SECTION 5

Industry, Innovation, and Transport

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Our economies are the heirs of the first industrial revolution, driven by the use of hydrocarbons. The coming industrial transformation must take us beyond the era of fossil fuels and develop sustainable solutions to feed, house, and provide access to clean water, employment, and industrial goods to 10 billion people by 2050.[1019] In a world of finite resources, growing demand for goods and services will call for transitioning to renewable energy sources and greater resource efficiency.

Achieving the 17 SDGs could open up a market opportunity of US$12 trillion by 2030 in four major economic systems—food and agriculture, cities, energy and materials, and health and well-being—by 2030.[1020] Across all these sectors, the development and deployment at scale of innovative technologies, business models, and policy approaches will be essential to accelerate progress. There is also particularly significant potential for innovation deployment in small and medium-sized enterprises as well as SOEs. Governments and business must work in tandem to achieve the full potential of this transformation.

First, governments and businesses must proactively anticipate these changes and act early to boost innovation, build their competitive advantage, and avoid economic or social losses. Proactive and ambitious action will be critical given the potential of this transition to trigger a major restructuring of the value chains and shifts in the geographical locations of several key economic sectors, such as steel, chemicals, and automotives, just as cost competition has shifted some industrial activities to emerging and developing economies in recent decades. To strengthen industries and create jobs in the upcoming green industry revolution, countries, and companies have an interest in building their competitive advantage early and benefiting from the increased economic productivity triggered by innovation (see also Box 6). China, for instance, is already positioned as a leader in green industries and transport: Sixty-eight of the 200 publicly traded companies with greatest revenues from clean energy in the world in early 2018 were Chinese companies.[1021]

Digital technologies and innovations, such as dematerialised services, the 'Internet of Things', blockchain, and AI, have the potential to radically increase efficiency and enable new business models across all sectors: from smart home appliances that reduce energy consumption and ease dependence on the grid to the use of blockchains to enable traceability of sustainable food and land-use products. As these proliferate, policy-makers must, in parallel, put in place strong social safety nets, as well as educational, distributional, regulatory, and other policies to ensure that societies benefit from the far-reaching effects of these new technologies.

Second, enhanced government support for research, development, and deployment (RD&D) and the careful use of targeted and time-bound industrial policies can help drive the development and scaling of low-carbon and climate-resilient solutions and rapidly bring down their costs to competitive levels. This was a key component benefitting innovations around wind, solar, batteries, and EVs. Supporting RD&D efforts and subsidising early deployment significantly helped to get industries to the stage where scale was achievable, which, in turn, enabled cost reductions and learning curve effects. But energy-sector public RD&D in 2016 was less than half of what it was in the late 1970s in real terms, with a share still going to high-polluting, fossil fuel exploration and production.[1022]

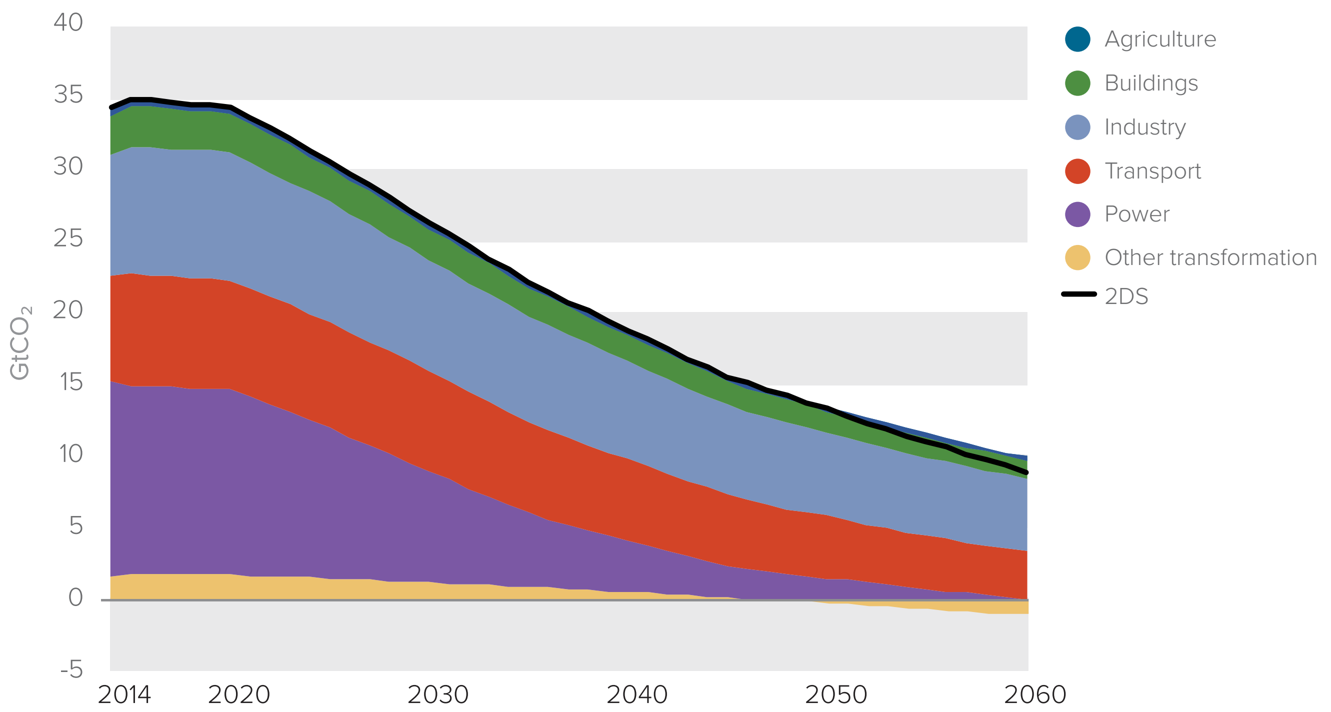
Third, efforts must be made to understand and tackle the specific innovation challenges facing key high-emitting sectors of the economy, particularly heavy industry (in particular steel, cement, and plastics) and heavy-duty transport (heavy road transport, shipping, and aviation), which will constitute the vast majority of remaining CO_2 emissions by 2040 in an under 2˚C scenario.[1023] These 'tough-to-crack' sectors jointly contribute 13 Gt of emissions annually, roughly the equivalent of annual emissions from China and India together.[1024] This number is unlikely to reduce significantly as demand for industrial products and mobility continues to grow in emerging economies.[1025] But there are exciting innovations that can help bend the curve. The best available technologies, for instance, if deployed globally could keep energy consumption from heavy industry flat, despite steady growth in demand.[1026] A key challenge, however, is to deploy these innovations in newly industrialising countries. Other, more radical process innovations or substitutes that are not yet cost competitive could be boosted through the application of a carbon price and by the continued fall in the cost of renewables, putting the electrification of heavy road transport or shipping within reach with potentially large benefits for human health due to reduced air pollution (see also Section 1.A).[1027] There are also fruitful business opportunities to applying the circular economy approach to these sectors, for instance, increasing the reuse and recycling of carbon-intensive materials, such as steel and plastics, or product re-design and increasing the usage of more resource-intensive existing goods, such as switching from car ownership to new mobility services.

While decarbonising industry will be challenging, there is a wealth of experience from countries already taking action. In Europe, the significant reductions in emissions in recent decades came in part from a relocation of industrial activities to non-OECD countries but, more significantly, from a combination of major efficiency improvements (especially in restructured iron and steel plants), changes in energy sources (switching to biomass and waste), and changes in consumption patterns.[1028]

Annual global industrial sector carbon emissions must drop by 40% between 2014 and 2060 to stabilise warming at 2°C above pre-industrial levels (see Figure 29). This may be a smaller reduction than other sectors (power-sector emissions, for instance, must drop by 99%), but it poses a significant challenge given rising demand and current technologies. Significant reductions will also be required from heavy transport as demand for services continue to rise.[1030]

There is increasing—and welcome—momentum from businesses with an increasing number of major companies making commitments to reduce their GHG emissions, whether direct or indirectly produced by the use of their products and services. In 2018, over 6,300 companies representing some 60% of global market capitalisation disclosed their environmental impact through CDP.[1031] Over 400 major multinationals, including Coca Cola, McDonalds, Danone, HP, Pfizer, Tetrapak, and Unilever, are working with CDP, the UN Global Compact, WRI and World Wildlife Fund (WWF), committing to set SBTs for GHG emissions reductions

Figure 29
The Remaining CO_2 Emissions in a 2DS Scenario.



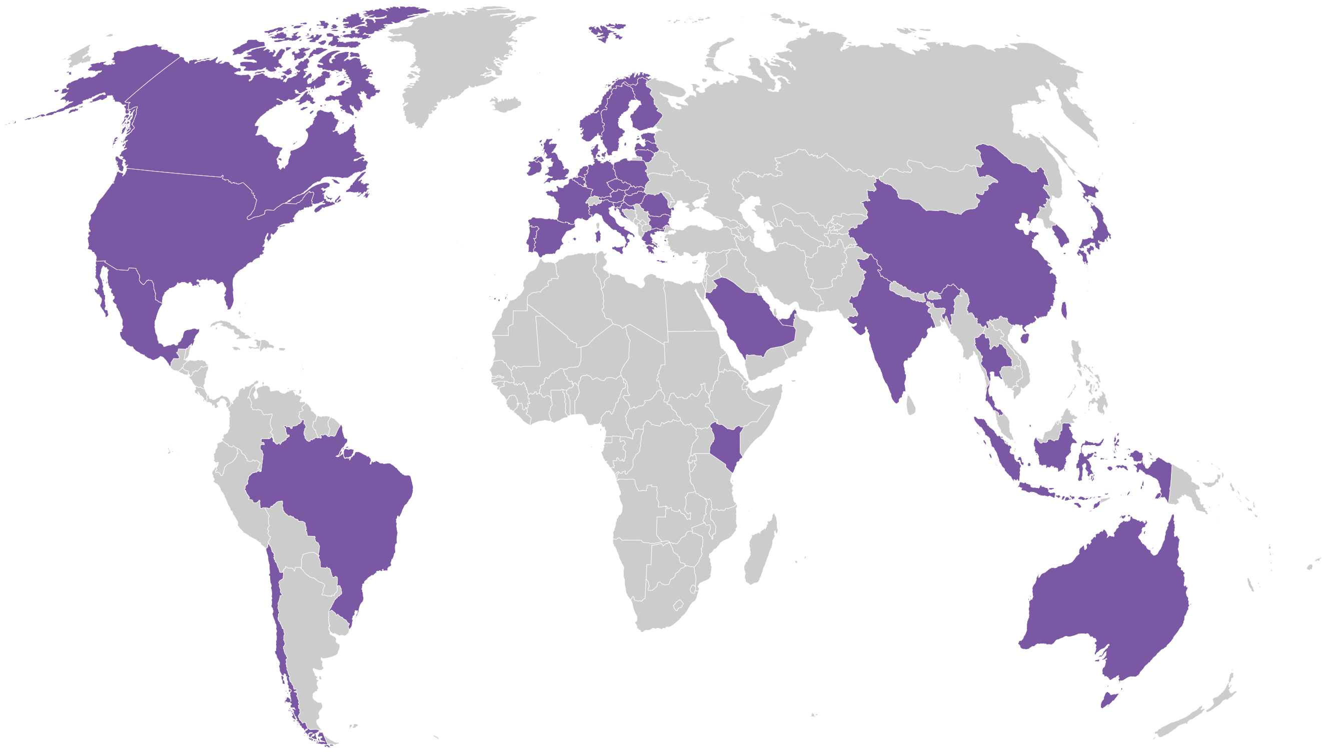
Source: IEA, 2017. Energy Technology Perspectives.[1029]

aligned with 2°C climate stabilisation pathways.[1032] Over 1,400 companies have adopted or plan to soon adopt internal carbon pricing (see also Box 6 and Section 1.A).[1033] And the recently published TCFD recommendations can help investors to stress test their portfolios against climate risk.[1034] Drastically accelerating implementation efforts by businesses, in combination with supporting policy and institutional reforms, will be a critical element of the new growth agenda.

