UNLOCKING THE INCLUSIVE GROWTH STORY OF THE 21ST CENTURY: ACCELERATING CLIMATE ACTION IN URGENT TIMES

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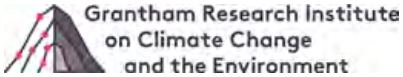

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August 2018

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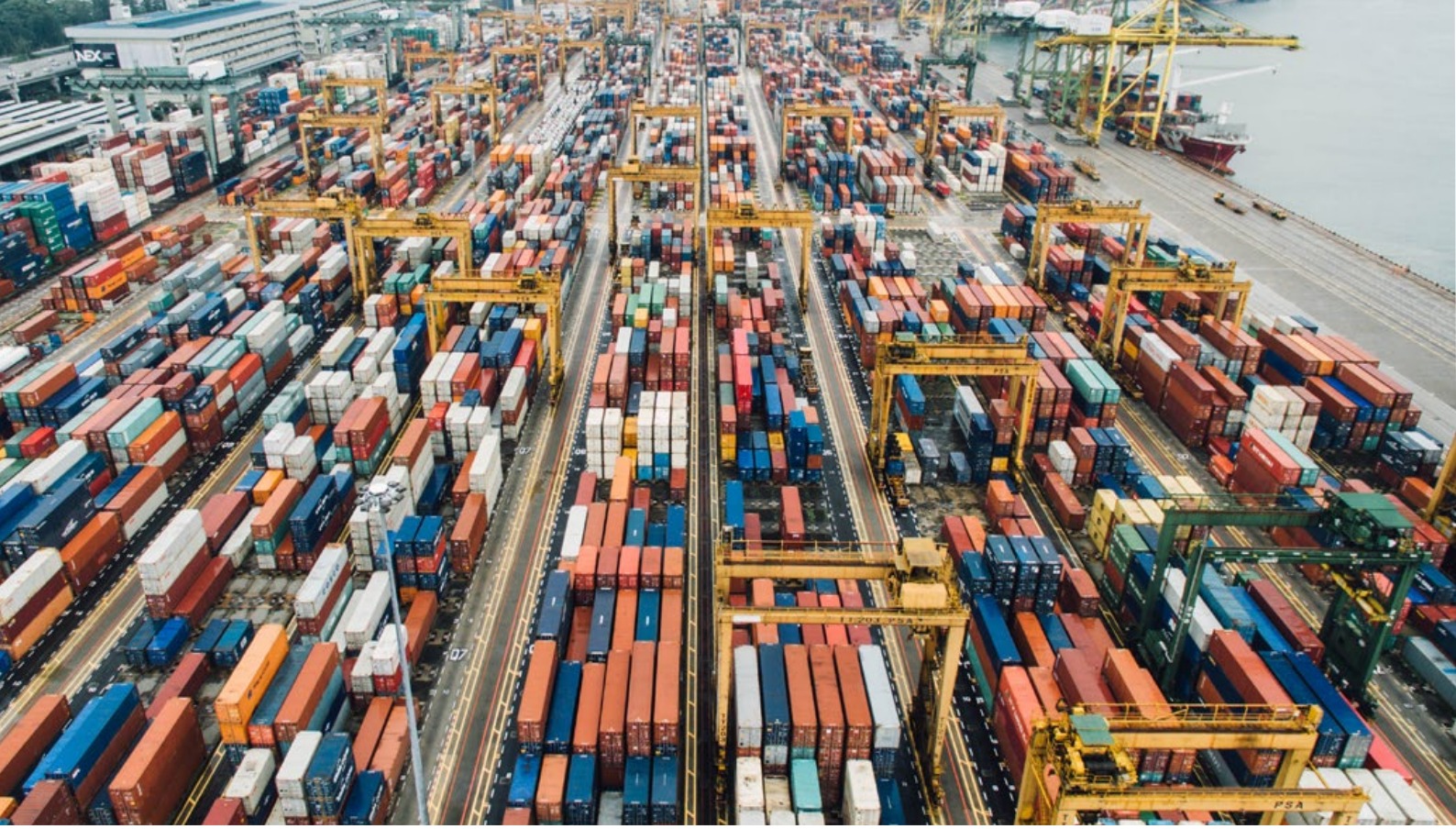

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The New Climate Economy

The Global Commission on the Economy and Climate, and its flagship project the New Climate Economy, were set up to help governments, businesses and society make better-informed decisions on how to achieve economic prosperity and development while also addressing climate change.

It was commissioned in 2013 by the governments of Colombia, Ethiopia, Indonesia, Norway, South Korea, Sweden, and the United Kingdom. The Global Commission, comprising, 28 former heads of government and finance ministers, and leaders in the fields of economics, business and finance, operates as an independent body and, while benefiting from the support of the partner governments, has been given full freedom to reach its own conclusions.

The Commission has published three major flagship reports: *Better Growth, Better Climate: The New Climate Economy Report,* in September 2014; *Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate,* in July 2015; and *The Sustainable Infrastructure Imperative: Financing Better Growth and* Development, in October 2016. The project has also released a number of country reports on Brazil, China, Ethiopia, India, Uganda, and the United States, as well as various working papers on cities, land use, energy, industry, and finance. It has disseminated its messages by engaging with heads of governments, finance ministers, business leaders and other key economic decision-makers in over 60 countries around the world.

This Report was prepared by teams from the following institutions: the Brookings Institution, the Energy Transitions Commission (ETC), the Coalition for Urban Transitions, the Food and Land Use Coalition (FOLU), the Grantham Research Institute on Climate Change and the Environment, the Overseas Development Institute (ODI), SYSTEMIQ, and World Resources Institute (WRI). For a full list of the authors and contributors to this Report, please see page 205.

The New Climate Economy's work on this Report is made possible with support from, among others, the government of Denmark, the government of Germany, the government of Norway, and the govenent of Sweden. The views expressed here do not necessarily reflect the opinions or official policies of these institutions.

The Global Commission on the Economy and Climate

This Report was produced on behalf of the Global Commission on the Economy and Climate. The Global Commission comprises former heads of government and finance ministers, and leaders in the fields of economics, business and finance. Members of the Global Commission endorse the general thrust of the arguments, findings, and recommendations made in this Report, but should not be taken as agreeing with every word or number. They serve on the Commission in a personal capacity. The institutions with which they are affiliated have therefore not been asked formally to endorse the Report and should not be taken as having done so.

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“The growth story of the 21st century will unlock unprecedented opportunities and deliver a strong, sustainable, inclusive global economy. The benefits of climate action are greater than ever before, while the costs of inaction continue to mount. It is time for a decisive shift to a new climate economy.”

—The Global Commission on the Economy and Climate

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Unlocking the Inclusive Growth Story of the 21st Century: Accelerating Climate Action in Urgent Times

Key Findings

- We are on the cusp of a new economic era: one where growth is driven by the interaction between rapid technological innovation, sustainable infrastructure investment, and increased resource productivity. This is the only growth story of the 21st century. It will result in efficient, liveable cities; low-carbon, smart and resilient infrastructure; and the restoration of degraded lands while protecting valuable forests. We can have growth that is strong, sustainable, balanced, and inclusive.
- Over the last decade, we have seen amazing technological and market progress driving the shift to a new climate economy. We are seeing real results in terms of new jobs, economic savings, competitiveness and market opportunities, and improved wellbeing for people worldwide. And this progress in the real economy has been delivered on the back of often weak or even contradictory policies in countries. How much more could be achieved in the coming years with clear, consistent policy signals?
- In 2014, the Global Commission on the Economy and Climate concluded that ambitious climate action does not need to cost much more than business-as-usual growth. The evidence today shows that climate action is even more attractive than we imagined then. This remarkable new growth opportunity is now hiding in plain sight.
- Yet we are not making progress anywhere near fast enough. While many private sector players are stepping-up, policy-makers in most countries still have the hand-brake on. We are now at a fork in the road.
- The next 10–15 years are a unique 'use it or lose it' moment in economic history. We expect to invest about US$90 trillion in infrastructure to 2030, more than the total current stock. Ensuring that this infrastructure is sustainable will be a critical determinant of future growth and prosperity. The next 10–15 years are also essential in terms of climate: unless we make a decisive shift, by 2030 we will pass the point by which we can keep global average temperature rise to well below 2°C.
- We know that we are grossly under-estimating the benefits of this new growth story. Current economic models are deeply inadequate in capturing the opportunities of such a transformational shift, or the grave dangers of climate inaction. We need a new class of economic models that can capture the powerful dynamics at play, including transformative technological advances, preservation of essential natural capital, and the full health benefits of cleaner air and a safer climate, including the containment of pandemic diseases.
- While recognising the shortcomings of current economic models, analysis produced for this Report found that bold action could yield a direct economic gain of US$26 trillion through to 2030 compared with business-as-usual. And this is likely to be a conservative estimate.
- Making such a shift would also limit dangerous climate change. With each passing year, the risks of unabated climate change mount. The last 19 years included 18 of the warmest years on record, worsening food and water security risks and increasing the frequency and severity of hazards such as wildfires. Disasters triggered by weather- and climate-related hazards were responsible for thousands of deaths and US$320 billion in losses in 2017. Climate change will lead to more frequent and more extreme events like these, including floods, droughts, and heat waves. It is increasingly our 'new normal'.
- The challenge now is to accelerate the transition to a better, more inclusive, new climate economy in five key economic systems: energy, cities, food and land use, water, and industry.

- We have a remarkable window of opportunity to do so now, given the major structural changes the world faces, notably rapid urbanisation, increasing globalisation, shifts to service-based economies, and increasing automation. The opportunities are great, but so too is the potential for stranded assets, stranded communities, and stranded workers. The transition to a low-carbon, resilient economy is just one part of this broader transformation, which—if managed well—has the potential to deliver more equitable and prosperous growth. Ensuring an inclusive transition is essential: women, for example, will play a critical role in delivering the promise of this new growth era.
- **The next 2—3 years are a critical window** when many of the policy and investment decisions that shape the next 10—15 years will be taken. Priorities for urgent action are:
    - **Pricing carbon and moving toward mandatory disclosure of climate-related financial risks, as part of a broader policy package.** Carbon pricing is now in place or planned in 70 countries or jurisdictions, but in most places the price levels are too low to drive transformational change. Deepening and widening carbon pricing is essential. Implementing the recommendations of the Task Force on Climate-Related Financial Disclosure (TCFD) on a broad scale will enable radical transparency for investors to better understand the risks of current investments and the opportunities of shifting toward low-carbon, resilient alternatives. Both measures will need to be part of broader, complementary policy packages that include for example regulatory and research and development measures.
    - **Accelerating investment in sustainable infrastructure, supported by clear national and sub-national strategies and programmes.** This is a central driver of the new growth approach. It requires integrating climate action and sustainability at the heart of growth strategies, investment plans, and institutional structures to facilitate the flow of public and private finance. It includes investing in the natural infrastructure that underpins our economy, such as forests and wetlands. Multilateral development banks (MDBs) and other development finance institutions (DFIs) play a key role and should double their investment in infrastructure and ensure it is sustainable. Essential actions include making infrastructure an asset class and ensuring it incorporates sustainability criteria.
    - **Harnessing the power of the private sector, including to unleash innovation and advance supply chain transparency.** Many companies and investors are already demonstrating leadership, and others are ready to align this agenda with the right policy signals. Regulations and incentives that hamper the shift to a low-carbon and more circular economy should be reformed, such as subsidies to fossil fuel production and use or harmful incentives for agricultural expansion. A big push on innovation, in particular through international partnerships and financing to tackle challenges beyond energy, is needed. For example, a combination of new monitoring techniques, strategic partnerships, the right incentives, and corporate leadership is helping to develop deforestation-free supply chains for key commodities.
    - **Ensuring a people-centred approach, such that the gains are shared equitably and the transition is just.** Active, targeted regeneration can support economic diversification and the delivery of quality jobs. In developing economies, the low-carbon transition provides an opportunity to leap-frog the inefficient and polluting models of the past, with falling costs of renewables and other technologies making it even cheaper. As a priority, all governments should establish zero-emission Energy Transition Plans, working with energy companies, trade unions, and civil society to ensure a just transition for workers and communities.
- Accelerating action will require decisive leadership, strong collaboration, and finance. Finance ministers and DFIs play a critical role in guiding investments in the short-term to meet the long-term needs of society, and in setting the right policy and institutional conditions to unlock much-needed private capital at scale.
- The train is fast leaving the station**.** Leaders are already seizing the exciting economic and market opportunities of the new growth approach. The laggards are not only missing out on these opportunities but are also putting us all at greater risk. Over US$26 trillion and a more sustainable planet are on offer, if we all get on board. The time to do so is now.

Report Summary

We are entering a new era of economic growth. This approach can deliver growth that is strong, sustainable, balanced, and inclusive. It is driven by the interaction between rapid technological innovation, sustainable infrastructure investment, and increased resource productivity.

- At the heart of this new approach to growth are liveable, compact cities which have an economic dynamism that can attract creative talent, companies, and capital while higher densities enable cheaper service delivery and avoid costly urban sprawl. Powering the new growth will be affordable, clean, energy systems which are more productive and can expand energy access to the more than a billion people that currently lack it, replicating and amplifying the impact of mobile telephony on equitable growth. Agriculture and forests can become a third engine of economic growth, delivering greater food security, more nutritious food, greater rural prosperity and more equitable growth, strengthened resilience, and valuable ecosystem services. Industrial sectors, now waking up to the potential of the circular economy, will radically cut the demand for energy-intensive primary materials, driving up both material productivity and cutting waste.
- This new growth approach will deliver higher productivity, more resilient economies and greater social inclusion. The poorest do not benefit from the current low-productivity agriculture nor from landslides resulting from deforestation. They do not benefit from inefficient cities where daily commutes often take hours a day, exposed to highly-polluted air. The poor are those most exposed to the impacts of climate change, with just one bad weather season having the potential to push low-income families below the poverty line.
- This new approach is the only economic growth path that is sustainable. It is the growth story of the 21st century.

"This new growth approach will deliver higher productivity, more resilient economies and greater social inclusion."

In 2014, the flagship report of the Global Commission on Economy and Climate conclusively showed that higher quality growth can be combined with strong climate action.

- The evidence today of the potential economic benefits are even greater than before; and the downside risks of inaction on climate change are even more stark.
- Leading companies and investors are already getting behind this new approach, creating a new competitive race. So too are ambitious policy-makers.
- The decisions we take over the next 2—3 years are crucial because of the urgency of a changing climate and the unique window of unprecedented structural changes already underway. The world is expected to invest about US$90 trillion on infrastructure in the period up to 2030, more than the entire current stock today. Much of this investment will be programmed in the next few years.
- This is our 'use it or lose it' moment. Investing the US$90 trillion to build the right infrastructure now will deliver a new era of economic growth. Investing it wisely will help drive innovation, deliver public health benefits, create a host of new jobs and go a long way to tackling the risks of runaway climate change. Getting it wrong, on the other hand, will lock us into a high-polluting, low productivity, and deeply unequal future. For example, the multi-trillion-dollar Belt and Road Initiative will have a significant impact on the shape and sustainability of growth in the over 70 coutries in Asia, Africa, and Europe it spans.

"This is our 'use it or lose it' moment: the decisions we take over the next 2-3 years will determine our growth and climate future."

The core proposition of the Global Commission is simple. We can build a better, more people-centred, more resilient growth model by accelerating structural transformation in five key economic systems:

- **Clean energy systems**: The decarbonisation of power systems combined with decentralised and digitally-enabled electrification technologies can provide access to modern energy services for the billion people who currently lack it; strengthen energy security and reduce exposure to energy

price volatility globally; build overall system resilience to increasing natural hazards (especially in vulnerable, small island states); and cut the costs of outdoor air pollution worldwide. The clean energy transition is well underway, driven by market forces and plummeting costs of renewable and storage technologies. The world now adds more renewable power capacity annually than from all fossil fuels combined.[1]

"The world now adds more renewable power capacity annually than from all fossil fuels combined."

- **Smarter urban development**: Better urban planning and strategic infrastructure investment, particularly the expansion of public and non-motorised transport networks, can overcome bottlenecks to economic growth—such as congestion and air pollution—for more liveable cities. More compact, connected, and coordinated cities are worth up to US$17 trillion in economic savings by 2050[2] and will stimulate economic growth by improving access to jobs and housing. They can strengthen resilience to physical climate risks and could deliver up to 3.7 gigatons per year of CO_2e savings over the next 15 years, just shy of the total emissions of the European Union (EU) today.[3] Integrated national urban policy frameworks can guide sustainable and inclusive urban development.[4]

"Coordinated, compact, and connected cities could result in US$17 trillion in economic savings by 2050."

- **Sustainable land use:** The shift to more sustainable forms of agriculture combined with strong forest protection could deliver over US$2 trillion per year of economic benefits;[5] generate millions of jobs, mainly in the developing world; improve food security including by reducing food loss and waste (a third of all food produced is lost or wasted along the food chain[6]); and deliver over a third of the climate change solution.[7] At the same time, restoration of natural capital, especially our forests, degraded lands, and coastal zones, will strengthen our defences and boost adaptation to climate impacts, from more extreme weather patterns to sea-level rise.

"Sustainable agriculture and forest protection together could deliver over US$2 trillion each year in economic benefits."

- **Wise water management**: Today, 2.1 billion live without readily available, safe water supplies at home, and 4.5 billion live without safely managed sanitation.[8] Water will also be where climate change impacts will be felt most keenly. Water scarce regions, notably the Middle East, the Sahel, Central Africa, and East Asia could see gross domestic product (GDP) declines of as much as 6% by 2050 as a result of climate change, spurring migration and sparking conflict.[9] There are enormous opportunities to curb these impacts by using water better, whether though deployment of improved technology (from drip irrigation to remote sensors to water-efficient crops), planning and governance, use of water prices with targeted support to the poor, or by investing in public infrastructure. Today, poorly managed and often under-priced water results in the over-use and misallocation of resources across the economy. Addressing the water-energy-food nexus will be critical, particularly in increasingly water-stressed regions.

"Today, 2.1 billion live without readily available, safe water supplies."

- **A circular industrial economy:** From 1970 to 2010, annual global extraction of materials grew from almost 22 to 70 billion tonnes.[10] Each year, at least eight million tonnes of plastics leak into the ocean, contributing to a major new challenge for the 21st Century.[11] Microplastics have been discovered in 114 aquatic species, many of which end up in our dinners.[12] This challenge, however, is not just a social or environmental issue; it is also economic. Today, 95% of plastic packaging material value—as much as US$120 billion annually—is lost after first use.[13] Policies which encourage more circular, efficient use of materials (especially metals, petrochemicals and construction materials) could enhance global economic activity, as well as reduce waste and pollution. Shifting to a circular industrial economy, combined with increasing efficiency and electrification, including for hard-to-abate sectors and heavy transport, could decouple economic growth from material use and drive decarbonisation of industrial activities.

"95% of plastic packaging material value—US$120 billion annually—is lost after first use."

Transitioning to this low-carbon, sustainable growth path could deliver a direct economic gain of US$26 trillion through to 2030 compared to business-as-usual, according to analysis for this Report.

"Low-carbon growth could deliver economic benefits of US$26 trillion to 2030—and this is a conservative estimate."

- The Report also finds that taking ambitious climate action could generate over 65 million new low-carbon jobs in 2030, equivalent to today's entire workforces of the UK and Egypt combined, as well as avoid over 700,000 premature deaths from air pollution compared with business-as-usual.
- Subsidy reform and carbon pricing alone could generate an estimated US$2.8 trillion in government revenues per year in 2030—more than the total GDP of India today—much needed funds that can be used to invest in public priorities.
- Given the limitations of modelling exercises, it is likely that the benefits of a climate-compatible transition are much greater than even these estimates suggest.[14] Such modelling exercises generally cannot capture the magnitude and dynamism of the economic and financial opportunities of climate action, or to adequately reflect the risks of climate change in baseline growth scenarios. For example, even the best energy analysts in the world have consistently under-estimated the potential penetration of renewable energy year-after-year, and it is likely that the same errors are now being repeated with electric vehicle (EV) penetration.

This transition would also avoid the high risks of a changing climate. The scientific evidence is ever more alarming. The human and economic toll of inaction is rising.

- Concentrations of GHGs continue to reach new records and are now at the highest level in millennia.[15] The last 19 years contained 18 of the warmest years on record globally.[16]
- The impacts of climate change, such as sea-level rise and more frequent and more intense extreme weather events, are now obvious across the world and are increasingly becoming the 'new normal'. We face the possibility of crossing tipping points beyond which very severe consequences become unstoppable and irreversible.[17] Many of these involve feedback loops, increasing the risk of major discontinuities and runaway climate change. Forecasts from climate scientists are now observed or even exceeded, including accelerating sea-level rise, Arctic summer melt, ocean circulation disruption, and increasing extreme weather events, such as floods and heatwaves.
- The United Nations Environment Programme warns that "it is clear that if the emissions gap is not closed by 2030, it is extremely unlikely that the goal of holding global warming to well below 2°C can still be reached".[18] Without further strong and rapid reductions in emissions, we will not be able to avoid the risks of dangerous climate change.
- Globally, in 2017, disasters triggered by weather- and climate-related hazards led to a staggering US$320 billion loss.[19] Also in 2017, devastating floods in South Asia took over 1,200 lives, while communities in the Caribbean are still struggling to recover from the unprecedented hurricane season.
- The risks of adverse health outcomes will also increase under unabated climate change, due to more intense heatwaves, floods, droughts, a greater risk of food and water-borne diseases, and more rapid spread of pathogens.[20]
- Business-as-usual growth could mean over 140 million climate migrants by 2050, according to the World Bank.[21] While much of the movement may be internal, this is still more than double the total number of all refugees today and will further exacerbate the likelihood of conflict.

"Business-as-usual growth could mean over 140 million climate migrants by 2050."

- Climate change is not the only risk of our current growth trajectory. Outdoor air pollution, largely from fossil fuel combustion, is estimated to result in over 4.2 million premature deaths annually.[22] The costs of congestion are growing, with recent International Monetary Fund (IMF) estimates suggesting a cost of over US$350 billion per year, based on lost productivity and health impacts.[23] It is estimated to cost as much as 5% or more of GDP in Beijing, Sao Paulo, and Bangkok.[24]

We have seen some incredible progress in implementing a new climate economy in the last few years. The new growth approach is now hiding in plain sight.

- Countries from China to Uganda, from Indonesia to Sweden, and from the United Kingdom to India are working to realise the benefits of integrating low-carbon and sustainable development objectives into their economic and budget planning processes.
- Investment in sustainable infrastructure is now recognised as a central driver of growth and the delivery of the Sustainable Development Goals and the Paris Agreement. The G20 adopted "strong, sustainable, balanced, and inclusive growth" as its goal. Major development finance institutions (DFIs) are shifting their capital towards sustainable investments.
- The central importance of cities as engines of economic growth is now received wisdom. However, maximising the economic benefits of urban growth depends on coherent land use, housing, and transport planning. The difference among countries is pronounced: For every 1% increase in urban population, for example, per capita GDP increases by 10% in China, 4% in Indonesia, and 13% in India.[25] Mayors are showing international leadership on climate action, poverty reduction and local economic development, fostering innovative solutions from Bus Rapid Transit (BRT) systems to participatory budgeting that can be replicated at scale with support from national governments. The role of mayors as the CEOs of cities has transformed over the past decade, with cities actively competing for talent and capital based on their green credentials.

"Renewable energy auctions are coming in at prices under US$ 3 cents per kilowatt hour, out-competing fossil fuels in many places."

- Progress on low-carbon and energy-efficient technologies, especially in the energy sector but also in mobility, buildings, and agriculture, has been much faster than predicted. Auctions for long-term power contracts are generating unsubsidised bids from renewable energy producers at prices under US$3 cents per kilowatt hour, out-competing fossil fuel alternatives in more and more locations.[26] Companies shifting to hydrofluorocarbon (HFC)-free refrigerants in line with the Montreal Protocol have reported energy-efficiency improvements of up to 40%, as well as electricity cost savings and emissions reductions.[27] The costs of energy storage and of the software for energy demand management are also plunging. Major car companies are declaring the end of the internal combustion engine is in sight as EVs take a strong position in the market. Increasing digitalisation and electrification of the economy, including for transport and industry, are also opening up new opportunities to radically reduce emissions and increase efficiency.
- Leading energy companies, investors, and market analysts view peak demand for coal, oil, and gas over the next 20 years (starting with coal in the next 5—10 years) as entirely plausible. This has led to a major shift in capital allocation within the energy sector in just the last few years and an alliance of over 60 governments, businesses, and organisations signing up to "Powering Past Coal". Around US$280 billion was invested in new renewable energy generation in 2017, continuing a six-year trend of outstripping global fossil fuel generation investments.[28]
- Closing the forest frontier is an increasingly urgent priority for countries and companies. Since 2010, over 470 companies have made commitments to eliminate deforestation from their supply chains, covering, for example, approximately 65% of global palm oil production.[29] A number of countries are now making notrable progress: For example, Indonesia's recent reductions in deforestation in 2017, including in areas of peat forests,[30] have coincided with significant economic growth rates.[31] The restoration of 160 million hectares of degraded land, as committed under the Bonn Challenge, could be a major win for the economy of up to US$84 billion per year.[32] Meanwhile, ensuring tenure security for indigenous forestland in the Amazon could generate as much as US$10,000 per hectare in ecosystem benefits.[33] While successfully tackling the double burden of obesity and malnutrition globally could save trillions of dollars each year.[34]

"Restoring 160 million hectares of degraded land, could be an US$84 billion boost per year."

- Capital markets have woken up to the opportunity of this new growth approach, and the risks of business-as-usual growth. More than 160 financial firms responsible for over US$86

trillion in assets have committed to support the recommendations of the TCFD.[35] This is creating greater transparency around the extent to which companies and investors are exposed to climate-related financial risk and how they are managing these. Green bond issuance in 2018 is expected to reach US$250 billion, with some calls for a target of US$1 trillion in new green bonds by 2020.[36]

"Financial firms responsible for over US$86 trillion in assets have committed to disclose climate-related financial risks."

- Leading companies are seizing the opportunities of this new approach: over 450 companies across all major sectors have committed to setting science-based targets in line with the Paris Agreement, with more than 120 targets already established.[37]

But, overall, we are still not making progress fast enough toward a new climate economy. The policy hand-brake is still on. Policy-makers are not taking sufficiently bold action to escape the legacy economic systems.

- National climate pledges to support the Paris Agreement, while a profoundly important first step, fall far short of what is needed to keep global average temperature rise to well under 2°C. Policies and subsidies continue to prop up the old, polluting, and socially unequal economy at the expense of new cleaner, more inclusive growth. In some cases, captured by vested interests, governments are going in the wrong direction.
- Fossil fuels as a share of final energy consumption remains stubbornly around 80%—roughly the same percentage as at the beginning of the 1990s. And this status quo is supported by fossil fuel subsidies and tax breaks, amounting to an estimated US$373 billion in 2015 according to the OECD and IEA.[38]
- Carbon taxes or emissions trading systems are now in place or planned in 70 jurisdictions worldwide, covering one-fifth of global emissions.[39] Half of all carbon prices from these policies are less than US$10 per tonne CO_2e—far short of what is needed to drive transformational change.[40]
- Progress on protecting forests, while encouraging in the first half of this decade and continuing in some major forest-rich countries, has now slipped back globally with almost 16 million hectares of tree cover loss in the tropics in just 2017, an area the size of Bangladesh.[41] Agriculture subsidies amount to about US$620 billion per year. Far too often these benefit large producers at the expense of small farmers and support food production that is bad for the climate.[42]

Seizing the economic benefits of low-carbon and resilient growth will only be possible if we act boldly over the next 2—3 years.

- Mixed policy signals and hedging is slowing the momentum driving the new growth approach. It also triggers market uncertainty and increases stranded asset risk. Economic decision-makers, especially in the policy world, now need to step up.
- The cost of hedging—taking action, but too slowly and with mixed signals to the market—is rising. Estimates suggest that mixed signals could lead to US$12 trillion of stranded fossil fuel assets by 2035.[43] By comparison, the bail-out for the stranded mortgage assets, which triggered the 2008 financial crisis and put over 200 million people in poverty,[44] was US$250 billion.[45]

"Estimates suggest US$12 trillion stranded fossil fuel assets possible by 2035."

- Even with these inconsistent and contradictory policy signals, amazing technological and market progress has been seen in the last few years, well beyond what most of the traditional economic models projected. How much more can be achieved in the coming years with clear, consistent policy signals?

We have now run out of time for incremental steps, generic proposals, or statements of broad principle. To capture the net economic benefits of US$26 trillion through to 2030 and shift the world economy onto a more stable climate pathway, the Global Commission calls upon economic decision-makers in the public and private sectors to take the following actions immediately:

1. **First, governments should put a price on carbon and move toward mandatory climate risk disclosure for major investors and companies.** Implemented together, these two actions would provide the strongest, clearest signal to market participants that policy-makers are committed to a new growth approach. They are important elements of the broader policy package to tackle climate change, including appropriate standards and regulations (e.g. on energy and

fuel efficiency), investment in research and development (R&D), green public procurement, and labelling and information-based incentives.

- The major economies, led by the G20, should put a price on carbon of at least US$40—80 by 2020, with a predictable pricing pathway to around US$50—100 by 2030, as recommended by the High-Level Commission on Carbon Pricing.[46]
- All major economies should phase-out fossil fuel subsidies and harmful agricultural subsidies and tax-breaks by 2025, with others doing so as soon as possible, and use some of the revenues saved to provide better-targeted support to tackle energy poverty and ensure more sustainable food and land use systems.
- Lessons gained from successful carbon pricing and subsidy reforms in countries around the world should be utilised to help design reforms in order to address concerns about potential distributional and competitiveness impacts, as well as the challenges around vested interests.
- As recommended by the Global Commission in 2016, companies and investors should be required, as a matter of good corporate practice, to disclose their climate-related financial risks and how their business strategy is compatible with the Paris Agreement, following the TCFD recommendations.

2. **Second, all economies should place much greater emphasis on investing in sustainable infrastructure as a central driver of the new growth approach.**
   - The first step is not about the money. Rather, it is to build stronger leadership and technical capacity to shape robust growth strategies, investment plans, and institutional structures that can align with sectoral policies and facilitate the flow of private investment to sustainable infrastructure. This includes better designed buildings, transport, energy and water systems, and cities but also investments in the natural infrastructure that underpins our economy, such as the forests and wetlands that purify water and provide valuable flood control.
   - MDBs and other DFIs need to double their collective investment in infrastructure and make sure it is sustainable, aiming to invest at least US$100 billion per year by 2020. DFIs should also aim to more than double their mobilisation of private sector investment, including from institutional investors. This will entail working closely with governments and private investors to unlock investment and scale up blended finance, as well as ensure a continued strong capital basis for the MDBs. This would include greater use of risk mitigation instruments and structures and country-led sector infrastructure plans and investment platforms. More broadly, the DFIs can play a critical role in accelerating this new growth approach, but their portfolio-wide activities will need to be aligned to support the sustainability transition.
   - Together with major private financial institutions, the G20 should continue its work on infrastructure as an asset class, on incorporating sustainability criteria into its core definitions, and on developing the tools needed to both support implementation and deepen the pools of green finance. A deeper recognition of the value of natural infrastructure, and effort to attract the finance to maintain and restore it, is needed.
   - Global and national-level platforms that pool expertise in project preparation for sustainable infrastructure investment should be scaled-up and replicated.
   - Developed countries should fulfil their commitment to mobilise US$100 billion per year in climate finance from public and private sources for developing countries by 2020, and the climate finance architecture must be strengthened to utilise these resources for maximum impact and leverage.

3. **Third, the full power of the private sector and innovation needs to be harnessed.** Many companies and investors are already demonstrating leadership, and others are ready to align around this agenda with the right policy signals.
   - By 2020, all Fortune 500 companies should have science-based targets that align with the Paris Agreement. Shifting their brand and marketing to products that are climate positive will engage consumers as active agents of the solution. For only the top ten global retail companies, this could translate into almost US$4 billion each day of purchasing power moving toward the low-carbon economy.[47]

- Companies and investors are ready to advance on this agenda, but they cannot get there on their own. Current regulations, incentives and tax mechanisms are a major barrier to implementing a low-carbon and more circular economy. For example, they slow-down the penetration of new building materials in construction activity. In agriculture, they subsidise the application of too much mineral fertiliser, diverting innovation activity away from more sustainable forms of farming. They make it cost-competitive to deploy single-use forms of plastic packaging, contributing to the plastics crisis we are now seeing in the oceans. They make it hard to design products in a way that maximises component reuse. Along with getting carbon pricing right, we also need to tackle a host of other policies which are protecting the old inefficient, polluting economy.
- A big push on innovation is needed, with at least US$50 billion of new capital by 2020 committed to breakthrough climate challenges beyond the energy sector. Today's progress on renewable energy, energy storage and low-carbon mobility is not an accident. It is at least in part the outcome of decades of investment by governments, universities, foundations and the private sector in mission-driven innovation. Recent technological developments (and new partnerships) have, for example, helped to advance the radical transparency and accountability necessary to achieve deforestation-free supply chains, although there is more to be done to achieve these in practice.
- We need to put in place and capitalise private-public partnerships in each major sector to pilot, scale and share learning around the deployment of new low-carbon and climate-resilient technologies. We have plenty of examples about how to do this well (and badly). What is currently lacking is sufficient political and business leadership.

4. **Fourth, a people-centred approach is needed to ensure lasting, equitable growth and a just transition.** It is good economics and good politics.
   - If managed well, the low-carbon transition offers the potential for new opportunities and more equitable growth. Active, targeted regeneration can support economic diversification and the delivery of quality jobs. In developing and emerging economies, the low-carbon transition provides an opportunity to leap-frog the inefficient and polluting models of the past.
   - All governments should establish clear Energy Transition Plans to reach net-zero energy systems, and work with energy companies, trade unions, and civil society to ensure a just transition for workers and communities. Successfully diversifying local economies as we shift away from coal and eventually other fossil fuels will require multi-stakeholder dialogue, strategic assistance, re-training, and targeted social protection.
   - Diversification and regeneration funds should be targeted to affected areas. There are multiple examples of areas previously reliant on industrial or mining activities that are now seeing new growth as a direct result of repurposing the assets, networks and capabilities of the old economy.[48] Better food and land use systems can deliver vital jobs, better incomes, and more inclusive growth to disadvantaged rural communities. Businesses, universities, and city governments can work with national governments, workers, and civil society to help revitalise and ensure prosperous communities.
   - Women will play a critical role in delivering this agenda in an inclusive and people-centred way. In countries where more women participate in political life, parliaments are more likely to set aside protected lands and ratify international environmental treaties, while ensuring their full participation in the economy could, by some estimates, boost global GDP by as much as US$28 trillion per year by 2025.[49]

This Report is a roadmap for how we can accelerate action to turn better growth and a better climate into reality. We can eliminate extreme poverty, prevent dangerous climate change, and improve the lives and livelihoods of millions. But only if we set out to do so decisively now. This is not just about avoiding a future we do not want. It is about creating the future that we do want.

PART 1

The New Growth Agenda

Photo credit: Vishu Bahaji

The Purpose of this Report

We are on the cusp of a new economic era: One that is driven by the interaction between rapid technological change, sustainable infrastructure investment and increased resource productivity. This new growth story draws direction from the ambitious landmark international agreements of 2015 and 2016,[50] embodied particularly in the Sustainable Development Goals (SDGs) and the Paris Agreement, each signed by over 190 countries. These agreements aim to deliver strong, sustainable, balanced and inclusive growth, to reduce global poverty and to secure a better and more sustainable future for people and the planet for decades to come.

The new growth agenda recognizes that the objectives of growth, climate action and development are interrelated and complementary. This complementarity resonates not only with the goals of the agreements themselves but also the policies and investments that can deliver on them. Its main drivers are investment at scale in sustainable infrastructure, innovation and discoveries that push at the frontiers of what is possible, and resource productivity with a particular emphasis on conserving natural capital. This is an agenda which will boost shorter-run growth from increased investment in the low-carbon transition; spur innovation, creativity and growth in the medium term; and in the longer-term, provides the only feasible growth path on offer.

The pioneering 2014 Global Commission report, *Better Growth, Better Climate*, made the seminal case that there was no trade-off between growth and strong climate action. Following this, the 2016 Global Commission report, *The Sustainable Infrastructure Imperative*, highlighted the central role of sustainable infrastructure in this new global agenda, in driving strong and inclusive growth, delivering on the SDGs and providing a pathway to meet the ambition of the Paris Agreement to limit global warming to well below 2°C and foster climate resilience. The US$90 trillion investment in infrastructure that is needed by 2030 would not cost much more if it was sustainable and, in fact, because of the falling costs of clean solutions it could deliver savings instead.

The opportunities offered in this new growth agenda are even greater than they appeared four years ago. Technological advances and falling costs of renewable energy have made sustainable investments even more attractive, to the point that many are now more cost competitive than traditional fossil fuel-based technologies. The world now adds more renewable power capacity annually than from all fossil fuels combined.[51] The co-benefits of investing in sustainable infrastructure are increasingly evident: cities where we can move, breathe and be productive; resilient power and water systems and housing that withstand increasingly frequent and severe climate extremes; and ecosystems that are more productive, robust, and resilient. Discourse has shifted from the costs of inaction to how to exploit emerging opportunities in this new economy. Also increasingly evident is that such a path avoids the costs of high-carbon development, including remedial measures that become progressively costlier over time. The new climate economy is the new growth story.

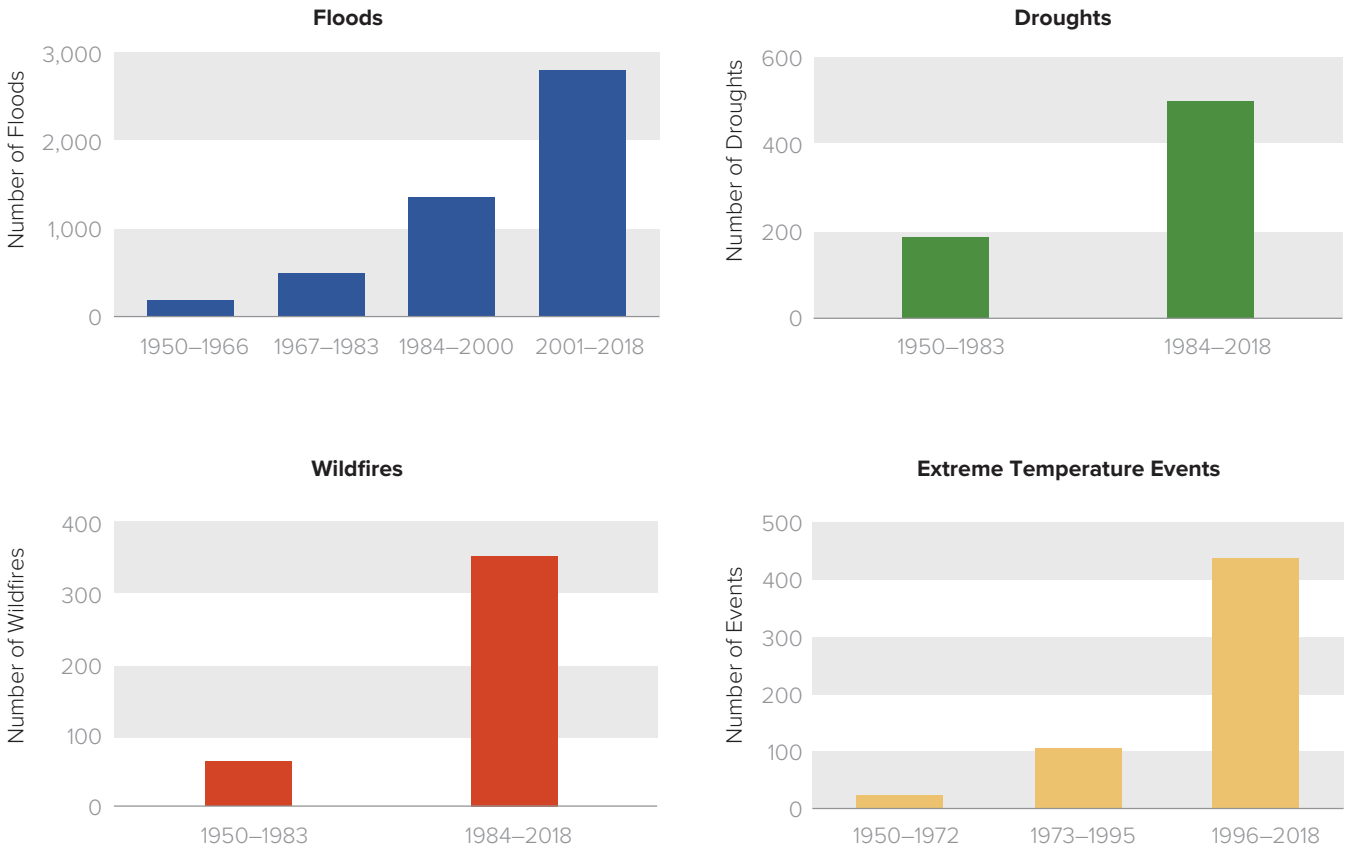
Risks and costs of inaction are mounting faster and are greater than previously recognised. 2017 was the second hottest year globally since 1880 when modern record-keeping began,[52] reflecting a broader trend with 18 of the 19 warmest years occurring since 2000.[53] Concentrations of GHGs continue to reach new records and are now at the highest level in millennia.[54] More frequent and more intense extreme weather events are becoming the 'new normal' (see Figure 1). Globally, disasters triggered by weather-related hazards caused as much as US$320 billion in losses in 2017, significantly higher than average, as well as thousands of deaths.[55] Forecasts from climate scientists are now observed or even exceeded, including accelerating sea-level rise, Arctic summer melt, ocean circulation disruption, and increasing extreme weather events, such as floods, droughts and heatwaves. Planetary boundaries are under severe threat not just from carbon emissions, but from polluted air, threats to fresh water and oceans, degradation of agricultural land and natural landscapes, and loss of biodiversity and ecosystems.[56]

A changing climate will also particularly impact the poorest and most vulnerable. Business-as-usual growth could mean over 140 million climate migrants by 2050, according to the World Bank.[57] While much of the movement may be internal, this is still more than

double the total number of all refugees today and will further exacerbate the likelihood of conflict. Adverse health outcomes could also increase under unabated climate change, due to more intense heatwaves, floods, droughts, a greater risk of food and water-borne diseases, and more rapid spread of pathogens.[58] Outdoor air pollution, largely from fossil fuel combustion, is estimated to result in over 4.2 million premature deaths annually.[59]

If we are to limit the worst effects of a changing climate by keeping to a path consistent with the goals of the Paris Agreement, global GHG emissions will need to get to net-zero emissions in the second half of this century.[60] As the forthcoming report of the Intergovernmental Panel on Climate Change (IPCC) will show, urgent action is needed now to keep global average temperature rise to well below 2°C and pursue efforts to limit it to 1.5°C, as countries committed to do through the Paris Agreement. It is also already clear that there is a significant gap between the national commitments (Nationally Determined Contributions or NDCs) made and the emissions reductions needed.[61] Three years on from the Paris Agreement, very few countries have adopted plans to sufficiently reduce emissions.

