold policy support to ensure a 'just transition'. Nonetheless, policymakers and others have found innovative ways to get the job done

Finally, the scope of the climate crisis is forcing policymakers to take a multi-decadal view of the problem but policies are only as good as the frameworks that exist to implement and enforce them. Policymakers must recognize that to attract investment for low-carbon technologies – and enjoy the associated economic benefits – they must construct governance structures that are durable.

Pillar 1. Accelerate deployment of mature climate solutions

While much of the climate discussion centers on long-term goals 20, 30 or even 40 years away, achieving intermediate goals is also critical. Thankfully, due to the extraordinary progress achieved over the past decade, zero-CO2 emitting technologies exist today that are lower cost to operate than their fossil-fueled rivals. The list includes wind and solar power projects in most of the world and electrified vehicles in a small but growing number of nations. Yet these climate-friendly technologies do not always flourish, in part due to policies that explicitly protect incumbents. This emphasizes the need for immediate, concrete policy action to accelerate decarbonization today.

BloombergNEF's New Energy Outlook 2021 (NEO) highlights that emissions must fall to 30% below 2019 levels over the coming decade, or decline an average of 3.2% per year, for the world to be on track by 2030 to cut emissions sufficiently in the long run. Little suggests we're on the right path. Global emissions have started growing again as the globe recovers from the Covid-19 pandemic and energy emissions rose 0.9% year-on-year in the five years leading up to 2020.

In the immediate term, the power sector must certainly drive decarbonization of the economy, but other sectors cannot be overlooked. NEO 2021 finds that more than three quarters of the abatement effort through 2030 falls to the power sector and the faster deployment of wind and solar PV. Another 14% is achieved via greater use of electricity in transport, building heat and to provide lower-temperature heat in industry. Greater recycling in steel, aluminium and plastics accounts for 2%, and growth of bioenergy for sustainable aviation fuel and shipping another 2%. Below we examine how mature climates solutions can be deployed at greater speed and scale in each of the major emitting sectors.

Emitting sectors and industries				Finance	Civil Society
Energy	Materials and Industry	Transport	Agriculture		
Speed construction of clean power plants	Embed goal of a 'circular economy' in all appropriate decision-making	Speed deployment of EVs and charging infrastructure for road transport	Implement sustainable management systems	Replicate proven private investment models in more mature markets	Support public acceptance and understanding of clean alternatives
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Promote efficiency retrofits for homes and commercial buildings					

Source: BloombergNEF, NetZero Pathfinders

Energy

Speeding construction of clean power plants is one of the pivotal and most logical steps to get on track this decade. Either wind or solar PV is the cheapest form of new-build electricity generation in countries accounting for two-thirds of world population, more than three-quarters of global GDP, and 90% of all electricity generation. Furthermore, it is now cheaper to build new renewables from scratch than operate existing coal and gas plants in a growing number of countries, including China, India and much of Europe. With the most cost-effective zero-carbon solutions and large, established supply chains, clean power is an obvious pathway to decarbonization for the energy sector. Decarbonizing power at a faster clip is vital to getting CO2 reductions on track by 2030. NEO 2021[1] finds that power sector emissions need to drop 57% from 2019 levels, which means delivering around 55GtCO2 of abatement.

Overall, although both utility-scale and small-scale clean energy technologies are becoming more popular across the globe, the progress remains concentrated among richer nations. BNEF's Climatescope project highlighted that the power sector CO2 emissions trajectories have differed widely between the world's wealthiest nations and emerging markets, reflecting in part their very different stages of economic development. Developed nations' power sector emissions have dropped 25% since 2012 but risen significantly in emerging markets over the same period. Lack of robust clean energy policies and sufficient investment have limited growth unnecessarily. This discrepancy has to be addressed in order to reach and sustain a net-zero world.

Renewable energy policies are the most widely implemented climate-related policies and remain fundamental to ensure the sector's continued growth. A good clean energy policy framework provides clarity to investors, minimizes bureaucracy and incentivizes construction of new capacity. Typically, strong frameworks have included at the very least an overall clean energy target, plus reverse auctions for clean power-delivery contracts, or feed-in tariffs.

As generation of intermittent sources grow, it is also fundamental **to accelerate build-out of current energy storage technologies.** These will be key to integrate renewables, allow deeper penetration of variable clean energy and ensure resilient supply in all markets.

By end of 2021, the world had installed around 56GWh of behind-the meter and utility-scale storage systems, excluding pumped hydro, up from just 16GWh three years before. Still, over half of it is concentrated in the US and China. In other markets, especially developing economies, deployment of energy storage has been limited due to high technology costs and lack of adequate policy frameworks.

Under the New Energy Outlook 2021 "green" scenario[2], to get on track in the power sector, the world would need to add 245GWh new battery storage on average every year to 2030. This is over 26 times the amount of battery storage added in 2020.

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[1] The New Energy Outlook (NEO) is BloombergNEF's annual long-term scenario analysis on the future of the energy economy. Click here for more details.

[2] NEO Green Scenario is a clean-electricity and green-hydrogen net-zero pathway. Here, hydrogen produced from water using electrolyzers powered by wind and solar is applied in sectors such as industry and heavy transport, as well as in power generation to complement electrification. Click here for more details

Storage has multiple applications, but we believe that those related to flexibility present the greatest short and medium-term potential for decarbonization. Ensuring sufficient system flexibility will become a priority for system operators as variable sources of supply grow and traditional sources of flexibility decrease. A flexible system is one that can respond to planned and unplanned variations in order to balance supply and demand over multiple time frames. Electricity demand and supply need to be matched at all times yet currently power systems have limited storage capacity, and imbalances can result in blackouts.

Specific subsets of increasing flexibility requirements include, among others frequency regulation, peaking capacity, renewable energy integration and transmission and distribution network management. Enabling energy storage for frequency regulation often requires market reform. In competitive markets there typically needs to be some kind of premium compensation for faster-response and accuracy or a carve-out. In some cases, high energy prices encouraged generators to invest in lithium-ion on their own accord. They were then able to ramp up their thermal assets without worrying about their reserve obligations.

Peaking capacity resources are often contracted to ensure they are available in scenarios of peak demand. Increased share of renewable generation supply can intensify the demand for peaking capacity as the renewable energy output may be unavailable during peak demand times. There are a number of market design mechanisms that are being deployed to either incentivize new capacity build or to ensure that existing capacity stays online, including:

- Energy-only markets with carbon markets linked to strong carbon constraints. This may include a strategic reserve or capacity payment, in order to guarantee reliability and ensure that backup plants are kept in the money

- Central auctions for renewable energy, accompanied by centrally-administered capacity markets or reserves

- Energy supplier obligations for de-carbonization. More radical still would be to mandate energy suppliers both to de-carbonize and to guarantee resource adequacy.

As renewable energy resources become more widespread, system operators are grappling with how to efficiently integrate them without compromising reliability. This becomes more challenging, and probably more costly as penetration rises. Concerns include system-level constraints and network congestion management.

Transmission and distribution (T&D) network operators constantly extend and upgrade their infrastructure. Transmission utilities need to ensure transmission lines continue to transport electrons from centralized distant power plants to load centers, while expanding capacity to do so in new locations. Distribution utilities also upgrade their networks on an ongoing basis as infrastructure ages or as demand in certain locations increases, but they are also adapting to higher levels of distributed energy resources (DERs) and changing demand patterns.

Distribution utilities are overhauling their management of the network, moving from a static seasonal approach to active grid operations which, to date, has been achieved by modernizing grid equipment, and deploying advanced software and sensors. Increasingly though, DERs are viewed as offering part of the solution to the challenges they pose. In order to use energy storage for this application, utilities or network operators will need regulations that provide a framework to consider energy storage when doing resource planning. The regulator will need to allow the utility to rate base investments in energy storage assets in the same way it would pass through the costs for traditional network reinforcement.

Residential and commercial buildings account for almost a third of global final energy consumption on average. Despite differences because of climate, the majority of this energy is consumed in residential buildings for use in space heating, hot water and cooking. Thus, **proliferating heat pumps and other clean technologies to buildings** is a major measure to be on track this decade.

A range of electric heating technologies is available, including direct electric boilers, radiators and heat pumps. However, policy makers often focus on heat pumps because of their high coefficient of performance – the measure of heat pump efficiency. Because they transfer heat from the ambient air, water or ground for use in buildings, they consume less total energy from the grid to produce the same amount of useful heat in the home. There are two common types: air-source heat pumps, which take advantage of the ambient air for heat energy, and ground-source heat pumps that absorb thermal energy from the ground. The former have a lower upfront cost and are simpler to install compared with the latter, which require underground pipes to be laid. This makes air-source heat pumps the most popular type today, although ground-source models are more efficient, particularly in colder climates.

Heat pumps have the potential to play a significant role in decarbonization strategies. But their high upfront costs compared with gas and oil boilers, poor building insulation (which can increase their cost) and challenges around noise and lack of qualified installers remain key barriers. In most of the world, heat pumps struggle to compete with gas-fired boilers and furnaces. While they are often more competitive than oil on a lifetime cost basis, high upfront costs can still lead to long payback periods for purchasers. As such, policies can play a big role in improving the economic competitiveness of heat pumps against fossil-fuel units.

NEO 2021 estimates that, for buildings, getting on track for net-zero means cutting emissions 16% from 2019 levels by 2030, or 1.5% a year. Emissions in this sector grew around 1.3% per year 2012-2019.

Low-carbon heating solutions like heat pumps, low-carbon district heating and direct electric heating can be used instead of fossil fuel based heating units to provide space heating and hot water, thereby reducing emissions. In the case of heat pumps, the solution also results in lower total energy consumption. NEO 2021 finds that the world would need to add an average of 18 million new heat pumps each year to 2030, or 186 million by the end of the decade to be on track.

In addition to deploying clean technologies, **promoting energy efficiency retrofits for homes and commercial buildings** will be necessary. Energy-efficiency improvements seek to reduce energy consumption for heating and cooling and thus help to achieve long-term decarbonization goals.