This chapter presents achievable pathways to accelerate the transformation of industries in support of the low-carbon transition. While this chapter is not comprehensive for all industries, it focuses on specific opportunities in the following areas: heavy industries of steel and cement, plastics, heavy-duty transport, and the broader set of innovations that can boost the delivery of the SDGs.

Figure 30

Locations of Transformative Examples in Industry, Innovation, and Transport Highlighted in this Report.



Note: In addition to other examples highlighted in the Report, this map reflects all countries that are members of Mission Innovation.

Box 47
Finance for Innovation, Industry, and Transport

Accelerating the development and deployment of green technologies, especially in the industry and heavy-duty transport sectors, requires different types of financing mechanisms, mixing public and private sources of finance. These include R&D spending, early deployment support for new technologies, infrastructure investment, and investment in major industrial projects.

Meeting sustainability and climate goals necessitates higher levels of innovation than we see today, which in turn requires boosting both public and private investment in innovation (see Section 5.D). As a new green industry revolution unfolds, the private sector will be incentivised to accelerate spending on green innovation as it becomes a key driver of future competitiveness. This can be reinforced by public support directed to R&D and to early deployment of innovative technologies. Governments should work together to establish a Mission Innovation for SDGs modelled after the Mission Innovation for Clean Energy (see Box 63)—to accelerate overall public RD&D spending with clear SDG-related goals.

To ensure that early-stage technologies do not stay in labs, public RD&D spending should encourage and facilitate joint public-private research projects with safeguards in place to ensure that private-sector agents do not selectively gain from such collaboration (see Section 5.D). One example is the Swedish multi-stakeholder public-private R&D partnership for zero-carbon steel, which has a multi-decade commitment from the Swedish government to co-fund R&D and knowledge-sharing across industry partners (see Box 52).[1035] This type of programme can be replicated by governments in partnership with industry in other locations and in other sectors. Investing in challenge prizes is another proven approach to stimulating industry-led innovation (see Box 62).

The public sector also has a key role to play in early deployment of new products or goods. This sector can serve as an early buyer through public procurement to create initial market demand and therefore enable cost reductions and learning, while also demonstrating commercial viability. As seen in the early stages of the renewable energy market, such industrial policies can be powerful tools to promote disruptive innovations, but they also need to be time-bound with clear sunset clauses to be efficient.

We know that making infrastructure sustainable, including in industry sectors, is not likely to cost much more, but it requires shifting the way we invest.[1036] In the transport sector, recent OECD estimates suggest that total infrastructure investment requirements amount to US$2.7 trillion per year to 2030, constituting about 40% of total infrastructure investment needs.[1037] Just over half of the infrastructure investment required is currently flowing, with the largest gap in developing countries.[1038] Both public and private investment are needed.[1039] The main challenge lies in the deployment of new infrastructure: fast charging for EVs, refuelling for hydrogen trucks and ships, and overhead wiring on major roads for long-distance electric trucks. This type of investment can typically be carried out through a public-private partnership model. But some investment requirements extend beyond infrastructure to include vehicles—especially ships—most of which is in the hands of the private sector.

Within industry, challenges include high capital intensity and long investment cycles for emission-intensive industries of cement and steel (see Section 5.A). Fierce competition, overcapacity, and low profit margins also hinder investment in new technologies and processes. Some sort of conditional public support might be helpful to trigger investment, especially in developing economies where MDBs and DFIs could play a major role as a co-investor in new industrial plants. The deployment of carbon capture ultilisation and storage (CCUS) also depends on the financing of transport and storage infrastructure, which is likely to require investment from a mix of actors, including the public sector, carbon-intensive industries, and suppliers of storage (such as oil and gas majors).

Business leadership also is needed to shift the finance landscape. An increasing number of companies are disclosing carbon footprints and other environmental impacts, for example, by reporting through CDP (see Section 1.A and Box 6).[1040] CDP's own assessment of progress in this area, however, suggests that businesses SBTs are achieving less than one-tenth of their potential for emission reductions as targets are relatively low in ambition, and the coverage of businesses with such commitments remains limited.[1041] Governments could provide more incentives and mandates for companies to enhance disclosure and implement TCFD recommendations, which, in turn, can become a tool to support investors taking environmental performance into account when making decisions. Leading corporations can also accelerate change through private procurement and by committing to buy clean products and services across their supply chain, such as is seen in the RE100 and EV100 campaigns.[1042]

5.A. Material Matters: Energy Efficiency, Resource Efficiency, and Decarbonisation in Heavy Industry

Cement and steel are the building blocks of infrastructure. Given the projected growth in demand for infrastructure, especially in emerging economies, it will be essential to reduce emissions from the cement and steel industries,[1043] which account for roughly 10% of total emissions.[1044] Many cement and steel companies are making use of more efficient technologies to achieve cost savings, particularly in steel where competition is international and efficiency improvements are therefore especially important to maintain competitiveness. However, to accelerate the shift for heavy industry overall, investments in breakthrough innovations are required for which short-term incentives are currently missing.

Industry initiatives, such as the Cement Sustainability Initiative or the Ultra-Low CO_2 Steelmaking coalition (ULCOS), have built decarbonisation road maps and identified promising technologies. For example, Indian Steel manufacturer Mahindra Sanyo Special Steel has committed to reducing emissions per tonne of steel produced by 35% by 2030 against a 2016 base year.[1045] But governments need to trigger accelerated development and deployment of low-carbon technologies by providing proper incentives for the search for innovative solutions, including through carbon pricing, standards and by creating a market for green materials with sustainable public procurement policies. Chile, for example, created in 2012 a Chilean Energy Efficiency Agency, which has implemented a US$42 million energy-efficiency programme supporting pilot projects in prioritised areas, increasing the industry know-how and developing financial mechanisms through existing energy efficiency credit lines and partial guarantee funds.[1046]

Evidence of the Benefits

Upgrading industrial processes can significantly reduce production costs, especially in developing countries. The UN Industrial Development Organization (UNIDO) has estimated that implementing the best industrial technologies could reduce energy intensity worldwide by as much as 26% in the next 25 years, triggering a 32% reduction in global CO_2 emissions from the energy system as a whole.[1047] More ambitious scenarios estimate that by deploying best available techniques in developing economies, global energy demand from heavy industry could be kept relatively flat despite growth in materials demand.[1048] China's experience demonstrates that improving energy efficiency in industries triggered significant savings: During the first four years of the 12th Five Year Plan (2010—2014), energy productivity increased significantly across a number of key sectors (for instance, by as much as 26% per unit of cement produced) delivering US$18 billion economy-wide annual energy cost savings.[1049]

Increasing energy efficiency up to current best standards could reduce energy consumption by about 15—20% in the steel sector and 10—-20% in the cement sector.[1050] Developing countries, where current technologies still have further to go in terms of improvements, have a greater margin for progress: For steel, for instance, OECD countries can expect an improvement of about 8-10%, whereas for emerging and developing economies, it could be as high as 20—25%.[1051] For example, the Indian company, Dalmia Cement increased earnings by a staggering 70% and cut costs by 27% by implementing a sustainable strategy (see Box 48). Other critical cost reductions, which also make better use of resources, include waste-heat recovery in cement (which can boost earnings by 15%),[1052] or increasing circularity in the steelmaking value chain. One hundred fifty-three Mt of steel are currently lost in production and collection annually,[1053] and producing scrap versus virgin steel could yield 56% energy savings.[1054]

A key benefit to improving recycling of energy-intensive products could be to maintain industrial jobs in geographies that have suffered from a decline in their industrial bases over the past decades. In the United States, for instance, the scrap industry has played a prominent role as a local job creator in locations where the virgin steel industry is fading, generating over 150,000 direct jobs and 323,000 indirect jobs in 2015.[1055]

Box 48
Low-Carbon Cement in India

In 2015-16, Dalmia (Bharat) Cement Limited put in place a range of sustainable practices from best-in-class technologies to implementing international energy management standards to increasing the use of 'blended' cement. By using industrial waste products such as blast furnace slag from the steel industry and fly ash from thermal power plants, blended cement can extend the lifespan of cement and reduce both the energy intensity and use of natural resources for cement. Aiming to stay ahead of the sustainability curve, the company has commissionered 8 MW of new solar power, and it became the first cement company in the world to join RE100 in 2016. The company also commissioned 9.2 MW of waste heat recovery capacity with plans to expand its green power project investments. And although cement manufacture is not water-intensive, the company evaluated water ecosystems as high risk and undertook targets to become 'water positive'. The company's water harvesting potential tripled versus total freshwater use in 2016—17, and plans are now under way to replicate this success in all its plants and ramp up ambition by fivetimes by 2020. Not only did the company's earnings go up by 70% and costs were cut by 27% from FY15-16, but Dalmia Cement has achieved the lowest cement carbon footprint in the world according to CDP.[1056]

Box 49
Charcoal from Renewable Forests for Carbon-Neutral Steel

Charcoal produced from biomass is considered renewable because the carbon cycle via wood (biomass) is very short (5—10 years), compared to fossil coal (approximately 100 million years).[1058] By using charcoal derived from biomass in steelmaking, the potential to reduce emissions could be as much as 55%, if all the coke in the blast furnace is replaced by charcoal.[1059]

However, important controversies arose in the last 20 years around charcoal production in Brazil, due to poor labour conditions and deforestation caused by burning forests. Charcoal for industrial use therefore needs to be produced sustainably, without adding to pressure for deforestation. A better understanding of the opportunities of renewable charcoal could be transformative in Brazil. Roughly 46% of pig iron and steel could be produced with sustainable charcoal by 2030, reducing Brazilian steel emissions by 31%.[1060]

Through its Brazilian subsidiary company BioFlorestas, ArcelorMittal is managing 100,000 hectares of eucalyptus forests, creating enough renewable charcoal to meet the needs for virgin iron of one of their steel-recycling sites (steel recycling requires 20% virgin iron in addition to 80% scrap steel). They are developing a denser wood and a charcoal better suited to blast furnaces, which the company describes as "creating value … with minimal costs". In their efforts to produce carbon-neutral steel, they are also piloting a project to harness the energy from the gases released during charcoal production.[1061]

Other, more disruptive changes in industrial processes can open new economic opportunities along with environmental benefits. These include process changes (such as a shift to direct reduced iron in the electric arc furnace in virgin steel production), feedstock changes (clinker substitution in cement could yield production savings of US$274 billion and avoid up to 440 million tonnes of emissions annually),[1057] switching to alternative energy sources (see Box 49), and carbon capture, utilisation, and storage use (see Box 50 on CCUS). The potential to capture carbon on cement plants and then inject it into concrete to improve the strength and durability of the material constitutes an interesting example of a circular loop in the cement value chain. This technology has been deployed in Australia and in the United States in more than 50 cement plants. Substituting products, for instance by using timber instead of cement, can also promote the development of new industrial sectors (see Box 51).