Figure 1
Global Occurrences of Extreme Weather Events.



Source: The International Disaster Database. Author calculations.[62]

The scale and urgency of the challenge ahead cannot be underestimated. Over the next 15 years, the stock of infrastructure is expected to more than double;[63] the world economy will likely double over the next 20 years;[64] and urban population will nearly double over the next 30 years.[65] These transformations will primarily happen in emerging markets and developing countries but there is also a pressing need to replace aging and polluting capital stock in developed economies. With the scale of investment that will have to be made in the next two decades, we cannot afford to lock-in polluting technologies and inefficient capital. The window for making the right choices is uncomfortably narrow because of a shrinking carbon budget and because remedial measures will become progressively costlier.

At the same time, we must achieve important social objectives: by mid-century, we will need to feed a global population of almost 10 billion people; provide billions with clean and affordable electricity and water and sanitation services; upgrade skills, including through education; secure better health for all; and close the gender gap. We must also remain cognizant of the social disruptions that this transition will entail, requiring all actors to manage the transition justly and ensure that this growth path leaves no one behind.

The transition to a low-carbon, resilient economy is also just one part of major structural changes already underway in the world today, including rapid urbanisation, increasing globalisation, a shift to service-based economies, and increasing automation. If managed well, this transition has the potential to deliver a safer, more prosperous future.

Momentum is building on the shift towards a new growth trajectory. First, countries are recognising the need to articulate and align growth and development strategies with sustainability, with efforts already underway as, for example, in China's upcoming 5-year plan (see Box 1) and the UK's long-term strategy. Second, broad-based efforts are now underway to align behind and support the global agenda, encompassing major intergovernmental processes and institutions, including the G20, the United Nations (UN) system, the multilateral development banks (MDBs), the IMF and the OECD. Third, there are welcome shifts underway in the private sector and particularly, private finance, to align with and deliver a sustainable and prosperous future. Encouragingly, the private sector is poised to play a much greater role as a driver of investment and innovation. And fourth, technology and innovation are already pushing the frontiers of what is possible, ranging from improving energy efficiency, particularly for heavy industry, to radically improving the monitoring of supply chains such as for deforestation-free commodities.

Despite this momentum, and the emerging coalitions driving this agenda forward, too much progress today is incremental, piecemeal, and falls short of the pace and scale needed. A number of worrying economic trends—from increasing international trade tensions, to volatile oil and gas prices, and to stressed public balance sheets and mounting debt ratios in many developing countries—are further reasons to ensure a decisive transition now to this new growth path. Predictable, coherent, long-term policy signals are essential to spur innovation, open markets, lower financing costs and attract private investment. The decisions that we take over the next 2—3 years are crucial because of the mathematics of climate change and the fundamental structural changes that will shape the future of people and planet for this century and beyond.

The choice we face today, therefore, is not whether or how to act, but how quickly we will do so: we can either make a gradual shift locking us into an unsustainable future or a decisive change of direction towards this new growth agenda.

If countries move tentatively: there will be no breakthrough on carbon pricing and innovation; some, but not all, cities will be built in a sustainable, resilient, and inclusive way; rainforests will continue to be slashed, albeit at a slower rate; power grids will be decarbonised but only where it's easy to do so. Although this is progress, it is nowhere near close to enough and will lock us into an unsustainable growth path, with global warming of potentially more than 3°C, severely disrupting the lives and livelihoods of billions, from residents of coastal Asian megacities to farming communities in America. Within our lifetime and those of our children we are already seeing harmful impacts of imperfect development and a changing climate which are placing significant and a possibly fatal strain on the global economic system.

If countries, businesses and the global community act decisively, however, we will instead see change that is transformative and at scale: new projects will transition to a climate sensitive pathway; ageing and polluting infrastructure will be phased-out rapidly and existing fossil projects will be revaluated and many shelved; governments—in partnership with investors and the private sector—will steer the economy to a

new path in record time. The transition of millions of workers and communities affected by the transition away from high-carbon sectors will be managed sensitively, responsibly, and in a way that promotes upskilling and the transfer of labour to new growing sectors necessary for the transition. We will unlock the multiple benefits of fixing our broken food system, thanks to better forest and farm practices, including large scale reforestation. We will deliver on multiple development goals, keep global warming to under 2°C and avoid the most catastrophic consequences of climate change.

Now is the time to accelerate actions to deliver on the great promise of the new growth agenda and radically reduce the dangers of the old.

The New Growth Agenda in Action

This report highlights opportunities in five key economic systems—energy, cities, food and land use, water, and industry - chosen because of their transformative importance in driving growth, meeting development objectives and supporting climate action.[66] These are the economic systems where transformative change is needed now, in the critical 2-3-year window ahead of us, to ensure 'strong, sustainable, balanced and inclusive growth', as laid out in the G20 Hamburg Action Plan.[67]

This new growth agenda will deliver higher productivity, more resilient economies and greater social inclusion. The poorest do not benefit from the current low-productivity agriculture nor from landslides resulting from deforestation. They do not benefit from inefficient cities where daily commutes often take over four hours a day, exposed to highly-polluted air. The poor are those most exposed to the impacts of climate change, with just one bad weather season having the potential to push low-income families below the poverty line.

Therefore, at the heart of the new growth story, are liveable, inclusive and compact cities which have an economic dynamism that can attract creative talent, companies, and capital while higher densities and affordable housing enable cheaper service delivery and avoid costly urban sprawl. Powering this new story will be affordable, clean, energy systems that deliver much more economic activity for each unit of energy and expand energy access for the first time to more than a billion people in rural and urban areas, replicating and amplifying the impact of mobile telephony to enable equitable growth. Agriculture and forests can become a third engine of economic growth, delivering greater food security, more nutritious food, greater rural prosperity and resilience, and valuable ecosystem services, including water management, soil fertility, pollination and carbon sequestration. Better land use as part of sustainable infrastructure investment is also key to resilient growth and sustainable water resource management to secure clean water for all. Industrial sectors—construction, heavy-duty transportation, consumer goods, metals and chemicals - waking up to the potential of the circular economy can radically reduce the demand for energy-intensive primary materials, driving up both material productivity and cutting waste.

These five economic systems are where we must prioritise efforts to reorient policy and institutions, scale up and push investment, foster technology and innovations and manage the transition in a just and inclusive way. Across each we must harness key elements, such as the structural changes underway and the international division of labour, along with the potential of new and innovative technologies, and the dynamics of economic returns to scale. And a better understanding of the synergies between actions in different sectors can support more informed decision-making. In each system, the right infrastructure can reduce other costs over time and lead to real benefits: for example, more compact and connected cities could reduce infrastructure capital requirements by over US$3 trillion to 2030;[68] for every US$1 spent restoring degraded forests, as much as US$30 can be earned in economic benefits;[69] and climate-resilient water supply and sanitation services for all could save the lives of more than 360,000 children under five every single year.

For each of these economic systems, this Report identifies specific opportunities that can accelerate the shift to the new growth story. These opportunities are not exhaustive nor mutually exclusive. They offer, instead, striking complementarities that can reinforce, support, and accelerate virtuous cycles across sectors.

The intention of this Report is to help both policy makers and private investors chart their own paths in the context of the great new opportunities that lie in implementing this new global agenda. It is also intended to provide inspiration to those who are preparing, country by country, their revised NDCs and their long-term strategies in the next two years, building to COP26 in 2020.

For this Report, the potential benefits of scaling-up some of the exciting proof-points of successes were assessed through an economic model (see Box 4).[70] Such modelling exercises have many limitations, and their results need to be interpreted with care. This is because traditional economic models do not adequately capture the risks of climate change, which can have wide variations in scale and nature with drastic potential impacts, for instance, the submergence of coastal megacities, desertification, migration, or conflict. On the damage side, marginal change applied to growth models misses the scale and nature of risks; on the policy side, marginal models can miss the benefits of disruptive change to a new sustainable growth path, the dynamic public economics of systemic change and gains from innovation.

Given this, it is likely that the economic, employment, and health benefits of the low-carbon transition would be even greater than the models can capture, while the costs of continuing down a business-as-usual pathway instead would be even more stark.[71] Even with these caveats in mind, a global climate action scenario prepared for this Report using the E3ME model that combines a range of opportunities including the widescale use of appropriate carbon prices and phasing-out fossil fuel subsidies, seizing energy and industrial energy and resource efficiency gains, halting deforestation and restoring degraded lands, accelerating the penetration of electric vehicles, and integrating intermittent renewables into the power system—was found to deliver significant benefits. Transitioning to this low-carbon, sustainable growth path could deliver a direct economic gain of US$26 trillion through to 2030 compared to business-as-usual, according to analysis for this Report. Taking ambitious climate action could also generate over 65 million new low-carbon jobs in 2030, equivalent to today's entire workforces of the UK and Egypt combined, as well as avoid over 700,000 premature deaths from air pollution compared with business-as-usual (see Figure 2). Subsidy reform and carbon pricing alone could generate an estimated US$2.8 trillion in government revenues per year in 2030—equivalent to the total GDP of India today—much needed funds that can be used to invest in public priorities. While all economic modelling exercises have limitations, these results echo and reinforce recent analyses by leading economic institutions, such as the OECD.[72]

Figure 2

The Global Benefits of a Decisive Shift to a Low-carbon Economy when Compared with Business-as-usual.

Source: The results cited for the US$26 trillion in direct economic benefits are cumulative for the 2018–2030 period, whereas the other data points reported are for the year 2030. Source: Garrido, L., et al., 2018.[73]

Decisive Acceleration at Scale: What will it Take?

Decisive acceleration in the critical window ahead requires a shared understanding of this new growth agenda—the opportunities it offers, the risks of inaction—and strong leadership from world leaders and economic decision-makers at national, municipal, sectoral, and business levels. These efforts will need strong leadership and persistent follow-up by national and global economic decision-makers—national leaders, Finance and Economic Ministers, and business leaders. The role of Finance Ministers globally, and especially of the G20, will be central given their stewardship of economies and to ensure that global collective action buttresses national efforts.

Their efforts can be substantially boosted by global cooperation and collective action, not only driving positive action forward but helping to tackle and contain global spill-overs. International processes and meetings that take stock of progress and drive implementation on different facets of this new growth agenda can be used relentlessly to drive ambition and set out concrete actions linked to measurable goals and performance benchmarks. A global partnership on sustainable infrastructure, now underway, can ensure collaboration within the international community to lock in support at regional, national and local levels and across sectors.[74]

In particular, efforts are needed on four fronts:

Driving Change Through Markets

Governments and the private sector should accelerate the adoption of carbon pricing supplemented by other incentives and move towards mandatory climate risk disclosure. The establishment of a meaningful carbon price is one of the clearest signals that policy-makers can provide to market participants to show their commitment to the new growth story. While there are already carbon pricing mechanisms implemented or scheduled for implementation on every continent except Antarctica,[75] in most places, they are still too low to have meaningful impact. The High-Level Commission on Carbon Pricing has estimated that a carbon price of US$40-US$80 per tonne of carbon dioxide equivalent by 2020 is needed, rising to US$50-US$100 by 2030, and supported by other policies.[76] Fossil fuel subsidies and tax breaks, estimated at around US$373 billion per year in in 2015,[77] act as "negative" carbon prices, and must also be phased out as soon as possible, with the savings used to tackle energy poverty and more sustainable food and land use systems, among other priorities.

Governments have a leading role to play in setting credible policies and the price direction within their own jurisdictions, and in acting coherently across jurisdictions. As they do, implementation trajectories will vary to account for specific national conditions, including distributional and transitional impacts. Private firms and financial institutions also have an important role to play in anticipating and leading change. Already, almost 1,400 major companies and some large development banks have committed to applying a shadow internal carbon price to "future-proof" their investment decisions.[78] And multilateral institutions can lead change through their own practices, and by supporting and fostering implementation and global collective actions.

Carbon pricing alone cannot induce a transition at the pace and scale required to keep to a well below 2°C target and needs to be complemented by other well-designed policies. These could include city design and land use management; performance standards such as fuel efficiency standards and building codes; and the new methods and technologies. A large proportion of investment in sustainable infrastructure will be driven by government policy, and the planning, selection, and design of investments in infrastructure—where government policy and direction plays a key role—can also be a powerful means to accelerate the transition to a better growth path.

Alongside a meaningful push on carbon pricing and these other incentives, radical transparency on disclosure of climate-related financial risks can be a game-changer to shift investments and spur ambitious action. Climate risk disclosure is fundamental, and countries should now work with stakeholders to implement the (currently voluntary) recommendations of the Task Force on Climate-related Financial Disclosure (TCFD) and define pathways to move, as quickly as possible, to appropriate mandatory disclosure, as France has already done.[79] Strong policy reforms in China and the European Commission's High-Level Expert Group on Sustainable Finance (HLEG) and resultant Commission action plan are recent examples of building momentum on this front. Urgent work includes requiring institutional investors and asset managers to integrate sustainability considerations in the investment decision-making process and integrating sustainability into national financial supervisory body mandates. Central banks and prudential regulators can use their newly-established Network for Greening the Financial System

to develop and deploy clear methodologies to assess climate risks on their balance sheets and to govern the collateral they accept.[80] They should also look into the potential to develop a new risk weighting for climate risks, a so-called "brown penalising factor", into banks' capital requirements.

Investors and shareholders can also push to ensure that investments are sustainable, and we are seeing important signs of change. Already, individuals are making more informed decisions, joining shareholder movements and citizen groups to learn more about where their money goes and seeking to influence the direction of public and private investments alike. Institutional investors, insurers and banks, recognising the risks from high carbon investments and the opportunities in transitioning to their alternatives, have been pulling away from coal and tar-sands. For instance, in 2018, the New York City pension fund announced plans to divest its US$189 billion fund from fossil fuel companies.[81] Over the last two years, over 15 insurance companies, including Axa, Swiss Re, and Zurich, pledged to stop underwriting coal-related companies.[82] The Climate Action 100+ is a five-year global initiative that commits participating investors to active engagement with the 100 largest emitting companies worldwide to call on them to improve climate change governance, curb emissions and strengthen climate-related financial risk disclosure and management.[83] This initiative could have impact at scale in global financial markets if it is expanded as experience is gained by ramping up ambition, membership and the scope of action (see Box 7 on energy finance).[84]

Unlocking and Financing Sustainable Infrastructure at Scale

We need to substantially accelerate and shift investment towards more sustainable infrastructure, including natural infrastructure, to meet the ambitions of the new growth agenda.[85] Despite the recognized importance of sustainable infrastructure, we are falling behind on the scale and quality of investments because of two persistent gaps. On the one hand, we are unable to transform the huge needs and opportunities to realized investments, and too much of what is being invested is not as sustainable due to policy gaps and institutional weaknesses. On the other hand, while there are large available pools of savings,[86] we are unable to transform these into the right kind of finance at scale because of lack of proven and standardized financing models to mitigate risks and crowd in private capital.

National and sub-national governments are the driving force behind the development of integrated, well-articulated growth and infrastructure strategies and investment plans. These are a critical first step towards building ambition, political commitment, coherent and decisive policy actions across the different systems, and attracting private investment. However, most countries do not have coherent growth strategies or well-articulated investment plans that recognize the imperative for greater sustainability and resilience. Instead, there is a fragmentation of efforts with Finance Ministers often focused on the growth agenda, Development and line Ministers on the SDGs or on specific sectors, and Environment Ministers on climate. A whole-of-government approach is called for with integrated and coherent strategies and frameworks of action. NDCs need to be embedded in these strategies and made more ambitious.

Building robust policy and institutional foundations that can deliver on the scale and quality of sustainable infrastructure needed to anchor the new growth agenda is work in progress in most countries and requires sustained commitment with the support of international financial institutions. The policy and institutional underpinnings necessary for the sound design of programmes and selection of infrastructure projects is complex, encompassing upstream planning and project prioritisation, regulations and legislation, sound frameworks for procurement and public-private partnerships, and effective institutional capacities and governance. These requirements have become more challenging as an increasing proportion of investments are now undertaken at the local and municipal levels. The capacity of local governments and municipalities, especially in the planning and implementation of infrastructure, will need to be bolstered to successfully manage rapid urbanisation.

A focus on sustainability at the outset will bolster quality and avoid subsequent costs and the risk of stranded assets. Sustainability criteria need to be more explicitly incorporated into decision making, starting from initial planning to project prioritisation, to procurement and public-private frameworks, to the design of individual projects. Key to the delivery of sustainability goals will be adhering to good practice in use of public private partnerships,[87] including by ensuring that climate change and other sustainability objectives are integrated into public procurement at all levels of government.[88] Though such procedures take time to develop and need to build on local expertise and engagement, the Netherlands Public Infrastructure Authority (Rijkswaterstaat) offers an example of good practice in procurement

for infrastructure aiming to trigger sustainability innovations, demonstrating that procurement can be a powerful tool for shifting infrastructure investment to achieve sustainability outcomes.[89]

Additionally, beyond national development strategies, there is a need for more systematic focus on cross-border and regional connectivity infrastructure to generate sustainable growth and employment and create common markets and new value chains. The most important of these is the multi-trillion-dollar Belt and Road Initiative (see also Box 1 on China), spanning over 70 countries in Asia, Africa and Europe. Thee future growth paths of these countries will be significantly impacted by whether these investments flow towards infrastructure that is sustainable and delivers quality services and jobs in the host countries.

Better institutional structures are needed at the national and global levels to scale up and enhance the quality of projects. SOURCE, a global platform for advanced project preparation launched by the MDBs, can catalyse better project preparation at scale and provide a platform for engagement with all stakeholders including the private sector (see Box 2 on partnerships and platforms). While it is moving ahead, it needs to be taken to scale quickly. There is also a need to improve and streamline the multitude of project preparation facilities. Most importantly, platforms are needed at the country level for specific sectors/systems and sub-sectors that can bring together all relevant stakeholders based on clearly articulated objectives, policy commitments, common structures for project selection and preparation, and joint financing structures including for risk mitigation and crowding in private capital.

With government buy-in, platforms can be catalytic agents of change helping move beyond project-by-project approaches and really take efforts to scale. Country platforms need to be backed by effective cooperation and platforms at the regional and global levels to support country level actions as well as regional and global collective actions. Recent years have seen a range of standards and tools to quantify and assess the sustainability of infrastructure for instance, through high-level principles, safeguards and good practices, reporting guidelines, database and benchmarking, and infrastructure sustainability rating systems.[99] These can also reduce the transaction costs of investing in sustainable infrastructure as well as promote replicability and take investments to scale. DFIs and the policy research community can also help assess lessons and accelerate the spread of good practice.

Box 1

China: World's Highest Emitter and a Leader on Domestic Climate Action

China will, by virtue of its size and footprint, play a key role in shaping and driving the new global agenda.[90] It has already come so far so fast that many people are unaware of how much progress it has made at home, from investing in renewable energy to tackling air pollution. The growth of China's emissions decelerated during the time of their 12th Five Year Plan (2011–2015) after Copenhagen/Cancun (COP15/16), plateaued during the 13th Five Year Plan (2016-2020) and are expected to fall further during the 14th Five Year Plan. It has implemented a new urban agenda to address the deadly smog in its cities, home to more than 750 million people with actions from short term measures (switching to natural gas from coal and reducing production from heavy-emitting sectors such as steel) to longer term measures (such as investing in new public transport and targets to get 5 million electric cars on its roads by 2020).91 Trends have indicated that these efforts have paid off with air quality in 338 cities across China seeing a 6.5% improvement from 2016.[92]

In clean energy, China is home to five of the top six solar panel manufacturers and five of the top 10 wind turbine makers.[93] In 2017, it invested US$126.6 billion in renewable energy, the highest in the world.[94] It is building capacity at an astonishing speed, installing on average more than one new wind turbine every hour. There is now also evidence that China's coal consumption likely peaked in 2014.[95] Its emissions trading scheme, which was formally announced in late 2017, means that globally over 20% of emissions will now be covered by some form of carbon price.[96]

China's emerging green bonds market is expected to deliver about US$230 billion for renewable energy investment in the next five years.[97] Those parts of the financial sector that are not explicitly green are also making changes. The People's Bank of China has proposed mandatory disclosure of climate-related financial risks as part of reforms to make its banking system sustainable. A consortium of UK and Chinese financial institutions are piloting reporting in 2018 according to the recommendations of the TCFD to inform the direction of China's environmental disclosure guidelines.[98]

Box 2

Platforms: The Case for Enhanced International Cooperation

At the global level, platforms can ensure a shared understanding of what we mean by sustainable infrastructure; on how to tackle policy and institutional impediments with shared tools and benchmarks in key areas of action; and on setting up common platforms to scale up project preparation with adherence to high quality standards.

For instance, the new advanced project preparation platform launched by the MDBs, SOURCE, offers a great example of pooling expertise across institutions to aid in sustainable infrastructure project preparation.[100] At the national level, similarly there is a case to establish platforms rather than take a project-by-project approach, for example in renewable energy, power distribution, road networks or urban development. Such platforms can help to scale up and enhance the sustainability of investments while crowding in private investment and finance. Colombia's Financiera de Desarrollo Nacional, for instance, is a positive example for multilateral collaboration and coherence coupled with country-oriented platforms leading to large investment programming with private participation.[101] Replicating such platforms, tailored to national and local circumstances, can be a powerful means for acceleration.

Other examples of vital global partnerships to advance cooperation between public and private actors in key sectors include, for example:

- The **Powering Past Coal Alliance**, led by the UK and Canada, unites countries, businesses and civil society organizations to phase out existing traditional coal power, place a moratorium on any new traditional coal power stations without operational carbon capture and storage (CCUS) and committed to powering operations without coal.[102] At its launch, 27 national, provincial, state, and city governments endorsed its declaration to support the rapid phase-out of traditional coal power. As of July 2018, the number of alliance members had already grown to over 60.
- The **NDC Partnership (NDCP)**, a coalition of countries and international institutions working together to achieve ambitious climate goals and enhance sustainable development.[103] By mid- 2018, less than two years since it was launched, NDCP already counted 105 members, comprising nearly 80 countries and 19 international organisations, and efforts were underway in over 30 countries. Members of NDCP work to ensure countries have access to the support they need to implement their NDCs and related sustainable development goals by facilitating access to technical assistance and to financial support, as well as knowledge exchange. It aims to 'bridge the gap' between climate-environment and development-finance actors by uniting them in joint planning and coordination processes.
- The **Tropical Forest Alliance 2020** is a global partnership of over 120 businesses, governments, and civil society organisations committed to reducing tropical deforestation related to key global commodities by 2020, starting with soy, beef, palm oil, and paper and pulp.[104] TFA2020 makes the case for sustainable supply chains as an essential aspect of achieving the development and growth objectives.
- The **Global Platform for Sustainable Cities**, is a knowledge sharing platform supported by the Global Environmental Facility, led by the World Bank working with major city networks, like C40 Cities, ICLEI, and almost 20 other partners, to deliver sustainable and inclusive urban development.[105] Covering around 30 cities in 11 countries, the platform promotes an integrated approach to urban development, focusing on urban sustainability indicators, planning, and financing.
- The **Partnering for Green Growth and the Global Goals (P4G)** brings together hundreds of governments, businesses and civil society organisations in innovative and incubate public-private partnerships to advance solutions in food and agriculture, water, energy, cities and the circular economy.[106] P4G's public-private partnerships pursue specific global development goals in eight target countries through market-based actions with support provided in terms of funding, facilitation or recognition.

Concerted efforts are needed to develop the institutional architecture to mobilise finance at scale and align it strongly with sustainability. Robust multi-level public finance foundations are critical for infrastructure development especially as more investments are decentralised. This calls for strengthening capacity for revenue mobilisation and more effective spending. New tools and approaches that take advantage of advances in technology and best practices can help accelerate reforms and institutional capacity.[107]

The biggest opportunity and challenge is to mobilise the large pools of private capital especially those held by institutional investors. This requires both better mechanisms to tackle early stage risks and crowd in long-term finance once revenue streams and underlying cost structures are clearer. The work now underway in the G20 to develop infrastructure as an asset class can give an important impetus to the mobilisation of private finance, but sustainability needs to be a central focus of this effort.[108] These efforts need to be joined up with other innovations, including blended finance solutions. Indeed, as the work of the Blended Finance Task Force shows, scaling up and crowding in private investment and finance will require efforts on multiple fronts.[109] These include setting well-designed mobilisation targets for MDBs and across the whole value chain of development finance institutions (also see Box 3); revamping and standardising institutional structures, products and instruments; improving data and benchmarks for investors; and tackling regulatory impediments. Institutional investors—banks, insurance companies, pension funds, hedge funds, sovereign wealth funds and endowments—are also potential sources of substantial new capital to fund sustainable infrastructure.

International public finance is essential to crowd in private finance at scale, meet concessional financing requirements in poor and vulnerable countries, back more risky investments and mobilise finance for adaptation and natural capital where private returns may not be sufficient. A substantial scaling up of international public finance, both market-based and concessional, is needed to meet the scale of financing requirements. Developed countries should fulfil their commitments to mobilise US$100 billion annually of public and private finance to support developing countries act on climate change and the climate finance architecture must be strengthened so that these resources can be used for maximum impact and leverage. A significantly stepped up role of DFIs and the MDBs, in particular, is called for given the unique role they can play in in realising the ambitions of the new global agenda (see Box 3).[110] MDB finance for infrastructure today amounts to around US$50 billion per year.[111] It will be essential to ensure continued strong capital for MDBs if they are to double their infrastructure investments coupled with much larger private sector multipliers. World leaders and finance ministers need to break through the long-standing impasse on the reform of international financial institutions (IFIs). The forthcoming report of the Eminent Persons Group set up by G20 Finance Ministers provides an important opportunity to consider and push for decisive reforms.

Photo credit: SolarSister

Box 3

Strengthening the Multilateral Development Bank (MDB) System

A significantly stepped up role of international financial institutions and the MDBs, in particular, is called for given the unique role they can play in realising the ambitions of the new global agenda.[112] As countries implement efforts to support the SDGs as well as the Paris Agreement, the MDBs can support policy and institutional reforms in partner countries and build institutional capacity, enhance the quality of projects and programmes, and scale them up for transformative change. They are uniquely positioned to support the new growth agenda working with partner countries and by building multipliers with the private sector, creating and testing new approaches and methods, and bringing good ideas to scale.

In 2017, the MDBs with International Development Finance Club committed to align their full portfolios with the Paris Agreement. In addition, the MDBs' financial structure allows them to leverage contributions from their shareholders and multiply them into financing at low cost and use this financial capacity in turn to crowd in financing from other sources. For example, in 2017, the MDBs report that they committed US$35 billion in climate finance in developing and emerging economies, which was used to leverage an additional US$50 billion in climate-co-financing in that year.[113] With effective investments and implementation, MDBs have the potential to drive catalytic change, however they need to put in place a common approach to ensure transparency and progress over time, including to monitor and ratchet up mainstreaming of climate change across their full portfolios (see also Box 23 on MDBs accelerating clean energy access). Despite their inherent strengths, MDBs are constrained by their financial and institutional capacities, effectiveness of instruments, unclear mandates and governance shortcomings.

Unleashing their full potential will require greater coherence and political commitment across shareholders.[114] The Eminent Persons Group established by G20 Finance Ministers will make their recommendations by October 2018, providing an important opportunity to shape the future of the MDB system and could be particularly catalytic on three fronts: where they act, how they act, and how they expand collaboration. First, they should look to expand efforts in underserved client groups: fragile states, which need significant policy and institutional support; high-debt countries, where their efforts can help break the vicious cycle of higher debt hampering sustainable infrastructure investment and much-needed growth; and in upper middle-income countries, where not only are profits more reliably made, boosting the portfolios of the MDBs themselves, but also in expanding regional influence, such as by expanding sustainability standards and improving connectivity. Second, they need to become much more effective at unlocking private financing, ensuring that the right kind of capital is brought in at the right time in the project lifecycle. Importantly, this includes improving instruments and platforms for risk sharing and for mobilising private investment and where these prove effective, rapidly scaling these up to cover a significant share of their operations. And finally, there needs to be more effective collaboration across the multilateral system, speaking to and drawing from the strengths of each.

Harnessing the Private Sector and Innovation

The full power of the private sector and innovation needs to be harnessed. Many companies and investors are already demonstrating leadership, and others are ready to align with this agenda with the right policy signals. As private capital has started to shift towards sustainable investments, a recent wave of business action shows front-runners stepping up to enhanced ambition. One hundred and forty of the world's most influential companies already committed to 100% renewable energy (RE100),[115] 20 major multinationals committed to 100% electric vehicle fleets (EV100),[116] and over 450 have committed to develop Science-Based Targets (SBTs) to manage their emissions in line with ambitions to keep global temperature rise well below 2°C.[117] Government policy in many areas now needs to catch-up to these front-runner leaders.

Implementing the best technologies and practices available today could significantly reduce industrial energy demand, as is clear from leading companies in the cement, steel, maritime and other sectors. At the same time, efforts to scale up approaches to carbon capture, utilisation and storage (CCUS) will be essential for some hard-to-abate sectors.[118]

Especially for consumer-facing companies, shifting their brand and marketing to products that are climate positive can also engage consumers as active agents of the solution. For instance, shifting the diets of populations who consume a lot of animal-based foods towards plant-based foods—and especially away from beef—could result in global health-related

savings of almost US$1 trillion per year by 2050 as well as significant reductions in GHG emissions.[119] The challenge remains to extend and implement commitments and to scale efforts to other countries and business models, turning these successes into a wider shift in corporate action.

Innovation is already rapidly pushing the frontiers of what is possible, ranging from energy efficiency improvements, particularly for heavy industry, to radical process improvements using new digital technologies and to circular economy models that are drastically opening up opportunities to reduce, recycle, and reuse resources. Advancing innovation, meanwhile, can provide a major boost to our collective efforts (see for instance, Section 5).

The exciting landscape of cheaper renewables, better storage capacities, and electrification of the economy including the rapid rise of EVs has been as a result of supportive policies and investments by governments, universities, and foundations in mission-driven innovation combined with the enterprise and abilities of the private sector. In many other sectors, including food and land use, water and waste management, construction and heavy industry, the innovation gap is much greater and, as a result, the private sector further away from investing.

For those innovations that are at earlier stages, greater direct public investment in research and development (R&D) and targeted, time-bound industrial policies to encourage private R&D spending will be required. These can help get industries to the stage where scale is achievable, enabling cost reductions and learning curve effects.

For innovations that are closer to market readiness and could be deployed at scale in the next 5–10 years, the right public-private-philanthropic models with adequate finance and effective delivery mechanisms to fill these gaps at both the national and global levels will be key across sectors.

In particular, a big push on innovation beyond the energy sector will be critical to addressing the wider climate challenge. Tailored solutions, private-public partnerships, and financing modalities need to be developed or expanded for the global commons under threat including forests and natural landscapes, wetlands, biodiversity preserves, water bodies and oceans. These can strengthen cooperation on technology development and wide-spread adoption helping deploy the best available technologies and business models today and investing in next-generation technologies. These efforts can learn from the innovative partnership approach of the International Solar Alliance, for instance, an alliance of over 121 'sunshine countries' coming together to make solar power, technology, and financing more accessible to different countries.[120]

Ensuring an Inclusive Agenda that Puts People First

A people-centred approach is needed to ensure lasting, equitable growth and a just transition. Disruptions in the global economy—wrought by rapid technological change including digitisation, globalisation and the shifting international division of labor, and structural changes within economies—are all contributing to a changing employment landscape and social transitions in developed and developing economies alike. Accounting for these wider structural elements and proactively managing this transition well for those who are and will be most adversely affected is essential to build support and enable the shift for the new growth story and to avoid climate action becoming a scapegoat for wider structural disruptions. Managing for a just transition is good economics and good politics.

Successfully diversifying local economies away from coal and eventually other fossil fuels will require multi-stakeholder dialogue, strategic assistance, re-training and targeted social protection (see also Box 5). For example, in Australia's Port Augusta, workers and their unions at a dying coal-fired power station successfully lobbied for a solar thermal plant to be built in its stead. The plan was to allow local energy workers to transfer their skills to cleaner, more viable employment and the community to remain an energy hub.[121] As China has delayed or stopped work on 151 coal power plants, it has also created a US$15 billion fund for retraining, reallocating and early retirement of the estimated 5-6 million people who would be laid off due to coal or steel sector overcapacity.[122] Germany, Canada, Scotland, Uruguay and some Australian states have established dialogues amongst industry, workers, and government to identify approaches to ensure a just transition for affected workers and communities, while fossil fuel rich countries like Norway are exploring opportunities to diversify their economies. In developing and emerging economies, the low-carbon transition provides an opportunity to leap-frog the inefficient and polluting approach of the past. Alongside national governments, city governments, businesses, and universities can help revitalise and deliver prosperous communities. Training and

education will be key, as will moving—not just people to jobs, but vice versa as well—to help capitalise on the transition.

Empowered women and women in leadership are critical for the environment and for the global economy. Ensuring women's participation in the economy could, by some estimates, boost global GDP by US$28 trillion per year by 2025.[123] Women are playing a key role in delivering clean energy access solutions (see Box 20). They are also often the primary providers of energy, water, food and other resources for their families, placing them at the frontlines of a changing climate. Almost half the economically active women in the world work in agriculture, a sector already feeling significant climate impacts.[124] In cities, urban infrastructure has not always accounted for the needs of women. For instance, women face harassment and physical abuse on public transit,[125] which hampers their ability to move freely. That means women who can afford to, switch to private vehicle use, increasing traffic and congestion burdens. Poorer women, however, are often forced to change routes, often for less convenient or costlier options, or drop out of jobs or education entirely. Policies cannot be gender-blind. In countries where women participate more fully in political life parliaments are more likely to set aside protected land areas and ratify international environmental treaties.[126] In India and Nepal, for instance, forest conservation improved as a result of women's participation at community level in forest management.[127]

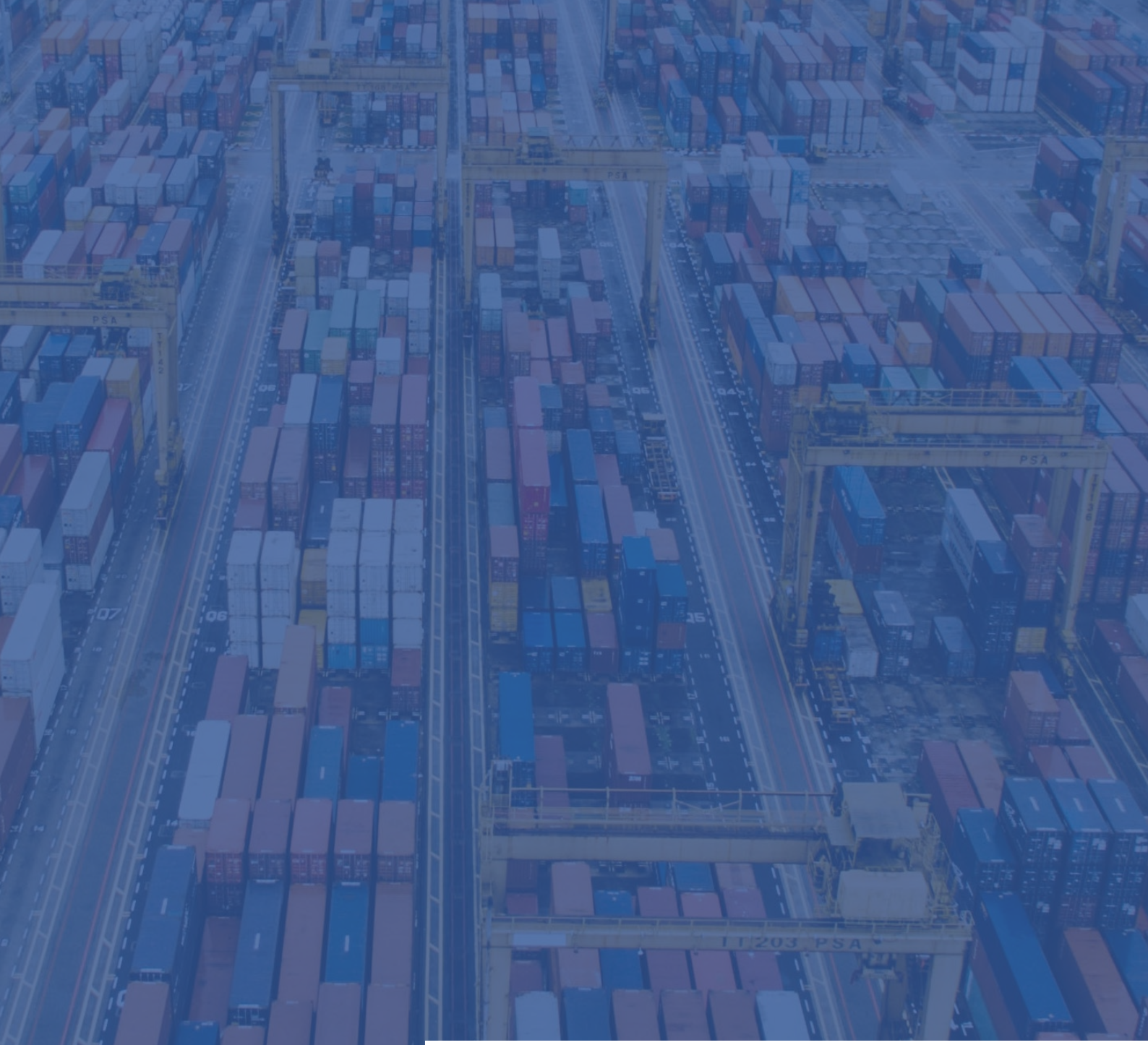
A greater focus on resilience and adaptation across policies and efforts are critical as climate impacts continue to hammer lives and livelihoods. The devastating floods in South Asia in 2017 not only took over 1,200 lives but also left over 20 million affected including 6.8 million children.[128] We can no longer choose between actions for today and those for tomorrow, adaptation to extreme weather events is already an essential feature of our collective response to a just transition as occurrences of climate-related disasters grow.

Conclusion

This is our 'use it or lose it' moment. Investing the expected US$90 trillion to 2030 to build the right infrastructure now will deliver a new era of economic growth. Investing it wisely will help drive innovation, deliver public health benefits and inclusive growth, create a host of new jobs and go a long way to tackling the risks of runaway climate change. Getting it wrong, on the other hand, will lock us into a high-polluting, low productivity, and deeply unequal future.

Decisive action now will clearly yield a far more attractive and less dangerous future, and it will require strong and concerted leadership. The purpose of this Report is to lay out what it will take and to demonstrate how acceleration can be achieved. It is to inform and give impetus to economic decision-makers—finance and economic ministers, business leaders, and investors—equipping them with the arguments and the evidence to drive the transformation.

It should be read as more than just a Report. It is a manifesto for how we can turn better growth and a better climate into reality, for how we can carry this call to action into board rooms, through the halls of government and over the airwaves. We must consciously and conscientiously legislate, innovate, govern, and invest our way to a fairer, safer, more sustainable world.



PART 2

Key Economic Systems

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The first part of this Report outlines a new global growth agenda that has the potential to deliver economic growth, development, and climate objectives together, with a focus on how to decisively accelerate action and deliver this transformative agenda at scale. Implementing this agenda must happen in each country at the national and sub-national level and **in five key economic systems**, namely: energy, cities, food and land use, water, and industry. These are the areas where we see the greatest potential for growth, as well as the greatest potential to reduce the risks of harmful climate change. As such, they are the areas in which to prioritise efforts to reorient policy and institutions, scale up and push investment, foster technology and innovations, and manage the transition in a just and inclusive way. The role of investment and innovation is critical across the whole agenda.