They focus on two main areas:

- Buildings: using better materials such as wall insulation or windows, or building structures that maximize efficiency to cut total heating and cooling needs.

- Appliances: improving the efficiency of equipment such as lights, boilers, refrigerators and other devices to cut fuel and electricity use.

Overall, governments are lagging behind on cutting emissions from buildings, and they must expand their strategies to achieve net-zero targets. The distributed nature of the challenge in the form of millions of structures, the need to educate multiple stakeholders, and higher costs of change all remain problematic.

Materials and Industry

Materials and industry – the supplying of raw materials to manufacturers and the production of finished goods to consumers – is not only a critical segment of the overall economy, but also a major user of energy and a massive producer of CO2 emissions. In all, the category accounts for around 30% of global energy consumption and a fifth of greenhouse gas emissions.

Processes for raw material production often require very high temperatures, which makes them highly energy-intensive and dependent on the burning fossil fuels. Steel production, for example, relies heavily on coal both as a fuel and as an agent in the chemical process itself. In petrochemicals, oil and gas are both feedstocks and energy carriers for the production process. Decarbonizing these high-heat processes is a challenge, especially in the short- to medium-term. However, there are abatement options available today that can get the sector on the path to net-zero.

Embedding goals of a 'circular' economy in all appropriate decision-making is an important first step towards decarbonizing materials and industry. The primary focus of the circular economy is to reduce waste and prevent materials at the end of their useful life from harming the environment. However, a secondary effect of making the global economy more circular is that it would also lower carbon emissions. Reducing material demand by reusing as much as possible avoids material production emissions, and making recycled materials typically has a lower carbon footprint than new (virgin) equivalents. For instance, recycled steel has 84% fewer emissions associated with it than new steel, and recycling plastics typically saves 50-60% of greenhouse-gas output compared to virgin production.

Decarbonizing the production of materials has proven quite challenging to date due to the requirements for high-temperature heat or petrochemical feedstocks. However, as materials are responsible for roughly 20% of global emissions, decarbonizing these processes is critical to reaching net-zero goals.

NEO 2021 finds that for industry to contribute its share for achieving a net-zero world, the volume of aluminum recycled must rise 67% from 2020 levels by 2030. For steel, the required improvement is 44% and for plastics 149%. This scrap is then feedstock for lower-energy and lower-emissions secondary production, which accounts for 43% of total steel, 37% of aluminum and 22% of plastics production in 2030. Greater recycling in these three materials accounts for 10% of the abatement effort required in industry to slash emissions to zero in each of BNEF's long-term scenarios.

Recycling also becomes increasingly important as the energy transition accelerates. As clean power additions grow, so does the looming challenge of sustainably managing their end of life. Demand for electric vehicles and stationary storage will create 2 million metric tons of lithium-ion battery scrap available for recycling per year by 2030, BNEF estimates. Regulators will therefore need to develop life-cycle management programs such as second-life applications, recycling, and safe disposal.

In addition to growing the circular economy overall, **speeding the use of bioplastics in consumer and business products** in particular can play a significant role in accelerating transition. Bioplastics are materials made from biological feedstocks like corn and sugarcane. They typically have much smaller carbon footprints in production than petrochemical plastics, and are gaining attention from consumer companies as a way to make their products more sustainable.

To date, however, there has been limited policy support for bioplastics. Producers of such materials complain that today they must compete with the established petrochemical industry on an uneven playing field where fossil-based chemicals are relatively unconstrained by the harm they cause to the planet. In countries that have sought to address this, the implemented policies have been weak.

Establishing and enforcing industrial energy efficiency standards can also significantly contribute to decarbonization by reducing energy consumption and thus emissions. Energy-efficiency measures are sometimes called the 'low hanging fruit' of climate policy because some require little change or outlay (in the long term it may reduce expenditure). However, broadly speaking, industry has less efficiency potential compared with other areas of the economy (eg, buildings): energy accounts for such a significant share of operating costs that companies are already incentivized to be as efficient as possible. Estimates of potential efficiency savings are around 15-20%.

Overall, industry-focused incentives are generally lacking, except for energy-efficiency standards. There may be good reasons why it will be difficult to decarbonize some industrial sectors. But governments with net-zero ambitions need to take action sooner rather than later, as even the most effective policy will take time to become effective, and industrial equipment has especially long lifetimes.

Transport

Transport is one of the fastest-growing sectors in terms of emissions, and passenger road vehicles accounted for 45% of the total transport emissions in 2018. Although electrification is not the only path to decarbonize the transport sector, electric vehicles (EVs) offer a commercially available, economically viable route. Between 2010 and 2021, average lithium-ion battery pack prices fell 89% to $132/kWh, bringing EVs closer to cost-competitiveness than ever. Our analysis suggests battery prices are on track to fall to $59/kWh by 2030. BloombergNEF's Electric Vehicle Outlook 2022 projects that unsubsidized price parity between EVs and internal combustion vehicles is achieved in most segments and countries by the late 2020s.

Therefore, **speeding deployment of EVs and charging infrastructure for road transport** is a crucial pathway towards decarbonization. NEO 2021 estimates that getting on track for transport means adding an average of 35 million electric vehicles each year so that by 2030 there are 355 million EVs. Still, in 2020, just 3.1 million, or 4%, of all global passenger cars sold were electric, up from 2.1 million in 2019 and 2.0 million in 2018. For two- and three-wheelers and buses, 44% and 39% of all sales were electric in 2020.

So far, EV sales have been concentrated in richer markets, thanks to more robust policies and competitive prices. BloombergNEF's G-20 Zero-Carbon Policy Scoreboard 2022 shows France, Germany and China rank the highest for road transport decarbonization policy, with all three countries offering the strongest support for EVs – starting with demand-driving EV purchase subsidies, to charging infrastructure deployment support and fuel economy targets to activate supply.

In addition to shifting from internal combustion vehicles to electric vehicles, governments should also lower car use by **boosting walking, micro mobility and use of public transportation.** Investments in walking and cycling infrastructure reduce emissions by reducing the number of short car trips. Meanwhile, greening and growing public transport networks can reduce emissions directly through vehicles with zero tailpipe emissions, and indirectly through modal shifts, lowering the number of journeys taken by private cars.

City-level and national policy-makers play a great role in incentivizing modal shifts. Governments can seek to make car ownership less necessary by making massive investments in public transit networks and smaller but meaningful investments in cycling lanes. These projects, however, would take time and require some modal shifts (i.e., behavioral changes) by consumers. Governments can also make car ownership less attractive and convenient by ratcheting up the cost of buying or restricting the use of cars in urban city centers.

Agriculture

Global emissions from agriculture have risen nearly a third over the last 30 years due to population and economic growth. Agriculture remains the fourth-biggest emitter, after transport, and provides a livelihood to some 2 billion people – a quarter of the world's population. But industrialization and other changes have meant that the sector's share of world greenhouse-gas output has shrunk by four percentage points to 12%. This conceals significant variation across countries, however. Looking only at the G-20, agriculture's share of national emissions in 2018 varies from just under half for Brazil (excluding land use and forestry) to 1% in Saudi Arabia (Figure 12).

Broadly speaking, developing and developed economies are seeing different trends in agriculture emissions: in the G-20, agriculture on average accounted for a tenth of generally wealthy Annex I countries' emissions compared with 17% for non-Annex I countries. One of the main reasons for this discrepancy is that wealth and population growth in developing economies have raised demand for agricultural products, especially livestock. In contrast, in Annex I nations, stagnating demand for beef, better feed quality, breeding for larger animals and improved animal healthcare have caused livestock emissions to decline.

Encouraging the sector **to implement sustainable management systems** will be a crucial step to tackling agriculture emissions. Given that livestock accounts for half of agriculture-related global greenhouse-gas output, more productive and efficient practices in this area could make a significant contribution to cutting emissions, especially of methane. For example, better feed quality, animal health and genetic selection do not necessarily lower overall greenhouse-gas output. But they have enabled farmers in North America and Europe to improve the ratio of emissions per animal to slow emission growth. Another strategy for greenhouse-gas savings (and potentially boosting profitability) would be to lower the number of unproductive animals on a farm. Improving 'stocking rates' can be combined with feed or breeding approaches so that the number of livestock kept in a given space may be reduced without reducing production volumes.

Fertilizer use is a major driver of agriculture emissions, especially in developing economies. Agricultural strategies involving regenerative or precision farming that enable the use of synthetic fertilizers to be reduced or replaced can create emissions benefits.[3] Regenerative farming practices focus on restoring soil health, increasing soil organic carbon and promoting biodiversity, while conservation farming promotes minimal soil disturbance and maintenance of permanent soil cover. With both systems, practitioners plant cover crops and use animal or green manure to provide nutrients to the soil, reducing or replacing the need for synthetic fertilizers. In contrast, such products are banned in organic farming, with farmers often using tillage to manage pests and disease.

Precision farming is the practice of using data and technologies to boost crop yields and efficiency. These techniques have been aided by the advent of new digital technologies. Big data analytics enable farmers to make more informed decisions on the use of crop inputs like fertilizer, and intelligent equipment allows variable rates of these inputs to be applied based on these analytics. As a result, agricultural suppliers have built digital-service divisions to help meet sustainability targets and customer demand for precision agriculture services.

Manure is another source of agriculture emissions – accounting for nearly 40% of the livestock total – without an easy fix. Intensive arable farming and a high number of livestock on industrial farms can produce so much manure that it cannot be spread as liquid slurry. Removing it to an outside storage facility has high mitigation potential under the right conditions, as does solid-liquid separation using gravity or a mechanical system. In addition, large pork and dairy farms in Europe and Australia have increased use of industrial biogas to manage manure emissions. But just under 90% of farms around the world are small (2 hectares or less) and may find biogas systems too expensive or not especially efficient at reducing emissions.