Box 50
Commercial-scale Carbon Capture Utilisation and Storage (CCUS)

Carbon capture—combined either with underground storage or with transformation and use of carbon in sectors like concrete—will be an essential technology to decarbonise heavy industry sectors.[1062] It is the only foreseeable way forward to fully decarbonise cement, where unavoidable process emissions need to be managed. CCUS will also likely play a significant role in sectors like steel and chemicals, in particular in regions with limited availability of renewable energy where this technology may well be the most cost-competitive decarbonisation option.

Current estimates suggest that as much as 8 Gt of carbon sequestration per year may be necessary by 2040 to put the world on an under 2°C trajectory.[1063] This can include a range of techniques that remove carbon from the atmosphere and permanently store it. The only proven, large-scale way of doing so is to enhance carbon sequestration through forests, soils, or wetlands. CCUS technologies can play a role alongside natural sequestration, but most are not ready for deployment, remain costly, and trigger controversies with regards to associated risks. The best strategy overall for achieving negative emissions at the scale needed will be to build a portfolio of carbon-removal approaches.

Some examples of commercial CCS or CCUS operations with the potential to be replicated include China's Yanchang Integrated Carbon Capture and Storage, which began construction in 2017 at two separate gasification facilities. As Asia's first such project, it is set to begin operations in 2018 and expects to capture 410,000 tonnes of carbon per year from a coal plant in the Shaanxi province. China has seven other projects planned that could store nine million tonnes of CO_2 a year.[1064] Abu Dhabi's Al Reyadah is the Middle East's first specialised company focused on exploring and developing commercial-scale CCUS projects.[1065] It developed the first fully commercial capture project on a steel factory, with potential to pave the way for other industrial complexes—such as cement, fertilisers—to capture and commercialise CO_2. In 2017, Norwegian Equinor, Shell, and Total teamed up to create a viable commercial CCUS model with plans to store carbon captured from onshore industrial facilities in East Norway and transported by ship to a receiving terminal located onshore in West Norway. The project is supported by Gassnova and other relevant government stakeholders.[1066] Current estimates suggest that the CCUS market is expected to grow at a healthy 25% over the next decade, reaching approximately US$16.2 billion, by 2025.[1067]

Photo credit: Flickr: IRENA

Box 51
From Cement to Timber in France and the United States

Compared with concrete as a building material, mass timber is cheaper and easier to assemble, which means its potential could be significant as we build sustainable and affordable housing for 440 million households by 2025 (see Section 2.B). Timber is also, somewhat counterintuitively, fire resistant, effectively acting as firebreak and maintaining structural integrity in line with building code requirements. And it is a carbon sink, sequestering the CO_2 it absorbed during growth even after it's been turned into lumber. According to one study, using wood substitutes for steel and cement in buildings and bridges—assuming forest regrowth and the use of sustainable timber and sustainable disposal of wood at the end of its life cycle—could avoid 14-31% of global carbon emissions.[1068]

In 2013, in France, a government-led programme called "New Industrial France" prioritised the use of timber in construction, prompting its share to reach 8% of all new building projects. The programme included simplification of building codes and public procurement objectives for local governments and incentivised the building industry to expand its timber-building portfolios. The trend for timber builds is likely to shoot up fast as wooden structures are going vertical as well: The highest wood structure building to date is an 18-storey timber building, completed in Vancouver in 2017.[1069]

Although the timber industry is often fragmented and not prone to foster innovation, there are exciting opportunities to accelerate. In a little over a decade, the US concrete industry's share of the critical mid-rise building market shrunk by at least 10%, thanks in part to an ambitious initiative by wood industry associations. Bolstered by new products like cross-laminated timber, the industry association's marketing campaign advocated for greater acceptance of softwood lumber products in construction, the adoption of favourable building codes, and tax breaks for wood construction. This helped nearly double the number of wood-constructed buildings in the mid-rise market to 40%, according to the American Concrete Pumping Association.[1070]

Similar trends are observed worldwide. For instance, European common standards around performance-based construction enabled the building of larger and taller timber buildings and have boosted the use of timber on the continent.[1071] These innovations, while welcome, must also be considered against potential trade-offs, namely how to make sure forestry practices are sustainable and protect against potential loss of biodiversity (See Section 3.A). Analytical work must be done on the global sustainability of such material substitution policies to inform decision-making.

Challenges

Given the high capital intensity and extended investment cycles of steel and cement, these industries tend to avoid radical process changes. This poses a challenge since the potential for easy-to-grasp efficiency improvements that can also drive down emissions depends on how advanced current practices already are. For instance, in the top steel plants in the United States and Europe, these improvements are nearing limits with existing technology,[1072] which means more significant changes in process and technology will be necessary to achieve further progress.

Moreover, fierce competition on cost, overcapacity, and low margins can hamper the investments required to develop and deploy new technologies. The lack of immediate financial incentives for investment is holding back progress. Most breakthrough technologies still represent a net cost for companies compared to existing technologies—especially early-stage technologies that have not yet benefitted from economies of scale and learning curve effects. Clear and credible policy signals, such as a significant carbon price or tighter emissions standards, are essential. Labels and regulations can also help create demand for green products that could be purchased with a premium.

For steel, implementing the best-in-class technology, namely, replacing of oxygen-based furnaces (OBF) by electric arc furnaces using direct reduced iron, would require extensive investments in new plants, the decommissioning of existing blast furnace facilities, and one-third higher yearly operating costs.[1073] Retrofitting existing OBF plants with CCUS could be a cost-effective alternative option. In parallel, the large-scale increase of the scrap-electric arc furnace process is currently limited by the availability and quality of scrap. Building scrap collection and copper decontamination infrastructure constitutes a major challenge to increase scrap-based steel production. In China, for instance, scrap recycling is a highly fragmented industry that lacks vertical integration and mainly operates in the grey market.[1074]

For cement, the substitution of clinker with more sustainable alternatives like fly ash or blast furnace slag could be limited by the lack of availability of these materials, especially as these are by-products of coal use in the steel and power sectors, where coal is also being phased out[1075] (see also Section 1.B). The deployment of carbon capture on cement plants is also made more difficult by the fact that the industry is geographically distributed and would therefore require an extensive carbon transportation infrastructure, unless there is a conscious move to concentrate production. Overall, cement is likely to be the costlier economic sector to decarbonise in comparison to steel.[1076]

High levels of uncertainty around which technology is most likely to break through in each sector also creates an unfavourable environment for private investment. Narrowing down the scope of the solution space would help clarify the possible pathways for both policy-makers and investors and focus R&D support, especially from governments that should encourage nascent opportunities (see Box 52 on zero-emissions steel efforts in Sweden).[1077]

Box 52
Developing Zero-Carbon Steel through a Public-private R&D Partnership

Hydrogen Breakthrough Ironmaking Technology (HYBRIT) is a joint venture among Swedish steel-producer SSAB, iron ore extractor LKAB, and state-owned electricity company Vattenfall, launched in 2016 with the goal of developing a zero-carbon steelmaking process based on hydrogen reduction. Research and pilot plant trials are expecting to run from 2018 to 2024 and demonstration plant trials from 2025 to 2035.

What is particularly unique about this effort is the public-private partnership element with each stakeholder bringing unique strengths to the table. First, the national government has committed to a low-carbon transition and is providing R&D support. As steel production is one of the country's biggest emitters, the government is keen to explore cleaner options. Second, Sweden already has low-carbon electricity readily available, making clean hydrogen production at large scale possible. Third, Sweden's steel industry is already top-of-the-line with some of the most efficient blast furnaces theoretically possible and has access to some of the world's highest quality magnetite-iron ore. Finally, the companies involved are able and willing to cooperate with each other because they are involved at different stages of the steelmaking process and are not directly competing with each other.

For the project to succeed, the government, the companies, and research partners will have to continue their cooperation for several decades. The Swedish government in particular will have to continue its financial support for the project, as well as ensure that the percentage of fossil fuels in the national energy mix reaches zero.[1078]

Finally, a geographical hurdle persists because decarbonisation technologies for industry usually originate in developed countries. Ensuring technology transfer within multinational industry players and between the R&D ecosystems of developed and developing countries will be an important component to overcome this challenge. Efforts to ensure technology transfer, including under the aegis of the UNFCCC, have a key role to play in bridging the gap between developed and developing countries.[1079]