For each key economic system, Part 2 of the Report identifies the main trends or issues that are shaping the current state of play and that are poised to create the greatest impacts on longer-term pathways, opening up transformative opportunities for acceleration of the new growth agenda. Significant changes in just the last few years have already fundamentally changed the landscape of these economic systems. These include the spread of exciting new technological advancements, political and policy shifts, or larger macroeconomic, consumer-driven, and societal forces. This part of the Report examines how to harness these for the decisive change of direction needed.

In each of the key economic systems, special attention is given to the important **cross-cutting themes** of successful change identified in Part 1. Across all five systems, securing finance, driving greater innovation, providing the right incentives, and managing a just transition (see Box 5) will be essential to drive the transformative change needed. The important, but often neglected, role of women and girls in the transition is given particular attention in this Report, as is the need to strengthen adaptation and resilience in the face of some amount of climate change that is already inevitable. The pace and scale of change needed to deliver this economic transition is unprecedented. While the economic, societal and climate benefits of making the transition are increasingly apparent, we know from experience that it will not be easy. New markets, business opportunities, and quality jobs will open up, yet in many cases these will also require shifts away from incumbent, polluting and inefficient industries, which have strong and sometimes well-organised political influence. There will be a need to sensitively and respectfully manage associated dislocation and other challenges for communities in transition.

For each of the five economic systems, the Report has selected **two to five specific opportunities** that can be seized to accelerate and rapidly scale up efforts to deliver growth and climate action together. The Report highlights the latest evidence of the potential benefits; compelling 'proof points' or examples of successes identified, along with how to address roadblocks to implementation and scaling action; and finally, a few **specific accelerators** that could dramatically boost efforts for each opportunity. Some new modelling-based analysis was developed for this Report to assess the potential economic, social, and environmental benefits of scaling up action in these opportunities (see Box 4).

Box 4

Understanding the Economic and Societal Benefits of Ambitious Climate Action: Modelling Analysis for this Report Using the E3mE Model

The policies and interventions for accelerating climate action discussed in this Report are strongly supported by empirical evidence of the economic, social, and environmental benefits they can deliver. The Report draws on a number of existing modelling exercises, as well as new modelling undertaken in partnership with Cambridge Econometrics, to assess the potential impacts of scaling up approaches that can both promote economic growth and reduce the risks of climate change.

The macroeconomic model E3ME (e3me.com), used for this analysis, is an integrated, global, dynamic simulation macro model that is estimated by econometric methods for a large set of countries, regions, and sectors of economic activity. Its structure is based on the system of national accounts, coupled with bottom-up technology diffusion models for the power and transportation sectors complementing the macro-econometric framework. E3ME has a dynamic error correction specification, which is important when considering short- and medium-term analysis and rebound effects. The model provides an approach that can add further insights to those from more traditional Computable General Equilibrium (CGE) models. The model is better able to reflect the interaction between the real economy and the financial system, and regulation and other policies may lead to increases in output if they are able to draw on spare economic capacity. The E3ME model is also better able to reflect the impacts on labour participation and employment. These are critical to assessing the socio-economic benefits of ambitious climate policies.

E3ME includes 59 countries or regions, 43 industry sectors, 28 categories of household expenditure, 22 different users of 12 different fuel types, and up to 14 types of air-borne emissions including six GHGs. The model can produce a broad range of economic indicators, as well as various energy and environment indicators. These include GDP and its aggregate components (household expenditure, investment, government expenditure, and international trade); sector output and gross value added, prices, trade, and competitiveness effects; international trade (imports and exports) by sector; consumer prices and expenditures; sector employment, unemployment, wage rates, and labour supply; energy demand, by sector and by fuel, and energy prices; CO_2 emissions by sector and by fuel; and social and health outcomes, including government health care costs and the number of years of life and work lost due to emission-related effects.

In conducting the empirical modelling exercise, the New Climate Economy and Cambridge Econometrics teams jointly defined a set of six economic modelling scenarios for climate action including in cities (urban retrofits, urban densification, and promoting EVs); energy (carbon pricing, subsidy and energy reform, and reducing energy waste); and industry and innovation (increased efficiency); together with implicit assumptions on policies for food and land use. A combined global climate action scenario that integrates all of these policies was also produced. The results of the scenarios are highlighted in this Report and elaborated in a Technical Note published separately.[129]

As a selective list, the opportunities and their accelerators are not meant to be exhaustive or to cover all the actions needed in each system. Rather, they have been chosen based on four underlying criteria that would substantively contribute to the new growth model, namely:

- **The potential to deliver clear and significant socio-economic benefits**, particularly in terms of economic growth, ensuring quality jobs, raising incomes, providing for vulnerable communities, reducing impacts on health, and reducing economic or social inequalities, including around gender or poverty.
- **The potential to deliver major climate benefits,** in terms of transformational reductions in emissions and the building of climate resilience, and consistent with the goal of the Paris Agreement to keep global average temperature rise well below 2°C.
- **Solutions that have been successfully demonstrated**, building on existing proof points of success in countries, cities, and businesses around the world. Practical policy-relevant experiences can help ensure a realistic understanding of the challenges, as well as the financing opportunities, the policies and incentives needed, and the critical governance choices required to accelerate the new climate economy.
- **The existence of clear approaches that economic and political decision-makers can take to replicate these opportunities at scale**, engaging relevant champions and coalitions to help deliver them.

The individual opportunities and their related accelerators are all explicitly grounded on actions that are already taking place, not on distant innovations or emerging technologies that are yet to be tried at scale. But most opportunities are only being seized in a piecemeal manner, with only incremental and halting progress. Co-ordinated and concerted acceleration could yield dramatic progress.

Policy-makers, business and other leaders must now turn the ad hoc advancements in each of these systems into a broad movement of action and a decisive shift commensurate with what is needed to respond to the global climate challenge. The opportunities described in the following pages offer practical guidance on how to accelerate progress for economic and political decision-makers, including national and local governments; development finance institutions; investors; and financial and business leaders. They are the building blocks of the new growth model.

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Box 5

Ensuring a Just Transition: "There are no jobs on a dead planet".[130]

The emerging new growth model has the potential to deliver incredible economic and development benefits together with climate goals, leveraging recent technological advances, new business models, and innovative financing mechanisms. This Report highlights a range of examples of successes in countries and sectors around the world that are delivering real benefits to communities today and will do so for generations to come.

The scale and pace of the broader economic transition that the world is now facing is unprecedented. We are already in the midst of major structural changes, including rapid urbanisation, increasing globalisation, a shift to service-based economies, and increasing automation. As with major economic and technological transitions of the past, this one will not necessarily be easy. New markets, business opportunities, and jobs will open up, but there will also be a shift away from the current high carbon-emitting industries and modes of energy, transport, and land use. Unless this transition is carefully and responsibly managed, there is a real potential for stranded assets, communities, and workers, as well as the risk of exacerbating the social exclusion of the poorest and most vulnerable. The transition to a low-carbon, resilient economy is just one part of this much broader transformation, and—if managed well—has the potential to deliver more equitable and prosperous growth. This transition is not only about phasing out polluting and unsustainable activities in various sectors, but also about diversifying local economies, generating new jobs and new industries, new services and new skills, all of which requires new types of investment and accompanying policies.[131]

Open and transparent dialogue to plan for the transition will be essential, bringing together government, business, trade unions, civil society, and communities.[132] Local universities and trade schools can also play a key role in envisaging and training for a more diversified economy in affected regions. Such broad-based and inclusive dialogues can help to identify specific measures to ensure a just transition, helping to reduce fears, opposition, and both inter-community and inter-generational conflict. Dialogues can bring together trade unions, government, and industry representatives to find common ground and ways forward to ease the transition.[133] According to the International Labour Organisation (ILO), a just transition is a bridge from where we are today to a future where all jobs are green and decent, poverty is eradicated, and communities are thriving and resilient.[134] Green jobs are those which support improving energy and resource material efficiency, limiting GHG emissions, minimising waste and pollution, protecting and restoring ecosystems, and supporting adaptation to climate change.

As noted, the shift to a low-carbon and climate-resilient economy is only one—potentially small—part of a much broader economic transition that is under way, including the so-called 'Fourth Industrial Revolution,' characterised by increasing globalisation and the rise of automation.[135] Indeed, the growth of new technologies and artificial intelligence (AI) is having a profound effect on labour markets, with some economists suggesting that automation could potentially replace over half of all jobs by 2055.[136] Traditionally middle-skill jobs (such as machine operators or clerical workers) are already declining compared to high- and low-skill jobs: across 24 OECD countries, all but two experienced some degree of job polarisation between 1995 and 2015.[137] Some of this shift can be explained by globalisation and offshoring, but there is also an important element related to technological process and growing automation of middle-skill jobs in manufacturing.

Growing social inequality and lack of inclusion in the old economic growth model is of particular concern and addressing it will be a necessary part of any just transition towards a new growth approach that minimises climate risks. In 2017, an estimated 82% of the wealth created globally went to the top 1% of the world's population.[138] Wages in many parts of the world remain flat. Despite important recent progress in tackling poverty, just under half of Africa's population still lacks access to electricity today.[139] Women continue to be under-represented and under-paid compared to male counterparts in the workforce in most sectors of the economy. Some studies suggest that growing automation may serve to exacerbate these inequalities, unless policies are implemented to actively manage the impacts.[140]

A well-managed and just transition is needed to ensure that the new growth agenda delivers not only economic growth, but also alleviates poverty, strengthens social inclusion, improves biodiversity and ecosystem services, and reduces the risks that a changing climate will pose to development prospects. A just transition requires social dialogues, clear plans, and pro-active policies. It requires active labour market policies and enhanced social security systems, while minimising disincentives to work. Robust social protection systems are essential, enabling the necessary support for the poor and vulnerable to improve livelihoods and seek formal employment and for workers and their families to meet basic needs during periods of unemployment, re-training, or education.[141] The more inclusive the social protection system, the more likely disenfranchised and displaced workers will feel empowered to move into new jobs, and the better communities will be at supporting economic diversification.

Box 5

Ensuring a Just Transition: "There are no jobs on a dead planet". (continued)

While the transition to a low-carbon economy is only a part of this much broader economic transformation, it is often an easy target to 'blame' for some of the job losses or dislocations that are taking place. Disentangling the impacts of climate-related policies from this broader transition can help to build political support for climate action and identify where there are real impacts that need to be carefully managed.

This Report highlights some of the examples where processes are facilitating a just transition to a new climate economy, identifying some of the barriers and challenges faced, as well as some of the factors that are leading to progress and successes. A number of examples are highlighted throughout the Report in more depth, a few of which include measures such as:

- Commitments to phase out coal use in the energy system and successful experiences in phasing out subsidies to fossil fuel production and exploration, including policies and approaches to carefully manage the transition for affected workers and communities. For example, following their 2016 and 2018 commitments to the phase-out of coal, the Province of Alberta and the Government of Canada have established social dialogues with coal workers and their communities (see also Box 17); Alberta's carbon price revenues were allocated to support the transition for coal communities and others;[142] and China established a dedicated multi-billion-dollar fund for retraining, reallocating, and the early retirement of workers laid off due to coal and steel overcapacity as part of its 13th Five-Year Plan (2016-2020). Most recently, in 2018 Germany launched its "Commission on Growth, Structural Change and Employment" to develop an overarching approach to managing the full range of impacts of the phase-out of coal in line with national climate commitments. It is seen as a potential model for just transition dialogues (see also Box 17).[143] The new Powering Past Coal Alliance, with over 60 partners including governments, organisations, and leading businesses, has the potential to galvanise social dialogues, building on experiences to date, and manage the transition in over 30 signatory countries or states (see also Section 1.C).[144]

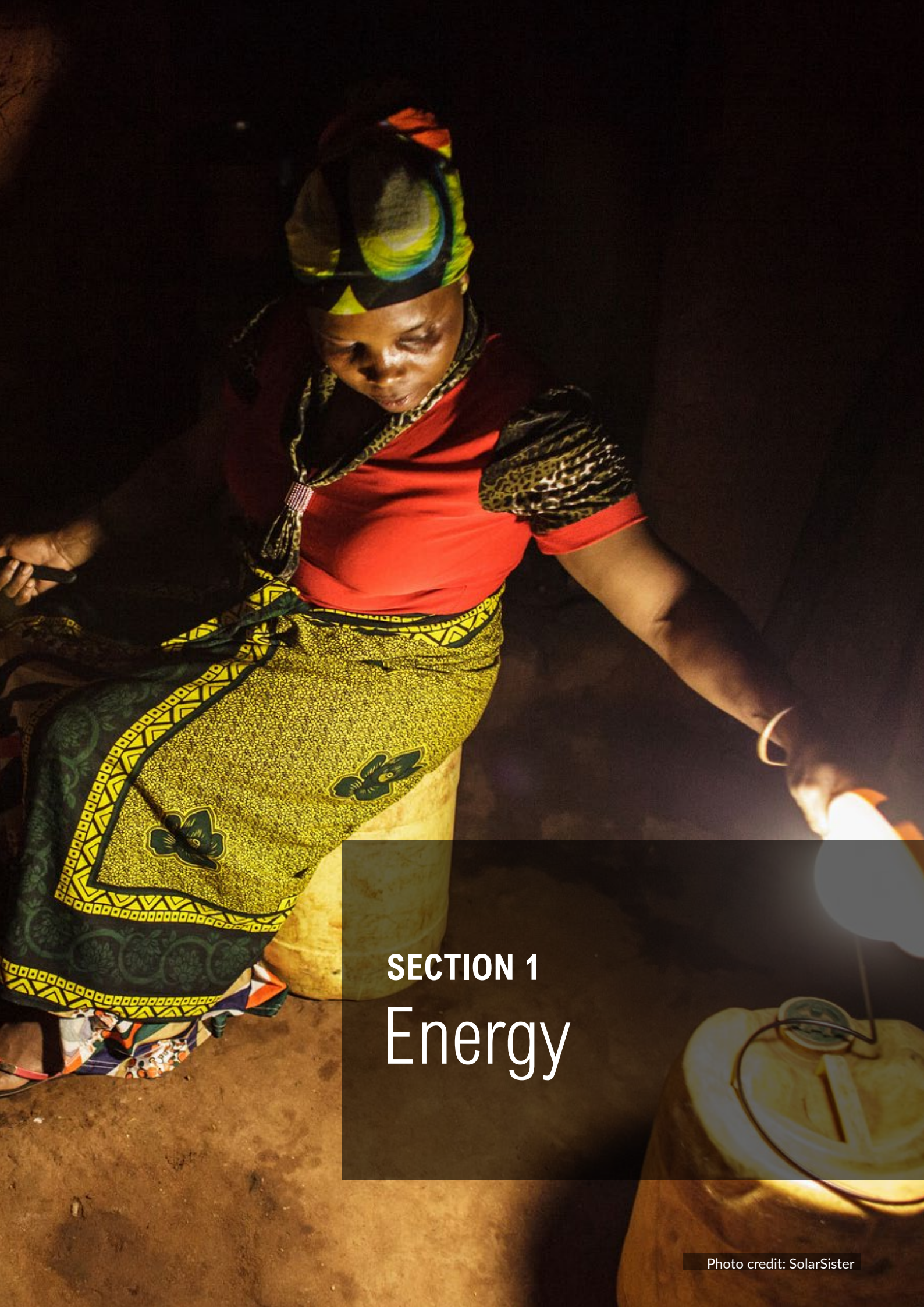
- Clean energy access policies typically target the urban poor and hard-to-reach rural communities and can offer huge economic and social benefits, notably for women and children. These policies can also provide important sources of income for locals providing the services. Brazil's successful approach to achieve near universal access to clean cooking in urban areas included the development of national infrastructure for liquefied petroleum gas (LPG) production and distribution, involving private entrepreneurs and subsidies to the poorest families to ensure affordability.[145] In rural Bangladesh, a government-led results-based financing programme supports private operators in implementing solar home systems in rural communities; small subsidies are offered to the poorest households, and the largest private operator made the training and employment of local women a pillar of its business model (see Section 1.D).[146]

- Approaches to restoring degraded lands back into productive use in countries from Ethiopia to Niger to China have ensured these efforts successfully lifted millions of people out of poverty and raised local farmer incomes (See Section 3.D).

- An economy-wide approach to the transition was launched in Norway through the Expert Committee on Green Competitiveness, which delivered its recommendations to the Prime Minister in October 2016 after extensive consultations amongst business, workers, and civil society. As part of this process, 11 key sectors—including transport, industry, petroleum and agriculture—developed long-term road maps to transition their sectors to a low-carbon growth model while maintaining global competitiveness. This has helped business, government leaders, and society more broadly overcome inertia and identify together the opportunities to transition more rapidly from a heavily fossil fuel-dependent economy to a more diversified, low-carbon economy (see Section 1.C).

- Uruguay's rapid energy transition in recent years shows the country moving from dependence on fossil fuel-based electricity and oil imports to having enough renewable power not only to supply over 94% of their own electricity system, but also to be able to export one third of the power they generate to Argentina. Uruguay has implemented ILO guidelines for a "just transition towards environmentally sustainable economies and societies for all" as part of this process, to assist the country in creating employment, ensuring decent work opportunities and social well-being in the process of a just transition towards a greener economy.[147]

As this Report illustrates, sector by sector, the low-carbon, climate-resilient aspects of the broader transition to a new growth model can unlock multiple benefits—a boost to growth in countries at all stages of development, new jobs in innovative industries, poverty alleviation, and improvements in other key indicators of quality of life. Ensuring that the transition is just is fundamental to building a safer, more sustainable, and prosperous world for all.



SECTION 1

Energy

Photo credit: SolarSister

Energy is ingrained in all aspects of human life: It is how we power our homes, schools, and hospitals, our businesses, factories, and transport. But today, 1 billion people live without access to electricity, and nearly 3 billion people live without access to clean cooking.[148] Even in developed economies, an estimated 200 million people, over 15% of the population, suffer from energy poverty.[149] Fossil fuels, which have been instrumental in powering growth to date and currently account for 80% of global primary energy consumption,[150] have resulted in economies that are vulnerable to volatile fuel prices and reliant on energy imports. Fossil fuels are also responsible for 75% of GHG emissions,[151] as well as outdoor air pollution which is responsible for 4.2 million deaths per year.[152]

"Ensuring access to affordable, reliable, sustainable, and modern energy for all" (SDG 7) is fundamental to our economies and human development.[153] The challenge is not only to meet our current energy needs, but also those of a projected 10 billion people by 2050 and to do so with low-cost, zero-carbon energy.[154] By the end of the century, estimates point to a tripling or quadrupling of energy demand globally.[155] Given the inextricable links of the energy-food-water nexus, growing energy demand and the energy challenge need to be considered in the broader context of wise water management (see Section 4) and sustainable food and land use (see Section 3). Together, they will significantly shape the global economy.

Transitioning to a low-carbon energy system to meet our current and growing needs is not only technically feasible but also economically and developmentally desirable.[156] Reducing fossil fuel use, for instance, can improve human health and well-being and lower public health expenditures. According to analysis for this Report, over 700,000 premature deaths due to air pollution globally could be avoided compared with business-as-usual in 2030 under a global climate action scenario (see Box 4 on modelling).[157] Additionally, switching to low-carbon energy sources—mostly by decarbonising power and electrifying a broader set of economic activities, first in buildings and light-duty urban transport (see Section 2.C), and then in heavy-duty transport and industry (see Section 5.C)—could deliver roughly two-thirds of the carbon emissions reduction required from the energy sector by 2040 to meet a 2˚C trajectory; energy efficiency improvements could contribute the remaining third, according to the Energy Transitions Commission.[158]

Many technologies that can accelerate the energy transition over the coming decades are already known, proven, and starting to be deployed at scale; yet impediments remain. Effective policies are needed, both to incentivise private investment in low or zero-carbon innovation, such as carbon pricing (see Section 1.A), as well as to directly fund research, development, and demonstration of clean energy technologies, sometimes in partnership with the private sector (see Section 5.D). For example, evolving digitizing, smart-grid and battery technologies can play a signficant role in enhancing the flexibility of the grid and its ability to swiftly tailor supply to meet demand or vice versa.[159] Continued technological innovation and deployment will remain key. But enabling policies are evolving too slowly to incentivise the required system changes.[160]

Carbon pricing offers a significant economic prize. Under a scenario of global energy reform, modelled for this Report using the E3ME model (which introduces carbon pricing in line with the prices recommended in the 2017 High-Level Commission on Carbon Prices, a phase-out of fossil fuel subsidies, and financial support for the introduction of renewables), carbon pricing revenues and fossil fuel savings to reinvest in public priorities could be approximately US$2.8 trillion in 2030. In this global energy reform scenario, emissions would also be expected to fall by almost 24% relative to the baseline in 2030.[161] Other benefits from this scenario would include an acceleration in the pace of economic activity, net employment generation, enhanced government budgets and improved health outcomes, among others. Despite the potential benefits of carbon pricing policies, at a global level, their use remains limited and has low impact today.

While we have a long way to go, momentum behind the shift away from fossil fuels is rapidly building with the pace of change varying from region to region, depending on legacy infrastructure and local resources. Overall, the cost of solar and wind is plummeting, down by 86% and 67% between 2009 and 2017, respectively.[162] Even unsubsidised renewable energy is increasingly becoming cost-competitive with fossil fuel power generation in more and more places. As a result, the deployment of renewables is accelerating in many regions of the world: The world now adds more renewable power capacity annually than from all fossil fuels

combined.[163] Ensuring reliability of supply when the sun isn't shining and the wind isn't blowing remains a challenge, but storage technologies that facilitate the integration of intermittent renewables into the grid are increasingly available at low cost, as the price of batteries has halved over the past three years.[164] Combined with other sources of flexibility, like existing dispatchable hydro and better demand response enabled by the 'Internet of Things' and the deployment of smart grid features, these technologies will make it possible to manage a near-total renewable power system by 2035 in most geographies.[165] Nuclear and gas (provided methane leakage are under control) will provide a bridge to a zero-carbon future, especially in geographies with more limited renewable energy resources. Carbon capture utilisation and storage (CCUS) is unlikely to play a significant role in power decarbonisation, as it will struggle to compete with increasingly cost-competitive renewables, but it may be critical in some hard-to-abate industrial applications (see Box 50 on CCUS).[166]

In parallel, the rate of energy productivity improvement has started to accelerate, rising from 1.4% per annum over 1990-2005 to 1.7% over the past decade,[167] mainly due to rapid progress in China (see Box 1 for China's outsized role in the energy transition). Reducing energy waste across the buildings, industry, and transport sectors contributes to ramping up global economic productivity, as does increasing resource efficiency, especially efficient use of energy-intensive services, such as energy production (see Section 1.B), freight transport (see Section 5.C) and products, such as steel (see Section 5.A).

The energy transition needs to be carefully managed, both to ensure that existing contradictory or incoherent policies are reformed and to ensure a just transition for affected workers and communities. While the shift to a low-carbon and resilient economy will create jobs, it will also be essential to ensure that the transition is just for workers, particularly for incumbent industries and sectors where the shift to cleaner energy will cause, along with other systemic forces like automation, employment numbers to fall. In the United States, for example, 151,000 people are employed in fossil fuel power generation, with an additional 887,000 people in extraction (74,000 in coal, 310,000 in gas, and 503,000 in oil).[168] Nearly half that number—about 476,000 people—are employed in solar and wind in the United States,[169] even though these sectors currently constitute less than 10% of the power mix.[170] It is expected that reduced employment in fossil fuels through the transition can be more than offset by a rise in employment in renewables and construction. Under the E3ME global climate action scenario examined for this Report, low-carbon employment is set to rise by 65 million people by 2030, more than offsetting employment reductions in some declining sectors to lead to a net employment gain of 37 million jobs globally by 2030.[171] Engaging affected workers and communities in social dialogue with industry and the government will be essential to ensure a just transition for individual workers and for regions where fossil fuel jobs are concentrated (see, for instance, examples of successes in managing the transition in Box 5). The size of the challenge is likely to be particularly acute in coal-rich emerging economies like India, where Coal India, a state-owned enterprise (SOE) that produces 80% of Indian coal, employs more than 300,000 people.[172]

It will also be essential to raise, steer, and blend finance towards low-carbon energy infrastructure (see Box 7). Finance has started to shift, especially around the disclosure agenda. The TCFD, in particular, raised awareness among investors about the risks associated with investments in fossil fuels, especially the potential for stranded assets as a result of enhanced climate policies and as the costs of competing renewables continue to drop (see Box 6). For example, estimates suggest that if investments in fossil fuels to 2035 continue along current trends, and countries enact policies to achieve a 2°C pathway and the low-cost producers sell out their assets accordingly, then approximately US$12 trillion of financial value could vanish from their balance sheets in the form of stranded assets.[173]

This chapter identifies several opportunities to accelerate the transition to low-carbon energy systems while fostering economic growth: removing fossil fuels subsidies and putting a price on carbon, enhancing energy efficiency to get more out of the energy we use, creating the conditions for the phase-out of coal and rapid scale-up of renewables, and improving access to electricity and clean cooking.

Box 6

Companies' Move Towards Climate-Smart Operations, Disclosure, Science-Based Targets (SBTs), and Carbon Pricing

In 2017, the TCFD released its recommendations for voluntary climate-related financial risk disclosures to be made part of mainstream financial filings. These recommendations provide an approach to assess the climate-related risks of investments, placing increasing pressure on publicly listed companies and their investors to take these risks into account and to plan for the transition away from fossil fuels.[174] More than 315 companies with a combined market capitalisation of more than US$7.1 trillion — including over 160 financial firms with assets exceeding US$86 trillion — have expressed support for the TCFD recommendations to give investors, insurers, and other stakeholders more information on the material risks and opportunities of a climate-compatible world.[175] In order to achieve climate-smart operations and investments, over 450 companies have committed to science-based climate action under the SBTs Initiative, which works with companies to develop specific emissions-reduction targets. Of those companies, over 120 already have emissions reduction targets approved by the initiative.[176] Nearly 900 additional companies have indicated ambitions to set science-based targets in the next two years.[177]

To achieve their climate targets, some companies are utilising internal carbon pricing and seeing financial and environmental benefits. Indian automotive and farm equipment company Mahindra & Mahindra Ltd. used its internal carbon fee programme to promote the faster adoption of LED lighting, increasing energy savings and giving it a competitive advantage.[178] The company's US$10 per tonne internal carbon price was so well received, it plans to expand pricing to its other businesses and along its supply chain.[179] In 2018, the parent company Mahindra Group committed to adopting SBTs across all US$19 billion of the conglomerate's operations.[180]

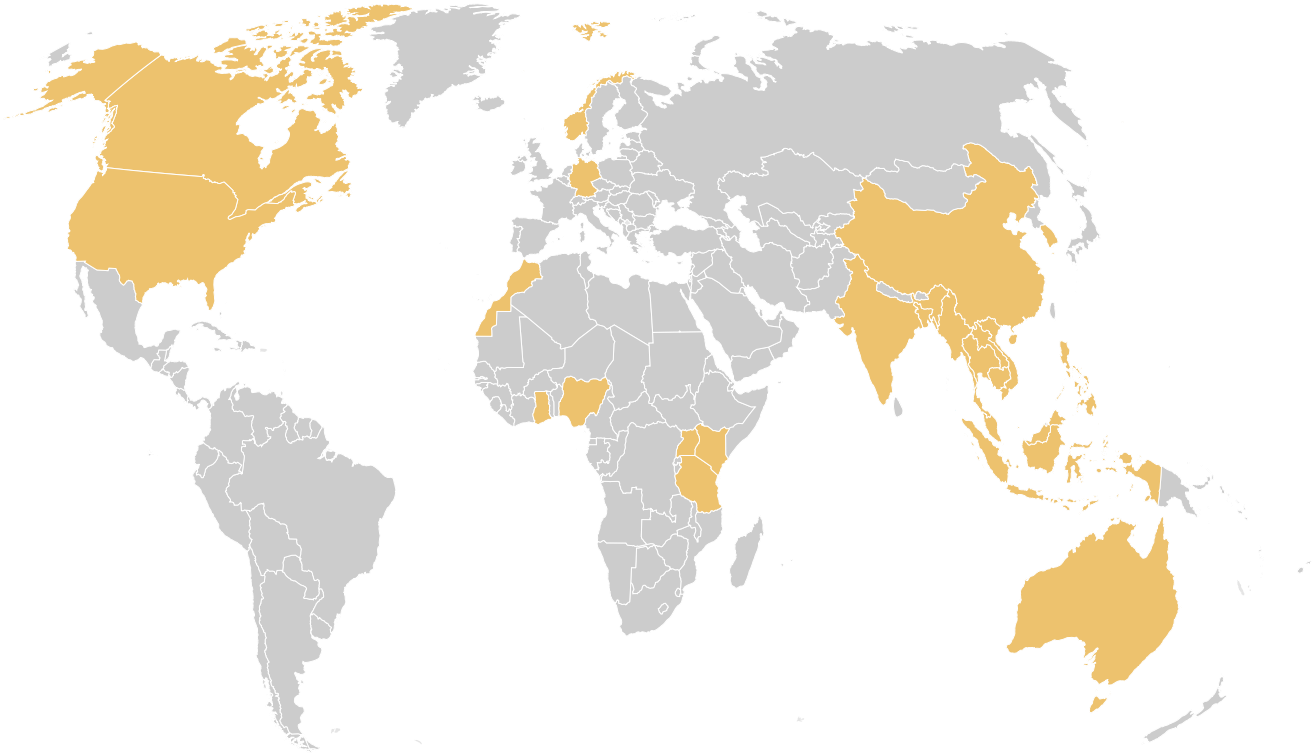
Despite good corporate leadership by some, a recent review of progress on disclosure and SBTs suggests there is much more to do on both fronts. For example, businesses with SBTs are achieving less than one-tenth of their potential for GHG emissions reductions as targets are relatively low in ambition, and the coverage of businesses with such commitments remains low.[181]

1.A. Put a Price on It: Reducing Emissions and Raising Revenue by Pricing Carbon and Eliminating Fossil Fuel Subsidies

Implementing strong carbon prices, including by eliminating fossil fuel subsidies, can harness the ingenuity of businesses and households to reduce emissions using least-cost approaches and by spurring innovation into new solutions.[210] Carbon pricing incentivises energy savings and use of cleaner fuels. Fossil fuel subsidies discourage investment in renewable energy and energy efficiency and encourage the lock-in of high-carbon assets. The IEA estimates that fossil fuel consumption subsidies were almost double the amount of renewable energy subsidies in 2016,[211] effectively acting as a 'negative' carbon price and counteracting policies in place to reduce emissions. This policy misalignment is expensive, inefficient, and socially regressive and reduces the effectiveness of climate policies.

More and more governments are using carbon pricing in the form of carbon taxes or emissions trading systems (ETS) as part of a broader policy package to tackle climate change. While the prices of carbon emissions facing energy users—or the effective carbon rate (ECR) — is primarily due to energy use or excise taxes rather than carbon prices in most jurisdictions, the number of carbon-pricing systems implemented or planned has quadrupled over the past 10 years, now covering over 70 jurisdictions and about 20% of GHG emissions globally (see Figure 4).[212] Major new developments in 2017 included the official

Figure 3
Locations of Transformative Examples in Energy Highlighted in this Report.



launch of the Chinese national ETS in December and the introduction of new carbon taxes in Chile and Colombia, as well as increased prices or tightened caps in most existing carbon-pricing systems. Carbon pricing at the sub-national level, in particular in US states and Canadian provinces, continues to build pace. A pan-Canadian carbon price will be implemented in 2018, and carbon taxes are scheduled to come into force in Argentina, Singapore, and South Africa in 2019.[213] Business support is also growing: Almost 1,400 major companies and some large development banks have committed to applying a shadow internal carbon price to make their investment decisions 'future-proof.'[214]

There has also been notable progress in phasing out fossil fuel subsidies, with at least 40 countries starting or accelerating subsidy reforms between 2015 and 2017 (see Figure 5).[215] Egypt, for instance, raised fuel prices by 78% in 2014 and plans to double them by 2019. Indonesia raised gasoline and diesel prices by 33% in 2013 and another 34% in 2014. India eliminated diesel subsides in October 2014, removed price controls on gasoline, and has launched a successful campaign to get wealthier consumers to give up subsidised LPG (see Box 9). Saudi Arabia announced a five-year plan to raise fuel prices in 2015, and Mexico removed transport fuel subsidies and introduced a modest carbon tax in 2014.[216] In 2016, G7 leaders committed to eliminate “inefficient fossil fuel subsidies” by no later than 2025.[217] Following Germany’s leadership, the EU committed to phasing out subsidies to hard coal mining by the end of 2018.[218] Despite this progress, the latest data from the IEA and OECD suggests that known subsidies and other support to fossil fuel production and consumption globally have declined from recent levels of over US$400 billion per year to just over US$250 billion per year in 2015.[219] While this is in part due to real reform efforts, it is also partly attributable to recent low oil prices (resulting in a lower gap to cover to keep consumer fuel prices low), so it will be critical to ensure that these subsidies do not rise again as oil prices are on the increase again in 2018.

Box 7

Energy Finance

Energy will account for just under a third of total core and primary energy sustainable infrastructure investment to 2030, or around US$1.7 trillion per year. Meeting a 2°C scenario requires slightly more investment and large increases in spending on energy efficiency, at double current levels if not more, but this is offset by lower investment requirements for primary energy such as coal and oil.[182] The investment challenge includes providing access to the nearly 3 billion people for clean cooking and to 1 billion for electricity.[183] Making sure energy infrastructure is sustainable will not cost much more, but it requires shifting the way we invest.[184] This shift requires supportive policies that reveal the value proposition of renewables and energy-efficiency investments and that level the playing field. Policymakers also need to spend better, with the right objectives and with the use of relevant metrics for success in dealing with sustainability. Essential policies include the reforming of fossil fuel subsidies, alignment of taxation and other policies offering financial incentives, raising and allocating public funds to sustainable infrastructure, and the smart use of limited public funds to attract private investment.

Previous analysis conducted for the Global Commission estimates that only half of the infrastructure investment required is currently flowing and about 70% of the spending gap is in emerging and developing economies.[185] Both public and private investment will be needed. Overall, public infrastructure investment appears to be on the rise though it remains well below levels required to meet demand for infrastructure services. In developing countries, roughly 60% of infrastructure investment is from the public sector, while in developing countries it is only about 40%.[186] On the private investment side, although the level of investment required is manageable on a macroeconomic basis, with enough global savings to cover the need, it has historically been a struggle to channel private finance to green energy infrastructure and energy-efficiency investment, especially in developing economies. The levels of returns and investment risks (real or perceived) have been key barriers to increased private investment. To address these common barriers and facilitate commercial investment, the G20 is advancing a 'Roadmap for Infrastructure as an Asset Class' which in turn should foster the development of infrastructure as a heterogeneous asset class.[187]

Disclosure policies can also help shift private investment by requiring institutional investors and corporate and other financial actors to identify, track, and report on climate-related financial risks. Such policies also provide investors with the information needed to develop transition plans and strategies to manage these risks.[188] For example, France's legislation of mandatory disclosure of climate-related financial risks for businesses and investors provides a framework to other G7 countries about how to mainstream the findings of the TCFD into national law.[189] Much more can be done also working directly with and through large, institutional investors as they exert influence over corporate behaviour. The Climate Action 100+ (CA100+) initiative, a five-year global initiative, commits participating investors to active engagement with the 100 largest emitting companies worldwide, including energy companies.[190] Such action can have real results, for example as seen when the board of Exxon Mobil agreed to report on climate related business risks.[191] However, the ambition, membership and approach of the CA100+ initiative needs to be stepped up to have impact at scale in global financial markets.[192]

Public investment also needs to shift. In 2014, the public sector accounted for more than half of ongoing investment in coal-fired power, showing the need for more climate-consistent strategies in the power sector.[193] Even with notable progress in phasing out fossil fuel subsidies in some countries, these were estimated to be an estimated US$373 billion in 2015 according to the OECD and International Energy Agency (IEA), well above renewable energy subsidies in 2015.[194] This effectively creates a negative carbon price and disincentivises investment in clean energy alternatives. At the same time, the number of carbon pricing systems is growing, now covering over 70 jurisdictions and about 20% of global GHG emissions (see Section 1.A, Figure 4).[195] Yet over 75% of emissions covered are priced at an effective rate of less than US$10 per tonne,[196] far from US$40—80 per tonne by 2020 recommended as a floor price by the 2017 High-Level Commission on Carbon Prices.[197] Absent consistent and sufficiently high carbon pricing, the risk-return proposition for investment in clean energy remains weak, and continued subsidies for fossil fuels raise the risks of stranded assets in the future.

Scaling grid-based renewable energy investment requires tackling high up-front investment costs and costs of capital that are higher than alternatives due to more limited investment track records, as well as political risks around the future price of electricity (see Section 1.C). Capital scarcity in developing countries, due in part to their weak capital markets, also raises the cost of capital. But solutions to these challenges do exist, notably by introducing appropriate reforms of policies and regulations, along with planning and operational protocols, to set out the right domestic and

Box 7
Energy Finance (continued)

international conditions to attract capital. For example, well-functioning power markets that provide enough certainty on future prices of electricity will reduce risks for investors along with policies that ease the cost of doing business and strengthen local capital markets.[198] Auctions are a particularly attractive mechanism to lower electricity price uncertainties for investors (see Section 1.C).[199] Good practice includes building local capacity through infrastructure development agencies to coordinate across energy (and other) sector policies, investment planning, and project development and to establish platforms to attract local and international investors.[200] Provided the right sector policy reforms are in place, the strategic use of public and philanthropic finance—in the form of blended finance—can reduce risks for private investors, attract and drive down the cost of capital, particularly in developing countries.[201] Here, MDBs and other DFIs play a key role, as illustrated in the case of the Lake Turkana project in Kenya, where their use of a range of instruments such as first loss capital and guarantees attracted private investors (Box 18).

Achieving a sustainable energy transition also requires delivering clean energy access for billions of people lacking electricity and clean cooking (Section 1.D). The IEA estimates investment requirements at about $US786 billion in total, or $US56 billion per year, between 2017 to 2030 to meet SDG 7—about 95% of which is for electrification, and 5% for clean cooking.[202] This represents less than 4% of total energy infrastructure requirements to 2030 and will deliver huge economic development benefits, particularly for women and the poor.[203] Decentralised solar technologies are expected to dominate investment strategies as countries push to reach the 'last mile' of those without access by 2030.[204] Pay-as-you-go (PAYG) and micro-financing schemes are helping meet demand for electrification by delivering solar home systems (SHS) at affordable prices, increasingly on commercial terms, in Africa and Asia (Boxes 21 and 22),[205] but mini-grids, grid expansion, and upgrading will be needed to deliver higher levels of electrification. Mini-girds alone represent a $US300 billion investment opportunity to 2030,[206] but will require structured financing and some subsidy to kick start.[207] MDBs and other DFIs can play a key role by providing support for early-stage projects, for example, through dedicated funds or facilities for micro-grid electrification, off-grid solar, and clean cooking programmes. National governments can incentivise investments in decentralised solutions by implementing policies that plan grid expansion and set targets for integrated grid, mini-grid, and off-grid supply. DFIs can also work with local financial institutions, for example, the French Development Agency (AFD) is working with Mauritius Commercial Bank to provide a long-term financing and currency hedging through an 'AFD green line' of credit.[208]

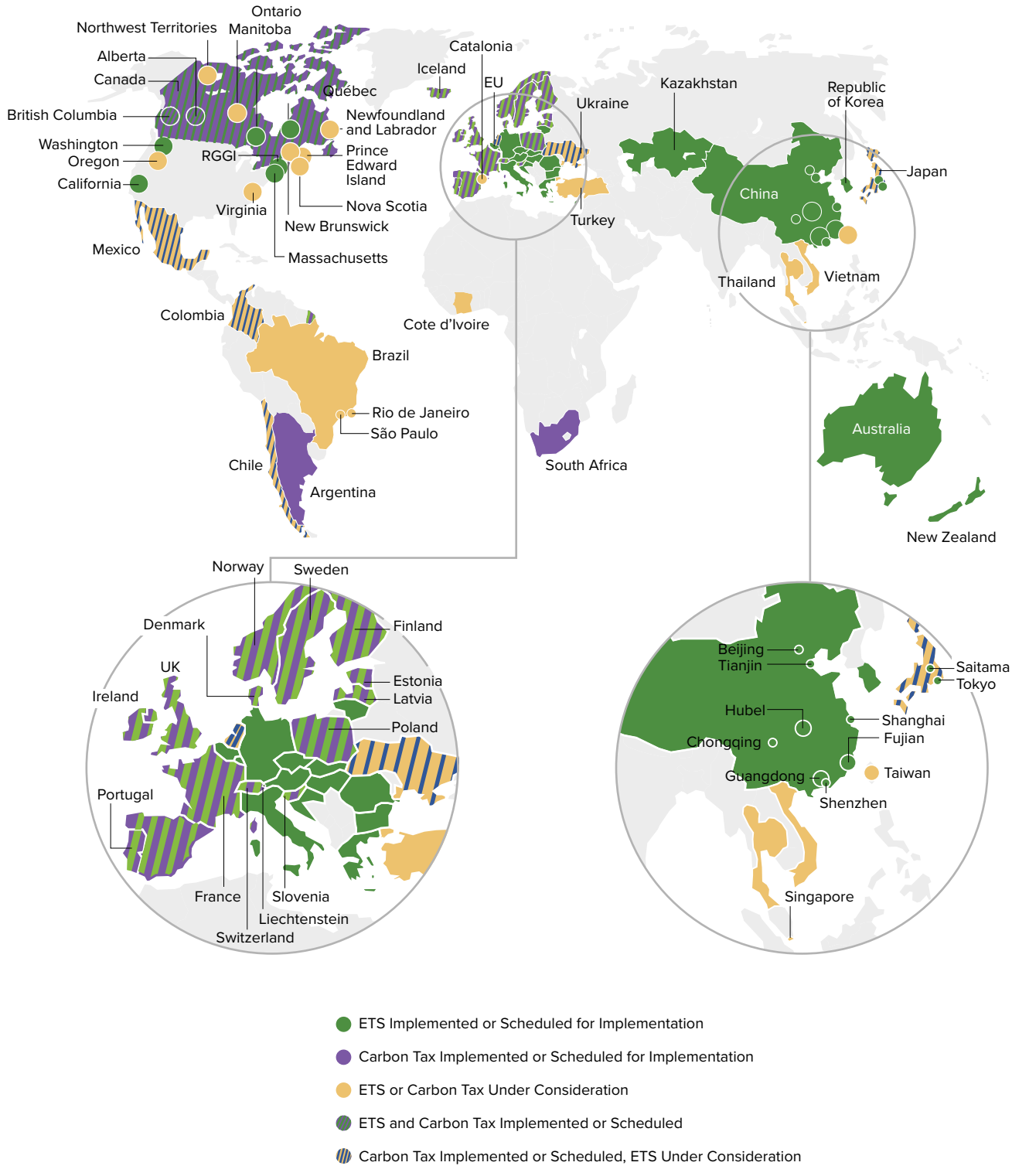
Energy efficiency is also critical to limiting GHG emissions to achieve a below 2°C scenario, and energy efficiency is amongst the most cost-effective of options to provide clean energy (see Section 1.B). More than doubling energy-efficiency investments requires national and local governments to work alongside utilities to expand financial tools to address up-front capital costs, often a barrier to private investment. Options include property assessed financing, such as Property Assessed Clean Energy (PACE) financing in the United States.[209] or other on-bill financing, as well as financing programmes operated through various government-led public-private partnerships, for example, Germany's Development Bank KfW's (formerly Kreditanstalt für Wiederaufbau) programme for buildings (Box 15) and India's Energy Efficiency Services Limited (EESL) programme for appliances (Box 10).