However, even where measures have been put in place, farmers have reported a lack of understanding and clarity about what to do. In some cases, policies unrelated to climate action deter practices that reduce emissions, and in others, enforcement and compliance of regulations have been weak. 'Soft' or technical resources can therefore address the lack of awareness and understanding in the agriculture sector regarding the need for climate action and understanding of how best to act. Government-funded training programs could focus on improving workers' academic qualifications as well as demonstrating practical skills.

Measures required to cut agriculture emissions can spark opposition from farmers and others. Getting stakeholders on board early can improve the chances of a policy success as can partnership approaches at all levels of government and with regulators and the agriculture sector. Such collaborations may facilitate discussions on how to achieve climate mitigation and adaptation,

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[3] BloombergNEF, Technology Radar: Precision Agriculture Edition; Advancing Agriculture: Majors Bet on Digital Technology; and Advancing Agriculture: Regenerative Farming.

[4] Study backed by UN Food and Agriculture Organization: Crippa, M., Solazzo, E., Guizzardi, D. *et al.* Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions, *Nat Food* 2, 198–209, 2021.

or they may focus on testing and deploying specific new technologies – for example, the use of digital services to improve the precision farming methods.

The presence of carbon-pricing regimes can also help drive change in agriculture. In some jurisdictions with such schemes in place, farmers can earn revenue by selling offsets from low-carbon projects to participants in carbon-pricing programs or companies with sustainability mandates. Agriculture and forestry offsets tend to garner higher prices on the voluntary market than those from other areas such as clean energy production.

Encouraging sustainable food consumption is another important area where governments can help to cut emissions. The food system is resource-intensive and responsible for around a third of global greenhouse-gas emissions.[4] Not only does the food system contribute to global warming but it is also at risk from the effects of climate change. Indeed, food security is already impacted by rising temperatures, changing precipitation patterns and more frequent extreme weather events. And it will be increasingly affected by future climate change as well as other factors, including population and income growth, and demand for animal products.

Increased use of fertilizers for intensive arable crops has significantly increased nitrous oxide emissions in recent years, especially in developing economies. Indeed, global emissions from the use of synthetic and organic fertilizers rose 28% over 2000-17, meaning it will be important for governments with net-zero targets to **support targeted fertilizer usage and use of low-carbon products.** This area is particularly important for developing countries, as non-Annex I parties doubled fertilizer emissions over the period, in most part driven by China and India, which saw increases of 30% and 49% over 2000-17. However, despite higher usage of fertilizers, the Asian countries have not seen significant yield improvements: even though the U.S. had lower fertilizer emissions, its cereal yield exceeded that of China and of India by over 2,000 kilograms and 5,000 kilograms per hectare .

One of the principal reasons behind this trend is government subsidies for fertilizer application: in India, for example, this funding is substantial – 1.3 trillion rupees ($11 billion) was included in the revised estimates for the 2020/21 budget, 4% of total government spending.[5] Manufacturers receive the subsidy when the fertilizer has been sold to farmers or other buyers. But this shields them from market competition, while farmers are insulated from the true cost of the fertilizer and, as is often the case with fossil-fuel support, subsidies tend to disproportionately benefit richer farmers. In addition, in some countries such as India, there is no cap on purchases. Hence over-use is common, causing residues to vaporize into the atmosphere as nitrous oxide – the main source of greenhouse-gas emissions from fertilizer use.[6]

As discussed above, an alternative approach could be for governments to promote agricultural strategies that involve less (or no) use of synthetic fertilizers such as precision or organic farming.

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[5] Government of India, *Union Budget (2021-22) – Department of Fertilisers*, Feb. 2, 2021.

[6] In addition, excess nitrogen leaches into streams and oceans, so they become over-rich in nutrients ('eutrophication'). This leads excessive plant and algal growth, and ultimately the death of organisms. Fertilizer over-use also results in soil acidification, depleting naturally occurring microbes and affecting nutrient cycles and crop production.

Finance

Replicating proven private investment models in more mature markets is fundamental to accelerate deployment of today's net-zero technologies. Despite progress in energy transition investment, investor appetite for clean technologies often exceeds the volume of investment opportunities.

The Climate Finance Leadership Initiative (CFLI) highlights that in part, this stagnation is due to policy reversals or uncertainty, which undermine the stable revenue models that support clean energy investment. Development of new coal-fired power plants continues even in markets where low-carbon alternatives are already cost-competitive, particularly in emerging markets with rapidly growing power demand[7].

As clean energy projects have increasingly come to resemble traditional infrastructure investments rather than risky alternatives, a larger pool of investment capital has emerged. However, project developers and banks are still responsible for the majority of financial flows. Asset managers and asset owners still face challenges to investing in clean energy due to a lack of financial products suitable to the asset allocation approach of many larger investors.

CFLI points out that this presents an opportunity for private finance to show leadership and to scale sustainable financial products accessible to institutional investors. The growing success of financial products that are labeled "green" or "sustainable" demonstrates that private-sector institutions within the investment chain can work together to scale up low-carbon finance. The securitization of clean energy project debt in bonds has allowed project developers to access capital markets for long-tenor, fixed-rate financing and expanded funding opportunities beyond the use of non-recourse loans.

Accelerating public investment in less mature markets is pivotal for a global decarbonization. The recent rise of clean energy investment – both public and private – is highly concentrated in high-income countries, China, and a select group of fast-growing economies. Despite rapidly increasing energy demand, other emerging markets have struggled to attract capital for mature clean energy technologies – even in cases where wind and solar may be more competitive than fossil fuels. This lack of investment is due to several factors, including country- and project-specific risks, a lack of policies and regulations to support clean energy markets, underdeveloped local capital markets, and the absence of experienced project developers and value chains. Such factors can deter investment or significantly raise risks for investors compared with advanced markets. The resulting increase in the cost of capital disproportionately affects capital-intensive investments such as renewable energy projects.

CFLI highlights that development finance institutions (DFIs) can be critical for opening new markets and sectors to private investment by establishing a track record for investment, facilitating the regulatory change needed for commercial investment, and supporting project pipeline development through project preparation facilities. In more mature markets and sectors, DFIs can unlock more capital by partnering with banks and asset managers to co-finance projects and developing fixed income and structured finance products for other institutional investors. In instances where

[7] For more details see CFLI report Financing the Low-Carbon Future

commercial opportunities do not exist, DFIs can leverage private investment through risk-sharing tools, such as guarantees and political risk insurance, and their ability to source and coordinate catalytic finance from donors and third parties.

The private sector can also help unlock new low carbon markets. In addition to providing asset financing where enabling conditions permit, international equity and debt providers can invest in or partner with local developers or other companies along the value chain. Investing in developers, rather than projects, can also offer higher returns and earlier stage access to growth markets. Private-sector organizations can also communicate clear guidelines for factors that make projects more appealing to investors.

Civil Society

Public acceptance and understanding of clean alternatives is fundamental to ensuring fast deployment of green technologies and solutions. In the power sector, for example, local 'NIMBY' (not-in-my-backyard) opposition has hindered wind project development in certain parts of the globe leaving developers struggling to find sites.

Civil society organizations and governments can play pivotal roles in enhancing public understanding and acceptance of clean technologies. For example, the Let's go Zero 2030 campaign unites and supports U.K. schools to become zero carbon by the end of the decade. In addition to reducing GHG emissions, the initiative helps students and their families see the benefits of thinking and acting more sustainably.

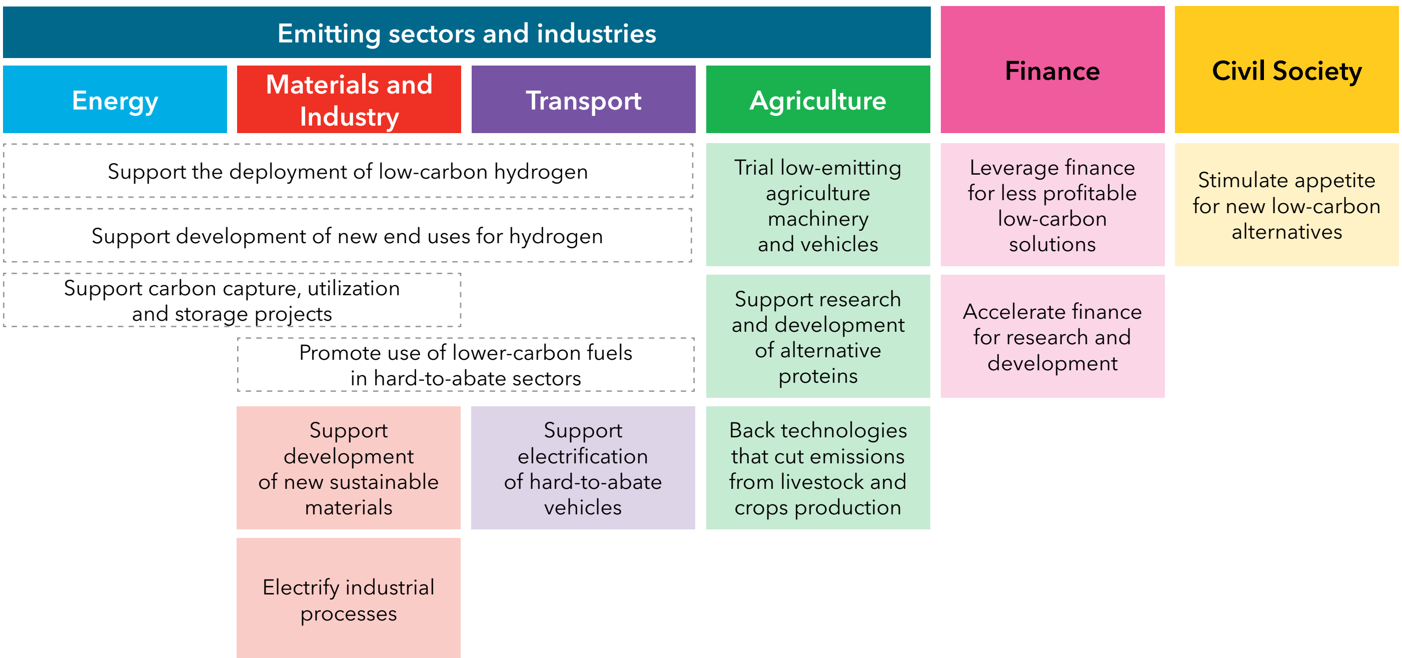
As consumers become more important and directly involved in the transition, **making clean solutions easy to choose** is also key. Ride hailing companies can allow users to choose to call an electric vehicle, rather than an internal combustion engine car. Power suppliers can allow customers to choose the type of electricity that they would like to purchase.