Accelerators

- **Major industrial countries—in particular the United States, China, and India—should further develop large-scale programmes of industrial energy efficiency to drive the uptake of best available technologies.** The scope for energy savings through efficiency improvements could be as much as 20% in the steel and cement sectors,[1080] with greater margins possible in developing countries. For example, China's national energy and industrial efficiency programmes, such as the Ten Key Programs, have helped to improve energy productivity in line with national targets, in many cases by providing economic incentives for local governments and industries.[1081]
- **The EU should launch an ambitious plan for zero-carbon and near-100% circular steel by 2040.** Scrap could meet all of Europe's steel demand under the condition that losses in scrap handling and production are reduced, and copper levels are managed.[1082] A coordinated effort from governments and industries should focus on R&D on developing zero-carbon steel technologies and tackling the copper contamination issue that currently prevents high-quality recycling, mandatory recycling to increase collection rates, and creating demand for zero-carbon circular steel through new standards on key steel-consuming sectors like the automotive and construction industries. Europe has the opportunity to be a role model in the steelmaking transition from blast furnaces to electric arc furnaces, whereas other regions' steel industries are not yet as mature. Governments should provide policy and institutional support for example, training programs or tax incentives) for companies to set and implement SBTs for emissions reductions. This would leverage company-level knowledge to achieve least-cost technology innovations.
- **The IEA should develop revised net-zero emissions road maps for hard-to-abate sectors, particularly steel and cement.** These road maps targeting net-zero emissions by the second half of the century would be much more ambitious than existing sectoral road maps, which currently only aim to achieve emissions compatible with a 2°C trajectory and generally assume only limited need for carbon emissions reduction from industry. Revised road maps would provide public and private decision-makers with a more robust vision of the long-term pathway to full decarbonisation in these sectors, therefore helping to identify technological improvements or breakthroughs required, anticipate investment needs (including in infrastructure), and, in turn, reduce uncertainty. These revised road maps should be strengthened through deep industry engagement—potentially backed by SBTs. The recent revision of the cement road map represents a collaborative effort between the IEA and the Cement Sustainability Initiative, although it does not yet aim at net-zero emissions from the sector.
- **Governments should fund joint public-private R&D efforts as a means to enhancing knowledge sharing and investment in the capital expenditure- driven, low-collaboration environment of heavy industries.** These efforts should primarily focus on the most transformative decarbonisation technologies. For instance, the ULCOS Coalition, supported by the European Commission, or the zero-emissions HYBRIT steel project developed in Sweden (Box 52) provide successful examples of knowledge breakthroughs achieved through public-private partnerships. Financial backing from governments reduces costs of long-term R&D investment for private-sector players and enhances cooperation among stakeholders, helping to overcome competing or restricted knowledge transfers.
- **National and regional governments should develop strategies, in partnership with industry players and trade unions, to support employment as industries transition to low-carbon models**. Managing the transition for workers and communities sensitively and responsibly and in a way that promotes the transfer of labour to new in-demand sectors is key (see Box 5 on the just transition). Efforts should include a focus on retraining solutions for laid-off workers as well as identifying job creation and retraining opportunities in new activities. China, for instance, included a US$15 billion fund in its latest Five-Year Plan to help retrain and resettle workers in overcapacity coal and steel sectors (see Box 2).[1083] The US scrap industry is proving to be a strong local job creator where the virgin steel industry is fading.[1084]

5.B. From Waste to Value: Reduce Emissions from the Plastics Value Chain

Plastics are a preferred material choice in designing and developing complex consumer products: From construction to electronics and from packaging to vehicles, plastics are omnipresent in today's world. Plastics contribute to the provision of major social services (for example, food safety and affordability, insulation). From 1970 to 2010, the annual global use of materials grew from almost 22 to over 70 billion tonnes.[1085] In 2016, plastics production amounted to 335 million tonnes[1086] and the World Economic Forum projects that it will increase to 1,125 million tonnes in 2050,[1087] as demand grows in emerging economies. Ninety percent of plastics are produced from virgin fossil fuel sources,[1088] and plastic manufacturing is estimated to use 6% of yearly global oil production,[1089] with projections going up to potentially as high as 20% of total oil consumption by 2050.[1090] Without a profound change in industry practices, the plastics sector could account for 15% of the global annual carbon budget by 2050.[1091]

The main sources of emissions from plastics are during the production process (due to fossil fuels used for heat production) and end-of-life degradation, which respectively account for roughly 20% and 80% of the product's lifetime emissions. Approximately 50% of plastics made are for single use, meaning that they are quickly disposed.[1092] The rate at which end-of-life emissions are then released depends on whether plastics waste is burnt (immediate release), landfilled (progressive release depending on the lifetime of the plastic), or recycled (release delayed in time). Additional emissions also come from transportation, whether during or after production, as well as when plastics are collected for waste management. Booming plastics use therefore represents a ticking time bomb for carbon emissions.

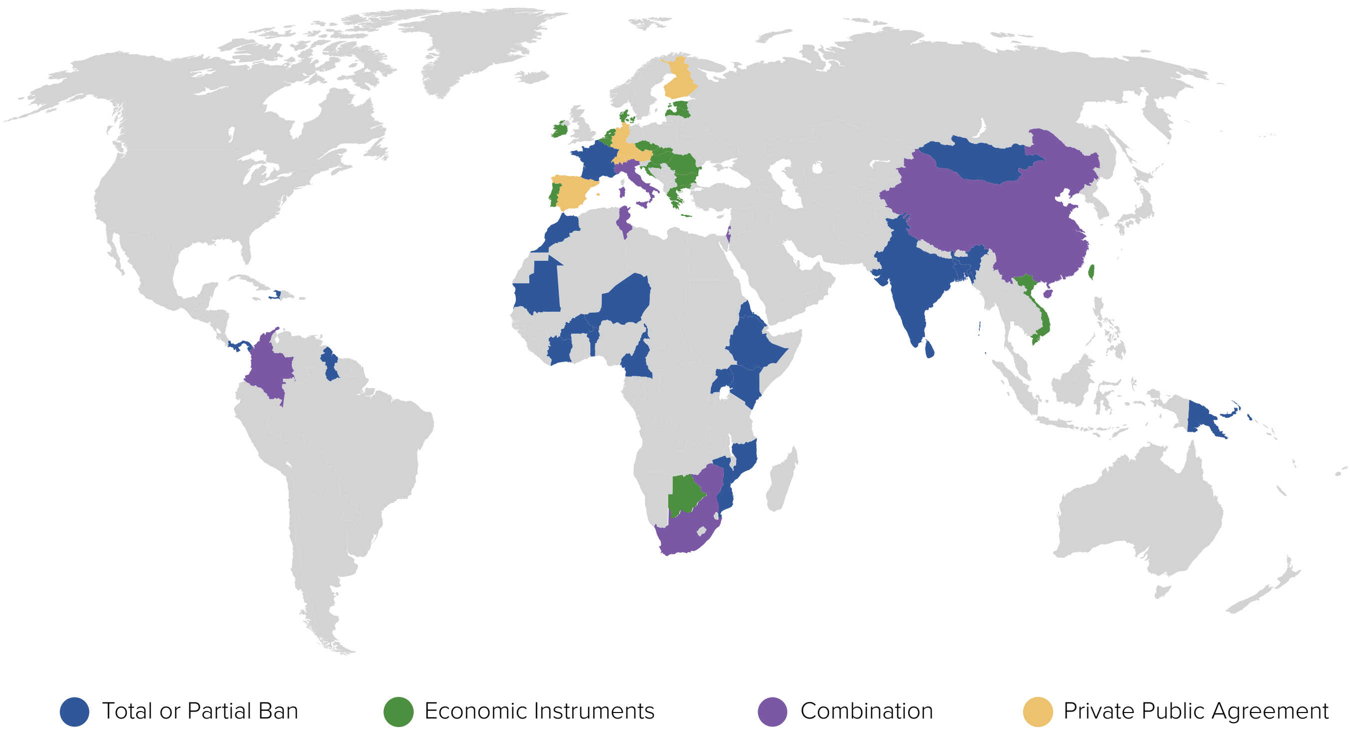
Beyond carbon emissions, plastics are also a huge source of environmental damage, with some plastic items taking 400 years to break down[1093] and with particular issues regarding their overflowing into waterways, most notably in Southeast Asia. Each year, at least eight million tonnes of plastics leak into the ocean.[1094] Indonesia, the biggest source of plastic marine waste in Southeast Asia and the second biggest in the world after China, had an estimated 3.2 million tonnes of plastic waste polluting its waters in 2010.[1095] In addition to harming biodiversity worldwide, the implications for human health can also be significant. For example, for every square kilometre of the Mediterranean there are 40 pieces of plastic marine litter.[1096] As these disintegrate into small pieces, they release toxins poisonous to marine life; and they are often mistaken for food by fish, turtles, or whales, with the potential to harm human health when entering the food chain after being ingested by fish.[1097] Microplastics have been discovered in 114 aquatic species, many of which are a source of food for communities.[1098] Overall, the environmental cost to society of consumer plastic products and packaging was over US$139 billion in 2015, of which half related to the climate-change impact of plastics.[1099]

Photo credit: Flickr: ICIMOD Kathmandu

After a short first-use cycle, 95% of plastic packaging material value, or US$80—120 billion annually, is lost to the economy.[1100] Waste minimisation efforts, namely policies to discourage waste and encourage product longevity thorough product design and incentive structures are needed to support secondary reuse and recycling efforts. Recycling remains low: In Europe, only about 10% of plastics are recycled, and in other parts of the world this is even lower.[1101] This is because adequate recycling efforts would require reshuffling and integration across the full value chain, rather than the current splintered set of incoherent after-use systems, as well as tailored recycling facilities for the newer plastics in circulation.[1102] This level of coordination across the value chain would need to start with product design that anticipates and facilitates future sorting and recycling as well as conceiving products that can be easily disassembled. And a more thorough accounting of lifecycle emissions should also be done. For instance, it is important to ensure that the transportation of plastic products that are often bulky in size and light in weight, such as plastic bottles or packaging, does not itself cancel out the potential economic benefits and mitigation potential of recycling in the first place. Similarly, the environmental and other impacts of the plastics' substitute materials must also be considered in policy decisions. Regulatory policy and tax reforms, such as carbon pricing systems or tax on the feedstock for plastics, will also improve the economics of recycling.