Evidence of the Benefits

Carbon pricing can go hand-in-hand with strong economic growth, as seen across a wide range of countries and regions applying carbon pricing for years and even decades. Sweden, one of the first countries to apply a carbon price in 1991 and now reaching prices of over US$150 per tonne of CO_2, has also seen robust GDP growth while emissions fell by 25% since the tax was introduced. California, representing one-seventh of the US economy, has grown at a rate that consistently outpaced the US national average since it launched its economy-wide emissions trading scheme in 2012.[222] British Columbia has similarly outpaced growth in most of the rest of Canada since introducing a carbon tax in 2008 (see Box 8).

Figure 4

Map of Government Carbon Pricing Systems in Place or Planned Worldwide.

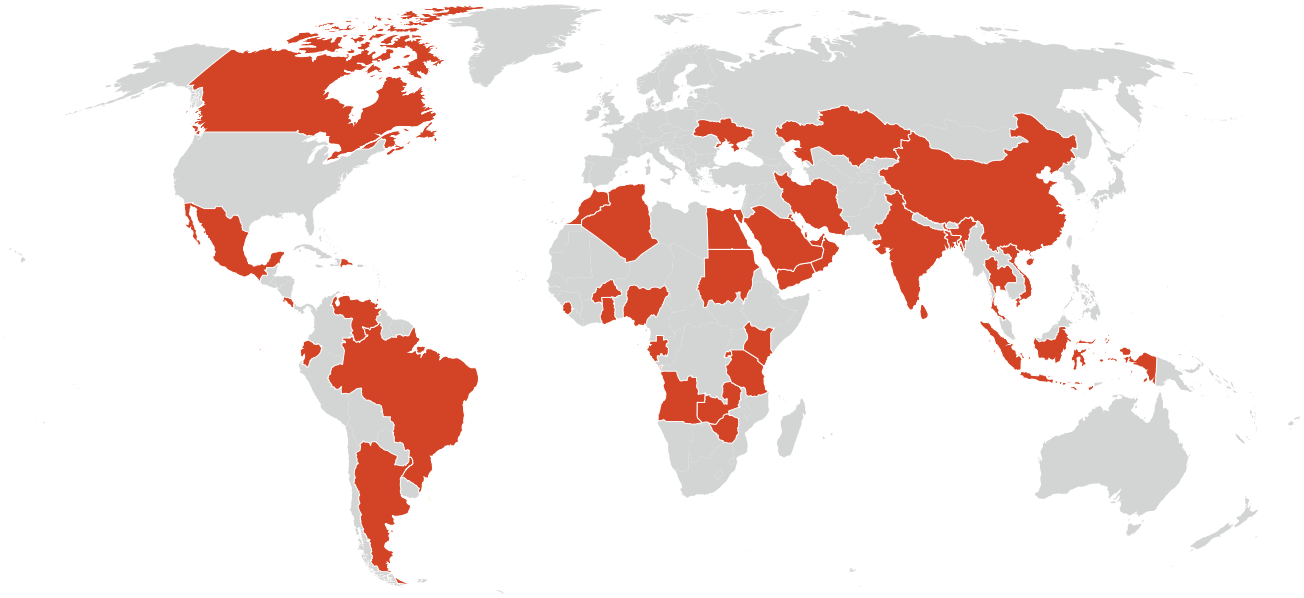


Note: This graph represents data as of August 2018.

Source: World Bank Group, 2018. Carbon Pricing Dashboard.[220]

Figure 5

At Least 40 Countries Partially Reduced Subsidies for Fossil Fuels between 2015 and 2017.



Countries implementing some level of fossil fuel subsidy reforms in 2015-2017

Source: International Institute for Sustainable Development, 2017; based on own sources and data from IEA, World Energy Outlook 2016.[221]

Box 8

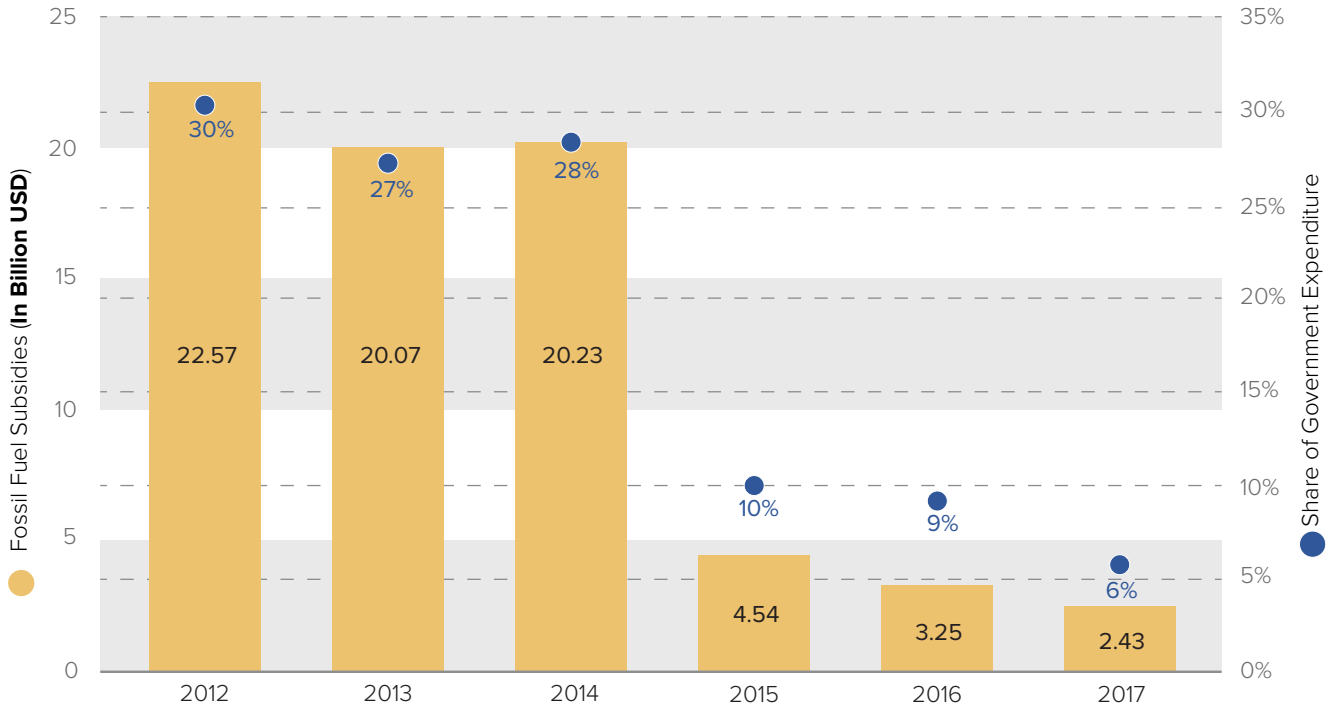
Carbon Pricing in British Columbia

In 2008, British Columbia introduced a carbon tax covering three-quarters of its emissions. With a starting price of US$8/t$CO_2$e it gradually increased to US$24/t$CO_2$e by 2012.[223] The revenue from the tax is returned to the people through corporate and individual tax rate cuts and a low-income climate action tax credit.[224] For fiscal year 2015/16, the carbon tax brought in CAN$1.2 billion in revenues, benefiting in particular low-income households based on the revenue recycling scheme.[225] From 2007 to 2015, British Columbia's real GDP increased by 17% while net emissions decreased by 4.7%.[226] One study found very limited impacts on industrial competitiveness, with the exception of two companies in the cement sector that lost market share; in comparison, the province is now home to a growing clean technology sector, with over 200 companies.[227] Some aspects credited with the success of the tax include strong political leadership (it was a signature policy of the British Columbia Premier), the revenue-neutral nature of the tax, strong communication around the benefits of the tax, and the effects of revenue recycling. Starting in 2018, all of Canada will be required to have some system of pricing carbon starting at a minimum of CAN$10/t CO_2e, and rising to CAN$50/t CO_2e in 2022.[228] After having frozen its carbon price for some years, which slowed progress in reducing emissions, British Columbia will raise its price to CAN$50/t$CO_2$e by 2021 and will use some of the revenues to invest in green initiatives like home retrofits and low-carbon transport.[229]

In addition, implementing strong carbon prices and eliminating fossil fuel subsidies has the potential to raise (or save) significant government revenues, a particularly important factor, given often stretched government budgets (see Figure 6). Carbon pricing schemes raised about US$33 billion in government revenue in 2017,[230] and annual revenues could be in the trillions if strong carbon prices were widely adopted.[231] Empirical results for this Report using the E3ME model indicate that pricing carbon and the removal of fossil fuel subsidies could generate an estimated US$2.8 trillion in government revenues in 2030, more than the GDP of India today.[232] Revenues can be used to spur economic growth, including through growth-enhancing tax reform, to ensure a just transition for fossil fuel-dependent communities and to invest in basic infrastructure, education, poverty reduction, and climate resilience (see Box 4).

In Indonesia, after raising prices on gasoline, diesel, and kerosene in 2005 and 2008, the government distributed multi-tranche cash transfers to approximately 19 million poor and near-poor households to offset the higher energy prices.[233] According to the World Bank, despite some difficulties in implementation, more than two-thirds of the total benefits went to the poorest 40% of the population, and cash transfer recipients showed improved education, health, and labour outcomes.[234] At the end of 2014, Indonesia further reformed gasoline and diesel subsidies at the same time as world oil prices fell. As a result, it saved IDR 211 trillion (US$15.6 billion) on fossil fuel subsidies, equal to 10.6% of all government expenditure.[235] The fuel subsidy savings in 2015 were reallocated to major investments in social welfare and infrastructure through increased budgets for ministries, state-owned enterprise, and transfers for regions and villages.

Figure 6
Fossil Fuel Support from the Government of Indonesia.



Source: OECD, 2018. Data: Indonesia Fiscal Policy Agency, Ministry of Finance, 2017.[236]
Note: This chart is based on information by the Fiscal Policy Agency of the Central Government of Indonesia. It reports estimates of fossil fuel subsidies converted into US dollars using annual market exchange rates for rupiahs.

Putting a price on carbon also provides significant benefits to human health: In the nine US states that participate in the Regional Greenhouse Gas Initiative (RGGI)[237]—a cooperative effort establishing CO_2 allowances for the power sector and therefore defining a cap on emissions from power—the public health benefit of the resulting reduced air pollution from power plants has been calculated at more than US$1.4 billion per year for a total of $US5.7 billion over 2009—2013.[238] It is estimated that phasing in a US$70 carbon price in China could prevent nearly 4 million premature deaths from air pollution up to 2030.[239]

Pricing carbon and removing distorting fossil fuel subsidies is also often the most cost-effective approach to reducing GHG emissions. For example, it is estimated that the phase-out of fossil fuel consumer subsidies could reduce GHG emissions by as much as 10% globally by 2050; while phase-out of production subsidies could result in a GHG emissions reduction of up to 37 Gt of CO_2 by 2050, equivalent to the total annual emissions from aviation worldwide.[240]

Challenges

Carbon pricing systems remain too limited and, where they exist, prices are far too low in most jurisdictions to drive transformative change. The 2017 High-Level Commission on Carbon Prices suggested that appropriate carbon prices should reach US$40—80 per tonne of CO_2 by 2020 and US$50—100 per tonne by 2030, with the ranges reflecting that different prices will be appropriate for countries at different levels of development.[241] While most carbon pricing systems saw an increase in prices in 2017 compared with previous years, the majority remain far too low compared with what is needed.[242] Half of all carbon prices are less than US$10 per tonne CO_2e—far short of what is needed to drive transformational change.[243] According to the OECD review of 41 countries, when including the carbon-price signals from excise taxes as well, and considering all CO_2 emissions from energy use, about 60% of emissions are not priced at all, and for those that are, 90% face a price of less than US$35 per tonne of CO_2.[244] Coal remains the lowest taxed fuel in most countries, despite being the most polluting. A number of jurisdictions — including Canada, the EU, and some US states — recently agreed on carbon price increases or established automatic mechanisms to ratchet up prices or reduce emission quotas, so some progress is notable. An important revision of the EU ETS was finally agreed to in 2017, and momentum to establish price floors, as in the United Kingdom and potentially others, will help ensure a more robust pricing signal.

Despite the expansion of carbon pricing systems recently, in many regions, there is still strong political resistance to implementing any new taxes in general. Sometimes carbon taxes face particular resistance, with opposition coming from major incumbent industries and consumers concerned about rising energy bills, making implementing or increasing carbon prices difficult. If past efforts to introduce carbon pricing systems in a given jurisdiction have failed or been poorly communicated, these can exacerbate citizens' lack of willingness to accept expansions or price increases, even in other jurisdictions. The inherently political nature of carbon markets often results in a high level of political uncertainty and challenges, and the threat of backsliding is real. For example, a newly elected provincial government in Ontario, Canada in 2018 has announced it will be looking to cancel the cap-and-trade scheme and fight the national carbon tax scheme.[245]

Similarly, fossil fuel subsidy reform has been particularly challenging in many countries, with reform efforts in some cases leading to major public protests, strikes and even government instability. The recent progress in over 40 countries as cited above is both a testimony to progress in understanding how to manage and communicate reforms successfully, and also in part a result of relatively low oil prices globally in recent years.

Experience has shown that there are ways to address the political challenges of subsidy reform: dedicating resources to support a robust and well-communicated reform process, providing clear information on the costs and impacts (both positive and negative), setting credible and staggered time frames for phasing out subsidies, providing targeted support to low-income households, and delivering on other social priorities (such as schools, hospitals, public transport) (see Box 9 on India).[246] In Indonesia, communications campaigns operated through newspapers and television have been foundational to the success of fossil fuel subsidy reform.[247] In Jordan, political will, cash-transfer schemes to lower-income households, and citizen communication and engagement contributed to reform success in 2012.[248] In Germany, the government has launched a commission on "growth, structural transformation and employment", which will work through the end of 2018 to ensure a just energy transition in the country. The commission will develop plans for, amongst other things, the phase-out of coal-powered energy production, outlining a gradual shutdown of fossil power plants and the financial compensation that might accompany this structural change.[249]

The advent of rising oil prices, as seen in 2018, may pose challenges to maintaining fossil fuel subsidy reforms in some countries. A number of recent reforms were in part successful as a result of low oil prices in recent years (given that a number of governments previously subsidised the difference between high oil prices in the market and fixed lower prices at the pump domestically). As and when prices rise again, ensuring other mechanisms to more directly target support to low-income households who may be at risk of energy poverty will be essential, as well as clear communication of these measures, to ensure continued support for the reforms. A shift toward greater reliance on renewable energy and electrification can also help to attenuate the effects of oil price fluctuations.

Absent new carbon taxes, some countries are adjusting existing taxes to better reflect their carbon and pollution content. Since 2012, some countries, including Ghana, have better aligned diesel taxes with gasoline taxes, and some low- to middle-income countries have increased taxes on transport fuels.[250] In the absence of the political will or readiness to implement a carbon price, these and other tax reforms can reflect environment concerns, but also make good budgetary sense. Similarly, air pollution charges, such as those accounting for black carbon, represent short-term policy options for countries not yet ready to implement carbon pricing systems.

Accelerators

- **Major economies, starting with the G20, should put in place carbon pricing and phase out fossil fuel subsidies by no later than 2025.** This would build on existing commitments under the G20 and G7, and recent progress in many major economies at the national or sub-national levels. In 2017, China launched plans for the world's largest cap-and-trade programme; in India, there is strong business leadership and important progress on subsidy reform and implementation of a coal cess; and the Indonesian reductions in diesel and petrol subsidies are expected to lead to long-term savings of US$15.5 billion.[258] Countries can enhance their progress by implementing best practices for subsidy measurement and by monitoring progress towards reform in a transparent and standardised way, by implementing adjustment packages, and by conducting impact studies to identify and manage political economy challenges. Building on this momentum and with the support of the international community like major intergovernmental institutions (World Bank, IMF, OECD), countries have an opportunity to design country-tailored approaches to rapidly accelerate action to achieve their growth, social, and climate goals.

Box 9
India's "Give It Up" Campaign

In 2015, Indian Prime Minister Modi's Government launched the "Give It Up" campaign to encourage higher income households to voluntarily withdraw from the Direct Benefit Transfer for Liquid Petroleum Gas (DBTL) scheme—the world's largest benefit transfer scheme—with the aim of better targeting India's poor.[251] The DBTL scheme was launched in 2013; and while it has reached up to 150 million people, it has also created an enormous burden on the public budget, costing US$1.8 billion in 2017.[252] This scheme is only part of the reason why, following the transmission and distribution of electricity, the oil and gas sector is the most heavily subsidised energy sector in India. Over 2014—2016, the Government of India spent over US$45 billion on oil and gas production, import, refining, and consumption.[253]

In 2014, the Government of India introduced reforms to remove incentives to divert to non-intended uses and remove the ability for beneficiaries to have duplicate connections.[254] Despite these efforts, the scheme was still not effectively targeting India's poorest. Instead of reforming the scheme's implementation procedures, the 2015 "Give It Up" campaign innovatively aimed to adopt a political 'nudge' approach—described as drawing on psychological and behavioural economic theory to send nudge signals to individuals, with the purpose of enabling more socially beneficial outcomes.[255] In 2016, the second year of the campaign, India's Ministry of Petroleum and Natural Gas estimated up to 30,000 people were voluntarily withdrawing from the scheme every day.[256] By April 2017, it was estimated a total of 10 million people had withdrawn.[257]

- **National and sub-national governments can build on recent momentum for carbon pricing by seeking synergies between environment and tax policy objectives.** Carbon prices are effective as revenue-raising mechanisms as well as delivering climate and broader environmental objectives. Combining decarbonisation with revenue-raising through well-designed carbon prices can strengthen support across government and with the public. For example, increasing excise on transport fuels, particularly where these are now comparatively low, can be a quick and effective way to raise effective carbon prices.
- **Countries should integrate fossil fuel subsidy and carbon-pricing reforms into broader energy sector transition plans.** Taking this approach can ensure a just and well-managed transition for workers, low-income households, and communities. Canada, Norway, and Germany all developed multi-stakeholder processes to support their energy transitions. Building on lessons learned from their experiences and recent successes in subsidy reform and carbon pricing in countries like Indonesia and India, there is an opportunity to use national and local dialogues engaging business, government, and social partners to develop low-carbon and climate-resilient energy transition plans.
- **Governments should utilise regional approaches, like the Carbon Platform of the Americas[259] and technical partnerships, such as the Partnership for Market Readiness,[260] to enhance carbon pricing and link existing schemes in a way that can address competitiveness concerns.** Carbon pricing is being successfully implemented in Canada, Mexico, Chile, Colombia, California, and the nine US RGGI states, with positive economic outcomes, benefits for low-income households, and reduced emissions. If jurisdictions in the Americas move towards more robust and aligned carbon prices of US$50—100 per tonne CO_2 by 2030, and phase out fossil fuel subsidies, they could realise over US$528 billion per year in revenues or savings by 2030, based on the E3ME modelling undertaken for this Report.[261]
- **DFIs should apply shadow carbon prices to all investment decisions.** The World Bank, the ADB, and the EBRD followed the example of the European Investment Bank and committed to apply a shadow carbon price.[262] The International Finance Corporation (IFC) uses an internal carbon price for three high-emitting sectors with plans to expand.[263] Many—though not all—of the DFIs have shifted away from financing coal power, and the World Bank will stop financing upstream oil and gas exploration from 2019 onwards. Between 2013 and 2015, MDBs collectively committed US$128 billion to infrastructure investment.[264] Internal carbon pricing ensures that this infrastructure will be sufficient quality to achieve long-term climate and sustainability goals, and it can help to trigger carbon pricing by the commercial investors and financiers given portfolio assessments. Public finance institutions—including multilateral, regional, and national development banks as well as export credit agencies—have a responsibility to lead in aligning their investments with the global climate goals endorsed by countries through the Paris Agreement.

1.B. Less Is More: Saving Energy through Greater Energy Productivity

Energy efficiency has the potential to meet a significant proportion of the needed climate action. Under the IEA's Sustainable Development Scenario, which is consistent with a below 2°C pathway, energy efficiency measures account for 44% of the CO_2 emissions reductions in 2040 relative to the baseline—a greater share than renewable energy (36%).[265] Without efforts to use energy more efficiently in buildings, transport, and industry, continued population growth and economic development is expected to lead to a 60% increase in energy demand by 2050.[266] Thus, it is imperative that policy action be as ambitious—or more so—for energy productivity as it is for renewable energy. Globally, buildings represent 30% of final energy consumption, second only to industry[267]—where significant energy savings can be achieved through the deployment of best available technologies across small and medium enterprises (SMEs) in multiple industrial sectors. Space heating and cooling accounts for 40% of buildings' energy consumption, and efficiency gains combined with decarbonisation of these services will be essential.[268] Energy-efficient homes and workplaces are cleaner and cheaper to run. Improving the energy efficiency of buildings reduces costs at every stage of energy production, including the need for new energy infrastructure. Each dollar invested in efficiency is estimated to save US$2 in new power plants and electricity distribution costs.[269] Beyond improving efficiency at end use is the opportunity to collect and manage 'big data' to leverage substantial efficiency gains

across many activities at once, for example by creating innovative energy management platforms and integrating these into 'smart' grid operations.[270] Energy-efficiency measures assessed through the E3ME modelling for this Report were found to lead to a full 23.4% increase in the amount of value added per unit of energy generated by 2030, that is, a 1.2% improvement in energy efficiency per year, which is roughly on a par with trends since 2010.[271]

Some appliances used by households and businesses, such as air conditioners and refrigerators, also emit hydrofluorocarbons (HFCs), powerful GHGs that can be up to 4,000 times more potent at trapping heat than CO_2. The 2016 Kigali Amendment to the Montreal Protocol implementing call for plans to phase down HFCs; such a phase-down could result in global electricity savings of 2,300 to 7,100 TWh[272] from 2018 to 2050 and avoid up to 0.5°C of warming by the end of the century.[273] Coupling the phase-down of HFCs with improved energy efficiency of air conditioning and refrigeration equipment requires aligning financing mechanisms with policies that promote energy-efficient buildings. President of the World Bank Jim Yong Kim, for example, underlines the institution's US$1 billion initiative in urban areas, "which overlaps with this HFC agenda,"[274] as part of the Bank's commitment to supporting energy efficiency in the HFC phase-down.

Evidence of the Benefits

More energy-efficient lighting and appliances can reduce electricity bills and energy poverty—and are important to achieving the Sustainable Development Goal of universal access to affordable, clean, and modern energy. Simply switching to LED lighting can offer savings of up to 50-70% - and up to 80% when coupled with smart systems.[275] More energy-efficient buildings also build resilience to climate change with the greatest benefits captured by the poor.[276]

Improving energy efficiency in buildings creates jobs. Each investment of US$1 million generates an average of 14 job years of net employment[277]—up to three times the number of jobs for the same investment in fossil fuels.[278] Energy-efficient buildings also bring productivity, health, and climate-resilience benefits, including improved respiratory health and reduced risk of heat-related illness or death; and they also improve worker productivity.[279] The health benefits of efficient buildings are worth approximately 8-22% of the value of energy savings in the developed world and likely much higher in the developing world.[280]

Over the last 25 years, building energy-efficiency measures have realised more than 450 exajoules (EJ) in cumulative energy savings worldwide, but the full potential for energy-efficiency gains remains unrealized.[281] Rapid deployment of high-efficiency lighting, cooling, and appliances would save 50 EJ in electricity demand between now and 2030—or nearly three-quarters of current electricity demand (see Box 10 on energy-efficient equipment). The IEA estimates that through 2060, building-related emissions reductions in a Beyond 2°C Scenario could be 275 $GtCO_2$ compared to the reference scenario—more than half the CO_2 emissions produced globally in the entire energy sector from 2006 to 2014.[282]

Box 10

Up-front Financing for Energy-efficient Equipment: EESL in India

Energy Efficiency Services Limited (EESL), founded by the Government of India in 2010, implements the largest energy-efficiency portfolio in the world. EESL creates markets for energy-efficient products through demand aggregation, on the one hand, and successive rounds of competitive procurement, on the other hand. EESL enables consumers to choose products with higher-than-normal first cost by providing support financing and a replacement guarantee. The successive rounds of competitive procurement incentivise manufacturers to invest in production facilities at scale, bringing product costs down, with the opportunity to secure large market shares in evolving markets.

EESL has invested US$670 million in projects such as LEDs, municipal water pumps, and air-conditioners. EESL's energy-efficient appliances and technologies save India over 35 billion kWh of energy annually. So far, more than 285 million efficient LEDs have been installed through its lighting program, saving US$2.3 billion and reducing carbon emissions by 30 million tonnes. Efficient water pumps financed by EESL have saved municipalities US$492 million annually and avoid 3.9 million tonnes of carbon emissions annually. By driving down prices for smaller consumers in residential and public sectors, EESL is making energy-efficiency products more affordable to the broader market. Recently, it has begun operations and collaborations in other countries like Malaysia, Saudi Arabia, and the United Kingdom.[283]

With regard to HFCs, replacing these with greener refrigerants has low up-front costs and can result in energy-efficiency improvements of 10—50% or more when the best available technologies are applied.[284] Many companies have already realised the benefits of non-HFC refrigeration. Both Coca Cola and Heineken report energy-efficiency improvements of about 40% from HFC-free coolers, with resulting electricity cost savings.[285] Replacing HFCs with alternatives in line with the Montreal Protocol is an important measure to significantly reduce GHG emissions.

Analysis undertaken for this Report using the E3ME model examined a scenario of global action to enhance energy efficiency in buildings, appliances, industry, and transport roughly in line with what would be required under the IEA World Energy Outlook 450 parts per million (ppm) scenario. Under this global action scenario, CO_2 emissions are expected to be 20.5% lower by 2030 relative to a baseline scenario. Co-benefits from this scenario include net employment growth, acceleration in the pace of economic activity, enhanced government budgets, and improved health outcomes through reduced air pollution, among others. Air pollution would be reduced compared to the baseline, which would, for example, translate into a drop in cumulative government expenditure on health of about US$2.5 billion in European countries by 2030 compared with the baseline.

Challenges

For investors, investments trigger cost savings, but the savings can appear to be risky or disproportionately low compared to high up-front capital costs, creating a barrier to investment. A challenge is in developing appropriate incentives and financing vehicles to cover these relatively high up-front costs. A number of the examples in the boxes below highlight innovative approaches to financing energy-efficiency improvements. But such successes need to be rapidly scaled: An estimated US$8.8 trillion in additional investment in energy-efficient equipment and infrastructure across buildings, transport, and industry is required by 2030.[286]

For policy-makers, a challenge lies in the fact that investments in energy efficiency are spread across multiple sectors, meaning decision-making is also highly distributed. It is hard therefore for public policy to find tools that can accelerate progress on multiple fronts simultaneously to reach meaningful scale.[287] Particularly in developing countries, a lack of enforcement of existing standards and lower adherence can result in less than expected impacts, frustrating investors. Price reforms offer an important means by which to harness demand side and distributed energy resources by incentivising investment in these. This challenge and set of opportunities can be illustrated by the case of building energy-efficiency policies. For property developers, payback times on investments made can typically take 10 to 20 years (if renovation and retrofit are extensive), and this is unattractive for a private organisation to take on without financial incentives.[288] Well-targeted policies can decrease the cost of these investments for consumers through financial incentives (such as subsidies for energy audits, energy-efficiency investments, or loans) or fiscal incentives (such as tax reduction, tax credit, or accelerated depreciation). Similarly, policies can incentivise energy utilities to invest in smart meters and digital technologies to achieve greater demand side flexibility. Financial incentives tend to be the dominant policy tool in countries surveyed by the World Energy Council with 87% use of financial incentives versus 13% use of fiscal incentives.[289] Building standards have also proven to be highly cost-effective in a number of jurisdictions, including for example California.[290]

In buildings—as in industry—the lifetime of the infrastructure constitutes an additional challenge: Where significant infrastructure build-up has already occurred, particularly in developed and emerging economies, improving energy efficiency requires retrofitting existing infrastructure. In OECD countries, roughly 65% of the building stock expected by 2060 has already been built. To put the global building sector on a net-zero carbon pathway, there needs to be a 30% improvement in global average building energy intensity by 2030, as much as a doubling of the rate of building renovation in the coming decade (see Box 11 on Seoul's retrofitting programme).[291]

Box 11

Accessible Financing for Comprehensive Building Retrofit: Seoul's Building Retrofit Program

In Seoul's Building Retrofit Program (BRP), the Seoul Metropolitan Government provides low-interest loans to building and energy service companies to lower the up-front costs of retrofit and make such upgrades accessible to broader range of citizens. Although the programme initially targeted public buildings in its 2008 launch, loans are now available for all kinds of buildings, including commercial and residential buildings of all sizes.[292]

BRP offers eight-year loans up to US$1.87 million per project at a 1.75% interest rate, compared to the 2014 market rate of approximately 3.8%. Borrowers are required to follow eco-friendly construction processes and energy-efficiency standards, with even stricter requirements for new buildings throughout design, construction, maintenance, and demolition. In 2013, approximately 14,000 buildings of all kinds were participating in the BRP. Future plans include requiring all buildings to report their energy efficiency and scaling up demand management efforts. Seoul's BRP advances its goal of reducing GHG emissions by 40% from 1990 levels by 2030.[293]

The main barriers for HFC phase-down include the lack of availability and high up-front costs of low global warming potential (GWP) fluids and technologies in certain markets; the lack of technical capacity for installation and maintenance; and restrictive safety codes and standards that restrict use of low GWP fluids that might be flammable, toxic, or operate at high pressure.[294]

Accelerators

- **National and sub-national governments should introduce building energy-efficiency regulatory policies for new and existing buildings.** This creates financial savings and builds resilience for the poorest.[295] Policies include mandatory building codes and code enforcement strategies;[296] benchmarking, disclosure, and sector retrofit targets; GHG mandates;[297] cap-and-trade programmes that include buildings[298]; and deep retrofit requirements. Codes for new construction are particularly important, as studies indicate that they result in greater energy savings than either retrofit policies or appliance standards and labelling (see Box 11).[299] In India, for example, building codes can reduce electricity demand by 25% and cooling loads by 70%, compared to business as usual in 2050.[300] Tokyo was the first city to include buildings in a cap-and-trade scheme (see Section 1.A), and by 2016, it reduced CO_2 emissions from covered buildings by 26%.[301] Coupling building standards with sustainable construction can compound energy savings. For example, combining passive house design with laminated timber materials (see Box 51 on the growing use of timber) could reduce lifecycle CO_2 emissions (embodied and operational) by more than 90%.[302]
- **National and sub-national governments should pass legislation enacting energy efficiency resource standards (EERS).** An EERS (also known as an energy efficiency obligation) establishes specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy-efficiency programs, and analogous to renewable portfolio standards. Policy action for energy efficiency needs to be commensurate with its mitigation potential. In the United States, 26 states already have adopted EERS, with Massachusetts and Rhode Island having the most stringent requirements, mandating more than 2.5% new savings annually.[303] A US national EERS could result in net consumer savings of more than $144 billion by 2040.[304]

- **National and local governments and utilities should expand financial tools and private engagement to address the up-front capital costs.** These tools include property-assessed clean energy (PACE)[305] financing in the United States, which is being developed in Europe;[306] on-bill financing[307] and government-led finance programmes; energy services companies, such as climate revolving funds;[308] and public-private partnerships. Melbourne has adopted an innovative environmental upgrade charge (see Box 14), and Seoul's BRP has made low-interested loans available to more than 14,000 buildings (see Box 11). Germany created the Energy Efficient Rehabilitation Programme, which blends finance, retrofit standards, and technical assistance (see Box 15), leveraging US$16 for every US$1 in government investment. EESL, the energy service company set up by the Government of India (Box 10), has saved the country an equivalent of 3% of its annual electricity use.
- **All countries should ratify the Kigali Amendment to the Montreal Protocol for the phase-down of HFCs.** Implementation of the Kigali Amendment is expected to avoid an increase in atmospheric temperature of 0.5°C by the end of the century.[309] As of March 2018, only 28 countries have ratified it — and not yet major emitters like China, India, and the United States.[310] All countries should accelerate the schedule of HFC reductions, such as including them as part of their next NDCs for climate action that are due to be submitted by 2020.
- **National governments should establish, enforce, and regularly ratchet up appliance minimum efficiency performance standards (MEPS) and ban high-GWP HFC refrigerants while also introducing labelling programmes that enable consumers to choose better products.**[311] Japan's 'top runner' programme makes the most energy efficient appliances the basis for the new standard.[312] Cross-country harmonisation on MEPS can further accelerate progress. The SHINE programme's AC standards are projected to reduce electricity consumption by 5,373 GWh per year across eight Southeast Asian countries, including Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Thailand, and Vietnam, saving the average households about US$260 (€217) over five years (see Box 13).

Box 12

Driving Energy Savings from the National Level down to the City: China's Building Codes

China was one of the first developing countries to implement a national building energy-efficiency code, first issuing it in 1986 for residential buildings in severe cold and cold climate zones, in an attempt to reduce building energy consumption by 30%. China now has national energy codes for commercial buildings and rural residential buildings, as well as energy codes for large residential buildings in four different climate zones that cover performance requirements mainly for the building envelope and some HVAC systems. While the current energy savings are already significant, analyses show that strengthening existing codes and extending them to include retrofits and rural residential buildings could result in savings of 22% by 2100.[313]

Tianjin, China, is one of four municipalities in China with provincial-level administrative status, giving it authority in policy-making, including enacting regulations more stringent than pertinent national ones. Tianjin has implemented its own mandatory code and has reduced the residential heating loads of buildings built after 2005 by 30 percent compared to the national code. Tianjin achieves close to 100% compliance, far better than other large cities in China, due to several factors: (i) a well-established building construction management system; (ii) standardized and structured procedures for compliance enforcement; (iii) broad-based capacity of the construction sector to meet compliance requirements, including technical skills and availability of parts and materials; (iv) consumers' ability and willingness to pay for the costs of code compliance; and (v) local government resources, support, and commitment to implementing increasingly stringent codes.[314]

While China has a unique social and economic context, this case study underscores a couple of critical elements for the success of building code policies: strong government leadership, engagement with and capacity of the private sector, and the adaptation of codes to the local context.

Box 13

Ramping up Minimum Energy Performance Standards through International Coordination: The SHINE Programme

In 2012, the Association of South-East Asian Nations (ASEAN) SHINE programme was set up as a public-private partnership focused on air conditioning (AC) units in eight different Asian countries: Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Thailand, and Vietnam. This programme was set up after close coordination with the UN Environment Programme (UNEP) and the International Copper Association,[315] an organisation that considers how to foster and develop the sustainable use of copper. Since its inception, the SHINE programme has harmonised air conditioning unit standards across all of the eight countries, improved the capacity of local AC manufacturers to design more highly efficient units, and designed national consumer awareness campaigns.[316] The program estimates that adopting China's MEP for AC would reduce electricity consumption in ASEAN by 5,373 GWh per annum, reduce CO_2 emissions by 2.7 $MtCO_2$ tonnes of CO_2 emissions per annum, and save the average household €217 over five years.[317] This cross-country coordination for air conditioning and ASEAN are now planning similar ventures for other electrical appliances, including lighting, refrigerators, televisions, and electric motors.[318]

Box 14

Accessing Mainstream Finance for Building Retrofit: Melbourne's 1200 Buildings Programme

Melbourne launched the 1200 Buildings Programme in 2010 to spur the retrofit of commercial buildings.[319] The programme turns on its innovative financing model. Participating building owners or managers enter into an agreement with Melbourne City Council, and then traditional financial institutions loan the funds to the building owner. The loan is repaid through an environmental upgrade charge that the building owners pays to Melbourne City Council along with their other relevant taxes. Melbourne City Council then passes those repayment instalments through to the financiers and also guarantees the loan as an underwriter.[320] This way, Melbourne removes the main barrier to retrofit financing through mainstream banks by reducing the financier's risk associated with the loans and overcoming the borrower's challenge of obtaining collateral.[321] To enable Melbourne City Council to levy this new form of statutory environmental upgrade charge, the state Government of Victoria had to amend the City of Melbourne Act 2001.[322] Since 2010, over 540 buildings have been retrofitted to improve energy and water efficiency.[323] This progress aligns closely with the city's goal to be carbon-neutral by 2020. Improving energy efficiency by 38% in commercial buildings would mitigate 383,000 tonnes of CO_2e/year, leverage US$2 billion of private-sector reinvestment, and create 8,000 'green collar' jobs.[324]

Box 15

Retrofitting to Scale: Germany's Energy-Efficient Rehabilitation Programme

Germany's Energy-Efficient Rehabilitation programme, financed by its development bank KfW, combines low-cost loans, an on-location consultation service by certified contractors, and retrofit standards to provide retrofitting at scale. The financing programme provides options for both comprehensive and singe-measure retrofits, and the comprehensive retrofits must comply with one of five energy-efficiency standards based on the level of energy saved in reference to the energy code for new houses. In 2010, the programme provided €8.7 billion in loans, supporting around 953,000 households and helping to create 342,000 jobs. The programme leveraged US$16 for every US$1 in government investment. It is estimated that the building rehabilitation programme saves 4.4 million gigajoule (GJ) of energy and 300,000 tonnes of CO_2 annually.[325]

1.C. Black to Green: Creating the Conditions for the Phase-out of Coal Power

Today, power represents 20% of global final energy consumption, and the global power mix relies heavily on fossil fuels (65%)—with a significant proportion of that being coal (37%)—while renewables only represent 24%.[326] But we are heading towards an increasingly electrified world: The deployment of electric cars and electric heating and cooking in buildings will drive power demand growth in the short term, while some segments of heavy-duty transport and heavy industry could also switch to electricity by mid-century. This could eventually lead to a tripling or quadrupling of power demand globally by the end of the century[327] and make power decarbonisation even more crucial to avoid disastrous environmental impact. Meeting growing power demand with low-carbon energy sources has the potential to transform the health of the planet and people. Results from the E3ME modelling analysis indicate that a shift away from fossil fuels and towards renewable sources of energy could yield a 37.8% increase in the amount of energy produced per unit of carbon emissions by 2030, which is a 1.8% annual increase in the carbon productivity of energy.[328] According to IRENA analysis, this shift towards renewables is also a massive economic opportunity: Doubling the world's renewable energy capacity by 2030 could save the global economy between US$1.2 and US$4.2 trillion each year, largely due to a massive reduction in the costs incurred from pollution by non-renewable sources.[329]

Worldwide, the equivalent of 1,500 coal plants are estimated to be in construction or planned,[330] but the deployment of large-scale renewables is accelerating due to rapidly falling costs and new developments in batteries and energy storage.[331] Wind and solar power are reaching cost-competitiveness with fossil fuel-based power generation, with prices hitting record lows—as low as US$ 3 cents per kilowatt hour—in recent auctions.[332] The Carbon Clean 200 index identified 366 publicly listed companies with more than US$1 billion market cap for which clean energy represents more than 10% of revenues,[333] demonstrating that clean energy is already an investable market. One hundred and forty companies with a collective revenue of over US$2.75 trillion have also committed to source 100% renewable electricity as part of the RE100 initiative.[334]

Meanwhile, more than 30 countries and states have already joined the Powering Past Coal Alliance, launched in November 2017.[335] In the United Kingdom, coal-based power generation in the winter months is estimated to be just a fifth of 2012 levels,[336] and there were several coal-free days in 2017 and 2018.[337] There is growing evidence that India will not need any new coal power plants to meet the increasing electricity needs of its population and economy over the next 15 years.[338] In 2018, Ireland became the first country to commit to divest from fossil fuels.[339]

The cost of managing the intermittency of wind and solar power generation is also tumbling. Battery prices have halved over the past three years,[340] and the deployment of smart grids makes it easier to manage and optimise use of multiple sources of flexibility in the power grid, in particular via demand response. By 2035, running a predominantly intermittent-renewable-based power system is likely to be cost-competitive with running a gas-based power system in most places, thanks to the combination of decreasing renewable generation costs and decreasing flexibility costs.[341] Gas-fired thermal plants will continue to be required to meet peak demand, especially seasonal peaks, such as winter heating, but continued use of gas during the transition period commands that methane leakage be under control, not to cancel the emissions benefits of a coal-to-gas switch.[342] Where they are available, other zero-carbon energy sources like hydro and nuclear power will play a complementary role in meeting power demand. Coal-fired plants with CCUS are not likely to be cost-competitive but could still be used in countries with recently built plants that could be retrofitted.