Pillar 2. Support development of new climate solutions

The current suite of cost-competitive zero-carbon technologies – wind, solar, batteries and electrified transport, among others – is poised to cut emissions meaningfully over coming decades. But to zero out emissions entirely, more technologies will be required to provide around-the-clock, zero-carbon power, to decarbonize industrial processes, to cut emissions associated with livestock production and to meet other challenges.

Thus, in addition to accelerating the deployment of mature climate solutions, this decade to 2030 also requires the piloting and scaling of new technology for phase II of decarbonization. The phase II encompasses 2030 to 2050, when decarbonization needs to accelerate in harder-to-abate sectors, and new solutions that complement clean electrification must be deployed.

To achieve global net-zero, every sector of the energy economy needs to eliminate emissions completely by mid-century. There can be no free riders. Even the hardest-to-abate sectors will need to adopt carbon-free solutions, only turning to carbon removals where absolutely necessary.



Source: BloombergNEF, NetZero Pathfinders

Cross-cutting solutions for energy, materials and industry and transport

While the world has made progress adding new renewable energy generating capacity, expanding the electric vehicle fleet, and transitioning to lower-carbon heating technologies, the burning of fossil fuels continues to account for the vast majority of global CO2 emissions. Policy makers and industry should therefore look to support alternative fuels with lower greenhouse-gas output or technologies that could reduce the emissions from fossil-fuel production and consumption.

Supporting deployment of low-carbon hydrogen is potentially fundamental for the next phase decarbonization. Not only can hydrogen be produced with low or no greenhouse-gas emissions under the right circumstances, it can potentially be used for heating and feedstock in a range of applications. It can be transported and stored, and could also help to extend the useful life of existing gas infrastructure. Although hydrogen does not play a meaningful abatement role in the 2020s, getting it to scale is a potentially critical task for this decade.

Under BNEF's long-term 'green' scenario for the energy transition, hydrogen accounts for 14% of the total abatement to net-zero by 2050. This includes hydrogen used to generate high-temperature heat in industrial processes such as steel making, chemicals and cement, hydrogen used as a fuel in transport, including aviation, shipping and some road and rail transport, and hydrogen used in boilers for space and water heating. Combining hydrogen in power generation and the end-use economy, it makes up 23% of total emissions reduction in the Green Scenario[8]. NEO finds that 1.9TW of electrolyzers need to get deployed by 2030 to kick-start the hydrogen sector, up from far less than 1GW of green hydrogen electrolyzers online now.

Today, nearly half of hydrogen produced is as an industrial by-product, while most of the remainder is made deliberately through fossil-fuel-based reactions. In 2018, less than 1% came from water electrolysis. If powered by renewables, electrolysis can produce zero-carbon hydrogen, while a low-carbon alternative is to use steam methane reforming or coal gasification with carbon capture and storage (CCS). On the demand side, almost all hydrogen is used as feedstock for manufacturing chemicals and basic materials. The volume produced via water electrolysis has mostly supplied small, distributed applications and its use is generally motivated more by economics, than a move to reduce emissions.

Hydrogen today is used in a limited number of applications: predominantly refining, ammonia and methanol. To unlock hydrogen's economic potential and realize its role as a tool for decarbonization, it will also be key to **support the development of new end uses for hydrogen** to expand it to all hard-to-electrify sectors – especially industry, buildings, heavy transport and backup power. This will require the development of new demand-side technologies and expertise.

In industry, switching plants to furnaces, boilers and other processes that burn hydrogen instead of fossil fuels, is key to decarbonization of high-temperature processes. In NEO's Green Scenario,

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[8] NEO Green Scenario is a clean-electricity and green-hydrogen net-zero pathway. Here, hydrogen produced from water using electrolyzers powered by wind and solar is applied in sectors such as industry and heavy transport, as well as in power generation to complement electrification. Click here for more details.

hydrogen-based heat replaces around 43% of fossil fuel use in industry to 2050. In buildings, hydrogen can also play a relatively large role. Hydrogen-fired boilers are responsible for around 40% of the abatement in the sector over the outlook.

In the transport sector, ammonia derived from hydrogen can become a dominant solution in shipping for new vessels post-2030, and hydrogen-fueled planes can emerge for short- to medium-haul flights between 500 kilometers and 4,500km. Hydrogen-fuelled trains can also see a small uptake in the next decades.

In the power sector, the dominance of low-cost renewables leave limited space for hydrogen, but the technology will still be fundamental to provide flexible and dispatchable power to complement wind and solar generation. It can effectively take over the role played by natural gas, especially as gas turbines can burn a range of fuels, including hydrogen.

Alongside hydrogen, **supporting carbon capture, utilization and storage (CCUS) projects** will be crucial for the next phase of decarbonization. CCUS is the process of reducing a facility's carbon emissions by separating, compressing and transporting the CO2 for use in industrial or drilling processes elsewhere or storage. It can also contribute to the 'circular carbon economy' by creating a second life for captured CO2 by 'upcycling' it into new products including concrete, nanotubes, chemicals or fuels. Some of these products are converted back into energy at the end of their life or decompose, potentially releasing the captured CO2 into the atmosphere. However, CO2 at stationary facilities can be captured again, creating a circular loop. Finally, CCUS can be used to produce low-carbon hydrogen from natural gas, coal or biomass and can even be applied to biomethane production sites. Like hydrogen, it does not play a meaningful abatement role in the 2020s, but getting it to scale is a critical task for this decade if it is to make major impact in the 2030s and beyond. Today, carbon capture is experiencing rapid growth with governments' and companies' net-zero targets being one of the drivers of this activity. However, in order for CCUS to play a significant role as a decarbonization technology, the industry needs widespread adoption to bring down costs.

In addition, a growing number of end-products that use and store carbon are emerging, although they remain at very early stages of commercialization. These include construction materials like aggregate and concrete, fuels and chemicals like ethanol and methanol, polymers like polyurethane, and additives like carbonates and carbon nanotubes. Each product uses a different amount of CO2 and has its own value and market size. Together, however, they could match or exceed the amount CO2 demand seen for EOR. Concrete in particular may be the 'low-hanging fruit' for utilization, due to its scale and relative insensitivity to CO2 prices.

Promoting use of other lower-carbon fuels in hard-to-abate sectors can also help close the gaps in high-emitting segments in industry and transport, where electrification, hydrogen or CCUS are not viable options. Other lower-carbon fuels include biofuels, biogas and biomethane.

Biofuels can play a role in power generation, heat or transport. Today, biofuels represent one of the few available options for cutting emissions from hard-to-abate transport sectors like heavy-duty road vehicles, shipping or aviation. Governments around the world have introduced incentives in their favor and biofuels production has risen more than 10-fold since 2000. But their use remains marginal, averaging less than 3% of transport energy consumption.

Biogas and biomethane are renewable sources of energy derived from organic matter, such as crops and waste. Biogas is most often produced in an anaerobic digester, which can break down a variety of organic feedstock including energy crops, municipal solid waste, manure and agricultural waste. Raw biogas consists of methane and carbon dioxide, along with a mix of other gases, and may be used to generate power and produce building and industrial heat.

When the methane is separated from this mixture to meet standard pipeline quality specifications, it is referred to as 'biomethane', or 'renewable natural gas' (RNG). From this point, it is fully compatible with traditional natural gas and can be used in existing equipment and pipelines. As with biogas, biomethane may be employed for baseload power generation and heating for buildings and industry, but it may be used for higher temperatures and for transport.

Aviation is a hard-to-abate sector where using more sustainable fuel is commonly regarded as the best path to cutting its emissions. Sustainable aviation fuel (SAF) is available today, but a lack of policy support, strict performance criteria, and competition for biofuel supply from other sectors, such as road transport, have held back wide-scale uptake. Currently there are just a handful of commercial plants producing SAF at scale. Cost has also been a barrier. Fuel makes up around 30% of an airline's operating expenses and SAF currently costs between two and four times conventional jet fuel. SAF can be produced using a variety of low-carbon inputs, such as biomass, municipal solid waste, or water, electricity and CO2 via hydrogenation.

NEO estimates that sustainable aviation fuels need to increase to 18% of total jet fuel use by 2030, and greater emphasis needs to be placed on operational efficiency in shipping as well as increasing biofuels use to 4% of fuel. National and state-level policy makers can incentivize usage of biofuels by setting demand-side targets or regulations mandating certain shares of biofuels be blended with fossil fuels.

In particular, policy makers need to ensure there is sufficient demand for the fuels to increase their competitiveness with fossil fuels and to attract investors in production capacity. Enough feedstock should be available to meet that demand and regulation to ensure its sustainability. For instance, Brazil and the U.S. account for over 60% of global liquid biofuels production and consumption. This has been largely down to policy. The most common types of incentives globally are demand-side targets or regulations mandating certain shares of biofuels be blended with fossil fuels.

Materials and Industry

New sustainable materials can play a key role in decarbonizing industry over the next decade. Steel, for instance, is the most widely used metal in the world. The scale of its production makes it one of the largest single sources of carbon emissions, and therefore a crucial sector to decarbonize. The Sweden's HYBRIT consortium – formed to make carbon-free steel using hydrogen (H2) – is one example of innovation in the sector. It produced its first sponge iron on June 21. This is an intermediate for steel production and a critical step on the path to zero-emissions steel.

Electrifying industrial processes to switch from using fossil fuels to electricity is the single most effective way to reduce sector emissions. This is an available option in many sectors where only low-temperature heat is required, particularly in petrochemicals and aluminum recycling. Other lower-temperature processes, such as those in food and tobacco, and in pulp and paper, can also be electrified. Under BNEF's long-term NEO estimates, switching to electricity can abate 41-46% of industrial sector emissions.