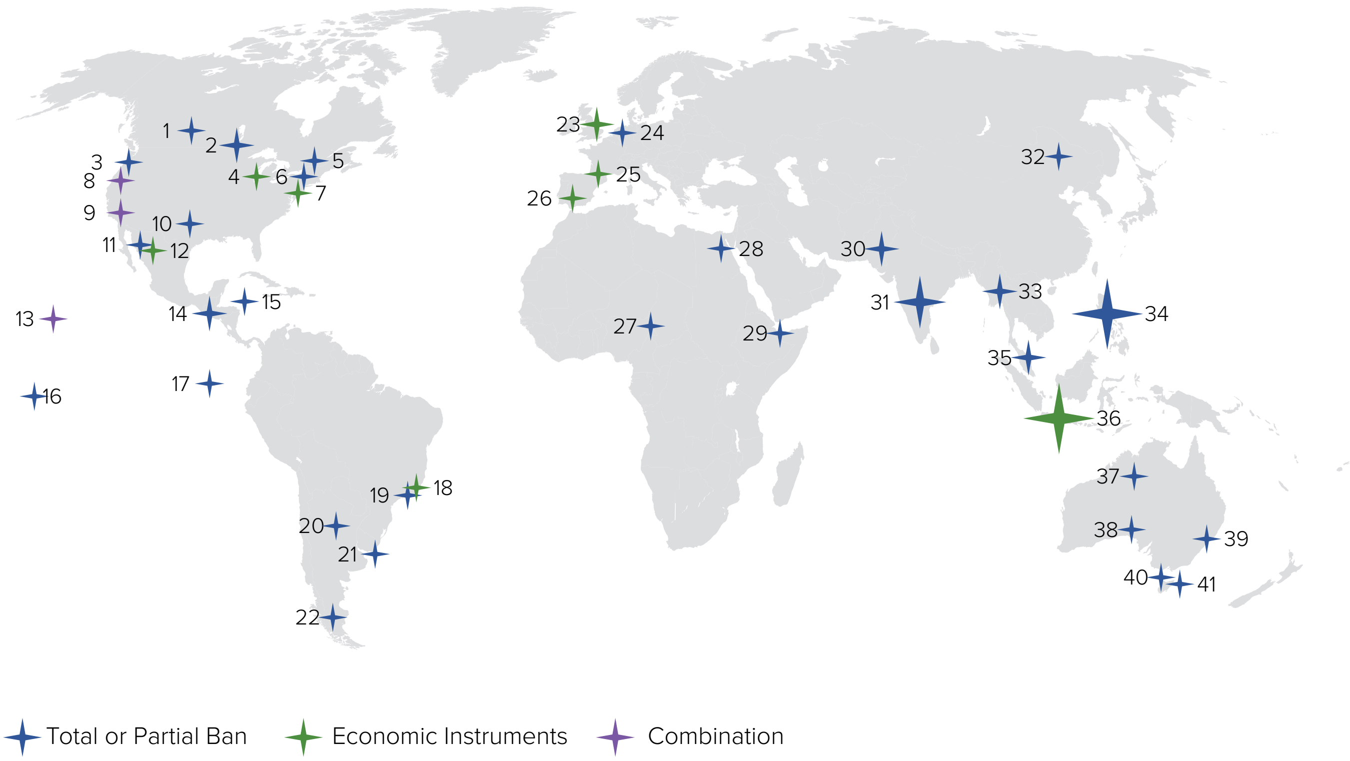
Despite the challenges, recent commitments by several governments of both developed and developing countries indicate an increasing willingness to improve the plastic value chain. For example, several national and subnational governments—including Taiwan,[1103] Malibu, California,[1104] Vanuatu,[1105] Rwanda,[1106] and Kenya,[1107]—have implemented or scheduled phase-outs of plastic bags or single-use plastics more broadly (see Figures 31 and 32). Although not all past efforts have been successful, momentum continues to grow. Most recently, India has committed to ending the use of single-use plastics by 2022.[1108] (See Box 53 on banning plastic bags). Moving forward, managing demand for plastics is also crucial, especially given the expected increased affluence in developing countries, which could translate into increased plastics use. This could range from improving product designs to make better use of less plastic to incentivising new consumer behaviour, including by introducing taxing or levies on usage.[1109]

Figure 31
National-level Plastic Bag Bans and Styrofoam Regulations.



Source: United Nations, 2018.[1110]

Figure 32
Sub-national-level Plastic Bag Bans and Styrofoam Regulations.



Source: United Nations, 2018.[1111]

Note: 1. Wood Buffalo; 2. 2 cities, Manitoba; 3. Seattle; 4. Chicago; 5. Montreal; 6. New York City; 7. Washington, D.C.; 8. San Francisco; 9. California; 10. Austin; 11. Querétaro, Mexico; 12. Mexico City; 13. Hawaii; 14. 4 cities, Guatemala; 15. Bay Islands, Honduras; 16. America Samoa; 17. Galapagos Islands,Ecuador; 18. Rio de Janeiro, Brazil; 19. Sao Paolo, Brazil; 20. Cordoba, Argentina; 21. Buenos Aires, Argentina; 22. Punta Arena, Chile; 23. 4 regions, UK; 24. 2 regions, Belgium; 25. Catalonia, Spain; 26. Andalusia, Spain; 27. N'Djamena, Chad; 28. Hurghada, Egypt; 29. Somaliland, Somalia; 30. 4 regions, Pakistan; 31. >9 cities/provinces, India; 32. Jilin Province, China; 33. 3 cities, Myanmar; 34. 27 cities/provinces, Philippines; 35. Federal Territories, Malaysia; 36. >20 cities, Indonesia; 37. Northern Territory; 38. South Australia; 39. Australian Capital Territory; 40. Tasmania; and 41. Coles Bay.

Box 53
Banning the Plastic Bag: A Long Journey Ahead

Plastic bags are omnipresent in modern daily life across the globe, developed or developing economy. Whether they are destroyed in incinerators, hidden in landfills, or left to enter the wider ecosystem (typically ending up in the ocean), plastic bags wreak havoc on the environment and are incredibly detrimental to the movement to decrease carbon emissions.

The oldest existing plastic bag tax is in Denmark, passed in 1993. As a result, Danes use very few light-weight single-use plastic bags: about four per person each year.[1112] There have been multiple taxes and bans imposed on plastic bags in various countries. African countries are taking a leadership role in this area. In South Africa, thin plastic bags were banned in 2003, and a tax was imposed for thicker plastic bags.[1113] Thin bag use decreased by 90% when the measures were first introduced,[1114] and thicker bag use decreased between 50—90% across different income-level retailers.[1115] Charging for plastic bags also works: A US$15 cent (€0.15) levy on plastic bags in Ireland reduced consumption of these bags by a whopping 92% and promoted the use of reusable bags by the majority of shoppers, with the money earned going towards waste management and other environmental initiatives.[1116]

The success of the plastic bags policies encouraged many European countries to target other single-use products. In France, microbeads in cosmetics are banned since 2018, and sales of plastic cotton buds will be forbidden from 2020 on.[1117] In the United Kingdom, a ban on plastic straws and cotton buds was discussed at the 2018 Commonwealth Heads of Government Meeting.[1118]

Evidence of the Benefits

The use of bio-based plastics can provide an alternative to carbon-intensive oil-based plastics. However, bio-based plastics are not yet cost-competitive in all markets, and there are concerns about the scale at which biomass production can be grown without creating tensions with other land uses.

In the meantime, policies encouraging the reduction, recycling (and reuse) and extended producer responsibility are key levers to transform the plastics industry. These may include taxes, charges or other fiscal policies, as well as regulatory policies such as outright bans. There is an economic prize attached to 'the new plastics economy': The cost of recycling can be reduced thanks to cleaner waste flows, increases in the scale of recycling, and technological improvement, which could unlock a 70% increase in revenues per tonne of treated plastic through increased yields and higher-quality recycled materials with higher economic value.[1119] The global plastic recycling market is projected to grow at 6.5% annually from 2017 to 2023, reaching a market size of almost US$54 billion by 2023.[1120] This expansion also has significant job potential, with estimates for Europe alone at about 15,400 jobs (see Box 54 on the European Commission's Plastics Strategy).[1121]

A range of companies have already proven that sustainable business models can be developed in the sector of plastics recycling (see Boxes 54 and 55). However, the realities of waste management and the nature of the plastics value chain may vary significantly. In developing countries, solutions exist along the entire plastics life cycle, ranging from upstream policies aimed at reduction in plastics to downstream investments focused on capturing leakages, promoting repurposing and upscaling, and devising innovative technological disposal options.[1126] Simply preventing plastic waste from entering the ocean is a crucial first step, while such action also needs to be accompanied broader waste management and reduction reforms. Additionally, developing countries must manage the transition for those in the informal recycling economy that already supports livelihoods, for instance, India's waste pickers and scrap traders.[1127]

Plastics recycling also has an estimated social value of more than US$100 per tonne collected for recycling, based on the saved impact on future generations, for instance, through changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs.[1128] Many of the countries who have or will implement plastics bans emphasise not only the

Box 54
The European Commission's Plastics Strategy: When Industry Collaboration and Policy Go Hand-in-Hand

In January 2018, the European Commission published a Plastics Strategy, continuing on from its 2016 Circular Economy Package, on the future of plastics use in the EU.[1122] The strategy's key aims include making all plastics packaging in the EU recyclable by 2030 and moving towards an increasingly circular economy, with less use of single-use plastics.[1123] The strategy also intends to improve the economics and quality of plastics recycling (for instance, through improved design, supporting innovations to make recycling easier), curbing plastic waste and littering (by establishing a clear regulatory framework for plastics with biodegradable properties), and driving investment towards circular solutions [raising investment of between US$10 and $20 billion (between €8 and €16 billion) to meet plastics recycling 2030 targets].

Collaboration with industry is a vital prerequisite of the success of the EU's Plastics Strategy. European processors and recyclers see a combination of their voluntary actions and strong regulatory framework from the EU as the key to achieving full potential for European plastics recycling. Six European industry organisations representing different segments of the plastics value chain have made a joint, voluntary commitment to a goal of recycling 50% of all European plastics waste by 2040.[1124] In parallel, major plastics users—including Sainsbury's, Nestle, and Coca-Cola—are committing to drive progress as part of a pledge launched by the Ellen Macarthur Foundation,[1125] which includes quantitative targets, achievable by 2025, on eliminating "problematic or unnecessary" single-use plastic packaging; ensuring that all plastic packaging is reusable, recyclable, or compostable; and ensuring that 30% of the content of all plastic packaging comes from recycled sources.

environmental benefits but the health benefits of reducing plastics waste. These efforts can improve human health by reducing exposure to toxic chemicals and reducing risks of transmission of vector-borne diseases like malaria.[1129]

Finally, on the emissions front, developing circularity in the plastics value chain could reduce 2040 emissions from the plastics industry by 47%.[1130] The average net CO_2 saving from recycling is estimated to be 1–1.5 tonnes CO_2 equivalent per tonne of plastics.[1131] Additional carbon emissions reduction can be achieved in the short term through a shift to low-carbon power in the plastics production process, greater fuel efficiency in the plastic logistics chain, and light-weighting of packaging.[1132]

Challenges

Plastics demand reduction can be triggered by policy, taxes, incentives, and education; and it is gaining momentum, as demonstrated by the recent strong commitments against single-use plastics in the European Union as well as India. However, if limited to uses that don't threaten food availability or safety, the volume reduction achievable through products bans (for example, straws, coffee cups, disposable cutlery) cannot exceed about 5% of global plastics consumption.[1139]

Box 55

Aquafil: A Successful Business Model in Plastics Recycling[1133]

Aquafil is one of the leading suppliers of synthetic carpet in Europe, both in business-to-business but also business-to-consumer markets.[1134] For over 40 years, the Aquafil Group has been producing Nylon 6, with a primary focus on manufacturing fibres used in carpet flooring, but also with experience in engineering plastics and synthetic apparel fibres. The Italian company developed a proprietary technology to recycle old Polyamide 6 yarn from used carpets or materials into a new material, Nylon 6. The Aquafil system, the ECONYL® Regeneration System,[1135] collects old fishnets and other nylon waste and turns it into a yarn that can be used for textiles, fabric, and carpets. What used to be thought of as waste is now food for their industrial process with no chance of the input material running out. The ECONYL system was a clear success: Thirty thousand tonnes of waste were recycled through the system between 2011 and 2013,[1136] whilst the company was still competing equally with virgin plastics on quality and price. In January 2018, Aquafil joined forces with Genomatica, to create sustainable caprolactam, a key ingredient for producing 100% sustainable nylon.[1137] There is significant potential for the private sector to innovate and create robust new recycled plastics products in a financially profitable way.