The rapid uptake in renewables globally over the past two decades has far surpassed the expectations of leading energy experts.[343] Maintaining the favourable policy environment that has helped to drive this progress is essential. As the share of low-carbon power grows and the clean energy transition progresses, greater focus will be needed on managing the social and political fallout from the phase-out of coal power generation and the increasing shift away from other fossil fuels. A number of countries, companies, and communities are organising multi-stakeholder dialogues or other processes to identify approaches that can help ensure a just transition for workers and affected industries (see Box 5). For example, Germany supports early retirement schemes for coal workers and shares the costs of reform with the industry. And China has put in place a US$15 billion fund for retraining, reallocating, and early retirement of an estimated 5—6 million people who will be laid off due to reductions in coal and steel overcapacity.

Evidence of the Benefits

The deployment of at-scale renewable power has the potential to deliver abundant low-cost low-carbon electricity, saving residential consumers money and enhancing industrial consumers' competitiveness (see, for instance, Morocco's solar deployment, Box 16).[344] It is expected that household energy expenditure for fuel consumption would drop below today's level during the 2040s in a 2˚C scenario.[345] Renewable energy also creates more jobs on a per MWh basis than fossil fuels: In 2017, renewable energy companies employed 10.3 million people worldwide, and they are the fastest growing source of jobs in several countries.[346] Based on E3ME modelling results, more than 65 million additional jobs can be created in low-carbon activities by 2030 from actions identified in this Report, relative to the baseline, which would more than offset an expected loss of about 28 million jobs in high-carbon activities (i.e. coal; oil and gas; manufacturing of fuels; and the supply of electricity, water, and gas) for the same period.[347]

The deployment of distributed renewable generation can also bring energy access to regions with non-existent or weak connections to the grid, in particular in rural sub-Saharan Africa, which will represent nearly 90% of those without electricity access by 2030 (see also, Section 1.D on energy access).[348]

Finally, in most countries, local renewable power generation can greatly enhance energy security, since it reduces the dependence on imported fossil fuels characterised by volatile prices, currency exchange, and geopolitical risks. Within the G20, countries that are currently net importers of fossil fuels would save US$1.95 trillion per year in energy import bills by 2050.[352]

The energy sector is currently the largest emitter of air pollution—indoor and outdoor - including from harmful pollutants such as sulphur dioxide (SO2), nitrogen oxides (NOX) and fine particulate matter (PM2.5), which are responsible for about 9 million premature deaths each year.[353] Outdoor air pollution, much of which is linked to fossil fuels, is linked to 4.2 million premature deaths per year.[354] The OECD estimates global welfare costs to be about US$3 trillion in 2015, possibly rising to US$18-25 trillion in 2060 without targeted policies to shift away from fossil fuel use and control air pollution.[355] A recent study found that doubling renewables in the global energy mix by 2030 could save up to 4 million lives.[356] IMF's analysis of the damages caused by fossil fuels shows that coal has the largest negative impact on human health, yet coal's use is pervasively undercharged in energy taxation and carbon-pricing systems (see Section 1.A).[357] Based on E3ME modelling results, European countries alone would benefit from improvements in air quality linked to carbon pricing and the removal of fossil fuel subsidies, with a consequent reduction of government expenditures in health of about US$7.2 billion between 2018 and 2030.[358]

Box 16
Morocco Leads with Ambitious Large-scale Solar Deployment

Morocco has experienced first-hand the impacts of climate change and the opportunities in addressing it: The country's economic growth fell to 1.5% in 2016 because of a severe drought in 2015,[349] and Morocco has begun taking decisive climate action with its ambitious solar plans and investments. In 2016, the Noor 1 power plant went online, the first phase of a massive concentrated solar power (CSP) project intending to provide renewable energy to over a million Moroccans. The advantage of CSP is its ability to make energy even when the sun is not immediately shining and without the use of batteries for storage.

Located near Ouarzazate, the Noor Solar complex will be the world's largest multi-technology solar plant by the time it is fully complete and online in 2019. Noor 1 alone, and its 580 MW of installed capacity, is large enough to be visible from space.[350] It is also projected that 1,600 direct jobs will be created on average per year during the construction of Phase 2 and 3 of the power plant, and during its initial 25 years of operation, the power station will create over 200 direct jobs and several hundred of indirect jobs with special efforts to boost women's employment in the region. Partnering with Faculté Poly-disciplinaire d'Ouarzazate, the project is offering targeted training programmes for women in the region for entrepreneurial and agricultural activities, and it is recruiting women in relevant decision-making roles to guide project activities.[351] Investment for the project came from a range of sources: concessional finance from the Clean Technology Fund, as well as from the World Bank, the African Development Bank, and others that helped lower the cost of capital for developers.

Accelerating the transition to a low-carbon energy system can further reduce air pollution and global warming by targeting emissions reductions of short-lived climate forcers, a class of pollutants that is associated with a higher GWP and increased air pollution at the local level. Reducing emissions from pollutants such as black carbon, methane, and HFCs (see Section 1.B) can improve local air pollution and health outcomes close to the source of emissions, as well as secure significant climate benefits. For example, methane—the key component of natural gas—has 34 times the GWP as CO_2,[359] and reductions in methane emissions can reduce toxic compounds at ground level.[360] Highlighting these local benefits to climate action can be an important means to gain public support for action.

Challenges

Fossil fuel use is a hard habit to break. After four years of flat emissions, global carbon dioxide emissions from fossil fuels and industry rose 2% in 2017, mainly driven by increases in China and other developing countries,[361] and world oil production has never been higher.[362] At the same time, methane emissions, particularly from oil and gas industries, are also growing.[363] In a number of countries, particularly fossil fuel-rich economies, there is a real challenge to diversifying the economy. Norway, a nation whose economy has been built on oil and gas revenues, has been a leader in reinvesting these revenues in current and future generations. The country has more recently set up a dedicated Expert Committee for Green Competitiveness, which worked with leading companies and civil society to identify 11 sectoral road maps for transition to a low-carbon future.[364] The process helped build widespread buy-in to the transformative changes needed to transition to clean energy and identified a number of innovative solutions, but implementation will take time and dedicated political leadership. The challenge for fossil fuel-dependent developing economies will be far greater, and support from the international community will be essential to enable them to identify and transition to alternative growth paths that can still deliver strong, equitable, and environmentally sound development.

As noted, there is potential to create stranded assets and with that the risk of stranding jobs. This debate is particularly visible in coal-producing countries like India or Poland. Making a green grid politically defendable will require carefully crafted strategies to phase out coal power generation, while providing alternative sources of revenue for the populations and regions that are affected by this shift. (See Canada's and Germany's efforts to manage the transition, Box 17). Dialogue with trade unions is particularly important in that context to help identify socially beneficial solutions. In Italy, for example, the closure of 23 coal-fired power plants by ENEL has been negotiated in an agreement with the sector unions so as to guarantee that there would be no involuntary redundancies and that the workforce would be redeployed within the company.[365] ENEL has committed to looking for employment-generating solutions, such as building renewable power or technology hubs in those communities.

Box 17

Canada and Germany Pioneering a Just Transition out of Coal[366]

In 2016, Canada announced a phase-out of coal-fired power by 2030, in line with the country's commitments as part of the Paris Agreement. Coal-fired power plants currently emit 8% of total national emissions and almost three-quarters of the emissions from the power sector. Canadian mines produce roughly 69 million tonnes of coal, of which 34.5 million tonnes are exported.[367]

Thermal coal production is concentrated in two regions[368]—Alberta and Saskatchewan—therefore triggering concerns for workers and their families in specific employment areas. Experience from other industries shows that social ties, home ownership, or poverty can make it impossible for people to move when the local employer shuts down, therefore triggering a need to create alternative employment locally. Deindustrialisation can also start a vicious economic cycle of a declining tax and revenue base translating into reduced funding for public services and long-term loss of economic attractiveness.

To address these socio-economic transition challenges, the central government committed to working with provincial governments and organised labour to "ensure workers affected by the accelerated phase-out of traditional coal power are involved in a successful transition to the low-carbon economy of the future."[369] A Just Transition Task Force with participation by labour representatives was established to oversee this process.

More recently, Germany launched its "Commission on Growth, Structural Change and Employment" to develop an overarching approach to managing the technical, legal, economic and social impacts of the phase-out of coal in line with national climate commitments. As part of Germany's overall low carbon transition ("Energiewende"), this commission is seen as a potential model for just transition dialogues. The government transfers responsibility for the controversial coal phase-out planning to an independent commission of diverse representatives from national and local governments, local coal authorities, the private sector, and civil society.[370]

Solar and wind are characterised by high up-front capital costs and low operating costs, which makes total costs particularly dependent on the cost of capital—that is, reflecting the rate of return required by different types of investors. Renewable projects still face relatively higher cost of capital than other infrastructure projects, due to the as yet relatively limited track record of investments in the sector and by political risks, especially on future prices of electricity. This is further accentuated in developing countries by capital scarcity provoked by a wider set of country risks. One way to lower uncertainties for investors is by providing increased certainty on future electricity prices. This is where tendering for power supply by auctions proves to be a particularly attractive mechanism.[371] Blended finance structures—that is, the strategic use of public or philanthropic development capital for the mobilisation of additional external private commercial finance—can also reduce risk for private investors, especially in developing economies.[372]

Box 18

De-risking Investments in Renewable Energy in Africa: The Lake Turkana Wind Power Project

A blended finance structure, strategically combining public and philanthropic capital to de-risk private investment, has enabled the development of the largest wind power plant in Kenya, which is also one of the largest private investments in Kenya's history. The total project cost is estimated at US$680 million and includes the cost of the envisaged 400 km transmission line from Lake Turkana to the Susua sub-station near Nairobi, as well as the cost of upgrading 200 km of roads and various bridges. Once completed, the wind park is expected to produce 310 MW of wind energy, which is 15% of Kenya's current installed energy production. The developers of the project are private companies, but a number of DFIs were involved to attract private investors by reducing risks through an innovative financing mechanism. The African Development Fund applied its first partial risk guarantee of about US$24 million (€20 million). The application of the EU-Africa Infrastructure Trust Fund financial instrument (which blends DFI monies with grant monies from the European Commission) was also crucial in filling the equity gap.[373]

Nuclear power can also potentially play an important role in deep decarbonisation. Nuclear currently provides 11% of world electricity, and the challenge of transitioning to zero-carbon energy systems over the coming decades is much greater if renewables need to replace nuclear. Countries with limited renewable energy resources will also continue to need complementary power-generation sources. But nuclear fission faces significant challenges, such as the high cost of maintaining aging plants, cost overruns on new projects, and concerns about proliferation, safety, and waste disposal; and nuclear fusion technologies are yet to be proven. A concerted public-private innovation push on so-called Next Generation or Generation IV nuclear designs holds the promise of potentially dramatic improvements in efficiency and safety, waste, and reduced construction costs.[374]

Finally, there is still a strong belief among policy-makers that the grid cannot absorb more than a certain level of variable renewables without jeopardising reliability of supply. On the contrary, recent analysis demonstrates that a grid relying significantly on variable renewables could be operated—and at low-cost—even if it relied only on two sources of flexibility in the grid: gas plants operating in times of peak demand and lithium-ion batteries.[375] Investing in transmission grids, including between neighbouring countries, and the technologies that facilitate demand response (such as smart meters) will make grid management easier.[376] Recent experience demonstrates the viability of grids relying significantly on renewables, thus countering the fear among policy-makers about reliability of supply.

Managing these different challenges calls for integrated energy-system planning at the country level in order to simultaneously and coherently plan for both shifts in power supply and in power demand across buildings, transport, and industry. The shift to the energy system also calls for use of multiple policies to drive change—for example, carbon pricing, power market design, and regulations. In particular, decision-making should not be based on outdated facts and paradigms. Institutional boundaries will need reshaping to include robust information systems and new technical know-how.

Accelerators

- **Countries should join the Powering Past Coal Alliance and commit to phasing out coal power production by 2025 or 2030 at the latest.** The closure of thermal generation capacity makes economic sense as renewable power reaches cost-competitiveness with coal-based power, as is the case in India today,[377] and even more so when considering the health costs related to coal burning. All countries will need to give careful consideration to their own context by establishing transition plans through multi-stakeholder processes and implementing these in a way that ensures a just transition for coal workers and affected regions. Countries should work together to share experience and lessons learnt as they move transition plans forward.
- **National and state governments should raise targets for renewables penetration into the grid well above 30% of power generation by 2030 reaching more than 50% by 2040 in most locations**. Higher targets should, in particular, be a key feature of the revision of the NDCs to the Paris Agreement. Given recent developments, there is evidence that this will not jeopardise the reliability of power supply.[378] Auctions are an essential tool to meet these targets at low cost. In parallel, jurisdictions should undertake 'grid of the future' exercises, like New York's Reforming the Energy Vision strategy and California's Flexible Capacity Procurement (Box 19), to prepare for the smooth integration of higher shares of intermittent renewables in the grid. Analysis of a low-carbon pathway undertaken for this Report using the E3ME model indicates an increase in the share of renewable energy from a quarter of the total generation in 2018 up to 43% in 2030 and to over two-thirds by 2050.[379]
- **Governments should make state-owned enterprises (SOEs) a driver of the low-carbon transition.** SOEs are prominent actors in global energy markets as investors in both fossil fuel power plants and renewable energy. A recent OECD report shows that SOEs in G20 countries account for roughly half of the currently planned or ongoing investment in the power sector, and they own 56% of the coal-fired power plants in operation and 52% of those planned; governments can use their ownership of SOEs to accelerate the low-carbon transition.[380]

Photo credit: Flickr: Knut-Erik Helle

- **International financial institutions, development banks, and philanthropic foundations should develop blended finance funds and support governments in policy reforms to deploy renewables at scale in emerging and developing economies.** Blended finance tools reduce both perceived and real risks associated with investments in renewable energy in developing countries (as in the case of the Lake Turkana project, Box 18). Concessional debt co-financing facilities and funds specifically aiming to support private sector climate investment, such as the ADB's Canadian Climate Fund for the Private Sector in Asia, provide a key means to blend finance to support of renewable energy in emerging and developing economies; established in 2013, the Fund is supporting solar investments in Cambodia and Samoa, hydropower in Georgia and wind and geothermal in Indonesia.[381] Moreover, India, South Africa, Mozambique, Cambodia, Mongolia, Uganda, Kenya, and Rwanda have recently been identified as particularly favourable countries for the development of blended finance for renewables (see also Section 1.D).[382]
- **All oil and gas producers—in particular national oil and gas companies—should join the Oil and Gas Methane Partnership** launched by the UN with nine oil and gas majors in 2014. Today, BP, ENI, Neptune Energy, PEMEX, PTT, Repsol, Shell, Equinor, and Total have committed to evaluate, monitor, report publicly on, and reduce nine key sources of upstream methane emissions.[383]

Box 19

California Incentivises the Provision of Energy Storage and Demand Response

The State of California committed to reach 33% of renewables in the power mix by 2020. To prepare for the integration of increasing levels of variable renewables in the grid, the state and the California Independent System Operator(ISO) put an increased focus on growing energy storage capacity. The California ISO led a stakeholder consultation exploring what changes in regulations would be required in the short term and in the long term to ensure that sufficient flexible capacity was available to accommodate for variations in renewable energy supply. In parallel, in October 2013, the California Public Utilities Commission adopted a procurement mandate for electricity storage by 2020, with targets increasing every two years between 2016 and 2020. The mandate distinguishes among three levels of flexibility provision (transmission, distribution, and customer levels—or demand side) and includes targets for a range of chemical, mechanical, and thermal technologies. An additional four laws were adopted in 2016 to increase and help reach this initial goal. California's strategy supported the uptake of energy storage technologies by providing market security to investors and suppliers through the creation of steadily increasing, utility-driven demand for energy storage. The state currently has over 4.2 GW of installed storage capacity, 96% of which is pumped hydroelectric. About 488 MW of energy projects have already been procured through the flexible procurement mandate, although most are still in the planning and contracting phases. This number should rise to 1,325 megawatts (MW) by 2020.[384]

1.D. Recipe for Energy Access: Distributed Renewables and Clean Cooking

Expanding electricity access through renewable energy and scaling up clean cooking drives productivity and growth, reduces poverty and pollution, and improves health and quality of life, with the largest benefits for women. Today, roughly 1 billion people do not have access to electricity, and nearly 3 billion people do not have access to clean cooking.[385] By 2030, planned policies are expected to deliver clean energy to millions, but population growth is expected to outpace progress, leaving 674 million people lacking electricity access and more than 2 billion people without clean cooking (Figure 7). Nearly 90% of those expected to be without electricity in 2030 are in rural sub-Saharan Africa, as are 40% of those without clean cooking access, while cooking with traditional biomass is also concentrated in developing Asia.[386]

A range of renewable energy solutions are emerging—from large-scale renewables to add to grid-based capacity to smaller-scale, off-grid solar—and all will be needed to help eradicate poverty and achieve universal access to modern energy by 2030.[387] Achieving the goals of the Paris Agreement and NDCs requires deploying renewable energy at scale as countries move to fill the energy access gap. Solar home systems are spreading quickly in some places, offering affordable access to limited amounts of electricity to power basic household or micro-enterprise needs (for example, lighting, phone charging, small fans, and/or television). Although solar-powered micro and mini-grids are not yet commercially viable in developing countries, they offer much greater potential for transformative, rapid progress on electrification and economic development as they can provide higher levels of electricity for more productive uses (for example, community schools, medical centres, or hospitals).[388] The IEA estimates that mini-grids offer a US$300 billion investment opportunity between now and 2030 and some countries are positioning to exploit this opportunity.[389] For example, India is strongly committing to development of renewable mini-grids and is finalising policy to add 500 MW by 2021 and achieve its ambitious energy goals by 2022; although it has not finalised its policy, the Government of India has begun to co-invest with companies in these systems, and, by early 2018, 63 new mini-grids were in place.[390]

Off-grid solar markets are rapidly expanding worldwide. By the end of 2017, they will have reached about 73 million households, transforming the lives of over 360 million people.[391] Growing at about 60% per year since 2010, market penetration in 2017 is estimated to be about 17% with a total market value of about US$3.9 billion.[392] Driving this market are new business models using mobile phones and mobile money to capitalise on rapidly declining costs of solar, batteries, and energy-efficient technologies. In less than one year, the number of households using pay-as-you-go (PAYG) solar systems doubled to almost 500,000 in East Africa in 2015 (see Box 21), while in 2016, it was 800,000.[393]

Box 20

Women and Clean Energy: Agents of Change

Leveraging women as agents of change is a key pathway to scaling clean energy access. Women often make household energy decisions and are also the greatest beneficiaries once access improves, freeing up time that could be used for income-generating activities, leisure, or childcare.[394] Women are thus uniquely well situated to identify, champion, and help deliver sustainable energy solutions.[395]

Growing evidence points to the success and opportunity for women to excel as entrepreneurs in clean energy access businesses. Solar Sister, for instance, is a women-led social enterprise operating in Nigeria, Tanzania, and Uganda with a mission to eradicate poverty by activating women's social networks to sell and deliver clean energy services to their communities in rural Africa.[396] Solar Sister recruits, trains, and mentors women and builds women-to-women networks of trust to achieve last-mile distribution for solar devices and clean cookstoves.[397] Operating since 2010, Solar Sister has a network of over 2,500 entrepreneurs that today provide services to over 350,000 people.[398] Results show positive social impacts ranging from raising incomes and the power of women within families to creating female role models for girls and more productive, healthier, and safer communities.[399] BURN Manufacturing in Kenya is a locally driven clean cook stove business, developing, manufacturing and distributing devices that are designed based on women's needs and preferences. BURN's Jikokoa stoves have been on the market since late 2013. They now serve more than 100,000 Kenyan households, benefitting over 500,000 people, reducing fuel costs and emissions compared to traditional alternatives by more than 60%.[400] The business also prioritises female employment: Women constitute just over half of its workforce of roughly 400 people working in manufacturing, sales, and distribution jobs.[401]

Engaging women in the production and provision of clean energy can also help challenge traditional gender roles.[402] In Ghana, for instance, the Lady Volta Vocational Centre for Electricity and Solar Power, which started in 2015 as a collaboration across two non-profit organisations and now partners with the multinational from Schneider Electric, trains women to work as technicians and managers in clean energy.[403] By 2018, the Lady Volta programme enabled dozens of women to become certified by the government to work in various clean energy trades and also offered a new course to help women to pass the Ghana Energy Commission exam and access management positions.[404] At an institutional level, regional policy for the Economic Community of West African States recently committed its 15-member West African governments to mainstream women into public and private-sector energy jobs and decision-making.[405] This builds on encouraging patterns showing that women in renewable energy jobs, representing about 35% of the workforce, outnumber their representation (20—25%) in the energy sector overall.[406]

Solar Sister, BURN Manufacturing, and Lady Volta are part of a growing coalition of actors committed to growing the distributed renewable energy sector in sub-Saharan Africa, exploiting business opportunities to deliver social impact.[407] The market is large: Looking at a single country, Nigeria, the replacement of kerosene lighting alone by off-grid solar lighting could save US$1.4—1.7 billion per year in avoided fuel costs.[408]

Grameen Shakti operates a larger-scale social impact business to supply and maintain SHS in Bangladesh. Its business model employs local women to promote, construct, install, and maintain the SHS, ensuring the local skills and woman power to deliver system reliability. Training sessions for women are led out of its 16 Grameen Technology Centres (GTC), each run by women engineers. The GTCs have trained over 3,000 women as renewable energy technicians to service rural areas in Bangladesh.[409]

Research shows that women as entrepreneurs often outperform male counterparts in terms of business capacity and job creation.[410] Beyond the direct benefits to women of clean energy in the home, engaging women in clean energy businesses brings revenue to strengthen their standing, their agency and status in the household, and the community. They can also actively engage their peers, building trust and increasing the chances of successful uptake of solutions by other women.[411] Women's engagement in the business of clean energy access can deliver results in multiple ways that matter: by promoting inclusive economic growth that gives women a voice and dignity of formal employment, by increasing household incomes through improved earnings as well as reduced fuel and health costs, and by increasing time savings for women and children. Reduced emissions are an important co-benefit for the planet.

Box 21

PAYG Solar in East and West Africa

Less than half of Africans have electricity access in their homes, but two-thirds have mobile phones.[412] With a PAYG business models, a company typically rents an SHS to consumers who use mobile phones to make payments until they own it, or pay for energy-as-a-service that also establishes a credit history for consumers.[413] This overcomes two major challenges around energy access: providing affordable financing to people who do not typically have access to credit and tackling the relatively high first-cost investment hurdle for investment in off-grid solar. There are more than 30 companies in more than 30 countries in Africa and South Asia, although the majority of sales are in Kenya, Tanzania, and Uganda.[414] More than 800,000 PAYG solar systems have been sold already, and cumulative sales are forecast to reach 7 million by 2020.[415]

PAYG solar systems allow households to save money while reducing the health risks and carbon emissions related to kerosene use. M-KOPA, one of the biggest companies, estimates that each household with an SHS saves US$750 because of avoided kerosene costs and eliminates 1.3 tonnes of CO_2 over the first four years.[416] In 2016, Lumos, which delivers off-grid solar in Nigeria in partnership with MTN, one of the Africa's largest mobile operators, secured US$90 million in investment, which it used to expand into Ivory Coast.[417] The PAYG model is also being used on a smaller scale for other sustainable solutions like renewable energy for water pumping and for clean cooking.[418]

In Bangladesh, a decade of policy effort, including grants for partial subsidies and funding for loans to support a microfinance business model, has successfully delivered about 4.12 million SHS installations, reaching 18 million people or 12% of the population (see Box 22).[419]

Box 22

Solar Home Systems in Bangladesh

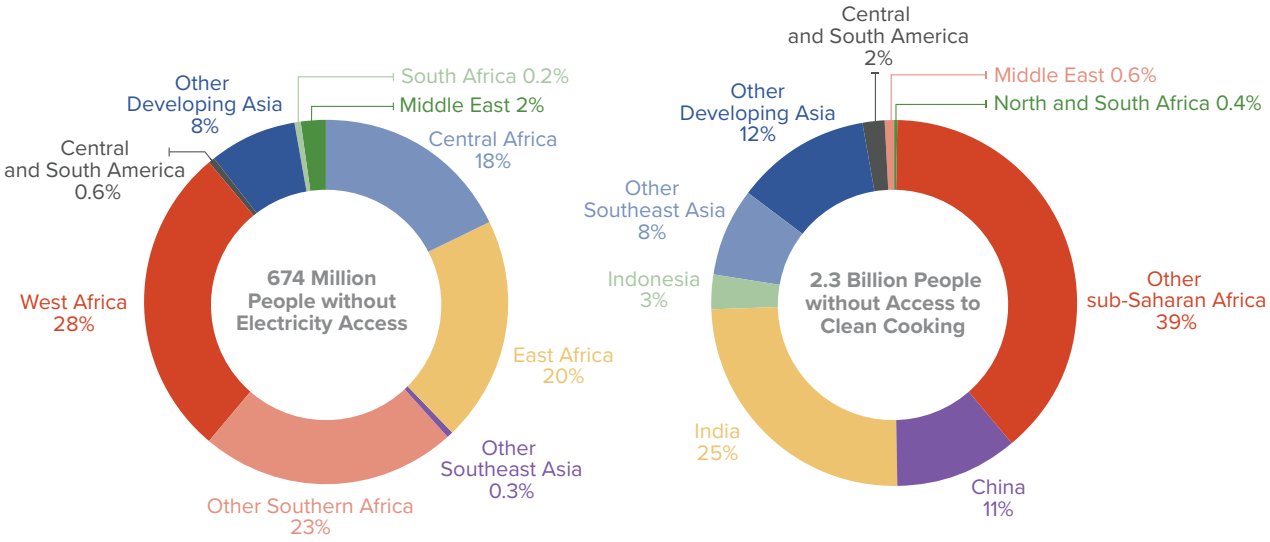
In the 1990s, a nongovernmental organisation (NGO) called Grameen Shakti piloted a successful SHS programme in Bangladesh. Drawing on Grameen Shakti's experience, the Government of Bangladesh established Infrastructure Development Company Limited, a public-private institution to support market development and service delivery, including operator certification and implementation of technical standards. The company has 56 partner organisations, most of which are commercial partners and with Grameen Shakti, the largest in the market.[420] Since 2003, 4.12 million SHSs have been installed in Bangladesh, and the goal is to finance another 6 million by 2021 to help achieve universal access.[421] Uptake of SHSs increased per capita income 9—12% by 2014.[422] Rural households have saved US$411 million in avoided kerosene costs as of 2017.[423] One hundred and fifteen thousand jobs have been created in sales, installations, and maintenance.[424] For example, Grameen Shakti has trained 3,000 women as solar technicians to install and maintain the SHSs in rural areas.[425] In addition to the economic and social benefits, the programme has also reduced carbon emissions by 160,000 tonnes per year; while this is equivalent to only a small fraction of the annual emissions of Bangladesh (that is, 0.1% of 2014 GHG emissions) the social and economic benefits of energy access are undeniably large.[426]

For clean cooking, a range of technical alternatives are possible, from improved biomass technologies to LPG solutions, with varying costs. Despite limited success, pockets of progress in some countries can provide lessons for others. For example, Brazil's creation of a national infrastructure for LPG production and distribution, the development of a retail market, and provision of subsidies resulted in 100% of Brazil's urban residents having access to LPG, delivering local air quality and human health benefits.[427]

Evidence of the Benefits

Electricity access at the household level increases employment and earnings and boosts the productivity of home-based enterprises, while increasing the likelihood that children, particularly girls, will finish school and that women will work outside of the home.[428]

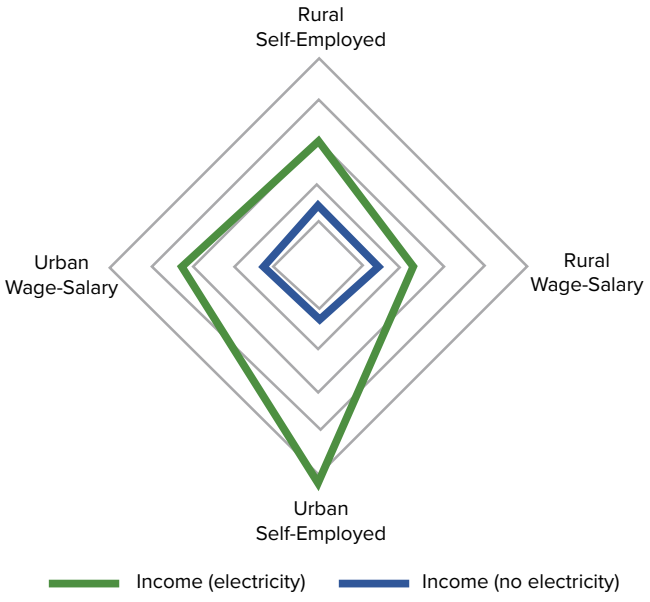
Figure 7
2030 Gaps in Access to Electricity and Clean Cooking—Planned and Current Policies



Note: The percentages reflect the percent of the total populations lacking access to either electricity or clean cooking in 2030 under current and planned policies. Percentages may not sum to one hundred percent due to rounding.
Source: IEA Energy Access: From Poverty to Prosperity, WEO Special Report, 2017.[429]

Census data from Brazil show girls with access to electricity to be 59% more likely to complete primary education than those without.[430] Larger benefits accrue to women when access is combined with use of time-savings appliances such as a washer.[431] The income benefits of electrification for women in Brazil are particularly pronounced in urban areas (see Figure 8).

Figure 8
Energy Access and Income for Women in Brazil.



Source: O'Dell, K., S. Peters, and K. Wharton, 2014.[432]

Rural electrification through SHS typically replaces kerosene or diesel use, generating financial savings in a two- to three-year period to consumers and GHG reductions.[433] There are also vast market opportunities for off-grid solar solutions in urban areas to compensate for unreliable or sometimes too costly grid infrastructure access, which in turn will yield large financial and human health benefits to urban households.[434] Clean cooking, which replaces traditional biomass use, also improves living standards by freeing up women's time and improving their health, while reducing GHG emissions.[435] Household cook stoves consuming solid fuel produce about 25% of global black carbon emissions. This is significant as black carbon has the second highest global warming impact after CO_2.[436] A shift to cleaner fuels and more efficient cook stoves to replace traditional biomass use is also likely to help curb deforestation in sub-Saharan Africa.[437]

The IEA estimates universal access to clean cooking alone could avoid 1.8 million premature deaths per year in 2030, free up billions of hours, and improve livelihoods for hundreds of millions of women.[438] Growing demand for distributed solar and clean cooking drives innovation and lowers the costs of alternatives. The rapid decline in solar technology costs combined with availability of high efficiency devices (for example, LED lighting) allows bundling of technologies to further lower the costs and raise the quality of services provided.

Photo credit: SolarSister.

Challenges

Many countries in developing Asia still have low-cost coal in their plans for expanding capacity, and much planning remains focused on grid expansion while ignoring off-grid opportunities for a strengthened and integrated system across both. Today, utility-scale solar and on-shore wind have become cost-competitive with fossil-fuel generation (even excluding external social costs of climate change and local air pollution) in some markets,[439] and Africa is experiencing a solar revolution.[440] Yet supportive policies and market incentives to further renewable off-grid and mini-grid systems are lagging, and financiers in local capital markets are reticent to invest due to limited experience with renewable technologies. There is often widespread failure in public governance of the energy sector in countries where energy access is a major challenge, for example where these basic failures lead to problems of quality or reliability of supply even after access is gained. Despite the great promise of decentralised solutions, a recent analysis of financing for energy access in 20 high-impact countries (representing 80% of the access gap) shows that a miniscule share of all traceable finance for electricity—less than 1% or about US$200 million per year—is supporting decentralised solutions.[441] The majority of electricity policy and finance is targeting grid expansion, ignoring the vast potential for decentralised solutions to complement the grid to accelerate electricity access.[442] Access to domestic capital is a barrier to timely investment; and while foreign investment has been driving the SHS business in Africa so far, costs of capital are driven up by foreign exchange risk, prompting some DFIs to partner with business to offer guarantees through currency hedging products to offset such risk.[443] Such guarantees remain relatively expensive, however, so a complementary, longer-term solution is for countries and DFIs to work with local financial institutions to raise awareness and capacity to boost local investment.

The business case for mini-grids is growing, but business models need to be tapered to local consumers and market segments; and, for the moment, they are not commercially viable in poorer developing countries.[444] Mini-grids require more up-front investment and patient capital, typically with a payback of 10—20 years.[445] Mini-grids may require a 50% public finance subsidy and public-private partnerships to attract necessary private investment.[446] By contrast, PAYG business models operate with a simpler form of consumer finance that has shorter payback of 2—3 years. Delivering SHS often requires limited or no public subsidy.[447]

On the cooking front, alternatives to traditional fuels also require solutions to be tailored to local contexts. Barriers to clean cooking include poor stove quality and inappropriate design; inadequate research and understanding of consumer needs; inadequate producer technical capacity and finance; lack of production at scale; lack of consumer

awareness; cultural preferences for other methods; and affordability, particularly of up-front costs.[448] In sub-Saharan Africa, for example, the cost of a basic improved biomass cook stove was less than US$15 in 2012, while the cost of a double-burner LPG or electric stove was at least US$50.[449] When factoring the costs of fuel, the annual costs of LPG and electricity can be 30—40% higher than wood.[450]

Additionally, monitoring electricity and clean cooking access can be challenging given lack of data as well as the binary definition as compared to multi-dimensional definitions of access, which would include measures of quality and quantity of supply. Information technologies today enable geospatial data collection and modelling, including use of satellite imagery, which together can help achieve better planning and integration of on- and off-grid electricity and clean cooking solutions.[451]

Accelerators

- **DFIs and national governments can work with local financial institutions to raise awareness and create local financial products to support investment in decentralised solar and clean cooking solutions.** In turn this will lower the cost of the capital.[452] This includes partnering with national development and commercial banks, among other actors, to put in place measures such as green credit lines and de-risking instruments to crowd in local capital alongside foreign investment[453] (see also Box 23).
- **National governments should set time-bound targets for clean cooking and for decentralised electricity as part of integrated energy and electrification plans, enabling the development of project pipelines.**[454] Plans, targets, and ensuing project pipelines need to be developed in close collaboration with local stakeholders. A key step is to improve data collection and monitoring to assess progress and guide decision-making, including measures of access as well as quality and quantity of supply. Policies in Brazil, India, and South Africa are paying off as they achieve near universal access to clean cooking and are on track to achieve universal electricity access before 2030. In Brazil, 98% of the population has access to clean cooking, due to a three-pronged approach that included the development of national infrastructure for LPG production and distribution, the creation of a retail market that featured the participation of private entrepreneurs, and the provision of subsidies to the poorest families to ensure affordability.[455]
- **Governments should support innovative business models to expand distributed solar and clean cooking markets by setting technical standards for solar technologies and clean cook stoves, reducing import restrictions and tariffs for technology components, and reforming kerosene and diesel subsidies.** In 2016, 800,000 East African households were using PAYG solar systems,[456] with thousands more in Nigeria served by Lumos.[457] PAYG is now being used by firms in Africa to deliver clean cooking solutions, such as LPG.[458] M-KOPA estimates that households with a SHS save US$750 because of avoided kerosene costs and eliminate 1.3 tonnes of CO_2 over the first four years. More than 4 million households in Bangladesh are serviced by SHSs. Non-energy policies will also be needed to enable innovation in the information and technology (ICT) and mobile money or banking sectors, as well as to ease the costs of doing business.
- **Development finance providers should provide early-stage support and dedicated funds or facilities for mini-grid electrification, off-grid solar, and clean cooking entrepreneurial activities.** The blending of public and private finance is key and could include carbon finance or social impact bonds. As part of the International Solar Alliance, India pledged a concessional credit line of US$2 billion to Africa for largely decentralised solar energy projects; it has announced interest from Indian companies to install 664,000 solar pumps and 56 megawatts of mini-grids and train 5,400 solar mechanics in Africa.[459] Beyond offering financial support, development cooperation providers can provide technical assistance for targeted design of solutions, including partnerships between grid and mini-grid operators or market creation for clean cooking devices and fuels.[460] The World Bank has piloted results-based financing and technical assistance for clean cooking markets in China, Mongolia, Lao PDR, Bangladesh, Uganda, Kenya, and Indonesia, helping companies to enter the market.[461]

- **DFIs, national governments, and the private sector should partner to build and promote women's skills and leadership to support the full clean energy access supply chain.** Grameen Shakti in Bangladesh has trained 3,000 women as solar technicians to install and maintain SHSs in rural areas.[462] BURN Manufacturing in Kenya is producing clean cook stoves and has a business model prioritising employment for women to support change through local distribution and servicing of its products. A special focus on training for women and women's leadership as an integral part of business models can accelerate social impact (see also Box 23 on ADB's efforts to support clean energy access and Box 20 on women as agents of change).[463]

Box 23

MDBs Supporting Clean Energy Access in Asia

MDBs have an important role to play in promoting clean energy access. For example, the ADB is targeting clean energy access in its energy portfolio through its leadership in the Energy for All Partnership, where ADB is working with like-minded partners to bring new and improved electricity connections and modern fuels to people in the Asia-Pacific region. Between 2008 and 2016 the Partnership brought electricity access and modern fuels to more than 120 million people and the Partnership's new goal is to double its energy access impact by providing modern energy access to 200 million people by 2020.[464]

This illustrates how DFIs can partner with national governments and other local partners, including local financial institutions, to bring investment in renewable energy solutions to scale. For example, the 2017 approval of a US$50 million loan for the Rooftop Solar Power Generation Project in Sri Lanka is providing financing for rooftop solar power subprojects equivalent to 50 megawatts while building capacity and awareness of relevant government authorities, private sector partners, and customers for longer term market development. By partnering with private financial institutions, the programme also aims to develop market infrastructure, including establishment of technical guidelines and standards for the system, and a bankable pipeline of subprojects for the solar power systems.[465]

The use of technical assistance has been important to support early stage mini-grid electrification and market development, leveraging public and private investment in these systems. In Myanmar, ADB funded US$2 million of TA to establish 12 village-scale solar photovoltaic (PV) mini-grid systems, which were completed in 2017. The project supported geospatial analysis and investment plans for off-grid energy access in the central dry region of Myanmar. The project developed a geospatial web-mapping tool to leverage potential off-grid public and private investment decisions and completed 10 training programs on solar PV mini-grids, bio-energy, micro-hydropower, geographic information system, and business models for mini-grids helping to establish essential market infrastructure.[466]

Finally, ADB is committed to building women's skills and promoting leadership in businesses as part of its clean energy access programmes. For example, in 2017 ADB approved US$12 million in grant and loan financing to Vanuatu for the energy access with the aim to increase energy access and renewable energy generation in the two islands of Espiritu Santo and Malekula. The project is assisting Vanuatu to install hydropower generation to replace diesel generation in Malekula and extending the distribution grid in both Malekula and Espiritu Santo. At least 100 female-headed households are being prioritized for connection in areas where grid expansion is occurring. During design and implementation, all community consultations include at least 40% female participation. The project also includes training on skills development in service coverage communities (with at least 40% female participation) on how to use electricity to increase income generation, e.g. agribusiness value-adding or handicraft production.[467]

SECTION 2
Cities

Photo credit: Flickr: Trevor Dobson

Cities, with their concentration of people, economic activity, and infrastructure, offer unique opportunities to reduce poverty, deliver greater prosperity, and tackle climate change. Today, 3.9 billion people live in urban areas, and the urban population is expected to grow by another 2.5 billion people by 2050.[468] By then, two-thirds of the world's population will be living with the infrastructure and planning decisions we make today. If done right, the cities of tomorrow can be places where people enjoy healthy, active, productive lives. More compact, connected, and coordinated cities are worth up to US$17 trillion in economic savings to 2050.[469] Cities can be engines of economic growth, generating opportunity and wealth for the whole country. And their density and dynamism offer governments the possibility of achieving human development goals while reducing environmental impacts.