In G20 countries, for example, at least 79% of industrial process heat is produced through fossil-fuel combustion. In some sectors, industrial-scale electrification is closest to commercialization among the technologies capable of reaching sufficiently high temperatures. Still, various electrification options under development remain pre-commercial and can only be used for certain materials and processes. For example, plasma heating has been used to provide heat for calcination in cement production. In the longer term, these electrification options could produce high-temperature heat as well as delivering efficiency gains and process improvements over fossil fuels.[9] Despite these potential benefits, there is generally a lack of government support for such technologies. The exceptions are product standards in some markets and a limited number of R&D programs.

Hybrid electric-fossil fuel systems are available for low- and medium-temperature heat production, potentially by being co-located with a wind or solar plant. These face lower energy costs, and may secure additional revenue by providing balancing services to the electricity grid.

An alternate electrification option is to install an industrial heat pump, which is as much about waste-heat recovery and efficiency as it is about electrification. Industrial heat pumps take waste heat from one process, and top it up to a usable temperature for another process.[10] This is in contrast to heat pumps for space heating and hot water, which use ambient air, ground or water as their heat source. While industrial heat pumps can be used for cooling, they are most often used to supply process heat. They are also limited in the operational temperatures they can reach, with current models able to achieve up to 180 degrees Celsius.

A key advantage of heat pumps is their efficiency, which is determined by the coefficient of performance (COP) – the amount of electricity needed to power the pump. A high COP boosts the heat output for the same amount of electricity, reducing power demand and thus operating costs. Their ability to reuse waste heat and integrate heating and cooling processes is also a benefit.

Governments at all levels can offer financial or fiscal incentives for industrial heat pumps than pure electric systems to help overcome heat-pump's high upfront costs, which are on average five times as high as for a conventional gas boiler.

Other barriers to the uptake of industrial heat pumps and electrification more broadly relate to technical feasibility, meaning governments could support research already underway. Some of this research is around output temperature: work is being done today to test the ability of heat pumps to reach higher temperatures, particularly of around 200°C. Since sectors requiring only low-to-medium temperatures account for around 60% of industrial heat use across the G20 countries, this could significantly expand the number of applications for which industrial heat pumps are

[9] While equipment fuelled by electricity are only slightly more energy-efficient than fossil fuels, industrial boilers have lower maintenance and investment costs. [1]

[0] BloombergNEF defines industrial heat pumps as those used for industrial process heat – not for buildings.

suitable. As well as implementing incentives for heat pumps in these areas, government should finance information campaigns and training courses to raise awareness and knowledge about the technology, and increase the pool of qualified installers.

Transport

Although smaller, opportunities to **support the electrification of hard-to-abate vehicles** also exist. In aviation, aircraft on commuter routes have the potential to become electric in the medium-term, for instance. However, these routes make up just 5% of total aviation fuel consumption.

In shipping, domestic and short-haul general cargo vessels, ferries, cruises and other light vessels could be electrified. Under BNEF's green long-term New Energy Outlook scenario, electric vessels are used for 10% of spoke routes[11] and 30% of domestic routes from 2030 onward. This would result in a 3% abatement of shipping emissions. In rail, there is good potential for electrification of freight that currently runs on diesel, which accounts for 1.6% of energy use in transport.

National governments can support the development of new electric vehicles for hard-to-abate sectors by implementing clear targets or roadmaps for the sector to give clarity to investors and support companies through R&D initiatives. In addition, carbon, fuel tax and credits policies can help spur the market by raising the cost of burning fuel and incentivizing airlines and shipping companies to seek alternatives.

Policy to regulate aviation emissions has been limited so far, but At COP26, over 23 countries signed up to the International Aviation Climate Ambition Coalition, which aims to cut sector emissions at a rate consistent with a 1.5-degree target.

Agriculture

Trialling low-emitting agriculture machinery and vehicles would help countries progress toward their net-zero targets, as energy use is the third main driver of emissions in the sector. Oil and diesel continues to dominate the fuel mix, although its share shrank 14 percentage points to 50% over 2000-19. Electricity has been the main beneficiary, although this trend's impact on emissions ultimately depends on the power-generation mix where equipment charges. Globally, use of renewables is modest at about 7%.

The previous sections discuss the growing electrification of the road transport market, especially for passengers and light-duty commercial vehicles. Yet the same trend has not been seen in the agriculture sector for practical reasons: current batteries lack the energy density required to power the pulling of heavy loads for long periods and farmers cannot afford long durations of downtime

[11] Planes, ships and trucks may operate on a centralized hub-and-spoke distribution model whereby routes are a set of 'spokes' connecting to a central 'hub'.

during intensive equipment-use periods, such as harvest time. (In comparison, a traditional fossil-fueled equivalent might be able to last 10-12 hours, with very little time required for refueling.) The components also need to be durable and withstand the wear and tear of operating off-road in vehicles with a potential lifetime of 20 years or so.

Electric tractors and other machinery are in development: conventional tractor developers are focusing on electrifying specific functions of the tractor first, while agricultural robot manufacturers are already offering fully electric versions of their systems. Electrification of farm vehicles and machinery only contributes to a country's net-zero target if farmers, including those in rural areas, have access to affordable and reliable power. Policy support to promote grid connections and deployment of off- and mini-grid power systems helped boost global electricity access 2013-19. However, progress varies significantly across countries: 75% of the population in Kenya had access to electricity in 2019 compared with 38% for its southern neighbor, Tanzania, and 1% in South Sudan to the northwest. As well as initiatives to promote energy access, governments can support research to test and demonstrate electrified agricultural equipment using mini- or off-grid power systems. They can also encourage deployment in rural areas by offering mobile repair services for electrified machinery, because risk of delays due to repairs and lost revenue can deter uptake.

Another barrier facing countries is that some farming activity still relies on manual labor or animals. This is more prevalent where the sector comprises a high number of small farms. For example, the U.S. and much of Europe have a mechanization rate of around 95%. In comparison, India stands at around half and China at 70%. In countries with low mechanization rates in the agriculture sector, policy makers can offer low-cost financing toward purchases of new machinery, or incentivize financial institutions to do the same. National government can set state-level targets for mechanization in farming, set up local facilities that loan out machinery, and create apps and websites that connect farmers with machinery-hiring services in their area.

Given that around half of global agriculture emissions are from livestock, consumers' dietary choice – more specifically demand for animal-based products – can have significant implications for countries' decarbonization efforts. One option therefore is for governments to **support research and development of alternative proteins**. Plant-based and cultured meat[12] have significantly lower emissions than conventional meat products. They also require less land and water.

The plant-based food alternatives sector is on the rise: the global retail market for such products could reach $162 billion by 2030 – up from $29 billion in 2020 – according to Bloomberg analysis. Today, the market is dominated by dairy milk substitutes but meat sales are expected to catch up by the end of the decade. Production costs are also expected to decline as the sector matures, closing the gap to price parity with conventional meat products.

Governments have a key role to play in supporting the development of alternative proteins and ensuring the right regulatory framework is in place. Regulatory uncertainty is likely to be a significant barrier to the

[12] Plant-based meat refers to products that imitate and act as substitutes of animal meats but do not contain animal products. Cultured (also known as lab-brown or in-vitro) meat uses engineering techniques found in regenerative medicine to grow, repair or replace damaged cells or tissue from a living animal.

roll-out of some alternative proteins, notably cultured meat. And companies are unlikely to expand their pilot manufacturing facilities (and help to bring down costs) until the regulatory framework is in place. Many of the ingredients used for growing cultured meat have yet to be reviewed and approved for food consumption in the vast majority of countries. This process can be long and expensive, and while industry players agree on the need to work together to overcome regulatory barriers, they are unlikely to be willing to share too many details on their products and processes.

Until deployment of plant-based products reaches a scale that triggers cost declines, national and state-level policy makers may want to consider adjusting the price signals in their favor compared with animal products. In such cases, they should consider the impact on low-income households, as meat demand may be relatively inelastic to changes in price.

The prior section outlined mitigation pathways relating to livestock and manure management that are already in practice. Another option is for governments to **back technologies that cut emissions from livestock and crops production**. Some of these strategies focus on enteric fermentation.[13] This part of the digestive process in ruminant animals (cattle, sheep, goats, etc.) produces methane and is responsible for nearly two-thirds of livestock emissions.

A number of companies and academic institutions are also developing novel feed additives that achieve significant emission reductions. For example, several recent studies have found that mixing asparagopsis taxiformis (a red seaweed) into feed could reduce methane emissions by 80% or more. The first licenses were granted in April 2021 to establish a commercial seaweed farm in South Australia to aquaculture company CH4 Global in partnership with Narungga Nation Aboriginal Corporation. This was followed in June 2021 by what's believed to be the first red-seaweed-offtake agreement: aquaculture company CH4 Global will initially provide Pirie Meats with enough asparagopsis seaweed supplement for up to 10,000 heads of cattle.[14]

Other companies are devising wearable devices that change methane into CO2 and water. For example, U.K. startup Zelp has created a mask-like accessory which it claims can more than halve methane emissions. Agriculture producer Cargill announced in June 2021 that it would start selling the devices to European dairy farmers in 2022.[15] A key barrier will be cost, although farmers may be able to recoup some of the expense by selling carbon offsets.

In addition, academic institutions and companies are investigating new technologies to cut emissions from manure. For example, lab tests to add tannic acid and fluoride to pig manure reduced ammonia emissions by up to 95% and methane up to 99%, according to researchers from the University of Southern Denmark and Aarhus University.[16] Their plan was to develop a granulate that farmers can add to manure but the technology costs must be reduced before roll-out.

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[13] The animal eats grass containing carbon. Microbes in the stomach help to digest the grass, and some of the carbon is converted to methane, which is then released into the air.

[14] Press release: Pirie Meats, CH4 Global, Organic Technology Holdings and Siemens Australia Launch Advanced Processing Collaboration, June 2021.