Box 56

Michelin's Move from Selling Tyres towards Selling Kilometres

Traditionally a tyre manufacturer and seller, Michelin launched Michelin Fleet Solutions in 2000 (today called Effitires™), a fleet tyre management service. The service offers transportation companies comprehensive tyre management solutions for their fleets of vehicles over a three- to five-year period, ensuring peace-of-mind benefits for the customers including better cost control, fewer breakdowns, and less administration. To be eligible for this new offer, the customer must have equipped at least 70% of its fleet with a telematics system and commit to fitting vehicles covered under the contract with energy-efficient Michelin tyres. The tyre product developed can drastically reduce rubber tyre waste due to better durability and efficiency of the collection system and save an average of 1.5 litres of diesel per 100 km.

It took Michelin a long time to reach the current state of delivering profit and high margins with its innovative solution offer. The company has invested massive R&D (€1.9 billion between 2012 and 2015, the period where the offer was redefined, and 250 patents deposited per year) to overcome internal barriers and customers' resistance to change and to fine-tune the business model. Today, Michelin Fleet Solutions works with a fleet of more than 300,000 vehicles across Europe. [1138]

A radical redesign of many aspects of the current plastics value chain will require strong policy frameworks and public and private coordination.[1140] The transboundary nature of the plastics value chain, from sourcing raw materials to disposal—including in shared waterways and regional seas—will require domestic as well as transboundary cooperation to develop strong policy frameworks. Actions will be needed across a range of sectors: from improvements in solid waste management, to investments in urban and water infrastructure, to managing microplastics in the food, to technological and business innovations.

Particular difficulties in increasing plastics recycling lie in the wide range of types of plastics used across multiple industries, which would all require a distinct recycling process. Indeed, given that plastics are usually mixed with other materials in end products, when the product reaches the end of its life, it is that much harder to separate materials. There are also challenges in setting up and enforcing plastics collection systems. All of these lead to low collection rates and low collection prices because further sorting is often required. These factors also make it more difficult to produce high-value recycled plastics, which would further incentivise the development of a circular value chain.

As a result, the majority of plastic recycling is currently mechanical open-loop recycling: Products are shredded and transformed into non-packaging or low-value applications (carpets, plastics bags), adding just one additional use cycle and inducing a severe quality degradation. The second recycling route—a closed-loop mechanical route (for example, turning one polyethylene terephthalate (PET) bottle into another PET bottle, rather than a lower-quality material)—requires a high waste collection quality and cannot yet achieve a quality as high as first-use plastic.

There is still a major cost barrier to scaling up recycling: Mechanical recycling carries a net cost of €200—300 per tonne today in Europe.[1141] However, if the whole value chain was to be redesigned to facilitate waste management and resource efficiency as well as end-of-life treatment, most plastics recycling could generate net savings, making plastics recycling a highly cost-effective carbon mitigation solution and an interesting business opportunity.[1142] Notably, the private sector is playing an important role in this space by working alongside of public sector actors in developing and co-financing innovative re-design, re-use and recycling systems.[1143]

Accelerators

- **Governments should develop integrated plastics strategies that combine regulation on use and recycling and provide clear policy signals that can unlock investment in innovative practices.** These practices should enable reductions of plastic usage in complex products, increase recycling rates, and provide incentives to shift behaviours. In developing countries, these plans may take the form of integrated waste management plans, including plastics strategies, and a focus on informal employment in waste recovery, reuse and recycling will be important. While many efforts have remained ad hoc to date, the European Commissions' Plastics Strategy (Box 54) is an exciting example of an integrated policy with the potential to scale solutions that clearly acknowledges the opportunities for business development, job creation, as well as environmental clean-up and emissions reductions.

- **Countries should reduce the use of plastics through a combination of disincentives, including taxes, charges, and bans that are well-designed and enforced.** Local and national government can institute such fiscal penalties to manage the use of plastics-related products, particularly the ever-prolific plastic bag. A US$15 cent (€0.15) levy on plastic bags in Ireland reduced bag consumption by 92%, by encouraging new consumer behaviours. Revenues from taxes or charges on plastics use can then be used to invest in the development of the plastics recycling value chain. Many countries, including Taiwan[1144] and Kenya,[1145] have also successfully opted for bans on plastic bags and or single-use plastics (see Box 53).

- **Industry leaders in plastics-consuming industries—that is, the retail, food processing, cosmetics, or automotive industries—should commit to SBTs that account for the lifecycle carbon emissions arising from plastic use.** These SBTs would trigger the search for innovative solutions to encourage the use of the five main types of plastics (for which recycling infrastructure exists), reduce the use of single-use as well as complex plastics (which are more difficult to recycle in products), and incentivise smart design of products in a way that facilitates the sorting and recycling of plastics.

5.C. Driving Change Forward: Develop Low-Carbon Solutions for Heavy-Duty Transport

Transportation is a fundamental element of economic activity, enabling the production and distribution of goods and services. It is a major economic activity in its own right as households, businesses, and governments directly consume transportation goods, such as vehicles, and services, such as public transit or airline transportation, to meet travel or trade needs. Three critical sectors within transportation hold the key to sizeable economic, developmental and climate benefits: heavy road transport, shipping, and aviation.

Heavy road transport employs millions of people—about 5 million in Europe alone—and generates billions of dollars in value.[1146] International shipping is responsible for carrying roughly 90% of world trade, with over 50,000 merchant ships registered in over 150 nations trading internationally and manned by over a million sailors hailing from virtually every nation.[1147] In aviation, around 3.7 billion passengers were carried by the world's airlines in 2016 alone.[1148] These industries already account for about a quarter of global emissions today,[1149] and without efforts to improve efficiencies and decarbonise the sectors, emissions are likely to almost double from today's 8.8 Gt to 12.1 Gt by 2040.[1150] In particular, with an expanding middle class in emerging countries, freight transport as well as passenger air travel will increase. Even as emissions from other sectors and from light-duty vehicles start decreasing,[1151] the remaining share from heavy-duty transport modes could skyrocket to more than 70% of the total.[1152]

Given the international terrain covered by shipping and aviation, international cooperation will be key to incentivise the development and uptake of clean technologies. Bodies like the International Maritime Organisation (IMO) or the International Civil Aviation Organization (ICAO) can play a key role and trigger significant savings. For instance, the IMO's design standards for new ships built from 2013 onwards could save roughly US$200 billion in annual fuel costs by 2030, at marginal cost in the near term, while avoiding harmful emissions.[1153] Many of the ships that entered the fleet in 2013 and 2014 already exceed the current design efficiency standards, so it is clearly feasible to strengthen them further in support of the IMO's recent initial climate strategy adopted in 2018. In aviation, the International Air Transport Association and Air Transport Action Group have developed a sustainability road map, targeting an average improvement in fuel efficiency of 1.5% per year from 2009 to 2020; a cap on net aviation emissions from 2020; and a reduction in net aviation CO_2 emissions of 50% by 2050, relative to 2005 levels. Furthermore, agreement on a market-based mechanism is also under way in aviation: The Carbon Offset and Reduction Scheme for International Aviation (CORSIA) is a voluntary, business-driven initiative aiming to accelerate airlines' effort to stabilise their net emissions via a carbon trading and offsetting scheme. CORSIA is set to have two voluntary phases between 2021—2023 and 2024—2026 before it becomes mandatory from 2027 onwards for all international flights.[1154]

Box 57
Hybrid and Fully Electric Ferries Take to the Seas in Asia and Norway

In 2017, Visedo OY, a leading Finnish manufacturer of electric drivetrains for marine vessels, debuted an electric motor on a ferry, effectively an electric hybrid vehicle, serving eight million passengers a year on the busy 650m route from the Taiwanese port city of Kaohsiung to the nearby island of Cijin. The electric propulsion will save more than 25,000 litres of fuel every year, a significant cost saving. Further reducing diesel-fuel consumption, the ferry can also run on a lithium iron phosphate battery. Plans are currently afoot to retrofit the rest of the diesel fleet, ensuring significant fuel savings and reduced pollution levels around Taiwan's largest harbour.

Visedo also helped turn Finland's oldest ferry into an all-electric vessel in early 2018.[1155] And Norway's first all-electric ferry has seen costs reduced by as much as 80% compared to fuel-powered counterparts, and emissions by 95%. For shallower waters and short-haul fleets, the future of electric and hybrid vehicles is bright.[1156]

Box 58
Electric Planes Flying High in Australia

Smaller lightweight aircraft could pave the way for the electrification of short-haul commercial fleets. The Pipistrel Alpha Electro became the first factory-built, that is, non-experimental, electric aircraft to fly in Australia in January 2018. It has been approved for flight in Australia. The two-seater electric plane has an all-composite body with electric motor. Its 20 kWh battery packs weight a total of 350 kg, and can stay in the air for one hour, but Pipistrel says that it has potential to fly for longer. Pipistrel, a Slovenian company, and Electro.Aero, the Australian firm that flew it, say that by summer 2018 it should be fully incorporated into their fleet of electric air taxis to carry passengers the 18 km distance from Perth city centre to Rottnest Island.[1157] This suggests the possibility of short-haul, fully electric aeroplanes in other geographies very soon: another exciting innovation opening new market opportunities.[1158] Electric planes could be particularly important for short-haul travel in geographies where high-speed electric trains cannot be an alternative to air travel, either because infrastructure building is difficult (for example, short-distance overseas, mountainous areas) or because low population density makes it impossible to reach a critical mass of travellers.