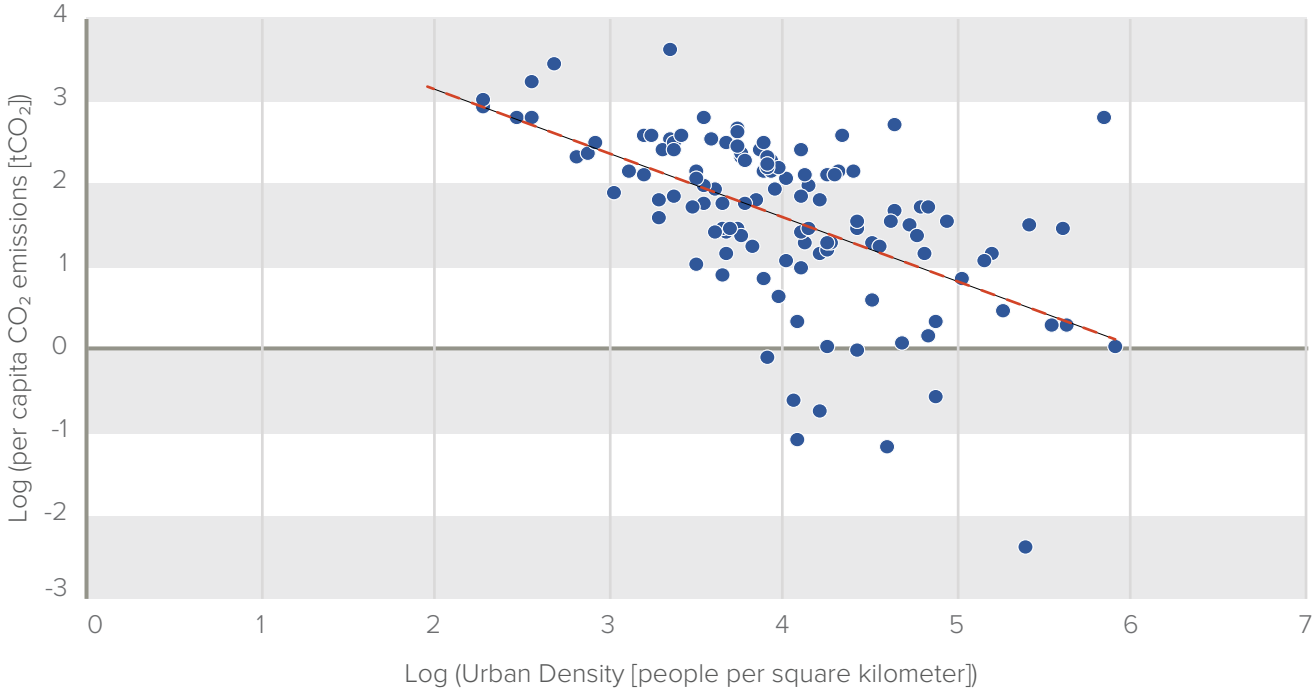
Yet urban areas are not fully realising their enormous potential to drive sustainable development. Nearly a billion urban residents live in informal settlements without access to decent housing, secure tenure, or improved water and sanitation.[470] Urbanisation is occurring in places with much lower average levels of income than historical averages, particularly in sub-Saharan Africa,[471] and new urban areas are emerging. Over 60% of the land projected to become urban by 2030 has yet to be developed,[472] and smaller cities are growing faster than mega-cities.[473] More mature cities are struggling with chronic congestion and toxic air pollution, yet private car ownership is projected to increase by as much as 60% in developed countries and up to 500% outside the OECD by 2050.[474] For cities to achieve their potential, it will be important to reduce the expected pressures resulting from the explosive rural-urban migration by balancing sustainable urban development alongside sustainable rural development.[475]

Tackling inequality alongside climate change and other environmental challenges is central to sustainable urban development. Soaring house prices are also contributing to growing inequality within cities and countries but there are also other drivers.[476] More extreme weather events—from extended heat waves to rising sea levels and flood risk—are exacerbating inequalities and reshaping sustainable urban planning and development.[477] The higher population densities of urban areas increase the need for risk-reducing infrastructure and services, such as drains, sewers, piped water, and paved roads, to reduce vulnerability to climate change. Balancing urban and rural development and managing urbanisation well will also be essential for ensuring resilience. Generating positive momentum from in-migration for better growth is possible but it will require adequate capacity in housing, transportation and other infrastructure and social services as well as consultative mechanisms for including migrants and other marginalised communities in decision-making. Institutions for planning, provision of infrastructure and other services will need reforming to ensure that all city dwellers enjoy a high quality of life and can enhance their economic productivity.

Unlocking the power of cities to deliver economic development in a sustainable way requires ambitious action. At its core, this depends on compact, connected, and coordinated use of urban land. Promoting density is critical to avoid locking in sprawling, inefficient and climate-vulnerable modes of growth, but the kind of density matters. 'Good density' means functionally and socially mixed neighbourhoods with access to green spaces, comfortable, affordable, and climate-smart housing for all, and high-quality public transport networks.[478] When done right, compactness improves residents' access to jobs, services, and amenities and, compared to sprawl, could reduce infrastructure capital requirements by over US$3 trillion between 2015 and 2030.[479] Densification is also more carbon efficient (see Figure 9) and resilient to climate change and disasters.[480] Promising examples of good density in action can be found all over the world today from Barcelona's car-lite Superblocks (see Box 25) to Singapore's green canopies (see Box 26), which are estimated to build resilience by reducing local peak temperatures by as much as 5°C, while also reducing energy costs associated with air conditioning.[481]

Figure 9

The Relationship between Population Density and Per Capita Carbon Emissions in Urban Areas.



Note: A Pearson's correlation on a dataset of 127 cities found that r=-0.3383, with p<0.05. Source: Coalition for Urban Transitions. Data source: Oxford Economics, 2014.[482]

To achieve greater compactness, established cities will need to retrofit, repurpose, or replace much existing infrastructure, and in some cases relocate people settled in increasingly areas increasingly vulnerable to disasters (for example, coastal zones), while fast-growing cities need to steer investment to new infrastructure and housing stock (see also Section 1.C on building efficiency). In both cases, governments will need to reform spatial plans, building codes, and tax incentives that favour sprawl[483] and that might exacerbate vulnerability to climate change and disasters.[484]

The most important factor in increasing the resilience and adaptive capacity of the built urban environment is to guide development that is out of harm's way at the systems and planning phase. Urban sprawl is often accompanied by an increase in vulnerability particularly amongst the poorest, who may be located in areas prone to flooding or landslides, and who lack adequate housing and infrastructure services. Planning for the multipurpose use of assets, such as connectivity and flood protection, can reduce risks at low cost. When infrastructure is at the design phase, choice of materials and other design features can be guided by the need to increase resilience to extreme heat, flooding and storms.

At the same time, care should be taken to avoid the displacement of low-income or other marginalised urban residents as inner-city areas become more attractive. New York's High Line, an abandoned elevated train line spur converted into an aerial greenway, displaced residents by boosting nearby property values a staggering 103% in eight years, despite a recession.[485] Inclusive urban planning, as modelled by Thailand's Baan Mankong programme (see Box 27), will be key to increasing density while enhancing the resilience and well-being of the urban poor.

Efficient, clean transport systems are essential for good density. Cities must avoid being physically locked into car-based transport systems and prioritise active and shared transport. Making walking and cycling safe and convenient is a universal priority, with particularly large potential in smaller and lower-income cities. Public transport is more complex, but there are opportunities to learn from front-running examples. Since the successful experiments in Curitiba, Brazil, and Bogota, Colombia, for instance, 164 cities worldwide have built bus rapid transit (BRT) systems, carrying close to 33 million passengers a day (see Box 2).[486] There are also opportunities to harness exciting new innovations in urban mobility, such as ride-hailing

networks, car- and bicycle-sharing systems, mobile trip-planning, and ticketing apps.[487] Where cities already have substantive car-based infrastructure, electrification can reduce noise pollution, air pollution, and carbon emissions. China is already seeing many of these benefits (see Box 30).

Analysis undertaken for this Report using the E3ME model suggests that a global shift to EVs could create about 11 million jobs by 2040, compared with the baseline, and would increase GDP (see also Box 4 on modelling). This is a scenario whereby new EV sales would climb to just over 1 per 100 people globally by 2030, and to a level whereby almost one in ten people have EVs by 2050.[488] To maximise the climate-change mitigation benefits, electrification of transport needs to be accompanied by a growing share of renewables in the electricity mix (see Figure 9).[489]

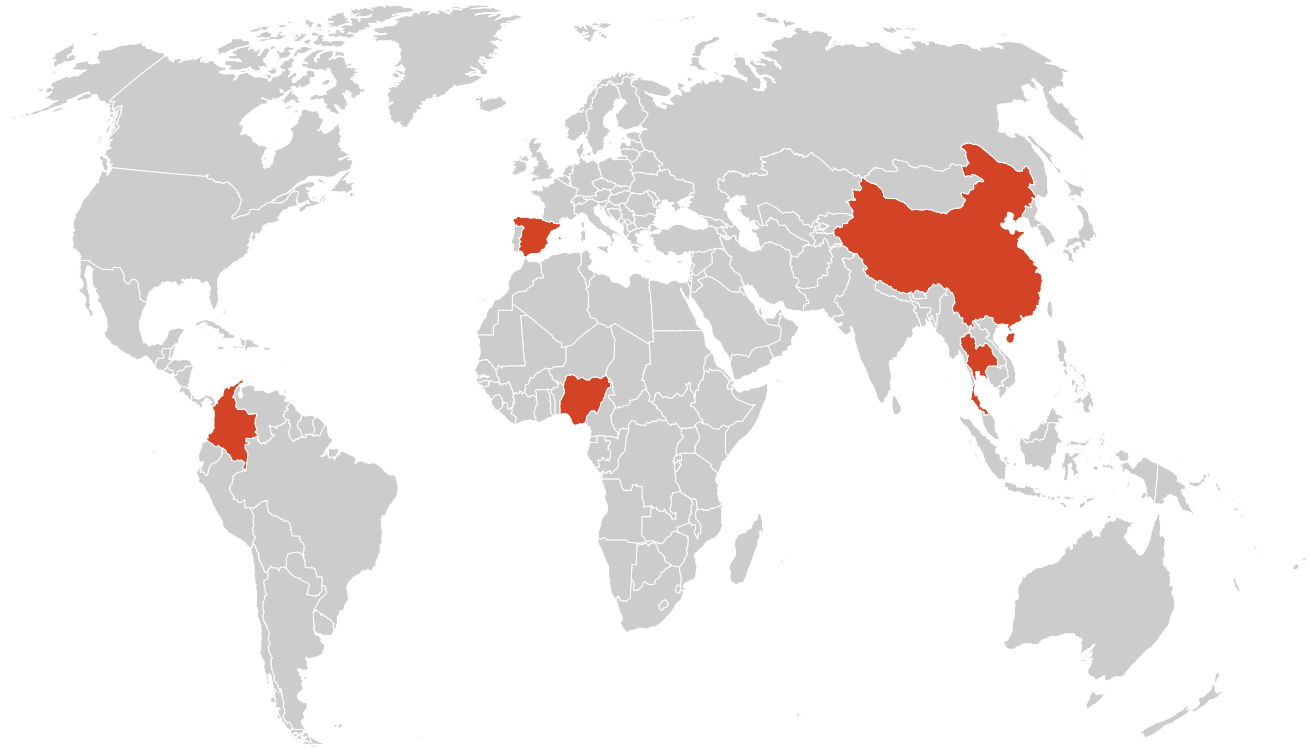
Because cities are shaped by governments but often built and financed by private actors, ambitious, integrated, and accelerated action in cities will require collaboration and coordination among many different actors. (See Box 24 on finance for cities). Aligning actors' behaviour and incentives behind a shared vision can make it easier to achieve compact and connected cities. National urban policies can provide an overall framework to guide sustainable and inclusive urban development through coordinated policies across different sectors. This includes more traditional 'urban' sectors like housing and transport, but also others not necessarily considered as urban, such as tax policies.[490] National and local governments need to work together to further develop of such frameworks, and this in turn, can provide a foundation for building climate resilience and environmental sustainability.[491] Effective national-urban policy frameworks include: getting the tax system right to maximise public fiscal capacity and create incentives for sustainable urban development; apportioning revenue collection and borrowing responsibilities and revenue allocations across different jurisdictions (including city governments); and implementing comprehensive, climate-smart national urban policies, including platforms and partnerships to finance the deficit in sustainable infrastructure in urban areas.[492]

Within these national urban frameworks, effective, accountable governments and institutions can facilitate public participation and develop and implement spatial plans and policies. Civil society organisations can foster environmental citizenship and harness community capabilities, for example to define sustainability in local terms and prioritise actions to build resilience to natural disasters. Domestic financial institutions, such as commercial banks and asset management companies, can provide much of the necessary investment, perhaps working with ministries of finance and development banks to increase bankability of projects and lower the cost of capital. And property developers, engineering firms, and construction companies can bring important technical and management capabilities to infrastructure and service delivery. Partnerships among these diverse organisations will be key to realising the vast potential of cities to create jobs, foster innovation, and advance the national economic interest.

This chapter identifies three key priorities that can anchor compact urban form today and lay the foundation for thriving cities of the future: densification to revitalise sprawling cities; the provision of sustainable and affordable housing; and investment in shared, electric, and low-carbon transport.

Photo credit: Flickr: ruich_whx

Figure 10
Locations of Transformative Examples in Cities Highlighted in this Report.



Box 24
Finance for Cities

NCE estimates that roughly US$2—3 trillion per year will be required between 2015 and 2030 to fill the sustainable infrastructure financing gap.[493] Infrastructure related to sustainable urban development is estimated to account for between two-thirds and three-quarters of all infrastructure investment to 2030.[494] There is also scope to lower the total investment needs though safeguarding and enhancing natural infrastructure, both blue and green (see Section 3). Yet governance and market failures are driving a financing gap of roughly 50%.[495] Investing in sustainable urban infrastructure does not mean it has to be more expensive. Indeed, making cities more compact and connected will lower investment requirements by as much as 10%.[496] Yet there remains substantial need to mobilise new resources to fill the financing gap.

Public finance has traditionally been a significant source of urban infrastructure investment, but public budgets are often insufficient for larger or more complex projects (with the notable exception of China). This is particularly true in the context of austerity, limited ability to collect revenues, or competing priorities for public budgets. The financing gap is most evident in cities in low- and middle-income countries: While Freiburg (Germany) and Bristol (United Kingdom) have per capita budgets of US$3,638 and US$4,907 respectively, Iwo (Nigeria), Pekalongan (Indonesia), and Feira de Santana (Brazil) have per capita per year budgets of only US$14, US$101, and US$399 respectively (see Figure 12).[497] Municipalities in developing countries typically have limited capacity or authority to raise revenues, but also the largest infrastructure deficits.

Although public budgets may be insufficient to meet investment needs, national governments have a critical role to play in raising and steering finance for sustainable urban infrastructure.[498] They have large opportunities to simultaneously increase the fiscal envelope and to create incentives for households and firms to behave in a sustainable manner through tax reform. This may be through urban-influencing policies, such as standards for weatherisation of built infrastructure, removing fossil fuel subsidies and introducing a carbon price, or urban-specific policies, such as eliminating subsidies for parking or reforming land and property taxes to favour densification.[499]

Box 24

Finance for Cities (continued)

National governments also have responsibility for boosting revenue-generation capacities at the local level. One study suggested that only 42% of countries devolve fiscal or legislative powers to subnational governments,[500] which means that many cities are almost entirely dependent on financial transfers from national governments. Clear legal frameworks outlining what revenues local governments can use will help incentivise them to improve the efficiency of both revenue collection and expenditure, thereby growing public fiscal capacity at local level.

Cities also have substantial scope to improve the efficiency of revenue collection and expenditure. Kampala, Uganda, offers an extraordinary success story, tripling its revenue in a five-year period by improving administration and compliance. Kampala Capital City Authority invested in an electronic platform called eCitie, which allows citizens to pay business licences, hotel taxes, property rates, ground rents, and other fees on their mobile phones. This increased people's willingness to pay, as they did not have to wait in long queues.[501] The platform eCitie also helped to tackle corruption and tax avoidance, as city officials could more easily track payments. Kampala Capital City Authority is now undertaking an ambitious valuation programme in order to update land and property registries, which is expected to triple revenues from the business district.[502] Many cities around the world, including Kampala, are working to increase their creditworthiness in capital markets. Creditworthiness effectively serves as a useful proxy for the quality of public finance administration, as it encompasses multiple factors including own-source revenue collection, asset management, and reliability of debt repayments.

Even if both national and local governments optimise their tax systems, there is a need to find new sources of public revenue and mobilise private investment. Governments and DFIs can use public finance strategically to leverage private finance by ensuring that urban infrastructure projects are bankable (by improving returns or de-risking investments) and by ensuring government entities are creditworthy.[503] Governments can tap into a large array of instruments for this purpose, including bank lending, bond issuance, public-private partnerships, land value capture (LVC), guarantees, and insurance.[504]

Local governments in developing countries can deploy these finance instruments more effectively with enabling national policies and technical assistance from DFIs, and DFIs are increasingly able to support cities' to take infrastructure investment to scale. The World Bank, for example, launched the "City Resilience Program" to work with cities on a pipeline of well-prepared and bankable investments to enhance urban resilience; it also acts as the banker for the city, improving access for private and institutional investors and facilitating strategic investments to build resilience.[505]

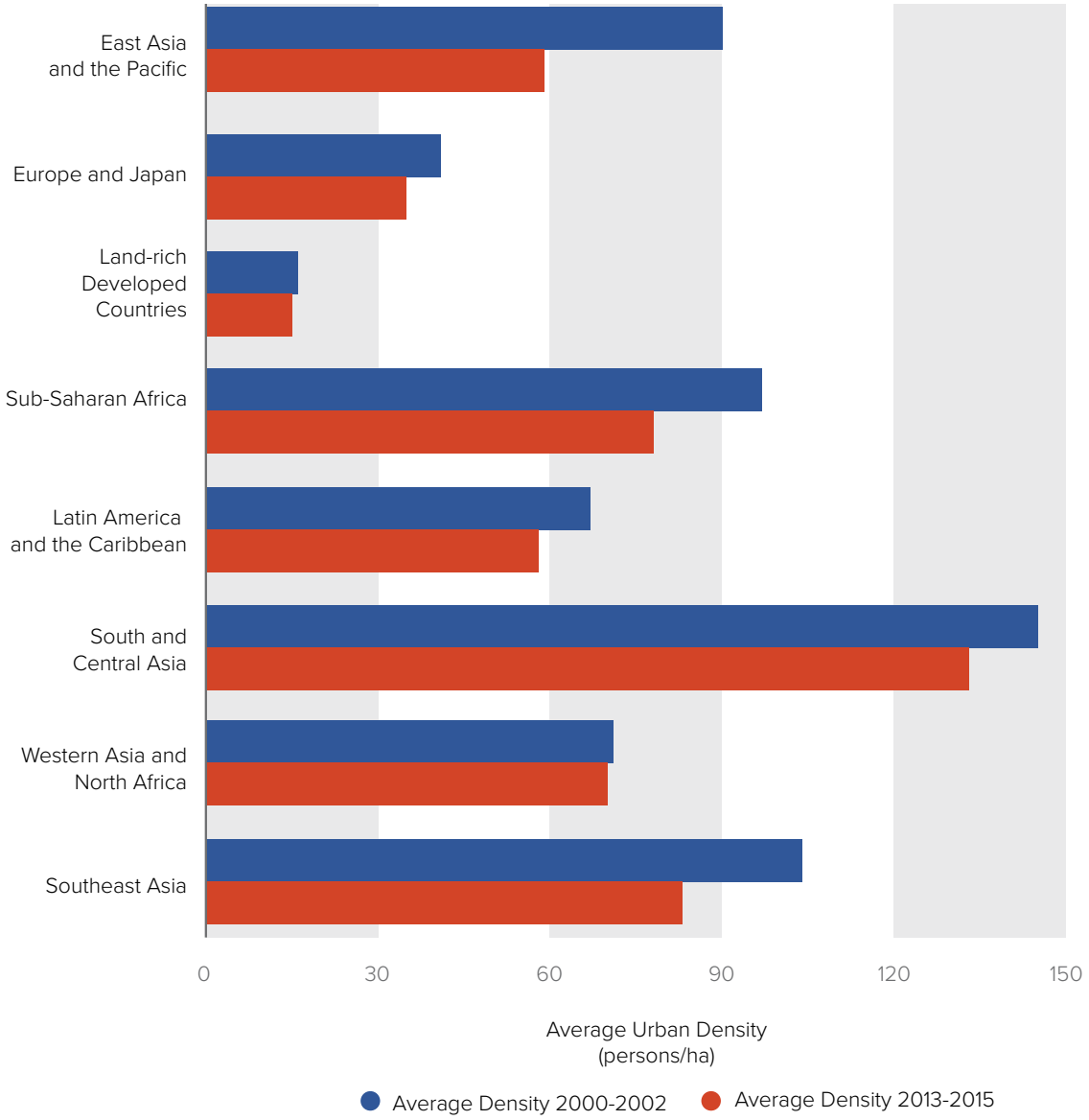
The case of bonds is also illustrative to attract private investment. Before cities can issue bonds, they need national legislation to clearly articulate whether they can borrow and under what conditions, including from which institutions, how much, in what currencies, and using what collateral. South Africa is a notable success story, explicitly and constitutionally enshrining the rights of municipalities to borrow. This has enabled both Johannesburg and Cape Town to issue municipal green bonds.[506] For example, Johannesburg's 10-year, 10.18% note raised more than US$125 million for investments in renewable energy, landfill methane capture, and hybrid-fuel buses.[507]

LVC instruments allow the state to secure a proportion of the uplift in land prices associated with sustainable infrastructure investment. These are much more effective when integrated into an effective revenue system as well as when there are transparent land and real estate markets and robust legal frameworks to guide the appraisal, appropriation and sale of land before and after public improvements. LVC is being deployed in an increasingly diverse range of contexts, including Addis Ababa, Harare, London, Portland, Quito, Shenzhen, and Tokyo.[508] Notably, almost half of the new Hyderabad Metro in India was funded through LVC instruments, primarily through issuing property development rights around the planned metro stations.[509] In a city where one in four people lives in informal settlements without clean drinking water, safe sanitation, or decent housing, LVC instruments offered an ingenious way to mobilise private investment in urban infrastructure. (See also Box 46 on LVC in Morocco). Infrastructure that meets sustainability standards by delivering low-carbon and resilient transport, water or flood protection services, will have higher value added over the medium to long-term, and thus provide a more stable revenue source for cities.[510]

2.A. Dynamic Downtowns: Well-Managed Densification to Revitalise Cities

Millions of urban residents live in private houses with their own gardens, and many more aspire to this type of suburban lifestyle. This cultural norm is reinforced by economic drivers, such as the lower cost of land around the urban periphery or tax policies that favour single-family dwellings. The result is a global decline in average urban population densities (Figure 11). While attractive to individual families, this kind of urban development creates substantial costs for the city as a whole. People have to travel farther to reach their workplace or public amenities, they face greater traffic congestion and air pollution, and it is more expensive to construct and operate the infrastructure needed to service sprawling communities.[511] In Sao Paolo and Rio de Janeiro, sprawl costs the cities 8% of GDP.[512] In the United States, sprawl is conservatively estimated to around 7% of national GDP.[513] Increasing urban density in ways that enhance residents' quality of life—providing green space, locating employment and services within walking distance of people's homes, and regenerating vacant and degraded inner-city areas—should therefore be a priority for cities around the world.

Figure 11
Average Density of Cities by Region in 2000—2002 and 2013—2015.



Source: Coalition for Urban Transitions. Data source: Lincoln Institute of Land Policy.[514]

Evidence of the Benefits

The clustering of people and firms in cities yields a wide range of benefits, and these benefits are larger with greater population and economic density. Densification can help to avoid the high costs of sprawl, including congestion, CO_2 emissions, air pollution, traffic accidents, and the increased investments needed to extend critical infrastructure to more dispersed populations. China alone could reduce infrastructure spending by up to US$1.4 trillion by pursuing more compact, connected urban growth.[515] Recent IMF estimates suggest congestion costs exceed US#350 billion per year, based on lost productivity and health impacts.[516] Many of these savings from densification will accrue to public budgets.

Beyond this, densification yields notable productivity benefits. A larger pool of employers creates incentives for workers to specialise, and a larger pool of workers allows employers to find the best fit with their team, enhancing the economic productivity of both individuals and firms.[517] Proximity encourages interactions whereby people can learn from each other and exchange ideas, thereby stimulating innovation. Evidence from Germany, Mexico, Spain, the United Kingdom, and the United States suggests that doubling a city's population is associated with roughly a 2-5% improvement in productivity.[518] This translates into significant increases in taxable incomes and assets, with commensurate scope to expand public fiscal capacity. In monetary terms, increasing economic density by 10% in urban areas is worth approximately US$71 per person per year due to higher productivity, US$62 due to higher job accessibility, and US$49 due to better access to services.[519] Higher population density also corresponds to lower per capita emissions (see Figure 9): One analysis suggests that low-density suburban development produces 2.0—2.5 times as many emissions per person as high-density urban core development.[520]

Challenges

Governments need to take immediate action to avoid further lock-in to inefficient, climate-vulnerable, and sprawling urban forms.[521] This will require retrofitting, repurposing, or replacing existing infrastructure. Neighbourhoods with single-family houses will need to be rezoned in order to increase the share of medium- and high-rise buildings, and public transport systems may need to be improved or extended to serve these hubs and improve connectivity.[522] This transformation will require mobilising substantial new flows of investment, as well as sophisticated planning capabilities and extensive consultations to design or refurbish infrastructure in a way that is climate-smart and meets the needs of affected communities. These consultations must involve local residents, as a lack of public support for densification or deep-seated preferences for existing urban forms can hinder government efforts to improve densification.

Efforts to densify can also be inhibited by zoning requirements that mandate minimum lot sizes, parking requirements, and single land uses; building codes that stipulate low floor-to-area ratios or building heights;[523] or government mortgage programmes that preferentially support single-family dwellings.[524] These policies may also reduce the supply of affordable housing within cities. For example, requirements that mandate two parking spaces per housing unit increase housing development costs by as much as 25%.[525] Governments will need to dismantle the legislation that incentivises sprawl and introduce new frameworks that steer investment into denser and more resilient urban development.

Densification must be carefully managed to avoid negative spillover effects, such as rising housing costs. Without appropriate safeguards, increasing the density of people living and working in a city by 10% could drive up rents by US$240 per person with the burden borne disproportionately by the poor and the young.[526] Densification must therefore be accompanied by programmes to expand the supply of genuinely affordable housing (see Section 2.B), ensuring that compactness does not improve urban life for more prosperous groups at the expense of lower-income residents. In addition, built-up areas are typically hotter, so there is a need to maintain urban green space to build resilience by tackling heat island effects.[527] Benefits of urban forests, parkland, and canopy cover include improved air quality, improved urban water management, and reduced runoff, which also enhance climate resilience.[528]

Accelerators

- **National and local governments can reform zoning ordinances, building codes, and tax incentives that favour urban sprawl.** Depending on the particular context, this might involve relaxing floor-to-area ratios and building height limitations; easing restrictions for government-backed mortgages; taxing unused property and parking lots; and offering density bonuses.[529] For example, Toronto

has raised US$309 million for public facilities through 'density-for-benefit' agreements whereby developers can offer cash or in-kind contributions in return for rights to exceed existing height and density restrictions.[530] Sao Paolo has eliminated parking minimums in favour of parking maximums, allowing only one space per residential unit along transit corridors to address crippling and costly congestion.[531]

- **Local governments can establish urban plans and programmes that promote connected parks, enhance natural ecosystems, and mainstream urban greenery.** The conservation of high-quality, accessible, and communal green space is essential for equitable and liveable urban density (see Box 26). 'Nature-based solutions', such as urban wetlands and forests, can absorb GHG emissions while building resilience to climate change and providing valuable ecosystem services, including services such as water filtration, flood buffering, biodiversity habitat, and temperature regulation.[532] For example, Colombo, Sri Lanka, is enhancing climate resilience and reducing flood risk by restoring wetlands,[533] without which the city would faces losses from flooding amounting to about 1% of GDP.[534] Increasing efforts to green low-income neighbourhoods, while welcome, should be carefully managed to avoid pricing out and displacing residents.[535]
- **Local governments should work with developers and civil society to ensure that densification is accompanied by a sufficient supply of climate-smart, affordable housing.** Proven strategies include fiscal support for public housing programmes, comprehensive protection for renters, legal requirements that new residential developments include affordable housing, and the formation of public land banks and community land trusts to acquire properties for redevelopment. Since the 1990s, Japan made it easier to re-zone urban land, re-purpose office sites for housing and construct taller apartment buildings. The expanding housing supply has meant that rents and house prices have risen at much slower rates than in many Western cities. Denver, Colorado, has been one of the most proactive cities in the United States, creating the Affordable Housing Trust Fund in 2015, a revolving fund that offers finance to low-income housing developers that is anticipated to grow to US$150 million over the next 10 years.[536] A suitable regulatory environment can also ensure that residential construction is climate-smart and keeps pace with demand, including in smaller, high growth and newly urbanising areas.[537]

Box 25
People-focused Superblocks in Barcelona

Barcelona is among Western Europe's densest cities.[538] Although known for its rich culture and pleasant cityscape, Barcelona struggles with air pollution, noise, limited green space, social isolation and—increasingly—climate impacts.[539] Up to 85% of the city's area is dedicated to private vehicles (including parking spaces).[540]

Local authorities in Barcelona are tackling these challenges with an innovative Superblock model, piloted in the central neighbourhood of Eixample.[541] Eixample's widened, octagonal intersections were meant as meeting squares, but many are now utilitarian, unfriendly intersections dominated by traffic. Barcelona seeks to revitalise these public spaces. Superblocks will form mini-neighbourhoods, typically comprising 12 blocks (400x400 metres) that house 5,000—6,000 residents.[542] The Superblocks' surrounding roads serve through traffic, but internal roads are reserved for residents' vehicles travelling below 10 km/hr. This improves access and safety for pedestrians and cyclists, as well as the quality of public and green space.

Initial interventions in Eixample require minimal infrastructure—mostly signage, road markings, and street furniture. Future plans include permanent installations like playgrounds, 300 km of new cycling lanes (from today's 100 km) and 23 new ha of car-free space.[543] In September 2017, Barcelona created the newest Superblock on 40 acres in the El Poblenou neighbourhood, and another five are planned by 2018.[544] In addition to decreasing traffic by 21%, the effort could also reduce emissions by as much as 75%.[545]

Box 26

Green Spaces in Dense Singapore

Typically, the ranks of the world's most liveable cities are topped by larger low-density cities, such as Sydney and Vancouver, or smaller established cities, such as Vienna and Zürich.[546] A common exception is Singapore, which squeezes 8,155 people into every square kilometre.

One of the reasons for Singapore's liveability is the provision of high-quality urban greenery throughout the city, thanks to policies such as mandatory roadside plantings, which have ensured that trees have been introduced systematically with enough growing space to provide substantial canopy cover. This creates a pleasant urban environment: Trees, parks, and other green infrastructure help to reduce temperatures, filter air pollution, and mute street noise.[547] Where permeable, these surfaces can support storm water management as well as prevent overflow from combined sewers handling both rainwater and sewage. Importantly, Singapore has focused on the distribution and connectivity of parks, not just on the total area of parkland. Hundreds of kilometres of green, pedestrian park connectors mean that people have easy access to green space despite higher density living.

Between 1986 and 2007, green cover in Singapore grew from 36% to 47%, despite a 68% increase in population,[548] and reduced average temperatures by between 0.5 and 5°C.[549] This builds resilience to climate change while also mitigating GHG emissions as a drop of 1°C in air temperature lowers peak electricity demand by as much as 4%, which translates into reduced energy consumption and emissions.[550] The government now requires property developers to replace any greenery lost during construction and covers 50% of the costs of installing green roofs and walls on existing buildings, spurring innovations to develop lighter and more robust rooftop and vertical greening systems. These systems are also cheaper: The cost of greening fell from S$150/m2 to S$100/m2 in a two-year period.[551]

2.B. House Proud: Provide Sustainable and Affordable Housing for the Urban Poor

Today, 330 million urban households currently lack access to affordable, safe, secure housing—a number that is projected to grow to 440 million households by 2025.[552] Whether, where, and how housing for these people is built will determine the health and employment opportunities of one in five urban dwellers. These factors will also shape urban form and function for decades to come, influencing emission intensity and vulnerability to climate change and disasters. Smaller, fast-growing cities in particular have the opportunity to avoid sprawling, incremental, inefficient and disaster-prone development in peri-urban areas. Instead, governments can establish policies and plans that will provide low-income urban residents with climate-smart, affordable, efficient, and well-located housing, served by basic infrastructure such as piped water and sanitation (see also, Section 4.A). The challenge is to meet demand for housing and services today while establishing spatial forms that can underpin sustained economic development and maximise resource efficiency in the longer-term while also limiting the risks of climate change. (See also Section 1.B on energy and building efficiency).

Evidence of the Benefits

Housing is an important asset to increase economic security, especially for lower-income groups.[553] Improving the quality of housing can improve the productivity of home-based workers, who account for a significant share of urban employment (14% in India and 6% in South Africa) and are mostly women.[554] Safe and affordable housing could also dramatically improve health outcomes for urban dwellers by reducing the health costs associated with everyday risks and catastrophic events. Flooding, disease, pollution, and fire all impose a heavy health burden that is disproportionately felt by low-income urban residents;[555] further, life expectancy for the poorest 20% of urban residents hovers at around 55 years, compared to over 70 years for the richest 40%.[556] Experience in Ahmedabad, India, illustrates such health benefits as slum upgrading as more than halving the incidence of severe water-borne disease.[557] Increasing the supply of climate-smart, affordable housing would especially climate urban women, who are twice as likely as men to face violence[558] and have fewer capacities and resources to respond to shocks and stresses.[559]

There are significant opportunities to steer planned investment in shelter and related infrastructure and services towards low-carbon and climate-resilient options. For example, in waste management, recycling and composting require substantially less capital expenditure than landfill or incineration infrastructure. Using renewable energy and passive design to improve the energy efficiency of urban housing can enhance resilience to climate change. Distributed renewable energy generation (particularly photovoltaic solar or biogas) can be more economically attractive than connecting to the grid and may also allow the state to defer capital investments to maintain and upgrade grids.[560] For the very poorest, there is scope to improve the availability and cost of low-carbon, local building materials (such as bamboo or compressed earth blocks) that could also enhance the durability and resilience of self-build housing.

It is important that new housing stock is constructed in places that help cities to achieve good density and resilient development, particularly by aligning spatial and infrastructure planning in a sustainable way. This could yield immediate fiscal savings: Higher population densities offer economies of scale for infrastructure[561] and service provision,[562] enabling governments to reach more residents at lower cost (see also, Section 2.A). To realise these gains, governments will need to align land-use, housing, and transport policies.[563] Complementary investments in mass transit can effectively expand the supply of urban land, thereby driving down housing costs while cutting demand for transport energy. In Mumbai, for example, the construction of feeder BRT systems would make new housing settlements on the urban periphery more financially viable to low-income residents.[564] In some cases relocation or retreat of existing settlements will be required to move them out of harms' way.[565] However, care must be taken not to exclude or push poor residents to the peripheries of cities. Strong public institutions are needed to achieve this. Ultimately, building housing and infrastructure in a coherent way today will be much more cost-effective in the long-run, enabling cities to avoid retrofitting, relocating, and re-densifying in the future.

Challenges

About 881 million people live in slum conditions, primarily in sub-Saharan Africa and Asia, according to UN Habitat (see Figure 13).[566] These estimates, however, understate the scale of the shelter deficit. In Indonesia, for example, UN Habitat calculates that 27 million people live in slums. This excludes residents

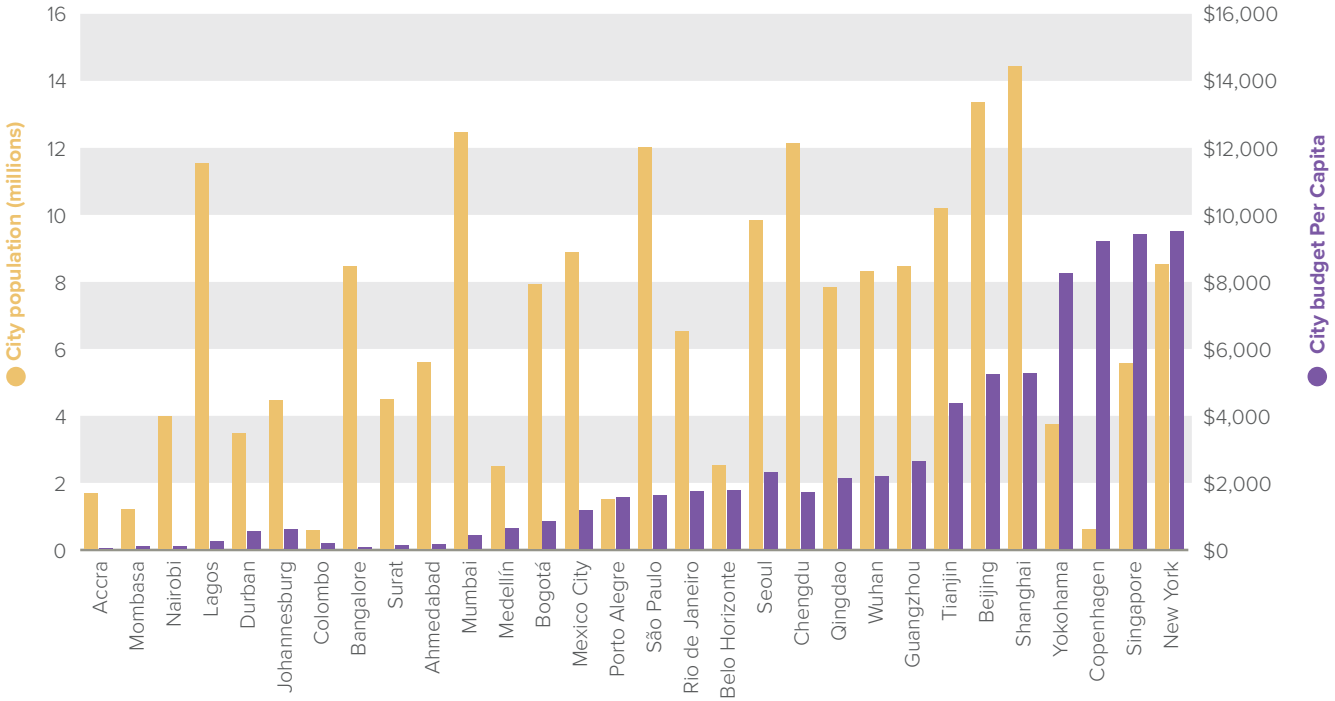
Photo credit: Flickr: Visty Banaj

with access to so-called improved water, namely from public taps, boreholes, protected springs, or other sources that do not necessarily provide safe or reliable drinking water in crowded urban contexts.[567] By applying a stricter classification that would more reliably indicate a safe water supply (such as water piped to a dwelling, yard plot, or neighbour), an additional 80 million urban Indonesians would be designated as slum dwellers. Applying more rigorous standards to 10 of the most rapidly urbanising countries suggests that official figures may understate the number of people living in slum conditions by at least 190 million (Figure 14)—nearly equivalent to the populations of Germany, France, and Spain combined.

The urban infrastructure deficit is likely to increase with rapid urban population growth. Most of the projected growth to 2050 is expected in smaller cities, many of which are the least prepared to manage such growth.[568] Municipal authorities in the most rapidly urbanising regions typically also have the smallest per capita budgets (for example, see Figure 12) and limited technical or institutional capacities.[569] These constraints make it difficult for governments to address pressing development needs, let alone shape urbanisation towards resilient, compact, and connected forms.

Figure 12

Cities in the Global North Typically Have Much Larger Budgets Per Capita Than Cities in the Global South, Irrespective of Population Size.