[15] Bloomberg, Cargill Backs Cow Masks to Trap Methane Burps, June 1, 2021.

[16] Dalby, F.R., Svane, S., Sigurdarson, J.J., Sørensen, M.K., Hansen, M.J., Karring, H. and Feilberg, A., 'Synergistic Tannic Acid-Fluoride Inhibition of Ammonia Emissions and Simultaneous Reduction of Methane and Odor Emission from Livestock Waste', Environmental Science & Technology, May 2020.

Other solutions involve the use of advanced biologicals – an emerging technology based on soil microbes that improves crop productivity and health while reducing chemical inputs to the soil.[17] The technology, however, is still at the early stage. Currently available biologicals could reduce nitrogen fertilizer use by 10-20% for specific crops in certain locations today. Some startups aim to ultimately replace fertilizer use entirely.

Finance

Leveraging finance for less profitable low-carbon solutions is pivotal to enable the solutions discussed above. In contrast to the growing cost-competitiveness of renewable energy generation and electric vehicles in the power and light-duty transportation sectors, fewer viable alternatives exist in other areas of the global economy with significant shares of emissions. These include heavy industry, heavy-duty transport and agriculture, forestry, and land use. In some cases, solutions for decarbonizing these sectors are technically viable but not yet economical due to high capital costs and lack of incentives or revenue models. In other cases, the necessary technologies require further development to reach commercialization.

Public funding can provide revenues for low-carbon investments, for example, through market-based subsidy mechanisms or other results-based finance schemes. Incentives leveraging public finance are especially attractive in markets and sectors where the introduction of fully fledged carbon markets is not yet viable or when carbon market prices are too volatile to support long-term investment.

Accelerating finance for research and development is also key to supporting development of new climate solutions. For technologies that are not yet commercially viable, R&D and demonstration projects from both the public and private sector can help bring innovative products to the market, while publicly financed incentive structures can create a more acceptable return profile for higher-risk technologies.

Public funding can be essential to the development of new technologies whose long R&D life cycles are difficult to support on corporate timescales. Public budgets can also support the commercialization of technologies through subsidy mechanisms and risk-sharing models like loan guarantees. Activities that help bridge the gaps between demonstration and commercialization will also be critical. Some coalitions of private investors, such as the Breakthrough Energy Coalition, that seek to enhance private support of early-stage technologies will be critical.

Risk sharing between public and private institutions in specific sectors can also help bridge the gap between demonstration and commercialization. In the HYBRIT partnership, for instance, steel producer SSAB, iron ore extractor LKAB, power company Vattenfall, and the Swedish government have joined forces to create a fossil-fuel-free steel plant that replaces coking coal with hydrogen.

[17] BloombergNEF, *Advancing Agriculture: Biologicals*

Civil Society

Adoption of new technologies is often intimidating, but consumers will need to catch up with the fast pace of the transition to ensure the world stays on the net-zero track. Thus civil society organizations and governments must implement initiatives that **stimulate appetite for new low-carbon alternatives**. This could include educational campaigns and public-private partnerships to promote novel technologies.

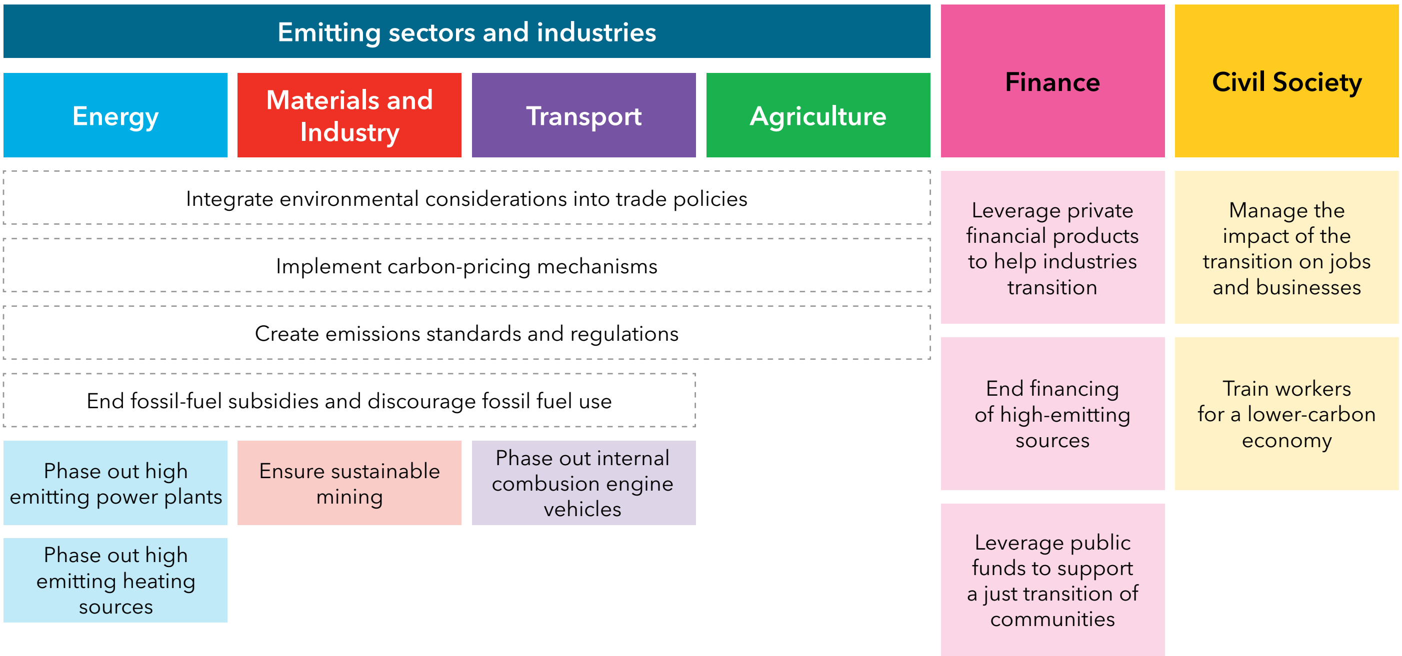
Pillar 3. Manage the transition or phase-out of carbon-intensive activities

Despite the immediate threat posed by climate change, national governments continue to build thermal power plants, subsidize the burning of fossil fuels or underwrite their extraction through state-owned companies. Over 2010-2021, fossil-fuel fired capacity grew by over 1,000GW, with coal accounting for more than half. Despite climate pledges, the world added over 220GW of new coal-fired power generating capacity since the Paris Agreement.

Phasing-out high-emitting sources and scaling back subsidies that artificially cap consumer gasoline and electricity prices can be politically challenging. However, these are fundamental measures to limit global warming.

Many assets in the real economy are long-lived, ranging from around 15 years for cars and buses, up to 50 years for fossil fuel power plants, and 100 years or more for buildings. However, many of these will need to be retired early to get the world on a 1.5- degrees trajectory. This will require a transformation of the corporations, utilities, and communities that have historically relied on their operation.

Although the benefits of the low-carbon transition will far outweigh the costs, the structural change implied by the change will need to be managed to ensure new benefits created are inclusive. As the global economy transitions from high-carbon assets to low-carbon alternatives due to market forces or regulatory interventions, workers and communities that rely on these assets must be supported, in what has been coined a "just transition." This will require a strong, coordinated action among governments, communities, investors, and businesses.



Source: BloombergNEF, NetZero Pathfinders

Cross-cutting solutions for energy, materials and industry and transport

Integrating environmental considerations in trade policies will become fundamental as the world transitions towards true decarbonization. Governments with ambitious climate goals will need to look across their economies for emissions-reduction potential, including sectors exposed to international competition. However, this raises concerns of 'carbon leakage' whereby a company moves operations to markets with lower environmental compliance costs (eg, no carbon price). If this occurs, then a carbon price or other policy has failed to reduce global net emissions – it has simply shifted them to another location.

As a result, governments implementing a carbon price have often granted concessions to companies deemed to be at risk of carbon leakage. These may take the form of lower tax rates, or a share of 'free allocation' in the case of emissions trading schemes such as the EU and South Korea markets. Companies granted such concessions have less incentive to decarbonize, even though they may need to reduce emissions for a country or state to realize its climate goals. As such, some governments are exploring whether to implement a carbon border adjustment mechanism (CBAM). These policy measures seek to ensure that domestic and overseas companies face similar environmental costs, hence removing carbon leakage risk.

A key solution to deterring the use of fossil fuels is to **implement carbon-pricing mechanisms**, which aim to force polluters to pay for the costs they impose on the environment and incentivize them to cut emissions. The most common types are carbon taxes or market-based mechanisms like emission-trading schemes. The former gives participants more certainty on the future cost of carbon but does not guarantee a specific level of emission reduction. Setting the tax rate at the right level is also tricky: too low and companies (and households) will choose to continue polluting and just pay the tax. If the rate is too high, costs could rise higher than necessary to reduce emissions, potentially hurting profits.

An emission-trading or 'cap-and-trade' program places an upper limit on emissions but the price is set via market forces, meaning more uncertainty for participants. Almost all cap-and-trade schemes today have mechanisms to stabilize the market because it is challenging to forecast emission trajectories accurately and the fixed cap often cannot respond automatically to changes in the supply-demand balance.

Many governments have incorporated into their carbon taxes or markets 'flexibility mechanisms' - measures that reduce the compliance burden for companies. These are especially common in the early stages of a program and can take various forms – eg, allocation of free permits, tax-free allowances, the ability to bank allowances into future years, and the option to comply by submitting offsets from low-carbon projects.

Another reason for flexibility mechanisms is the risk of carbon leakage – where companies move operations to markets with weaker environmental regulations – in sectors exposed to international competition. However, these concessions may mean that some companies are not incentivized to decarbonize, potentially running counter to a government's climate targets.