Evidence of the Benefits

Improving efficiencies in heavy-duty transport, especially as demand rises, could be a major game changer generating savings, reducing health impacts, and ensuring net zero emissions. For heavy road transport, improved efficiency translates into a reduction in cost of operations for trucking companies and large operators with integrated road logistics (see Box 59 on China's experience).[1159] In shipping, where air pollution standards have been tightened, tonne-mile efficiency has improved by 30% between 2008 and 2015, mostly due to slow steaming and the uptake of low-carbon fuels. Taking full advantage of efficiency measures could save up to half of total operating costs in shipping—over US$30 billion every year.[1160] Shipping design efficiency standards developed by the IMO for new ships are expected to save an average of US$200 billion in annual fuel costs by 2030 and avoid 300 Mt of emissions.[1161] Similarly, within the airline industry, American Airlines invested roughly US$300 million in fuel-saving measures since 2005 and has saved approximately US$1.5 billion in fuel costs.[1162] Applying currently available efficient aircraft technology and better air traffic management systems could save a significant proportion of fuel costs for airlines, which currently account for approximately one-third of airlines' operating costs.[1163] In shipping, taking full advantage of efficiency measures could save over US$30 billion in fuel costs each year for the industry as a whole and avoid 300 Mt CO_2 emissions per year by 2030.[1164]

Box 59
China's Green Freight Initiative

In China, trucks dominate the freight transport market. In 2014, for example, they were used to move more than 33 billion tonnes of freight in the country, totalling more than 75% of total freight.[1165] Energy-efficiency technologies and practices are also not well utilised, despite potential fuel savings and economic benefits. Freight trucks therefore contribute more than 50% of CO_2 emissions from transport, whilst totalling only 15% of the total vehicle fleet in China (excluding motorcycles).[1166]

The China Green Freight Initiative[1167] is China's national voluntary program, which aims to improve energy efficiency and reduce emissions from road freight. The programme design is inspired by the Green Trucks Pilot Project launched in Guangzhou, Guangdong Province, in 2012. The programme focuses on green management of the fleet (such as through better loading practices), the deployment of green technologies (such as through the development of green truck standards and issuance of a catalogue of energy-saving technologies), and green driving (establishing driver-training programmes to promote eco-driving, for instance).[1168]

The development of the China Green Freight Initiative is now in its fourth phase and has heavily encouraged China's logistics stakeholders to work together on establishing a green logistics industry. The initiative was led by the China Road Transport Association, the biggest transport association in China, and the Ministry of Transport's Research Institute of Highways and coordinated heavily with global, national and local public and private stakeholders.[1169] The Transport Ministry also identified green freight as a top priority in its 13th Five-Year Strategy. Fleets also will be required to meet even tighter air pollutant standards in the Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta regions. All of these initiatives are adding up to a more sustainable transport sector and a greener logistics market.[1170]

Cleaning up heavy-duty transport can also trigger significant benefits in terms of reduced air pollution and improved health. For road transport, the impact on air quality in cities,[1171] and the ramifications of long-term exposure are significant, including lung cancer, heart disease, stroke, asthma, and stunted lung growth in children. Benefits to cleaning up the system would include avoiding half a million premature deaths per year, a quarter of a million hospital admissions, and 100 million lost working days, cumulatively costing over €900 billion in Europe alone.[1172] Efficiency measures to clean up shipping, for instance the new 2020 0.5% sulphur standard, could save more than 100,000 annual premature deaths globally.[1173] And for aviation, the improvements could be significant, particularly for air quality around airports and reducing high-altitude non-CO_2 emissions.[1174]

Four modal shifts—from freight road transport to rail, from individual vehicles to public transport (see also Section 2.C), from short-haul passenger air travel to rail, and from larger to smaller cars—could reduce total transport energy demand by roughly 10%.[1175] In fact, moving more road freight to rail would also reduce road wear and tear, saving on road infrastructure maintenance costs. In some countries, such as India, where rail freight subsidises passenger rail, there is also clearly a political incentive to shift more transport to rail, such as through dedicated freight rail corridors, as the increase in revenues could be used to further improve and cross-subsidise passenger services. Modal shifts to rail could also reduce CO_2 emissions by as much as 1 Gt annually by 2040.[1176]

Introducing a carbon tax in both shipping and aviation sectors could also be a new source of revenue for governments. The tax would encourage further energy-efficiency improvement, create an incentive for modal shift, and lay the foundations for market-driven efforts towards the most cost-effective low-carbon alternative fuels. Implementing a carbon tax of US$30/tonne of CO2 on maritime and aviation fuels could raise around US$25 billion per year in revenues while also reducing emissions.[1177] The CPLC (see Section 1.A) and the maritime industry have been engaging around the challenges and opportunities of implementing a carbon price, particularly in seeking ways to enforce such a tax in a sector as distributed and difficult to regulate as shipping.[1178]

Challenges

Long-term pathways for significantly improving efficiencies and fully decarbonising heavy-duty road, shipping, and aviation transport remain uncertain, however, as several technologies compete and policies remain weak. Uncertainty persists around the relative future cost-competitiveness of different sustainable alternative fuels (for example, electricity, hydrogen, and ammonia) and related equipment (for example, specific fuel tanks and fuel cells), which makes for an unfavourable environment for private investment. Overcoming this will require defining probable pathways that absorb learning from pilot projects and can be used as reference points for decision-makers, especially with regards to R&D expenditures and early-stage investments.

Another critical challenge is the failure to price carbon adequately or at all in most countries and sectors (see Section 1.A), which accentuates the lack of cost-competitiveness of different technological solutions compared to fossil fuels options on three main fronts: namely, fuel costs, capital costs, and infrastructure costs. By 2035, for instance, the reduced cost of renewable electricity could push the competitiveness of electricity-based solutions, such as batteries, catenary wires for trucking, green hydrogen, and green ammonia (produced through electrolysis rather than a natural gas-based SMR process). However, the value chain to produce these alternative fuels is currently too small to create economies of scale. In the case of biofuels, crop-based fuels are currently still more expensive than traditional fossil-fuel based fuels and scaling them would also create significant tensions in terms of the allocation of arable land. Second and third generation biofuels, based on sustainable biomass management and algae, are more sustainable options but are not currently developed enough to be competitive with fossil fuels. The removal of fossil fuel subsidies and introduction of carbon pricing for key transport modes could tilt the cost-competitiveness balance.

The specific structure of heavy-duty transport sectors also poses unique challenges for either government regulations or industry-led initiatives to drive change. For shipping, especially for bulk and container ships, which represent the largest proportion of carbon emissions from the sector, the split incentives between ship owners versus charterers is such that the cost of investing in more efficient ships and equipment falls on owners who do not reap the benefits of reduced fuel costs. Similarly, while greater transparency on ship fuel efficiency could enable charters to select more efficient (and cheaper) ships, shipping companies see data transparency as a competitive issue and are reluctant to provide this information. Some countries have declared plans for maritime emission reductions: Argentina, China, India, and the Philippines submitted to the IMO their national plans to curb maritime emissions in September 2017.[1179] In early 2018, the IMO adopted its first ever climate change strategy. The strategy included a target to reduce GHG emissions from international shipping by at least 50% by 2050, compared to 2008. The IMO also advocated that emissions from international shipping should peak as soon as possible and that total annual GHG emissions should be, while, at the same time, the IMO should pursue efforts towards phasing them out entirely.[1180] In aviation, ICAO's market-based mechanism is a start to help cap aviation emissions, but the mechanism will be voluntary from 2021 to 2027 and will, at a maximum, offset only 22% of international aviation emissions.[1181]

Accelerators

- **Governments should maintain or strengthen the taxation of fossil fuels in heavy-duty transport, including through the implementation of a carbon price, to improve the cost-competitiveness of alternative solutions and reflect their environmental impact.** Implementing a carbon tax could raise significant revenues while also reducing emissions. Governments could draw from initial efforts between the CPLC and IMO to accelerate the use of carbon pricing as a means to enabling the industry to switch away from fossil fuels and accelerate decarbonisation. Emissions regulations can also boost innovation, such as California's cap-and-trade programme, which, by covering fuel distributors, has aided the development of alternative low-carbon fuels (see Box 60).[1182]
- **Governments should invest in no-regrets technologies that will necessarily play a role in the transition to low-carbon transport.** Key no-regrets technologies include batteries, electric charging infrastructure, fuel cells, green hydrogen production, and sustainable biofuels based on biomass and algae. The overall investment strategy should combine public R&D support: investing in the required infrastructure, such as charging infrastructure in transport hubs like ports and airports; electric, overhead catenary wiring of key freight roads (which enables electric trucks to be powered through overhead wiring on main routes, exactly like trolley or light rail lines offered in many cities today, and only disconnecting and using batteries for last-mile delivery);[1183] development of rail freight corridors; and using public procurement to create initial demand for new technologies. As many of these technologies also rely on the input of electricity, decarbonising the energy sector more generally (as described in Section 1.C) will also be necessary.

Photo credit: Flickr: Nonie Reyes / World Bank

- **The private sector should take on commitments, as part of the SBTs initiative,[1184] to reduce freight emissions.** Progress can be achieved through greater logistics efficiency, especially as digital technologies and monitoring provide a new set of tools to improve both the economic and environmental performance of freight transport. Examples like Tesco's (see Box 61) show that a modal shift can improve the economics of logistics operations while delivering carbon emissions reductions. Commitments to low-carbon freight transport modes should also be encouraged, as increased business-to-business demand for low-carbon freight would also create incentives for logistics companies to develop their low-carbon offers.
- **Trucking industry associations should take on voluntary sustainability commitments, while shipping and aviation should strengthen their commitments by setting net-zero objectives.** Industry initiatives can work with their members to accelerate progress through joint R&D programmes and pilot projects. The trucking initiative jointly launched by the Rocky Mountain Institute and the North American Council for Freight Efficiency provides an example of a bottom-up initiative seeking to achieve progress on the ground.[1185]

Box 61

Tesco's Voluntary Commitment: Every Little (Logistical Efficiency Measure) Helps

In the United Kingdom, the supermarket chain Tesco implemented a multi-solution logistical efficiency and modal shift strategy to save approximately 26 million lorry miles every year.[1193] Part of the supermarket chains' wider commitment to be zero-carbon by 2050,[1194] this could reduce emissions by as much as 80% depending on the route. Tesco has also transferred the most freight from road to rail of any retailer as part of its UK sustainability plan. These reductions have also been bolstered by Tesco's F Plan, which outlines a number of initiatives to reduce emissions but, in general, requires lorries to be fuller, drive for fewer miles, and improve fuel economy.[1195] Since the introduction of the F Plan in 2013, Tesco saved 56 million litres of diesel.

Box 59

California's High Emitters Pay for Excess Carbon Use

California's cap-and-trade programme is one of the state's key policies aiming to reduce GHG emissions with emission permits distributed by a mix of free allocation and quarterly auctions. The scheme is expected to reduce emissions from regulated entities by around 15% between 2013 and 2020 and by an additional 40% by 2030.[1186] As the fourth biggest trading scheme in the world—after the EU, South Korea, and Guangdong in China—the scheme applies to large electric power plants, industrial plants, and fuel distributors, which are responsible for some 85% of the state's emissions.[1187] This cap-and-trade programme is combined with a low-carbon fuel standard, established in 2007 with the objective of reducing GHG emissions from transport by 10% by 2020. This technology-neutral policy sets GHG emissions limits for transport fuels—gasoline and diesel used in road transport. The low-carbon fuel standard relies on lifecycle analyses to estimate a fuel's carbon intensity. This system effectively disincentivises the use of fossil fuels that emit more carbon in favour of lower-carbon fuels, such as second or third generation biofuels or synthetic fuels. Petroleum importers, refiners, and wholesalers are incentivised to develop or buy low-carbon fuel products (which they can sometimes blend with existing fuels). They can also sell and buy carbon credits.[1188] To further consolidate efforts, California is spending US$2.5 billion on a zero-emissions vehicle programme,[1189] including subsidies and funding for related infrastructure,[1190] to accelerate the number of plug-in hybrids and zero-emissions vehicles by 2030.[1191] A collaboration from across the Pacific has meant that China has modelled its EV mandate based on experiences in California—including policy lessons around mandates for automakers, incentives for consumers, and charging infrastructure.[1192]

5.D. Innovating for the SDGs: Taking New Solutions from Labs to Market

Innovative technologies and business models are a key driver of economic growth, with the potential to transform older, more costly systems into more equitable, cleaner, and cheaper opportunities. There are ample opportunities for increased innovation, evidenced even across the sections covered in this Report: in energy, the rapid improvements in the capacity of renewable generation and storage technologies; in cities, the potential of EVs or new mobility services; tree-planting drones that can restore lands at a rapid pace; or using satellites to measure and help monitor water use.