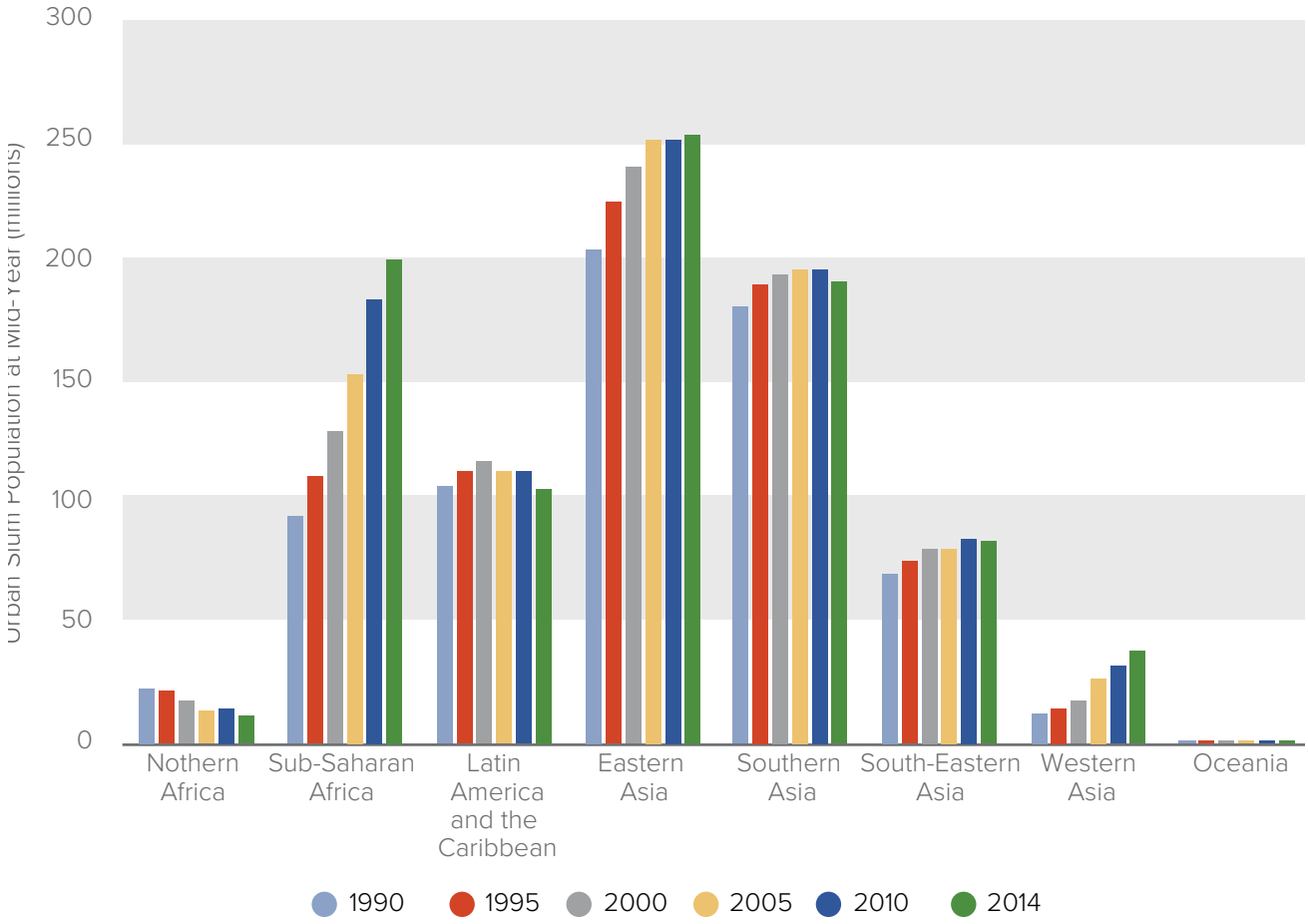


Note: Budget data represent years 2010—2016. Source: Beard et al. (2016).[570]

Policy distortions can further reduce the supply of urban land and housing and therefore increase their costs. Combined with low per capita incomes, increased costs keep many urban dwellers from participating in formal property markets. However, it is not solely economic factors that contribute to the chronic shortage in affordable, decent, formal housing. Discrimination in labour and land markets and a lack of legal or political rights means that the urban poor are vulnerable to abuse and exploitation.[571] As a result, informal shelter markets have developed in many cities.[572] In sub-Saharan Africa, for instance, over 75% of all housing stock is constructed informally.[573] Conventional urban planning, meanwhile, is often used to justify the eviction of low-income urban residents from well-located land.[574] This perpetuates poverty by reducing access to jobs, services, and amenities and contributes to sprawling urban forms with all their concomitant externalities, including increased vulnerability of the poor to climate change and disasters.

Figure 13

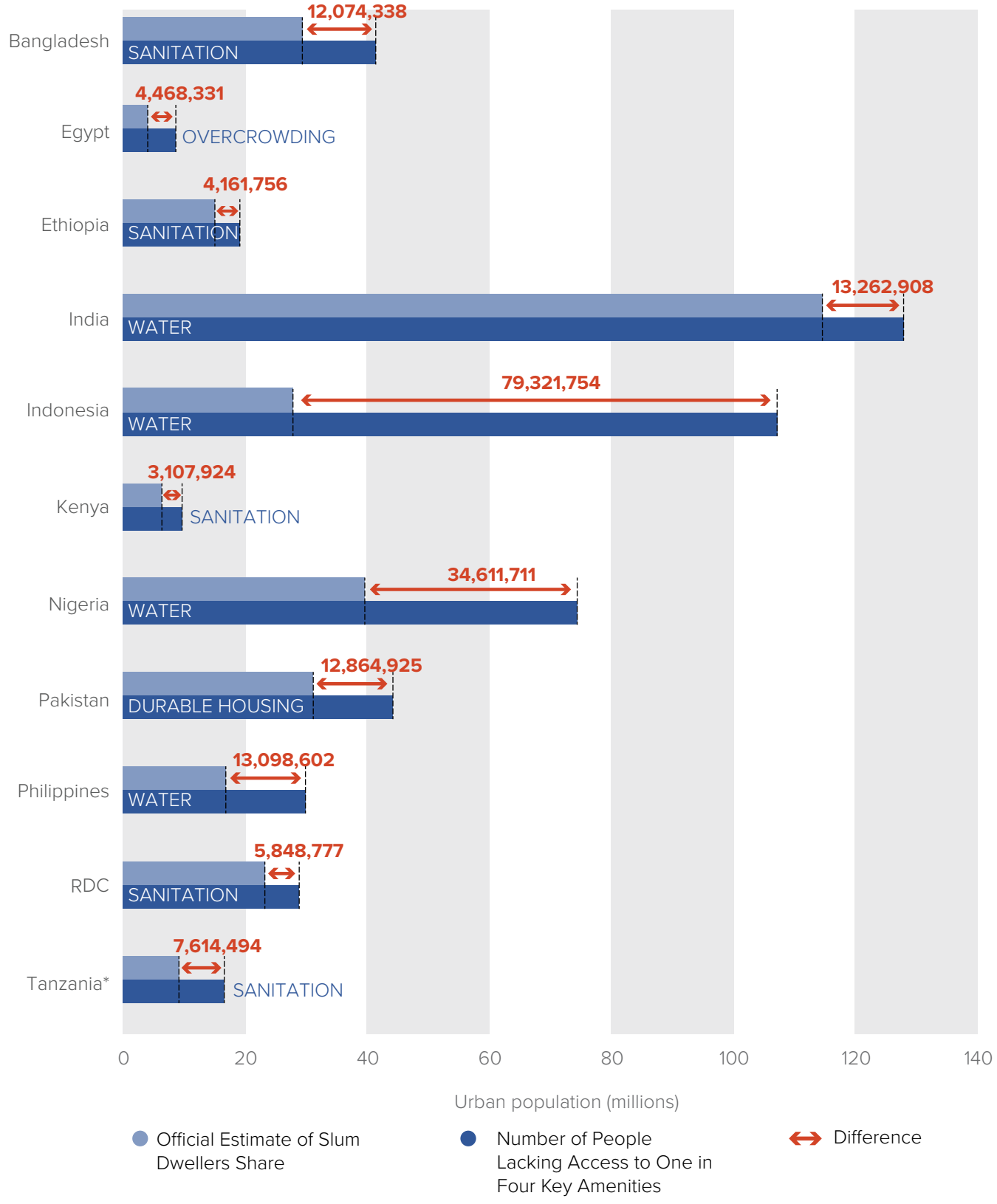
Official Estimates of the Proportion of the Urban Population Living in Slums are Based on the Number of Households Lacking Access to (i) Improved Drinking Water Sources; (ii) Improved Sanitation Facilities; (iii) Durable Housing; and (iv) Sufficient Living Space.[575]



Source: Coalition for Urban Transitions. Data source: UN Habitat.[576]

Figure 14

Underestimations of the Slum Population in Ten Rapidly Urbanising Countries.



Source: Coalition for Urban Transitions. Data source: UN Habitat[577] and national demographic and health surveys.[578]
Note: This figure shows official estimates of the urban population living in slums contrasted to the number of people lacking access to decent housing and basic services using more rigorous metrics: a piped water supply, a flush/pour latrine, durable housing and no more than three people to a room.

Photo credit: Flickr: Kzoop

Accelerators

- **Local governments can make serviced land available to low-income households at affordable prices and with occupancy rights.** This may need innovative titling arrangements to manage the risk of sale and gentrification, for instance, supporting collective tenure as the Baan Mankong programme did in Thailand (see Box 27). Local authorities and utilities should preferentially extend trunk climate-smart infrastructure to low-income neighbourhoods, as the per capita costs of networked solutions (such as sewers) are much cheaper than for individual solutions (such as septic tanks). (See also Sections 4.A and 4.B on water and resilient infrastructure). Involving local residents in planning and implementation can also dramatically reduce the costs of sustainable infrastructure development. In Karachi, Pakistan, for example, the cost of community-financed and managed infrastructure came in at a quarter of the cost of government-developed sewage systems.[579]
- **National and local governments should relax restrictions that constrain the supply of low- and middle-income housing and put in place enabling policies, that can unlock investment.** Building codes should be reformed to permit smaller plot sizes, higher floor area ratios, and support for incremental construction to enable self-build housing, while also ensuring it is climate-smart.[580] In Windhoek, Namibia, for example, this approach enabled the creation of affordable, formal housing units by low-income urban residents.[581] Financial organisations can also be created, supported, or mandated by governments to provide low-cost microloans to formal and informal households or communities. In Kenya, for instance, the Akiba Mashinani Trust provides loans with an annual interest rate of 10%, compared to 16% from commercial banks and 22.6% charged by microfinance institutions, to pay for land acquisition, greenfield housing development, and in-situ slum upgrading.[582]
- **MDBs should collaborate with grassroots organisations of the urban poor to ensure that marginalised groups have avenues to shape policy and programming.** Ensuring that connectivity, inclusivity, and resilience are at the heart of urban planning processes will be essential for resilient, prosperous cities. Community-based organisations, such as those federated within Shack/Slum Dwellers International and the Asian Coalition for Housing Rights, can construct housing, co-produce infrastructure, and shape urban land use in an inclusive and environmentally efficient way.[583] MDBs and development agencies can empower these organisations by providing bridging capital and project management expertise and by fostering relationships with commercial banks and other private investors.[584] This assistance can unlock substantial public and private capital, including mortgage finance, to scale affordable housing projects. For example, community engagement is key in a number of ADB projects supporting urban redevelopment and services in Ulaanbaatar, Mongolia, including a pilot on green, affordable housing which is co-financed by the Green Climate Fund and will be driven in part by private investment. These projects are using community development councils to advise on project implementation and increase community-based monitoring and control over service provision.[585] Engaging early with public and private stakeholders, from governments to local businesses, potential investors and community-based organisations, will help to ensure projects are bankable.[586]

Box 27

Improving Housing Conditions in Urban Thailand

Between 2003 and 2010, the Baan Mankong programme in Thailand improved the housing security and conditions of over 80,000 households across 249 urban areas.[587] The programme channels government funds, in the form of infrastructure subsidies and soft housing and land loans, directly to poor communities, which plan and carry out improvements to their housing, environment, and basic services themselves. In most cases, communities pursued in situ upgrading, secured legal tenure and connected to water and sewage systems. The programme also enabled communities to relocate to reduce their exposure to environmental hazards, which was critical, given the 13 million people affected by the 2011 floods in Bangkok.

The Baan Mankong programme was introduced and coordinated by the national government, which established a revolving fund to provide housing loans with subsidised interest rates and long repayment periods, as well as infrastructure subsidies to low-income residents living in informal settlements.[588]

The programme established a unique city-scale approach to slum upgrading, integrating low-income households into the social and physical fabric of the city. Local governments worked with low-income communities to secure legal tenure in their existing settlements or nearby parts of the city, using a combination of new planning permissions, leasing arrangements, land-sharing with formal land owners, and cooperative land titles.[589] The programme emphasised collective approaches to planning and upgrading, which helped build social capital and capabilities within low-income neighbourhoods.

The fund was initially capitalised with public capital but is now substantially resourced through private banks and loan repayments.[590] The total public investment of less than US$100 million,[591] translated to less than US$1,250 per household, further reinforcing the cost-effectiveness of community-driven upgrading, compared to conventional approaches.

The programme is still running in Thailand, and key features, such as the revolving fund and community-led upgrading processes, have been adopted in over 200 urban areas across Cambodia, Nepal, the Philippines, and Sri Lanka.[592]

2.C All Aboard: Shared, Electric, Low-Carbon Transport

Urban dwellers need transport to access jobs, services, and amenities. However, urban transport networks are often not convenient, flexible or affordable. Where they already exist, many struggle to keep up with increased ridership or maintain aging infrastructure. Existing urban transport systems are also responsible for over 11% of total global energy use—equivalent to about double the entire energy consumption of Africa[593]—and about 18% of global CO_2 emissions.[594] Where urban areas and transport systems are yet to be built, planning needs to embrace public and non-motorised transport.[595]

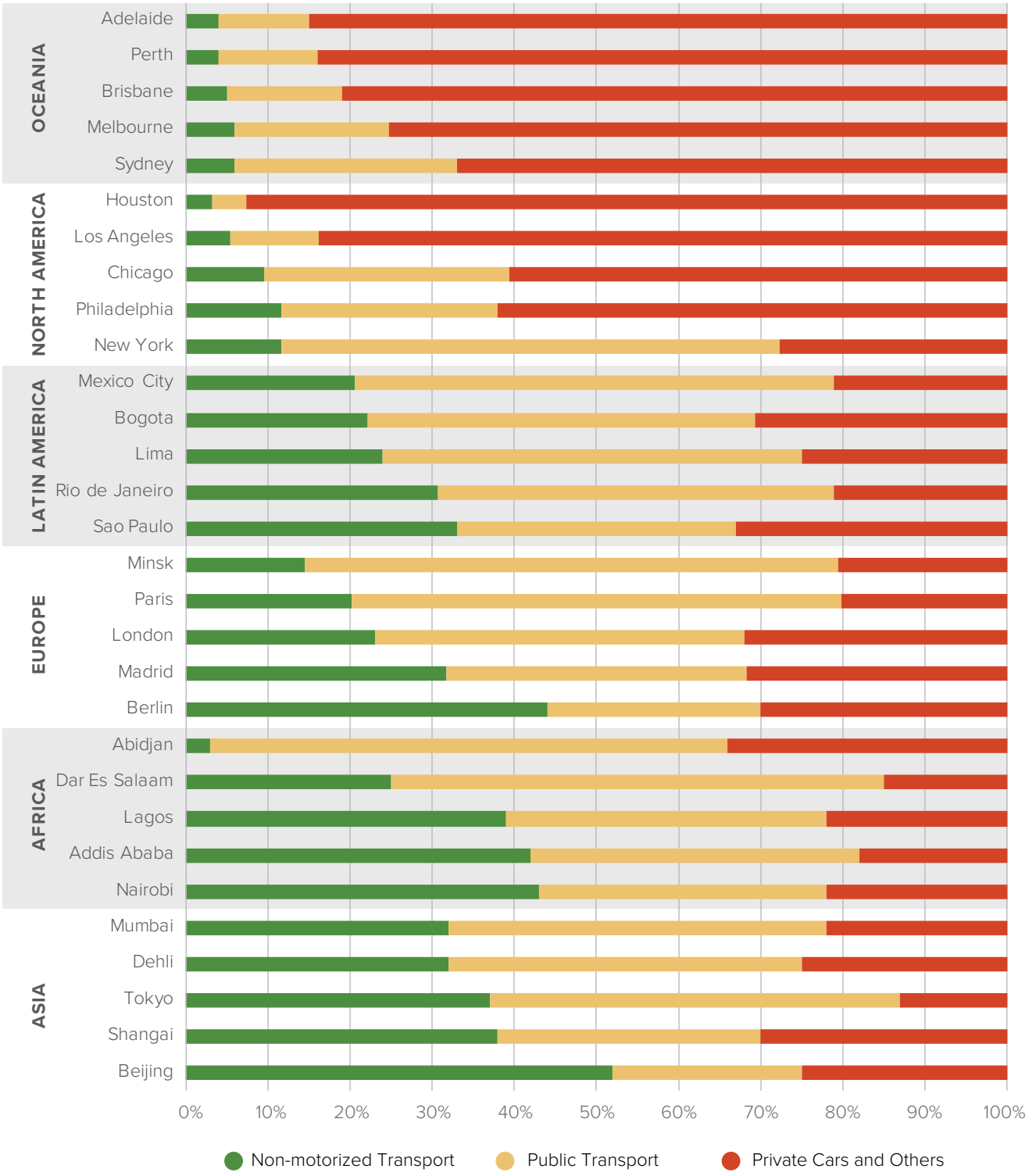
The more private cars there are on city roads, the greater the costs associated with air pollution, noise pollution, congestion, traffic accidents, and sprawl. In 2010, OECD countries incurred health costs of US$1.7 trillion from transport-related air pollution.[596]

Air quality is even worse in cities of the global South, where as much as 90% of air pollution can be attributed to cars in some cities.[597] Dependence on private cars also leads to more road crashes (which costs up to 5% of GDP in developing countries)[598] and more congestion (which costs 5% of GDP in Beijing, Sao Paulo, and Bangkok).[599]

Urban form and transport modes must shift for cities to meet 21st century challenges. Larger cities in North America and Oceania have typically invested heavily in car-based transport systems, with much urban land used for roads and car parks. Counterparts in Europe and Latin America are more likely to have well-developed public transport systems and cycling networks. In urban Africa, widespread poverty means that a large share of trips continue to be made on foot. Asian cities are more varied, but the trend is towards increasing dependence on private cars and commensurate urban sprawl. Historical patterns of and behavioural preferences for different types of urban transit continue to determine how people move

around cities today, as well as the strategies available to cities to enhance accessibility and decarbonise transport. However, rapid population growth means that swaths of new urban infrastructure will soon be built, particularly in the developing world, offering opportunities to leapfrog directly to active and shared transport modes.

Modal Share for Five of the Ten Largest Cities in Each Region, Divided into Non-motorised Transport (Walking and Cycling), Public Transport, and Private Motorised Options.



Source: Coalition for Urban Transitions.[600]

Evidence of the Benefits

In the near-term, investing in low-carbon transport infrastructure creates more jobs than those in car-based systems. A review across 11 American cities found that about 50% more jobs were generated by investments in cycling projects than road projects, with pedestrian projects averaging between the two.[601] In the longer term, net economic savings from reduced transport-related energy expenditure are estimated at US$10.5 trillion between 2015 and 2050.[602] These gains would be largely enjoyed by the urban poor: The average urban resident spends as much as 16% of household income on transport, while the under-served resident spends up to twice that share of income.[603] Results from the E3ME modelling analysis undertaken for this Report indicate that under a scenario of accelerated EV uptake, there would be an increase in employment in the motor vehicle sector engaged in EV production of half a million people globally by 2030 relative to baseline. This is associated with a larger value of the sector's GDP from higher sales relative to the base case. Under this scenario, reductions in air pollution could save 385,000 lives globally in 2030.[604]

Overall health and energy benefits from improved pedestrian and cycling amenities could recoup more than five times the initial investment cost.[605] The transition to walking, cycling, and public transport would particularly benefit low-income groups (see, for instance, the example of Medellin, Box 28), who are less likely to own cars but are more likely to be the victims of traffic accidents and to live and work in polluted areas.[606] It is important that new transit infrastructure is designed in ways that ensure the safety of women and other potentially vulnerable groups.[607] Harassment and physical abuse on public transport[608] has meant that poorer women lose out on economic or educational opportunities, while those who can afford to, switch to private car options.

Box 28
Medellin's Cable Car

Medellin, Colombia, sits in a valley, bordered by steep mountainsides that hold the *favelas*. These informal settlements were notoriously violent during Colombia's drug wars in the 1990s and are still among the city's poorest neighbourhoods. Traveling to the city centre took several treacherous hours on foot or depended on infrequent and unreliable buses.[609] This made it difficult for residents to access jobs, education, and other services.

Since the mid-2000s, Medellin's *favelas* have seen a transformation, much of which is credited to the installation of a cable car system. Opened in 2004, a network of nine cable car lines brings *favela* residents down the hillsides in 25 minutes for US$0.60.[610] About 30,000 favela residents use the system daily,[611] doubling residents' access to employment opportunities.[612] Strikingly, neighbourhoods with cable cars experienced 66% fewer homicides in 2012 than comparable neighbourhoods without them.[613]

Challenges remain, including improving the accessibility of the cable cars to all *favela* areas (walking and queuing times can exceed one hour at peak); their vulnerability to electricity outages; and their limited usage by women, children, and the elderly or infirm.[614]

Given their ability to connect hilltop areas to lower central zones cheaply and with less disruption to existing land uses, cable cars are growing in popularity.[615] Several other urban cable cars projects are operating in Latin America (Rio de Janeiro, Caracas, Guayaquil, Santo Domingo, La Paz, and Medellín), Asia (Yeosu, South Korea, Taiwan, Hong Kong), Africa (Lagos, Constantine), and Europe (London, Koblenz, Bolzano). The World Bank estimates that they cost US$10-25 million per km and can carry 1,000—2,000 passengers per hour in each direction, which compares favourably to BRT systems.[616]

At the same time, improving cycling and walking infrastructure through low-cost interventions—such as investing in street lighting, segregating cycle lanes and bike parking, and separating sidewalks and pedestrian crossings—can quickly recover public investments through health savings. For instance, if a quarter of all trips in European cities were by bike, the region could prevent 10,000 premature deaths each year.[617] More than 500 cities have constructed bicycle share schemes in the last 20 years.[618] Cities could draw from the experience of Rwanda's capital, Kigali, which has constructed an elaborate network for pedestrians including car-free streets—or Vienna, Austria, which has installed additional lighting to make walking at night safer for women.[619]

Challenges

Public transport infrastructure comes with significant challenges at both institutional and financial levels. Mass transit typically requires substantial capital expenditure, and cities in the developing world tend to have limited fiscal autonomy and a narrow resource base, and are often dependent on sale of publicly owned land to developers to raise revenue.[620] Additionally, governments may adopt high discount rates or use narrow cost-benefit analyses, which means that they do not always account for the long-term economic returns associated with transport investments, such as reduced expenditure on fuel and improved access to opportunities or agglomeration economies.

Effective land-use and transport planning are essential to construct compact and connected cities. However, many governments lack the technical or institutional capacities to design, construct, and operate public transport systems or to integrate transport with land-use planning.[621] Acquiring land for transport routes is typically expensive and complicated, especially in more established cities. If not managed carefully, land acquisition can lead to the displacement of informal settlers along proposed transport corridors.

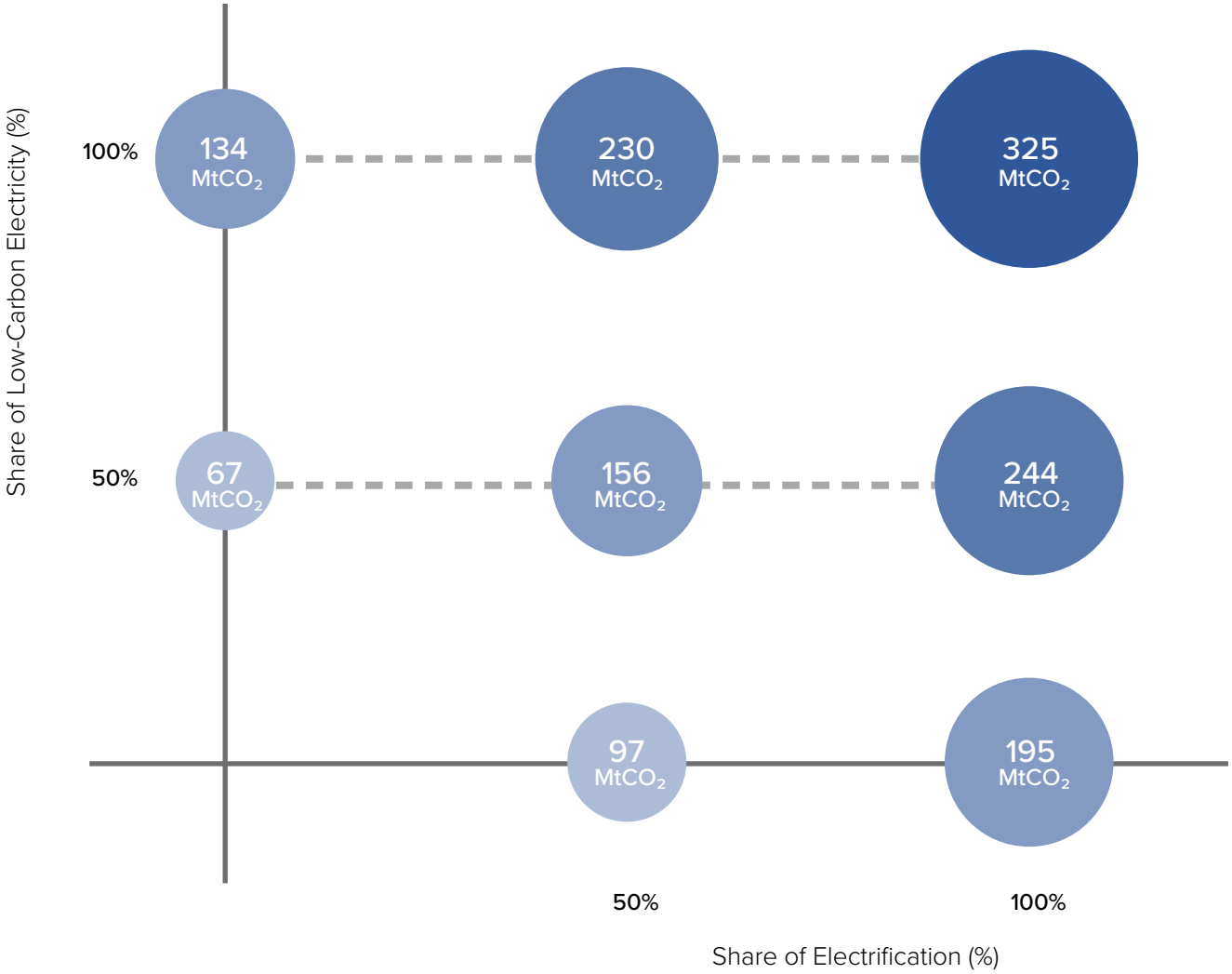
Electrification of the transport sector has the potential to reduce GHG emissions and local pollutants[622] and would likely require less radical changes to the built environment than a modal shift away from private cars to public or non-motorised transport. However, a transition to EVs will require substantial investment in grid capacity and charging infrastructure (see, for instance, China's example in Box 30). Achieving the full mitigation potential of GHG emissions and other air pollutants from electrification will also depend on shifting rapidly to renewable electricity sources to avoid trade-offs (Figure 15),[623] and this effort will require transit agencies to coordinate effectively with utilities and energy agencies.

In addition to the institutional and financial challenges, modal shifts and the electrification of the transport sector require behavioural changes from city dwellers themselves. Given historical patterns of transport, costs, and the private benefits that can come with urban sprawl (increased privacy, space, access to amenities, etc.), transport preferences can be difficult to change rapidly.

Photo credit: Flickr: New York City Department of Transportation

Figure 16

The Mitigation Potential ($MtCO_2e$) Associated with Varying (1) the Share of Low-carbon Sources in the Electricity Mix and (2) the Levels of Electrification of Transport Modes in 21 Megacities.



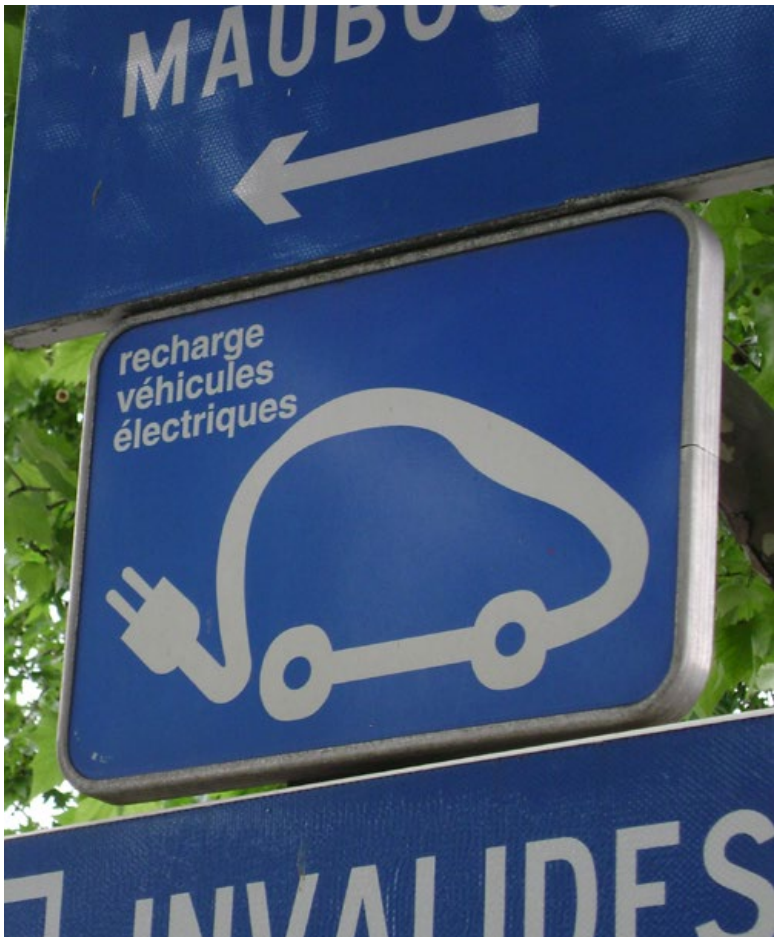
Source: Westphal and Kennedy (forthcoming).[624]

Accelerators

- **Local governments should prioritise investments in active, non-motorised, and shared transport and disincentivise the use of private vehicles.** This will help avoid 'green congestion' or 'electrification of congestion' and favour the expansion of pro-poor mobility networks. Low-cost interventions, such as street lighting, segregated cycle lanes, bike parking, separated sidewalks, and pedestrian crossings, can make walking and cycling more attractive and safer, especially for women. Bicycle share schemes have proliferated over recent decades. Kigali[625] and Vienna[626] are exemplars in terms of pedestrianising and making walking at night safer for women. Complementary policies can be adopted to deter car use. Stockholm, Singapore, Milan, and London have adopted congestion pricing,[627] while Nanjing Road in Shanghai, Broadway in New York, and Jalan Sudirman in Jakarta are car-free spaces. Reducing the availability and increasing the cost of parking spaces has proven highly effective in many European cities in incentivising non-motorised transport use.[628]

- **State and local governments should accelerate the deployment of land value capture (LVC) instruments to finance new transit-oriented infrastructure, enabled by national governments.** LVC instruments allow governments to capture a proportion of the uplift in land and property values associated with public investments. The use of LVC instruments at the local or regional level typically needs to be enabled by constitutional, statutory, and policy frameworks created by the national government.[629] LVC instruments have been used in such diverse cities as Bogota, Hong Kong, Hyderabad, and Tokyo,[630] but they remain under-utilized in the developing world (see Box 46 on LVC in Morocco). In Hong Kong, the "Rail Plus Property" LVC model has allowed the Mass Transit Railway (MTR) operator to capture the increase in property values along transit routes to fund railway maintenance and expansion. The government grants development rights around railway stations and depots to the MTR operator, which then builds properties in partnership with private developers. MTR receives a share of the profits from these properties, which it uses to cover their capital and operating costs. MTR is 77% owned by the government, which received a financial return of about US$18 billion on its investment between 1980 and 2005.[631]
- **Central governments should coordinate with national and local planning, energy and transport agencies in order to support the electrification of transport.** This might entail planning, procuring battery electric public transport, and financing in charging infrastructure, as China has done through its New Energy Vehicle programme (Box 30) or incentivising EVs through subsidies or low-emissions zones in cities like in Norway and the Netherlands.[632] This should be accompanied by city-led pilots and targets for electrifying public fleets, as Bogota has done by replacing diesel buses with electric or hybrid buses. To deliver the full climate and air quality benefits, governments and utilities must increase the capacity and reduce the carbon intensity of the electricity grid. At scale, electrifying the transport sector could mitigate 7% of global GHG emissions,[633] roughly equivalent to India's share of global emissions.[634]
- **MDBs and development agencies should support governments, particularly in low-income and lower middle-income countries, to maximise financing and increase technical assistance to accelerate the development of public transport in cities.** Mass transit must be tailored to local contexts and constraints, as with Nigeria's Lagos BRT-Lite system (Box 29) and Colombia's Medellín Metrocable (Box 28). While eight MDBs have committed to provide more than US$175 billion in finance for sustainable transport over this decade (2012—2022), road projects still dominate their investments.[635] The MDBs need to shift more investment to sustainable urban transport and planning. An example is the ADB's US$35 million loan to co-finance a bus rapid transit system and other transport innovations—from paid parking to better pavement for improved walkability—in Vientiane, Lao PDR.[636] MDBs and development agencies also bring substantive expertise in context-specific planning and construction in ensuring gender-sensitive and climate-resilient transport provisioning and in helping local agencies to procure equipment, operators, and digital technologies. DFIs can also play a key role in working with governments to manage early project risk to crowd in finance from private sources.[637]

Photo credit: Flickr: David Megginson



Box 29

Lagos BRT "Lite"

With a population of 21 million, Lagos in Nigeria is the largest city in Africa and the seventh fastest growing city in the world. Like many rapidly growing cities, Lagos' economic growth and development has been hampered by its transport system. Chaotic, slow, and unreliable, transit in Lagos has been dominated by thousands of yellow mini-buses called Danfos. In 2008, Lagos became the first African city with a BRT.

Lagos's 'BRT-Lite' opened on a 22 km,[638] 65%-segregated route with three terminals.[639] At just US$1.7 million per km, it cost a fraction of the US$6 million per km average of premium BRTs. The public transport operator, LAMATA, dropped features like level loading and fancy stations that did not fit Lagos's budget, enabling them to recoup their investment in just 18 months.[640] LAMATA was also able to secure substantial private investment: Private operators directly procured 100 new buses and leased a further 120 buses from a state-owned company.[641]

As of 2017, the Lagos BRT-Lite's 300 buses carry 200,000 passengers daily, with an average journey of 30—55 minutes. This is a time saving of 30% on average,[642] complemented by reduced transport expenditures of as much as 31% for low-income households along its route. Along its corridor, the Lagos BRT-Lite carries 25% of commuters while accounting for only 4% of vehicle traffic. Road accidents have decreased significantly since its construction,[643] and the project generated 2,000 jobs. A final benefit: Carbon emissions are down by as much as 13% along the corridor, and particulate matter reduced by 48%.[644]

Box 30

EVs Taking Hold in Chinese Cities

Chinese cities are at the forefront of transport electrification, thanks to clear policies and generous subsidies provided by the national government. China's ambitious efforts have, in part, been motivated by severe air pollution—up to 70% of Beijing's emissions come from transport, and some cities experience up to 129 days of emergency-level smog each year—as well as by climate mitigation targets and the opportunity to benefit the economy by capturing a growing share of a valuable new manufacturing sector.[645]

The national government invested over US$7 billion across every stage of the EV lifecycle.[646] This effort started in 2009 with the "10 cities, 1000 vehicles" programme, involving large-scale pilot projects electrifying public fleets with predictable driving patterns (such as buses, garbage trucks, and taxis). The up-front costs of the large lithium-ion batteries proved too high for commercial vehicles but are compatible with the investment abilities and long investment horizons of China's public agencies. This public procurement policy helped manufacturers achieve economies of scale and knowledge spillovers for the production of private electric passenger vehicles. The national government also helped local authorities to install chargers necessary for private ownership of EVs.

In 2015, China became the world's largest market for electric private passenger cars,[647] and the New Energy Vehicles Programme has a target of reaching 20% of the total vehicle market demand by 2025. As of 2017, the country had a total of 632,371 private electric cars on the road and an additional 200 million electric two-wheelers, 300,000 electric buses, and up to 4 million low-speed, two seater EVs.[648] Shenzhen alone has 16,359 electric buses and 12,518 electric taxis.[649]

E3ME modelling results for this Report show gains in employment, health improvements, and value addition from a scenario of global accelerated uptake in EVs. In China, EV ownership could increase to about 3 vehicles per 100 people by 2030, leading to an increase in total employment in the motor vehicle sector of more than 126,000 people and value-added gains in the same sector of more than 6% relative to the baseline. Under this scenario, in 2030, more than 110,000 deaths due to air pollution could be averted.[650]

SECTION 3

Food and Land Use

Photo credit: Flickr: World Bank

The global food and land use system is at a pivotal moment. Continuing down our current path will undermine the world's ecological foundations. It will also contribute significantly to a series of challenges, including rural poverty, social conflict, hunger, obesity, malnutrition, biodiversity loss, soil erosion, and climate change. Fix it, however—based on tried and tested policy reforms, better agricultural techniques and financial instruments, and the innovations these measures are sure to catalyse—and our food and land use system could instead provide stronger and more equitable rural socioeconomic development, deliver over one-third of the climate change solution,[651] keep secure our vital biodiversity, and generate massive improvements in public health. There is a clear economic case for fixing this broken system: Recent analysis has shown that developing sustainable food and land use-business models could be worth up to US$2.3 trillion and provide over 70 million jobs by 2030.[652] In short, the transition to sustainable food and land use systems represents an opportunity that no country, nor indeed the world, can afford to ignore. Not making the transition, meanwhile, entails risks and costs that no responsible leader should accept.

Current trends are disturbing. Despite the scale and urgency of this problem, today's food and land use system is failing to generate sufficient innovation, investment and attention.[653] Forest-related finance for countries with high rates of deforestation accounts for less than 3% of global climate mitigation-related development funding (see Box 32 on Finance for Food and Land Use).[654] Global demand for land to grow fuel, feed, and fibre is driving widespread deforestation and forest degradation, with just four commodities—palm oil, soy, beef, and wood products—accounting for more than 40% of tropical deforestation.[655] The effect on natural infrastructure is alarming: Biodiversity has declined by more than a quarter in the past 35 years.[656] The ramifications of broken food and land use systems on public health are also significant and growing. The convergence of global eating habits on resource-intensive Western-style diets—with the associated commodity consumption driving increased deforestation—is a major contributor to the rise of diet-related, non-communicable diseases that are rapidly becoming a leading cause of human mortality.[657] Around 2 billion people are obese or overweight.[658] At the same time, persistent inefficiencies and inequalities in the food system continue to leave 815 million people hungry[659] while a third of all the food that the world produces is lost or wasted.[660] Sticking with our current, unsustainable consumption models will only push these systems further out of balance as the global middle class, with higher incomes and consumption patterns, is expected to number 2.6 billion by 2025, with over 70% of that expansion in emerging markets.[661]

Instead, fixing our broken food and land use system could generate stronger, more resilient and inclusive economic growth, as well as better, more decent work for the several billion people whose livelihoods depend on food, forests and agriculture.[662] Reforming agricultural subsidy regimes, worth on average US$519 billion per year (2014-2016), that often lead to inefficient and inequitable economic, development and climate outcomes, could free up valuable public resources with which to achieve a better a food and land use system.[663] Halting deforestation could boost the global economy by as much as US$80 billion per year, as well as make it more resilient to a changing climate.[664] With a third of the planet's land degraded,[665] a global effort to restore degraded lands either to natural forest or to productive use could generate major economic, employment, and climate gains. In the United States alone, restoration and conservation activities generate an estimated US$3.8 billion a year and currently sustain 126,000 jobs.[666] Coupled with a strong commitment to forest and ecosystem protection, sustainably increasing agricultural productivity is essential to meet growing food demand and achieve equitable rural growth. While there have been striking productivity increases in many regions, achieving further productivity gains while reducing agriculture's climate footprint is possible and needed (see Figure 22).[667] Agriculture accounts for almost 70% of total employment in low-income countries worldwide,[668] which means that increasing yields and incomes will play a fundamental role in boosting rural livelihoods and ensuring country-wide economic development. Well-managed natural infrastructure can provide sustained economic benefits, which are particularly important for low-income countries, where natural capital constitutes nearly half of the wealth.[669] Women also have a vital role to play: If given equitable access to resources, women farmers could help alleviate hunger for 150 million additional people,[670] and there are important efforts under way to increase women's access to knowledge, technology, and resources in the food and land use sector.[671]

On the public health front, shifting diets from those heavy in animal-based and processed foods—and especially away from beef—towards more plant-based diets could result in global public health benefits, health-related cost savings of almost US$1 trillion per year by 2050,[672] as well as significant positive environmental impacts. Reducing food loss and waste is a major economic prize, as well as a moral obligation. Saving just one-quarter of the food currently lost or wasted would be equivalent to the amount of food needed to feed 870 million people annually.[673] Reducing food loss and waste also makes good business sense: Recent research of surveyed companies found a median benefit-cost ratio for investments of 14:1.[674]

In each of these action areas, momentum to reform our food and land use systems is growing, with a number of countries, subnational regions and companies showing the way. In addition, several valuable global collaborative efforts, platforms and sets of champions have emerged to raise ambition and accelerate efforts to reform food and land use systems. Examples of steps in the right direction include the Global Climate Action Summit's '30 x 30 Forests, Food and Land Challenge': A challenge to non-state actors across all sectors of the economy to take concrete action to ensure better forest and habitat conservation, food production and consumption, and land use, estimating that such action can deliver up to 30% of the 'climate solutions' needed by 2030. The Consumer Goods Forum's (CGF) Zero Net Deforestation Resolution, a resolution by companies to achieve zero net deforestation by 2020 in key commodity sectors, is another. The CGF's associated partnerships, like the Tropical Forest Alliance 2020, are also helping to turn commitments into action. The New York Declaration on Forests has galvanised a coalition of stakeholders—countries, sub-national governments, companies, indigenous groups, and NGOs—with ambitious global targets to protect forests and end natural forest loss by 2030. The Bonn Challenge, a commitment to restore 150m ha of degraded land globally, created a rallying cry for countries to undertake restoration activities. Building on this, international initiatives AFR100 in Africa and Initiative 20x20 in Latin America are driving significant activity locally. Coalitions and multi-stakeholder partnerships such as the Better Buying Lab and Champions 12.3 are working to accelerate sustainable consumption patterns and efforts to reduce food loss and waste, respectively.