In order for a carbon price to be an effective driver of decarbonization, it needs to cover a sufficient share of emissions and be sufficiently high. Today, around a quarter of global emissions are produced in jurisdictions that price carbon, but the vast majority of this operate under regimes with prices too low to spur change. An explicit CO2 price of $40-80 per metric ton is needed by 2020 and $50-100 by 2030 in order to limit global warming to 2 degrees above pre-industrial levels by the end of the century, according to the World Bank's High-Level Commission on Carbon Prices 2017 report.[18]

Carbon pricing is best used as part of a decarbonization policy package, with targeted supplementary measures. It is a careful balance because parallel policies (eg, a renewables portfolio standard) could lead to inefficiencies. In addition, these supplementary measures could cut greenhouse-gas emissions, thereby lowering demand for carbon permits and thus prices. This then reduces the incentive for participants to take climate action, could mean that carbon-intensive assets are locked in for decades more, and results in an imbalance in the cost of emission reduction across sectors.

However, there is a range of cases where additional government support is likely to be required. For example, funding may be needed to incentivize technological research because carbon pricing may not provide sufficient incentive for innovation, especially the types and scale of innovation likely to be required to reach a net-zero world. A fluctuating carbon price may also not provide the certainty required for companies to make long-term investments.

Governments with carbon-pricing plans may well need to take steps to bolster public acceptance, especially relating to the perceived fairness. One option is to set aside or 'recycle' some revenue

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[18] Carbon Pricing Leadership Coalition, *Report of the High-Level Commission on Carbon Prices*, 2017.

from tax collection or permit auctions for specific areas, such as environmental projects. Another is to implement measures to offset any regressive effects such as making payments to low-income households. Acceptance is also likely to be affected by overall trust in government, especially for taxes where policy makers fix the price. The pace and scale of price rises are important, as is clear and timely communication.

Emissions standards and regulations are diverse tools that can help deliver lower-carbon and cleaner products. Used well, emissions standards can signal to manufacturing industries and companies to reduce the emissions intensity of their products and processes.

Standards and regulations can be flexible policies established across the value chain for a product – including regulating upstream emissions from raw materials and energy use, or the operational emissions of a product sold to consumers. Such standards are often applied to products that combust fuel during their use – such as vehicles or heating units. Emissions standards can be designed to increase in stringency over time, by requiring new products to become cleaner. This can give a long-term signal to industry stakeholders and manufacturers to adapt their activities. A case study of this is the European Union's CO2 emissions performance targets for passenger cars. These standards affect automakers selling new vehicles in the region and are increasing in stringency over time.

There are additional layers of complexity that can affect the strength of emissions standards and regulations. Increasingly, some policymakers are considering standards that would calculate the lifecycle emissions of a product – rather than just assessing operational emissions alone. Such standards could prove challenging to implement in practice as they can be particularly complex to calculate and standardize. But they could help to boost discussions around the optimal way to incentivize sustainable value chains through regulation.

True decarbonization also means **ending fossil-fuel subsidies and discouraging fossil fuel use**. BloombergNEF estimates that the Group-of-20 countries alone provided $3.5 trillion in direct support for coal, natural gas, oil and fossil-fueled power in 2015-20. At today's prices, that sum could fund 4,376GW of new solar power plants – over 3.5 times the size of the U.S. grid on a capacity basis. These figures are probably under-counts, given the limited transparency.

Fossil-fuel support provided by G-20 countries slid 6% in 2020, based on provisional estimates. The 2020 overall decline was driven by a 29% drop in the value of subsidies for energy consumers as fossil-fuel and electricity usage decreased during the pandemic. Factoring out lower consumer price subsidies, total fossil-fuel support would have stayed level 2019-20 after governments and state-owned organizations provided special funding in response to the pandemic.

This support encourages the (potentially wasteful) use and production of fossil fuels. It can also distort prices and risks carbon 'lock-in' – whereby assets funded today will be around for decades, locking in high levels of future emissions. All of these factors hinder the climate transition. The lion's share of the subsidies (60% in 2019) goes to producers and utilities, despite government climate commitments and proliferation of cost-competitive clean technologies. Even consumer-targeted subsidies disproportionately benefit wealthier consumers. Subsidies can take a number of forms, from lowering the price paid by an electricity consumer, to providing grants to oil companies for drilling.

Eliminating fossil-fuel supports can be a slow and politically delicate process. However, national governments can implement other policies to offset these supports without the same potential downsides. These include financial incentives for renewables and energy storage, capacity mechanisms in the power market, and 'just transition' strategies to support companies, workers and local communities affected by the shift from fossil fuels to cleaner technologies.

Governments undertaking fossil-fuel reforms often find the process both slow and difficult politically. However, leaving such support mechanisms untouched distorts markets and risks carbon 'lock-in' – whereby assets funded today will be around for decades spewing emissions. Fossil fuel subsidies may be designed to ensure security of domestic energy supply, to protect vulnerable consumers or to support jobs. However, other mechanisms – eg, renewables incentives and 'just transition' policies – can meet these needs as well, without the same lock-in risk.

Energy

In addition to boosting clean energy additions, **phasing out fossil fuel-fired capacity** will be one of the most important steps to decarbonize the global economy. Under NEO's Green Scenario, the world has to retire than 100GW of coal-fired capacity on average each year so that by 2030 coal-fired power is 67-72% below 2019 levels. However, fossil fuel power-generating capacity grew by over 1TW 2010-2021 with coal accounting for over half the total. While the number of pledges to shut down coal plants is rising, significant additional effort from policy makers, utilities and investors will be needed to ensure follow-through.

As economics alone won't drive major buildings retrofits in the short term, governments must push to **phase out high emitting heating sources**. Bans on emissions-intensive heating options, such as gas or oil boilers are growing in G20 countries. While these types of policies can support a range of low-carbon options, heat pumps are a key beneficiary due to their comparability in size and application.

Materials and Industry

Ensuring sustainable mining is a pivotal step to establishing a truly decarbonized economy. This is especially important as a fast transition will create significantly higher demand for metals and minerals fundamental in the production of virtually every green technology. Electric vehicles, for example, have zero tailpipe emissions, but have associated upstream emissions battery manufacturing, in addition to power generation.

Transport

Setting a goal to phase out the use of internal combustion engine vehicles has the potential to accelerate the transition significantly in the transport sector. Moreover, moving away from conventional cars and trucks is critical for addressing climate change. According to BNEF's Long-Term Electric Vehicle Outlook, across all segments, sales of new internal combustion vehicles must cease post-2035 for the transport sector to contribute its share toward achieving net zero. Even then, some early retirements and conversions of older vehicles will be required in the 2040s.

Some countries have already issued plans to abolish ICE vehicle sales altogether over time. There are now at least 19 national-level targets to phase out sales of internal combustion vehicles. The list is rich in European countries, but Canada, Singapore, Costa Rica and Chile have also committed to phasing out ICE sales.

Finance

Bold commitments from investors to **end financing of high-emitting sources** are also fundamental to put the world on track for a successful first phase of the race to zero this decade. Multiple nations and investors have recently committed to end coal financing, but more remains to be done.

In June 2021, for instance, the G7 leaders agreed to end new direct government support for unabated coal-fired power stations abroad by the end of 2021 and accelerate the transition away from unabated coal capacity in line with 2030 climate targets and net zero commitments.

Leveraging private sector financial products to help industries transition from fossil fuel reliance will be critical. Investors and lenders can develop a wider range of financial products to support corporations that have adopted ambitious transition goals, such as transition bonds or corporate bonds linked to longer-term transition strategies. Supporting corporations in their transition can create a virtuous cycle: more money invested in clean companies can create a greater appetite for the transition – lowering financing costs and ultimately leading to more investment[19].

Leveraging public funds to support a just transition of communities is also fundamental, as a sector may account for a substantial share of local jobs and without policy maker intervention, a phase-out could result in mass unemployment and migration, and social unrest. Such a transition will require strong, coordinated action among governments, communities, investors, and businesses. Public policies that link climate, macroeconomic, industrial, and labor policies can help lay the foundation for inclusive growth, both through short-term programs that mitigate negative impacts on workers and communities (e.g., income support) and through longer-term industrial strategies or retraining programs. Investors, recognizing the long-term value of inclusive growth, can also integrate social factors into their investment strategies or how they engage with corporations. All of these must be done in consultation and offer transparent dialog with the communities undergoing a transition.

Corporations and investors can also support the just transition of communities and workers by incorporating social criteria into their investment decisions, investing in retraining programs, and recognizing the long-term value of inclusive growth. Public budgets can provide direct support to communities, households, and workers affected by the transition. This support can include measures to mitigate short-term impacts, such as providing compensation, workforce development programs, and community grants to diversify local economies, while also investing in longer-term industrial transition strategies that may not generate the level of financial returns needed to attract private investment.

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[19] For more details see CFLI report Financing the Low-Carbon Future

Civil Society

Many assets in the real economy are long-lived, ranging from around 15 years for cars and buses, up to 50 years for fossil fuel power plants, and 100 years or more for buildings. As a result, the financing decisions of the past can lock in carbon emissions well into the future. "Committed" emissions from existing fossil fuel-based assets in the power, industrial, and transport sectors are already incompatible with a 1.5-degree trajectory. Consequently, some carbon-intensive assets will likely need to be retired early, requiring a transformation of the corporations, utilities, and communities that have historically relied on their operation. Thus, policy makers and civil society organizations will need to implement initiatives that **manage the impact of the transition on jobs and businesses**. As new technologies emerge fast, all nations around the globe will also need to **train workers for the low-carbon economy**. This is fundamental to ensure that new technologies can be implemented fast and safely. Over the coming years, policy makers and civil society will need to prepare younger professionals and reskill workers from high-emitting sectors to install and operate green technologies.

Pillar 4. Create Appropriate Climate Transition Governance Structures

The scope of the climate crisis is forcing smart policymakers to take a multi-decadal view of the problem, which encompasses multiple sectors and stakeholders. But policies are only as good as the frameworks that exist to implement and enforce them. Policymakers must recognize that to attract investment in low-carbon technologies – and enjoy the associated economic benefits – they must construct governance structures that are durable for the long term. Investors, corporations and civil society all have key roles to play in ensuring that the transition is fast, but does not leave anyone behind.