The potential for enhanced technology-based approaches, new business models and even innovative financing structures, could be transformational. However, the success story of renewables shows that the tipping point for the rapid deployment at scale of sustainable, innovative technologies is reached when they become cost-competitive. Therefore, it is critical to get other technologies and business models that can deliver on the SDGs or on climate to tipping points. It is necessary to push innovations that are closest to market readiness and could therefore be deployed at scale over the next 5 to 10 years. For example, such a path can be achieved for EVs, which could reach cost parity with internal combustion engine vehicles without subsidies as early as 2020.[1196] (See Section 2.B).

Governments have a key role to play in encouraging the development and deployment of these new technologies and business models, especially in sectors traditionally suffering from market failures like those covered by the SDGs. The same infant industry policies that boosted renewables to self-sustaining commercial scale should be used to support innovation across all dimensions of the SDGs. This means, in early innovation stages, greater direct public investment in R&D, as well as targeted policies to encourage private R&D spending. Proven approaches to accelerate the search for innovative solutions to specific social and environmental issues include challenge prizes (Box 62) as well as joint public-private R&D projects (see Box 52 on Sweden's steel partnership).[1197] At later stages, governments have the ability to accelerate the rapid deployment of promising solutions, through adequate public-sector demand (for example, public procurement, in particular public auctions) and targeted market-based mechanisms (such as regulations creating private demand for a certain type of product), recognising that investments at scale in social and environmental innovations may only happen if market players are confident in future demand levels.

Box 62
A Challenge Prize to Source Innovations for Smallholder Farmers

In 2014, the UN Development Programme (UNDP) and UN Global Pulse launched a challenge prize to stimulate social tech entrepreneurs in designing innovative solutions to improve agricultural livelihoods in Indonesia.[1198] The Prize was set up to help smallholder farmers reduce expenses and increase crop yields, given their vulnerability in the face of weather variability, soil fertility, and low resistance to disease. One of the winners helped local farmers through precision agriculture using drones. Low-cost drones captured data that could provide insights on crop health so that farmers could make more informed decisions. Drones were equipped with infrared cameras to analyse photosynthetic levels: the higher the photosynthetic levels, the healthier the crops. As a result, farmers could use pesticides in a more targeted way, saving costs and increasing yields. After a few years, use of the drones helped local farmers reduce their expenses by 60% through precision agriculture. This project is now on track to be deployed in a larger zone: Drone mapping was added to the 2017 budget of the North Kayong district, and a local university is working on drones for agriculture and food.

Policies promoting industrial innovation must be well-targeted and time-bound. International technical assistance can help developing countries improve administrative capacity and establish conditions for success.[1199] These policies must also be carefully developed to avoid the risk that industrial policies are captured by private interests through corruption and rent-seeking. Countries can learn from a growing body of experience on practical approaches to insist on high levels of transparency and public accountability in government agencies; establishing clear market-based performance criteria; ensuring competition; and building strong networks that include government, the private sector, and civil society to identify targets and policies.

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Evidence of the Benefits

In recent years, innovations have drastically reduced the costs of cleaner, climate-smart technologies. In addition to the now-familiar evidence about the plummeting cost of solar, wind, and batteries (see Section 1.C), digital solutions can be a powerful accelerator of change, spreading up to 23 times faster than traditional approaches.[1200] This speed of diffusion is nothing short of revolutionary in developing countries. For instance, only 17% of sub-Saharan Africa's rural population is connected to an electricity grid, but 70% access to a digital mobile network, just 23 years after the first digital networks became available.[1201] This makes the region ripe for an expansion of PAYG models (see Box 21), expanding energy access, and improving financial inclusion, particularly if well managed, for women.

For the information and communications technology (ICT) investors who are as yet unconvinced of the benefits, digital opportunities that could positively affect the SDGs have the potential to generate a whopping US$2.1 trillion in additional revenue per year in 2030, a 60% increase compared to current ICT revenues.[1202] Innovative business models based on a circular and sharing economy—which have at their core the same principle of making better use of available resources, whether materials or products—have also taken off,[1203] and global revenues from the sharing economy are expected to grow from US$14 billion in 2014 to US$335 billion by 2025.[1204] Investing in these kinds of solutions is not just good for the planet, it is also very good for the bottom line.

Innovations in the delivery of economic, social, and environmental services also lead to better development impacts, helping sharpen efforts on who to reach and how to do so more effectively. Within the UN system, for instance, country offices that received support from the UNDP's central Innovation Facility, a dedicated fund and advisory service to incubate on-the-ground development interventions, were 30% more time-effective in delivering products or services, 24% more targeted in reaching the identified beneficiary group, and 65% more likely to work with young people to co-design the next generation of public services than their counterparts who did not draw from the Facility.[1205]

Challenges

Historically, public policy has played a significant role in driving innovation in renewable energy. Broad-based policies like, for instance, tradable energy certificates, can drive innovation for technologies that are already close to market readiness, but more forceful policies, such as feed-in tariffs, are needed to drive progress on technologies that are more early-stage and cannot yet compete with incumbent technologies.[1206]

Innovators across sectors also lack access to markets and capital, hampering their ability to scale. Key market failures mean that it is particularly difficult for innovation in sectors that are key to development or environmental outcomes to find commercially viable markets, access the benefits from early deployment cost-reduction effects, and reach the tipping points after which innovations can be deployable at scale. At the same time, ongoing research must be aligned with social and environmental needs through a set of demand-driven criteria that deliberately encourage the search for solutions to SDG or climate challenges.

A specific challenge lies in bridging public research with private sector R&D. Early-stage innovations arising from public research need to be connected to established companies that have the financial means, technical expertise, commercial know-how and market knowledge to rapidly bring those innovations to market. But there is a historical reluctance in many parts of the world for the public research ecosystem to be captured by business interests and for the private companies to join shared research programmes where intellectual property protection issues might arise. Collaborative efforts have lagged even more in the social and environmental space, due to relatively lower R&D in these sectors than in other industries, limiting opportunities to strengthen public-private research collaborations and the interdisciplinary and cross-sectoral approach that these solutions often require, beyond the capacity of a single company to undertake without having to build multiple complex partnerships. Moreover, action towards the SDGs and climate require disruptive innovation rather than incremental innovation, which not only increases risks for private-sector players in this field but requires a fundamentally different approach to current, incremental R&D.

In addition, where disruptive innovation is required in asset-heavy industries like built infrastructure, transport, and industry, progress can be slowed by uncertainty on which technology will break through between competing early-stage options. Overcoming this will require the development of sectoral road maps (such as those prescribed earlier for cement and steel, Section 5.A) that would help narrow down the scope of the solution space in which spending should be made and could be particularly transformative for newer cross-cutting energy-related technologies that are likely to play a role across different sectors, such as green hydrogen, bioenergy, and CCUS.

Accelerators

- **A 'Mission Innovation for SDGs' should be created to accelerate R&D spending on all the SDGs.** Such an initiative could take the form of an intergovernmental initiative uniting voluntary contributions from governments, mobilised to doubling or tripling their R&D spending in the SDGs by 2030. Following a similar model to Mission Innovation for clean energy research (see Box 63), the initiative should first identify priority innovation areas for each SDG and then orchestrate international efforts to accelerate progress in delivering them. Efforts that provide additional support for women and girls could be given an edge in terms of prioritisation.

- **Governments and international organisations should launch Challenge Prizes to stimulate innovative solutions to specific challenges hindering the implementation of SDGs.** Challenge prizes can constitute an efficient tool to both uncover existing early-stage innovations and trigger the search for new innovations that can provide a solution to a specific economic, social, or environmental issue. For example, the ADB's recent US$5 million innovation technical assistance focuses on cross-sector thematic innovative development solutions and the creation of platforms to develop solutions and business models.[1207] As above, defining priority innovation areas for climate and other SDG action are essential prerequisites to make such funding meaningful for the new climate economy. An example in the area of innovative financing is "the Lab," which is focusing on the need for sustainable investment; initiated in 2014, it is a public-private partnership with support from institutions around the world.[1208] In three years, it has endorsed 24 ideas and grown to four programmes targeting different regions and stages of investment. Lessons can also be learnt from other successful undertakings, such as the UNDP and Global Pulse challenge prize for smallholder agriculture (see Box 62).[1209]

- **Countries who are party to Mission Innovation should ensure that their increased R&D spending in the energy sector really leverages private capital by ensuring that public spending focuses on public-private R&D projects.** Twenty-two countries and the EU have already committed to double public clean energy R&D investment over five years under the terms of Mission Innovation (see Box 63).[1210] To maximise impact, this spending should be focused on collaborative public-private R&D projects. Involvement of the private sector, particularly established companies, is essential to open an easier road to market and scale for new innovations.

- Corporations should facilitate the uptake of new clean technologies by committing to buy clean products and services across their supply chains. These efforts would form part of broader commitments to the SBTs (see Box 6). Examples include existing initiatives on 100% renewable power supply (RE100 campaign) and 100% EV fleets (EV100 campaign)[1211] but could expand to a much greater scope: net-energy-positive commercial buildings, use of 'green' cement and steel in buildings, use of recycled plastics, steel, or aluminium in end products, use of low-carbon fuels in heavy-duty fleets, etc. Such business initiatives contribute to creating initial demand for new technologies, therefore driving scale and learning-curve cost reductions and accelerating broader deployment.

Box 63

Mission Innovation: An Intergovernmental R&D Initiative

Aiming to double its more than 22 partner governments' clean energy R&D investments in five years, reaching US$30 billion per year by 2020, the goal of Mission Innovation is to deliver public research to achieve net-zero emissions from energy systems and to de-risk private investment in clean energy technologies. Mission Innovation identified 11 areas of priority R&D investment, covering both energy supply (such as renewables, nuclear, bio-based fuels, and the power grid) and energy use (transportation, industry, and buildings). Within those broad areas, seven 'Grand Challenges' were prioritised for international collaboration.

Mission Innovation provides a space for international collaboration and sharing, but each government leads its own R&D agenda independently, through a national coordination group. Each government therefore has the flexibility to choose areas of R&D investment they want to prioritise as well as which grand challenges they want to take the lead on. The national coordination groups pay particular attention to harnessing their own national research capacity, as well as leveraging the strengths of their key industrial champions.[1212]

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