Emitting sectors and industries				Finance	Civil Society
Energy	Materials and Industry	Transport	Agriculture		
Establish independent bodies focused on climate goals and projects				Align financial institutions' portfolios with climate targets	Push for binding goals that include concrete CO2 reduction targets
Ensure continuity of climate goals and projects					
Enhance cross-government and cross-stakeholder coordination				Encourage climate-related financial disclosures	Drive social development and equality across the value chain
Encourage and enforce corporate climate commitments					

Source: BloombergNEF, NetZero Pathfinders

Cross-cutting solutions for energy, materials and industry, transport and agriculture

Establishing independent bodies focused on implementing climate goals and projects is key to supporting, informing and advising policy makers. These entities, comprised of independent experts, can ensure alignment between policy and the latest climate science, and enable better scrutiny over government decisions. Ongoing research and analysis by these entities can also help to hold policy makers to account for short-term progress toward longer-term climate targets. They can also help in the process of target-setting and identifying optimal pathways to achieving these goals.

Many governments already work alongside an official independent body that advises and scrutinizes policy at the national level. These are typically comprised of leading experts on climate and energy. For example, the U.K.'s Committee on Climate Change has a leading role in shaping the country's climate targets – and was notably the driving force behind the legislating of an economy-wide net-zero target by 2050.

Denmark also has established an independent council on climate change responsible for monitoring and evaluating progress towards emissions reductions targets and advising climate policy – the Klimaradet. Sweden's Climate Policy Council, Klimatpolitiska Radet, fulfils a similar role.

Governments should also ensure continuity of climate goals and projects. This means establishing and maintaining robust processes for policy making, with clearly communicated timelines for changes, and actively consulting with industry and experts.

Continuity in policies supporting clean energy and other climate-related projects is vital, because governments risk seeing investment activity deteriorate rapidly if they tamper with enabling environments that support clean technology projects. There are numerous examples of where sudden or retroactive changes to the policy landscape have badly damaged investor confidence in a market and limited progress towards clean energy goals.

Spain was an early mover in procuring large volumes of renewables to its grid. Wind and solar's share of installed capacity skyrocketed from 5% to 30% over 2000-10, driven by feed-in tariffs which created a boom in renewables installations. The country paid a hefty price for the generous subsidies that catalyzed its first renewables boom. Annual costs of maintaining renewables subsidies ballooned from 1.2 billion euros in 2005 to 8.4 billion in 2012. At 3% of GDP, this tariff deficit ranked the highest of any EU market.

The government imposed retroactive cuts on renewable assets and a 7% tax on all power generation. The cuts were particularly damaging to investor confidence in the market because they came at a time when new-build wind and solar were still dependent on subsidies to be viable. This severely undermined investor confidence and caused investment activity in renewables to flatline over 2012-16 due to high perceived investment risk. But the sector has since rebounded after the government reintroduced clean energy auctions and the economic viability of subsidy-free projects has improved with technology cost declines.

Another example is South Africa, which experienced uneven investment in clean energy due to a lack of stability in the government's clean energy auction program. Four rounds of the government's auction program, the Renewable Energy Independent Power Producers Programme (REIPPPP), were held between 2011 and 2015, spurring over 5GW of new renewables build with 20-year PPAs. This program is the primary route to market for new renewable energy projects, as South Africa's power sector is highly regulated.

Unstable policy led to large annual fluctuations in wind and solar project financing in South Africa, dependent on the signing of PPAs. The lack of auction rounds over 2015-2020 also severely limited the options for developers to build new projects and dampened investment. The announcement of the fifth round in March 2021 could help reactivate investment and get the country back on track to delivering its clean energy targets.

National, regional and local governments must work collaboratively to implement climate policies effectively and **enhance cross-governmental coordination**. Successful collaboration is particularly relevant when it comes to cutting emissions from buildings or the deployment of EV charging infrastructure. Local authorities are often responsible for relevant structural codes while states or national governments are the ones to set broader infrastructure goals or offer incentives such as tax breaks.

Under the banner of coordination, national governments must also ensure adequate funding is made available for local decarbonization initiatives. National governments have broader tax bases and often have well-established credit-ratings making their access to funding superior to that of most local governments. National governments should thus see it as their obligation to provide adequate funds to implement local decarbonization measures.

Data sharing and transparency is also crucial for successful cross-government coordination. For national funds to be effectively spent by local governments, it is crucial that local governments are consulted at an early stage of setting up new funding infrastructure. Local governments can influence national governments by providing them with valuable data and insights, which can aid policy and budget planning processes.

Coordinated timing of policy implementations lead to more successful outcomes. Pairing local regulatory measures with nationally available grants has proven to be a working solution for decarbonizing transport in many European cities. For example, in London the implementation of the Ultra Low Emissions Zone, an area where the most polluting vehicles must pay a levy in order to use the roads, has been expanded while the national government is providing a grant for anyone who buys a new zero-emission vehicle.

While many decarbonization efforts require coordination between government agencies at multiple levels of government, it is often useful to have a single entity take the lead in implementing a key policy. Lacking that, consumers, project developers or others seeking to take advantage of a program can get frustrated by excess bureaucracy.

Partnerships between governments and non-profit organizations, non-governmental organizations and others in civil society can also further decarbonization. In Ireland, for instance, knowledge-sharing is supported by organizations such as the Climate Action Regional Offices and the C40 partnership between mayors of major cities around the globe. In Canada, the British Columbia and Vancouver governments have partnered with companies in the building trades to establish a knowledge center for zero-carbon construction. In Indonesia, the government is counting on partnerships with global corporations to educate the workforce needed to set up large-scale EV manufacturing.

Transparency and disclosure requirements have the potential to **encourage corporate climate commitments**, which can play a key role in driving decarbonization. The European Union, for instance, set up a voluntary framework for how companies should disclose their environmental impact in 2017, and large companies have been mandated to disclose this information since 2014.

Voluntary codes and public procurement standards can also drive corporate decarbonization. By defining what counts as a "green" activity, the EU taxonomy stands to help investors navigate different ambition levels of corporate climate commitments, and thus indirectly encourages companies to set more ambitious climate goals. The taxonomy can also help governments set new climate-related requirements for public procurement. Industry-led initiatives, such as the RE100 initiative for companies committing to 100% renewable energy, are challenging companies to make specific, public pledges to clean up their activities.

Finance

Aligning financial institutions' portfolios with climate targets is fundamental to getting activities on track this decade to achieve net zero by mid-century. The financial sector must do more to account systematically for material climate-related information in financial decision-making. However, today, decision-useful information and methodologies to understand climate-related risks and opportunities are lacking. There is also an insufficient volume of low-carbon investment opportunities available across asset classes.

In addition, investors and lenders can work to more systematically align financial flows with a well-below 2°C pathway, including by partnering with corporations through investing and financing to achieve climate-related targets, transition strategies, and industry-specific transition pathways. Credit rating agencies can routinely, consistently, and transparently integrate climate-related risks and opportunities into their credit assessments. Including climate risk and transition analysis in mainstream ratings could steer private-sector capital to corporations that are best positioned in the transition to a low-carbon economy.

The sovereign shareholders of public and multilateral financial institutions – notably development banks, sovereign wealth funds (SWFs), and government pension funds – can lead by example by encouraging institutions to align portfolios with well-below 2°C pathways. Multilateral development banks and DFIs are already aligning their decision-making with the Paris Agreement, while a growing number of SWFs and government pension funds plan to integrate climate-related factors into their portfolio management activities.

Encouraging climate-related financial disclosures is pivotal to greening the financial system as investors need high quality, comparable and reliable information on climate risks.

Organizations across the investment chain can work to incorporate climate-related risks and opportunities into governance and financial decision-making. As part of this effort, financial-sector leaders can emphasize the importance of climate-related disclosure to inform their decision-making, such as reporting in line with the recommendations of the TCFD.

Spearheaded by Bank of England Governor and former Financial Stability Board Chair Mark Carney and chaired by Michael Bloomberg, the TCFD was the first private-sector-led initiative working to develop consistent climate-related financial disclosures to inform investing, lending, and underwriting decisions. The task force developed four widely adoptable recommendations on climate-related financial disclosures that are applicable to public companies and financial institutions across sectors and jurisdictions.

Civil Society

As the public's understanding of the eminent danger posed by climate change, civil society has a key role to play in **pushing for binding goals that include concrete CO2 reduction targets**.

Examples of increased public pressure for climate action have already be seen in the form of large-scale political protests and climate litigation. A strong example of successful civil society action can be seen in the Netherlands. In 2013, the Dutch NGO Urgenda initiated a lawsuit against the Dutch state aiming to order the state to reduce the country's GHG emissions by 40% at the end of the year 2020, or at least by a minimum of 25% in comparison the year 1990. In December 2019, the country's Supreme Court decided that the Netherlands has an obligation to take measures for the prevention of climate change and that it has to reduce its GHG emissions by at least 25% by the end of 2020, compared to 1990 levels.

Driving social development and equality across the value chain is fundamental to ensure that a fast transition does not translate into a greater economic disparity across the globe. Demand for metals such as copper, cobalt, nickel and steel will increase as the world transitions to a low-carbon economy. Over half of Africa's 52 countries host at least one of the metals required to support the energy transition.

In spite of the opportunity, Africa's economic share of the global value chain is low. Over 90% of cobalt produced in the Democratic Republic of the Congo is exported to China and refined into finished goods. Similarly, almost all the manganese produced in South Africa is processed into intermediary products and shipped to China. Investing in refineries and value addition in Africa could boost equity and ensure that the region is not marginalized as the world transitions to cleaner energy sources.

Some mining communities stand to be significantly impacted by the energy transition. South Africa's coal sector employs over 90,000 people. Thousands of others in the country rely on the industry. A diversification from coal without a comprehensive social transition plan has the potential to hurt communities. Factors like skills retraining, community programs and alternative sources of livelihood could help lessen the blow and offer new opportunities.

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