But to truly the fix the food and land use system, piecemeal progress to date must rapidly become a global effort to address these challenges in an integrated and systemic way, at scale. A first-order priority is to close the forest frontier once and for all through a combination of measures including land tenure reform, strengthening protected areas and indigenous peoples' reserves, effective law enforcement, and measures to ensure that agricultural development takes place on non-forested and degraded lands. Efforts to bring more 'radical transparency' to food and land use systems also need to be rapidly scaled. Enhanced transparency, traceability and legality, enabled by satellite imagery and other technologies, is now more feasible than ever before, thanks to tools such as Global Forest Watch

Photo credit: Flickr: Dow Maneerattana, World Resources Institute

and Trase.[675] The publication and disclosure of detailed supply chain sourcing data from agribusinesses and traders is required to enhance financial transparency and accelerate meaningful actions by companies and investors.

To scale these and other solutions, smarter and more diverse flows of finance must be innovatively deployed to address food and land use finance gaps and policy incoherence. For example, there are ample opportunities to make smarter use of public finance by reforming agricultural subsidies, implementing 'full cost accounting' or price reforms on selected foods, and using blended finance structures. In addition, promising food and land use innovations and new business models—from technologies to lower the cost of planting trees, to lab-grown meats and new forms of alternative proteins, to offering consumers healthier, more plant-based food options (see Box 31)—require further investment and the right policy and investment environments to achieve transformative scale (see Box 32). Governments and the private sector also need to strengthen their actions to reduce food loss and waste and ensure a sustainable, nutritious, and healthy diet for all.

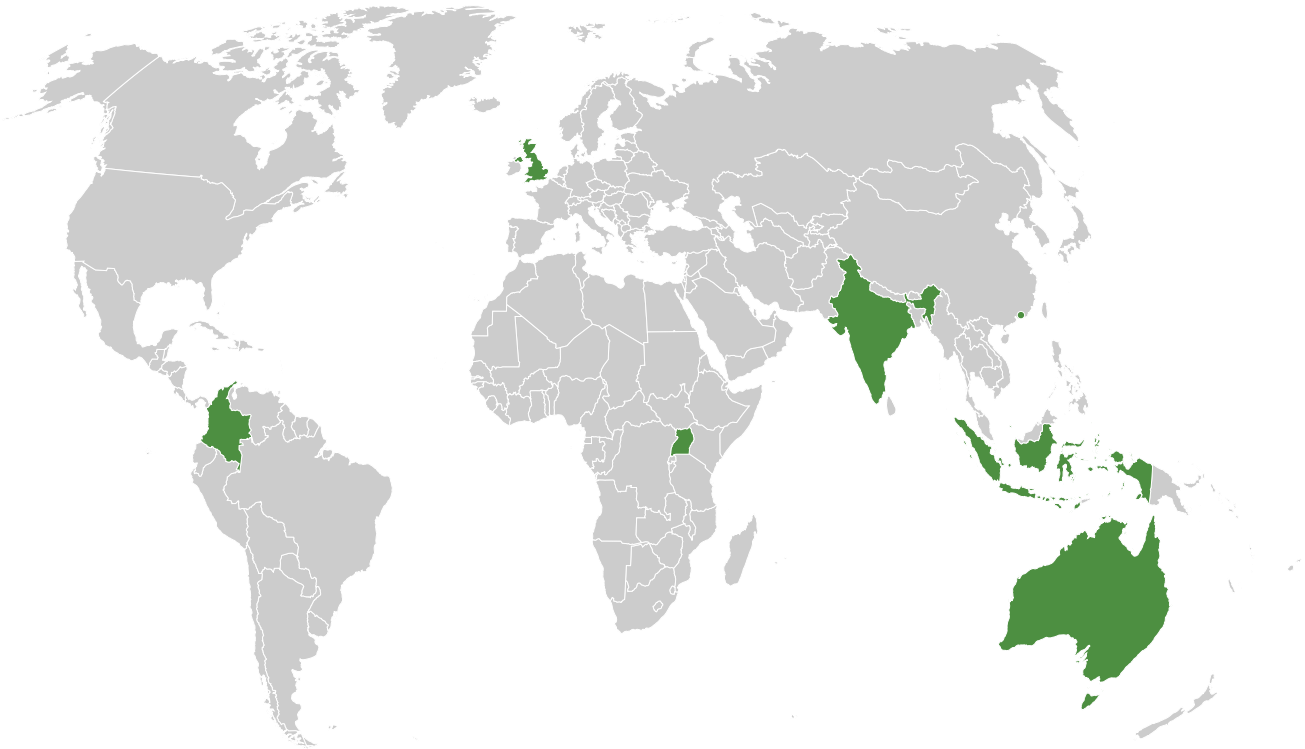
Box 31

Pret a Manger Enjoys Green Growth[676]

In 2016, café and sandwich brand Pret a Manger increased and improved the range of vegetarian and vegan recipes on their menus. A pop-up vegetarian-only outlet opened in London in the summer, accompanied by a "Not Just for Veggies" campaign. This promoted non-meat and plant-based dishes as appealing alternatives, particularly to non-vegetarians. The campaign was a significant commercial and reputational success. Sales in the pop-up surged, resulting in the decision to keep it open and to open two more 'Veggie Prets' in London in 2017. The brand credits its company-wide success in 2016 to its strengthened vegetarian range: UK sales rose by 15% compared to 2015 and profits by 11% to £93.2 million.[677] Pret launched their 'Not Just for Veggies' campaign in the United States, Hong Kong and France in 2017, including adding a 'Veggie Booth' in all of their Hong Kong stores. On launching the Hong Kong campaign, Pret enjoyed three weeks of record-breaking sales.[678]

Figure 17

Locations of Transformative Examples in Food and Land Use Highlighted in this Report.



Box 32

Finance for Food and Land Use

The transformation of the world's food, forests and land use system is critical to achieving economic growth, climate action, and the fulfilment of the SDGs. For many low-income countries, natural capital remains their most important asset—constituting over half their overall wealth. Public, private, domestic and international flows of finance will need to be substantially redeployed and re-tailored to deliver a new food and land use economy capable of nurturing and restoring this natural capital, and in so doing meeting the Paris Agreement and the SDGs.

Despite the scale of the role that the food and land use sector must play in delivering emission reductions by 2030,[679] since 2010, less than US$1.2 billion per year of global climate finance is estimated to have been invested to limit GHG emissions from deforestation and land use—a striking mismatch.[680] Indeed, overall investment in 'natural' infrastructure—forests, wetlands, peatlands, mangroves, and other critical ecosystems—is grossly undercapitalised and overlooked, despite its critical role in sustaining the climate and enabling development.

Halting deforestation, restoring degraded land and achieving more sustainable, climate smart agriculture will require much larger investments in these areas than those that exist today, particularly in developing countries. The private sector has a particularly critical role to play. For instance, previous work undertaken for the Global Commission estimated the gross investment needed to restore 350 million hectares of degraded forest landscapes to be between 2015 and 2030 at between US$350 billion and US$1 trillion, or US$23—67 billion per year, exclusive of land values.[681]

In addition to increasing investment in a more sustainable food and land use system, existing capital flows should also be refashioned to deliver greater conservation and restoration outcomes within a landscape.[682] The world's zero-deforestation commitments can only be achieved if commodity companies and their investors make their investments in agriculture conditional on zero deforestation being achieved. [683]

Another essential precondition for better food and land use systems would be for national governments to reform agricultural subsidies.[684] Across developed and developing countries, government subsidies to the agriculture sector currently amount to some US$519 billion on average per year (2014—2016).[685] These public subsidies, in addition to being economically inefficient, often lead to negative outcomes for the climate and environment, such as increased deforestation due to agricultural expansion in rainforest areas.[686]

Beyond subsidy reform, a range of other policies and instruments are available to governments. Better pricing and 'full cost accounting' to recognise externalities and public goods in the food and land use sector is of fundamental importance to creating markets that take into account carbon, ecosystems, waste, and health outcomes. For example, with the right land tenure policies, governments can incentivise forest protection, restoration, and better farming practices by giving landholders payments for the ecosystem services (PES) they provide; these payments can be results-based, following the REDD+ framework to reduce deforestation.[687] National instruments such as tax breaks or lower interest rates can incentivise greater investment in sustainable forest and landscape SMEs.

Using public money to mitigate investor risks in a particular project or fund is another way to mobilise more commercial capital to sustainable land use projects. Innovative blended finance structures like the Tropical Landscape Finance Facility (TLFF) in Indonesia provide long-term loans for rural project investments adhering to sustainability criteria. In February 2018, TLFF issued the first ever US$95 million sustainable land use bond (see Box 35).[688] Other examples include the new &Green Fund,[689] the Terra Bella Colombia Fund[690] and the US$1 billion Rabobank sustainable land use fund[691] announced with the UN Environment Programme.

Categorising forests and other sustainable land use investments as an asset class (for example, as natural infrastructure, real assets or commodities, or payments for ecosystem services) will also help facilitate commercial investment, as it may allow investors to better categorise risk characteristics and include these investments within existing asset allocations. The Climate Bonds Initiative is helping to standardise this natural infrastructure as an asset class by developing guidance for the use of proceeds from green bonds that target 'nature-based assets' including agricultural land, forests, wetlands, degraded lands, coastal infrastructure and land remediation.[692]

Disclosure and divestment are also powerful instruments. For example, in 2015, Norway's sovereign wealth fund dropped six palm oil and four pulp and paper companies from its portfolio, due to their involvement in destroying forests, as part of the country's commitment to divest from assets that contribute to deforestation.[693]

Box 32
Finance for Food and Land Use (continued)

Better pricing of food also offers a key instrument to help shift demand away from high environmental impact foods (those high in animal protein) and to achieve better health outcomes. Whilst achieving widespread behavioural change is difficult, promising examples show that careful taxation reforms may be an effective part of a broad behavioural change strategy that also includes labelling and education. Examples of pricing reforms to shift diets can be found in several countries including Chile, France and local governments in the United States, who have recently experimented with taxing certain foods (for example, those high in fat, salt, or sugar) to make other foods comparatively more affordable. Mexico's sugar tax, approved in October 2013, constitutes a 1 MXN per litre tax (around US$0.08) on sodas, along with a 5% tax on junk food. Data show that the tax is causing a fall in consumption of high sugar drinks, now for the second year in a row, although it is still too early to assess the health impact.[694]

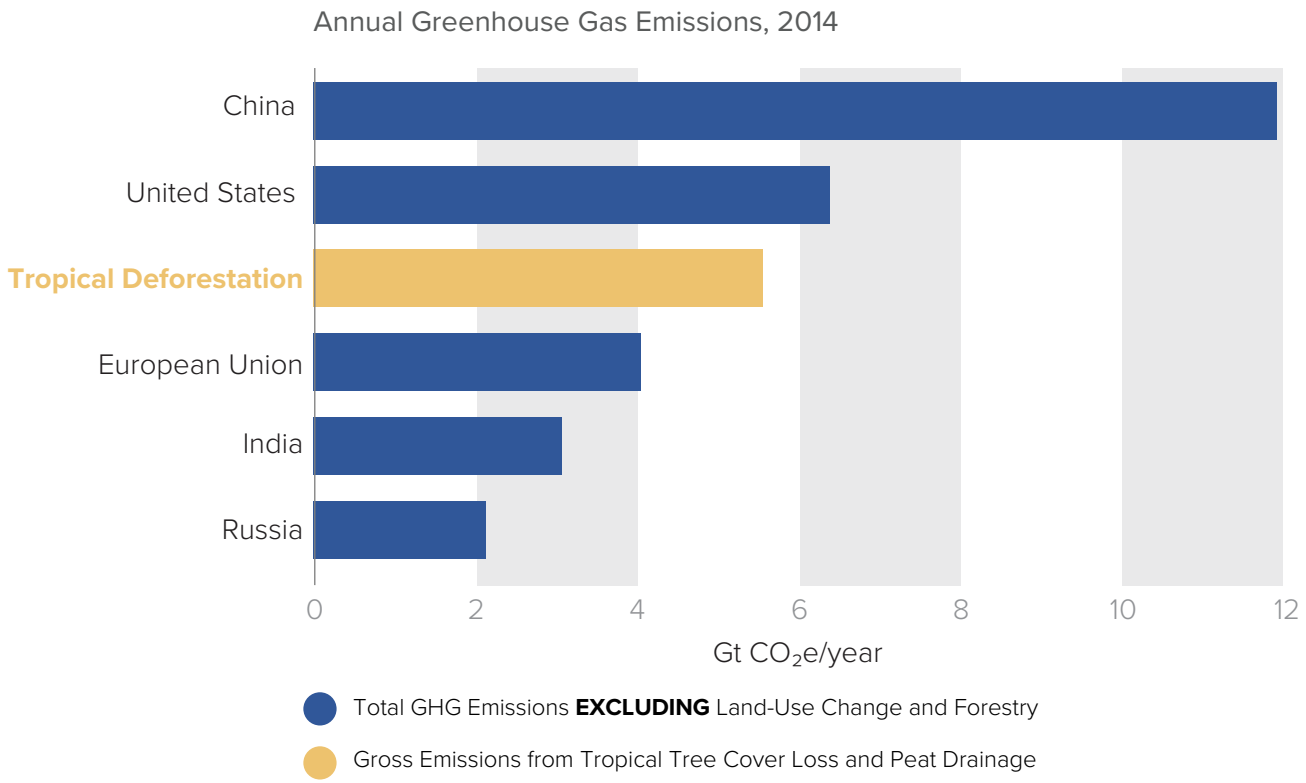
This chapter explores five inter-linked opportunities with the combined potential to shape global food and land use systems to meet humanity's needs while stabilising the climate. These opportunities include putting an end to deforestation and forest degradation by 'closing the forest frontier'; restoring degraded agricultural and forest lands, either to natural forest or to productive use; farming smarter to increase productivity on existing agricultural land; shifting diets to more sustainable, nutritious, health-promoting foods; and reducing food loss and waste. Together, these five sets of solutions will be instrumental to achieving a new climate economy, the Paris Agreement, and the SDGs. There is no time to lose.

3.A. Closing the Forest Frontier: Avoiding Further Deforestation and Degradation of the World's Forests

The world's forests (tropical, temperate and boreal) are major economic assets and could be drivers of growth for the countries and regions where they are found. Forests directly support the livelihoods of more than 1 billion people.[695] They generate multiple economic benefits, including improving soil quality, protecting biodiversity, and supporting ecotourism.[696] They underpin and regulate the climate on which the global economy and food security relies.[697] Critically, forests are the only currently available large-scale, proven, and cost-effective technology for carbon capture and sequestration.

Notwithstanding these national and global benefits,[698] deforestation—particularly (although by no means exclusively) in tropical countries—continues with alarming consequences. Indeed, if tropical deforestation were a country, its emissions would be greater than those of the European Union (Figure 18).[699] The Paris Agreement cannot be met without rapidly slowing and then halting and aggressively reversing, tropical deforestation.[700] Definitively 'closing the forest frontier'—through a combination of actions, including protected areas, indigenous peoples reserves, better land use planning and enforcement, land tenure reform and improved forest governance—will be critical to the global climate effort. Closing the forest frontier will also incentivise the necessary agricultural innovation and transformation in the degraded lands adjoining the forest, thereby putting an end to the perversity of the value-added economic activity of agriculture being outdone by free access to a good that serves a massive public function and that those exploiting have not invested in developing. 'Closing the forest frontier' globally will require decisive political will and leadership from countries and subnational governments, while the private sector, civil society organisations, donors, and the financial sector also all have critical roles to play.

Figure 18
Emissions from Tropical Forest Loss.



Source: Data from Climate Watch and Global Forest Watch. Author calculations. Adapted from Seymour and Busch, 2016.[701]

Evidence of the Benefits

Forests are critical to mitigating climate change because they act as a carbon sink, soaking up carbon dioxide that accumulates in the atmosphere. Halting tropical deforestation, while allowing damaged forests and other lands to recover, could secure an amount of carbon equivalent to one third of the emissions reductions needed for a below 2°C pathway.[702]

Forest industries contribute an estimated US$450 billion to annual national incomes globally[703] and over US$250 billion per year to developing country economies.[704] For example, forests have underpinned Costa Rica's tourism industry growth, which at 7.4% in 2011 was the strongest of the Americas,[705] with ecotourists representing more than half of the 2 million international visitors to the country each year.

Avoiding further deforestation could boost the global economy by at least US$40—80 billion per year.[706] Many of the benefits forests provide are in the form of ecosystem services, such as fuelwood and provision of other forest products, water purification, climate regulation, pollination, erosion control, and habitat protection. In Colombia, for example, maintaining the forested lands of the Colombian Amazon held by indigenous communities could yield as much as US$123 billion to US$277 billion in total ecosystem benefits over a 20-year period (see Box 33).[707]

Forests and mangroves also play a key role in adaptation: They reduce economic losses and overall risk from floods and droughts, which caused US$1.5 trillion in damage worldwide between 2003 and 2013,[708] and are expected to worsen with climate change. Unchecked climate change might result in global economic losses in the order of trillions of US dollars.[709] Given forests' vital role in climate regulation, therefore, the true economic benefits of reducing deforestation and forest degradation are of a similar order of magnitude.

Challenges

Deforestation happens for a host of reasons, including weak governance, policy incoherence, market failure and growing global demand for forest risk commodities. A lack of formal recognition of land tenure (see Box 33),[710] the misalignment of national

agricultural subsidies, and infrastructure development (particularly road construction) all drive forest encroachment. Insufficient or inadequate capacity for and enforcement of spatial and land use planning further undermines efforts to protect forests.[711] In the absence of a robust market that values the full range of services forests provide—in terms of carbon storage, water provision, climate regulation, and biodiversity—forests are generally considered more valuable for timber, cropland, or pasture than they are as standing, healthy, climate-protecting systems. The global public goods benefits from forests, which would be in the order of trillions if properly counted, are obscured by the more tangible private benefits through priced goods—timber, land for agriculture—accruing to those able to seize them. A first-order priority, therefore, is to recognise the true economic value forests offer; and then to establish a 'new forest economy' which reflects that value.

The drivers of deforestation vary: Whereas in the Amazon Basin it is primarily driven by cattle ranching and soya,[712] deforestation in sub-Saharan Africa is often attributable to the unsustainable use of biomass for cooking and energy (see also Section 1.D).[713] Across the world, commercial-scale clearing for agriculture is a major cause. Emerging market importers (China and India) and major emerging market producers and consumers (Brazil and Indonesia) account for a growing share of global demand for commodities linked to deforestation. There is a real opportunity for all countries to strengthen their supply chain sustainability commitments, enhancing their long-term resilience against water variability, reputational risk and price fluctuations. Where there are significant risks to the long-term resilience of these supply chains if sustainability concerns are not addressed, greater leadership from emerging markets could have a transformative impact.

The zero-deforestation commitments made by companies to date are limited by challenges in implementation and monitoring: Without harmonised definitions across company commitments, comprehensive tracking, and systems to account for third-party suppliers, it is difficult to assess progress and optimise the impact of these committments.[714] Encouragingly, in February 2018, Unilever became the first consumer goods company to disclose its palm oil suppliers—a mapping exercise of over 1,400 mills and more than 300 direct suppliers[715]—following similar commitments from suppliers. Nestlé followed soon thereafter. It is hoped that many other CGF companies will do the same. Meanwhile, a growing number of investors and companies are using their financial power to respond to the financial and reputational risks associated with deforestation, including through divestment from companies with a significant forest footprint (see Figure 20). Technical assistance programmes such as Partnerships for Forests have an important role to play in turning commitments into action by catalysing public-private investment. Greater effort needs to be made to encourage further commitments across the world's markets to achieving fully traceable and transparent zero-deforestation commodity supply chains, while urgently delivering on the commitments that have already been made.

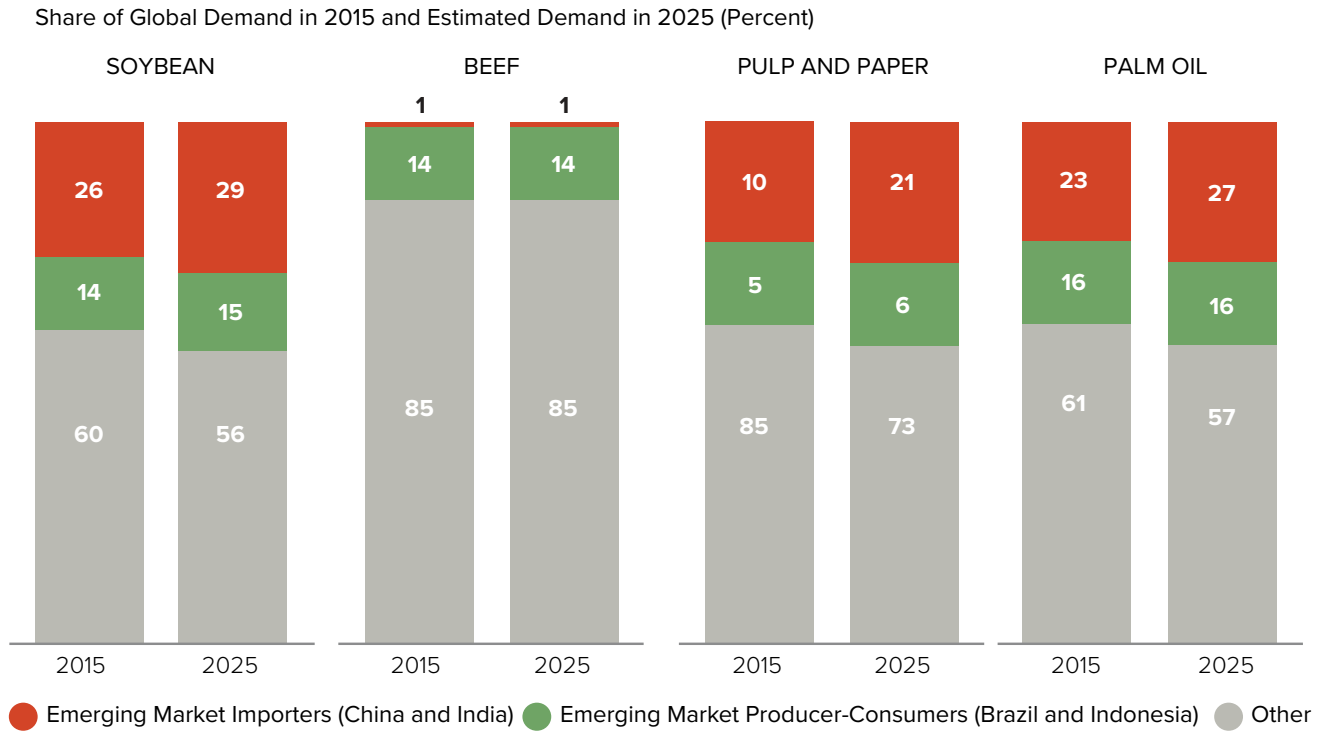
Efforts to reduce deforestation are also hampered by a lack of enforcement of laws and policies protecting forests. Communities or supply chains causing deforestation or harvesting timber illegally often face very little risk of getting caught.[716] However, improvements in satellite and monitoring capability, supply chain and blockchain technology, and fiscal and policy incentives offer options to help both companies and governments tackle some of these barriers, as well as to improve land tenure and land-use planning. The 'radical transparency' agenda—driven by increasingly sophisticated satellite imagery and data collection techniques, underpinning initiatives like Global Forest Watch and Trase—makes it possible to map suppliers at granular levels of detail, while blockchain technology could potentially offer ways to securely, transparently and efficiently track transactions along the supply chain.[717]

Box 33
Indigenous Rights and Land Tenure Reform in Colombia[718]

In the late 1980s and early 1990s, Colombia gave 30 million ha, approximately one-quarter of its land area, the formal status of indigenous reserves.[719] It also granted indigenous and forest communities legal recognition and recourse if their rights were infringed. Since then, large areas of the Colombian Amazon—7% of the Amazon biome—have enjoyed relatively high levels of forest conservation. The deforestation rate inside tenure-secure indigenous forestlands has been half the rate outside, where the drivers of deforestation—cattle, illegality, land speculation—are strong (and growing). The value of the total ecosystem benefits associated with securing indigenous forestland tenure in Colombia over the next 20 years is estimated at US$123 billion to US$277 billion. In carbon terms, securing indigenous tenure of forestland in the country has the potential to avoid more than 1 Mt CO_2 emissions per year, equivalent to taking 635,000 cars off the road over the same period.[720]

Figure 19

Share of Global Demand in 2015 and Estimated Demand in 2025 (Percent)



Source: Tropical Forest Alliance 2020, 2018.[721]

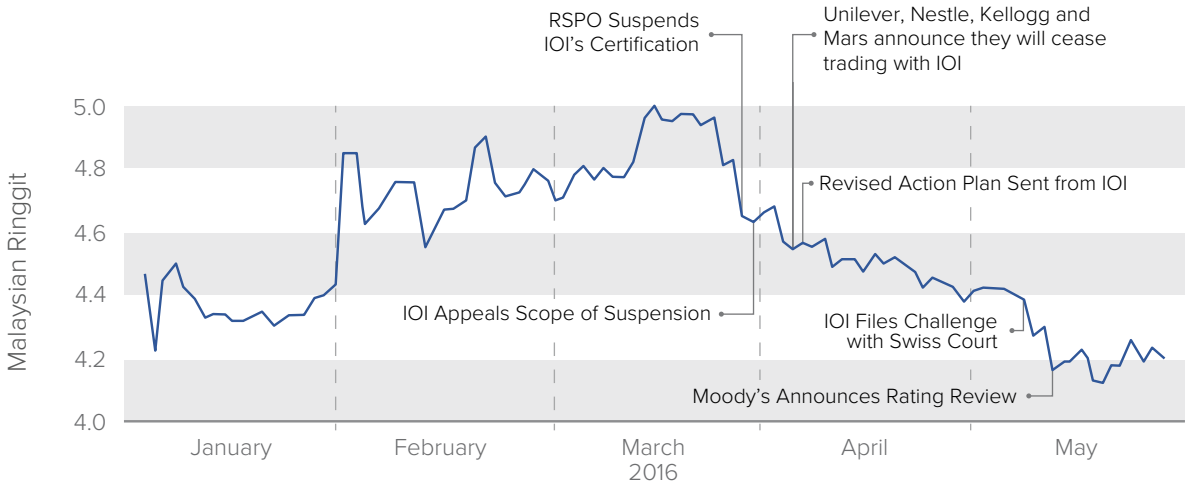
Accelerators

- **Countries should follow through on their commitments to protect and safeguard the rights and territories of Indigenous Peoples.** Governments and their partners should implement (or where necessary reform) their laws to provide Indigenous Peoples and communities with sufficient legal protections, and take other necessary actions to strengthen land rights, including mapping, demarcating, and formally registering this land (see Box 33).
- **Forest countries—with support from partners—should increase their efforts to take all necessary steps to close their forest frontier.** Critical measures to achieve this include strengthening protected areas; overseeing comprehensive land tenure reform; and ensuring robust and integrated spatial planning, enforcement, and land management. Examples of where elements of these efforts have been achieved—including in Brazil, Costa Rica, Colombia, Indonesia, Liberia, and Sierra Leone—demonstrate the significant climate and economic benefits and importance of these multi-sectoral or landscape approaches to closing the forest frontier.
- **Governments and companies should scale up their efforts to achieve radical transparency in the forest sector, especially for forest commodity supply chains.** Radical transparency—achieved through enhanced governance, disclosure and technological innovation—can lead to multiple economic benefits to forest countries, in terms of increased tax revenue and reduced illegality. In key forest commodity supply chains—from producer to trader, through to the consumer goods company and owner/financier—companies should commit to make their supply chain information publicly available in real time, from the individual farmer to consumers. In early 2018, Unilever and Nestlé became the first consumer goods companies to publicly disclose their palm oil suppliers and mills.[722] Separately, a number of other companies — including Colgate Palmolive, General Mills, Mars, Mondelez, P&G, and Reckitt Benckiser— have disclosed their palm oil producer lists. Although all the companies revealed supplies included from deforesting producers, the release of this information is raising hopes that full supply-chain transparency will inevitably become standard industry practice.[723]
- **Accelerate delivery on the zero-deforestation commodity supply chain agenda, bringing in new actors and strengthening implementation of**

existing commitments. Companies from across developed and emerging markets should urgently accelerate their implementation of zero-deforestation commitments, learning from progress made to date (including in timber, palm oil, and cocoa). China, India, and other globally significant commodity importer markets should further step up their efforts to encourage sustainable commodity production. Already, the Sustainable Soy Trade Platform is working to boost Chinese demand for responsibly produced South American soy.[724] And Chinese food and agribusiness giant COFCO now has two facilities in China that are certified by the Roundtable on Sustainable Palm Oil. COFCO has also become a member of the Round Table on Responsible Soy.[725]

- **International investors, including DFIs, should more closely screen collaboration and investment in deforestation-risk companies and divest from those that are not sustainable.** In doing so, investors can protect themselves against financial and reputational risks and help to shift the financial system towards greater sustainability. Investors are increasingly beginning to respond to these risks. In 2015, Norway's sovereign wealth fund dropped 10 palm or pulp and paper companies from its portfolio due to their involvement in destroying forests.[726] In 2016, the share price of palm oil producer IOI suffered significantly after it was suspended for six months from the RSPO and credit ratings agency Moody's considered downgrading the company (see Figure 20).[727] Only after IOI demonstrated sustainability improvements, committed to commission an independent verification of their actions, and was reinstated by the RSPO did its shares improve. IOI continues to suffer lack of access to buyers' and financial markets due to lingering reputational risk, and its share price has yet to return to pre-suspension levels.[728]
- **National governments should establish full policy coherence and alignment in policy frameworks to reduce deforestation as well as provide fiscal incentives for sub-national governments to maintain standing forests.** The more successful attempts to reduce deforestation, including Brazil's, have demonstrated the importance of a whole-of-government approach, ensuring alignment of policy and fiscal incentives and disincentives to protect forests. Brazil blacklisted municipalities responsible for deforestation, reformed its agricultural subsidies to encourage farmers to protect and restore forests, and rigorously enforced these policies.[729] India's National Agroforestry Policy (see Box 34) is another example. National governments should also provide fiscal incentives to sub-national governments to maintain their high levels of forest cover.[730] India's forest cover measure, which is directing an estimated US$6.9—12 billion per year of additional tax revenue to states from 2015 to 2020, rewards states on the basis of the extent of their forest cover.[731] This type of fiscal regime and similar (sub-national) fiscal incentives can be replicated in other geographies, such as in Indonesia, to complement ongoing flows of international REDD+ finance to support jurisdictions in their efforts to reduce deforestation and forest degradation.

Figure 20
IOI Share Price (Malaysian Ringgit) from January to May 2016.



Source: University of Cambridge Institute for Sustainability Leadership (CISL), 2016.[732]

Box 34

India's Agroforestry Policy

In 2014, the Indian government introduced a National Agroforestry Policy aiming to increase tree cover (with a national goal set at 33%), meet growing timber demand, improve farmer livelihoods, and tackle climate change. India saw the economic opportunity to meet increasing demand by scaling up agroforestry. At the time, 20% of India's timber was imported. The policy directs investments into research, extension services, and capacity-building as well as promoting agroforestry for renewable energy and sustainable development projects. It also provides farmers with incentives, insurance mechanisms, and greater access to markets for agroforestry products.[733] In 2016, the national government budgeted US$150 million to boost agroforestry. An additional US$60 million to be leveraged from state finances brought the total up to US$210 million, with money going to states that demonstrated progress in implementation. By 2016, seven major Indian states had reformed their regulations to support the policy.[734] The National Agroforestry Policy—coupled with India's forest cover measure target—demonstrates the power of national policy to drive real change to drive real change.

3.B. Seeing the Restoration for the Trees: Scaling Up Forest Landscape Restoration

Some two billion hectares of the world's landscapes offer opportunities for restoration. Restoring some of these landscapes to natural forest or to sustainable agricultural use would contribute to meeting the Aichi Biodiversity Targets,[735] SDGs 13 and 15, and the Paris Agreement. It would also be a major win for the economy: For example, restoring the 160 million ha of degraded land committed by over 40 countries under the Bonn Challenge could provide an estimated US$84 billion in annual economic benefits worldwide.[736] The climate gains alone (particularly from restoration to natural forests) would be remarkable. Nature-based climate solutions—including the restoration of forests, grasslands, and wetlands as well as avoided deforestation and better land management—could provide almost 24 billion tonnes of CO_2e savings per year through 2030.[737] Landscape restoration would also make a lasting contribution to adaptation, resilience and decreasing migration: The worsening impacts of climate change could force over 140 million people to move within their countries, due to a series of growing problems that could be addressed by restoring degraded lands into productive and healthy ecosystems.[738]

Large-scale restoration (including through reforestation, natural regeneration, and afforestation) is gaining increasing attention as a negative emissions technology (NETs), the term given to mechanisms for removing CO_2 from the atmosphere. Compared to many other NETs, which are either high cost (such as direct air capture)[739] or which involve changing ecosystems (such as ocean fertilization),[740] forest- and landscape-based restoration presents an attractive, proven, and cost-effective solution.

A number of international commitments have been made to restore degraded forests and agricultural lands. In addition to international initiatives like the Bonn Challenge and 4 per 1000,[741] regional initiatives such as AFR100 in Africa and Initiative 20x20 in Latin America have begun in recent years[742] and are beginning to deliver important action on the ground.

Evidence of the Benefits

Investments in restoration can create a variety of new income streams, including from the periodic sales of sustainably harvested wood (including for timber in buildings) and annual revenues from ecotourism. New income streams from such sources could boost smallholder farmers' incomes in developing countries by an estimated US$35—40 billion per year within 15 years.[743] In the United States, restoration and conservation activities generate an estimated US$3.8 billion a year and currently sustain 126,000 jobs.[744]

Restoration projects and better land management can also increase the capital value of the land as it becomes more productive,[745] improving total returns on investment. The New Forest investment model in Australia and New Zealand, replicated in Southeast Asia, is one example of the scale of returns to be made from long-term investments in sustainable forest management, ecosystem restoration, and conservation.[746] Peatland restoration under way

in Indonesia has the potential to deliver globally significant climate as well as lasting economic benefits to peatland owners, farmers, and communities.[747]

Restored land can also protect people from natural disasters, delivering a key adaptation benefit. Over the past few decades, South Korea has restored more than 6 million ha of degraded, sloping lands. The resulting erosion control and prevention of landslides have been valued at US$11.23 billion, and US$3.95 billion respectively.[748] Restoration in the Tigray region of Ethiopia and better land husbandry in Rwanda has enhanced farmers' resilience, water availability, and livelihoods in areas previously subject to poverty and desertification.[749] Restoring mangroves to their geographic coverage of the 1950s in the Philippines would deliver more than US$450 million per year in additional flood protection benefits.[750]

Challenges

Despite a multitude of examples of excellent progress at the project or even landscape scale, there are few examples of significant, national-scale restoration to date.[751] The institutional impediments to large-scale restoration are significant and include the absence of land tenure reform and adequate land-use planning, both of which are essential prerequisites for restoration to go to scale.

As a result of these impediments, there has been limited appetite to date from institutional investors to invest at scale in restoration. Investors have been put off by the inherent challenges with these kinds of investments, including scale, bankability, delayed revenue flows, and a lack of market mechanisms to monetise returns (such as a carbon price for the avoided GHG emissions or additional carbon stocks achieved by restoration). Land-use models that rely on novel environmental markets as important sources of revenue are often perceived as bearing additional risk and uncertainty. Even investors in more mature land-based asset classes, such as timber and agriculture, often require higher returns from sustainable ventures.[752] Despite the development of promising business and investment models for natural infrastructure, it remains a niche investor class. This is partly because private investors in restoration projects face considerable barriers to entry, such as high transaction costs, uncertainty around returns translating into high risk, and the lack of liquidity.[753]

Today, most of the returns to forest landscape restoration are either inadequately monetised or misunderstood, leaving the majority of forest landscape restoration efforts to rely on modest public financing.[754] Restoring degraded and deforested land at scale will require high-level government backing and political will, including alignment of regulations

Photo credit: Flickr: Mokhamad Edliadi/CIFOR

and incentives, alongside substantial institutional support. Initiatives like Initiative 20x20 and AFR100 represent positive steps in this direction by bringing together and matching public restoration and financing commitments with private investors, who have committed more than US$3 billion as part of the initiatives.[755] However, for forest restoration to truly take off and become a viable option for private investors at scale, tailored revenue generation models, financial structures and, at least initially, de-risking instruments will be required. Together, these can support the creation and capture of restoration's long-term economic value and attract private capital.[756]

Ultimately, restoration can only succeed if the world closes the forest frontier: Land degradation is a symptom of a cheap and poorly enforced forest frontier, with the 'free' wood produced by nature over thousands of years undermining value creation outside the forest. Once the frontier becomes more expensive (politically, economically, legally, or reputationally), investors will have more incentives to invest to improve the productivity of already cleared or degraded areas.

Accelerators

- **Governments should work to find and prioritise action on tracts of land most amenable to assisted natural regeneration.** To achieve low-cost restoration, the restoration community should make a concerted effort to identify those tracts of land most amenable to assisted natural regeneration. The success factors for assisted natural regeneration are capable of being assessed, mapped, and prioritised. Strategic interventions that reduce the existing pressure on the tract of land—such as pro-active fire suppression or pro-active enclosure/exclosure of livestock—could then be implemented. One concrete intervention would be to create national Fences for Farmers and Forests programmes. Another possible intervention would be to create national programs focusing on assisted natural regeneration on public lands.
- **Governments should develop a combination of national land-use plans, restoration strategies, and incentives to enable large-scale national and landscape-level restoration investment and implementation.** These plans can facilitate national governments' progress on a variety of international commitments and protect and maximise the many benefits that restored forests and lands provide. Restoration successes in China, in the Loess Plateau and in the nationwide Grain for Green programme have converted several million ha of degraded agricultural land back into agriculture or agroforestry on slopes.[757] Costa Rica has also seen large areas of the country reforested, in part as the result of the government reducing subsidies to the cattle sector in the mid-1980s.[758] Lessons from these and other successful examples should be replicated and scaled up elsewhere.
- **Governments should establish public procurement policies (as well as public building codes) that favour sustainably-sourced wood from restored areas to stimulate market demand.** Accelerating the use of responsibly-sourced wood from restored areas to replace more carbon-intensive materials in building construction (for example concrete, steel, see Section 5.A), packaging (for example, plastic, see Section 5.B), and other uses would result in additional market demand for sustainable forest products. (See also Box 51).
- **Private and non-profit sectors can build capacity and accelerate restoration through multi-faceted 'outgrower schemes'.** Outgrower schemes achieve multiple restoration objectives all in one package: They provide seeds/seedlings, technical assistance, financing, champions/leadership, aggregation, and market access to smallholder famers that, when combined, can make restoration in the economic interest of land managers. Some outgrower programmes are already demonstrating success. Komaza in coastal Kenya is a company enabling small-scale farmers to participate in industrial wood markets. It partners with rural farmers to plant woodlots that are collectively managed as a 'virtual plantations'. Farmers contribute land and labour, and are paid a fair price for harvested trees, while Komaza provides training, planting inputs, maintenance support, harvesting services, and a guaranteed market in wood processing and sales operations.[759] Komaza's model offers a new income stream to smallholder farmers, while reducing pressure on virgin forest and increasing the area of reforested land. To date, Komaza has 4,000 ha planted with 14,000 farmers—with aims to scale to 30,000 ha by 2019.[760]

- **National governments should create investment environments that encourage large-scale private investment in reforestation and forest landscape restoration.** This will allow private landowners to invest with confidence in restoring the landscapes they own and complement public finance flows. The right investment framework and public policies should include measures to clarify land tenure. Governments can also provide the right enabling environment—tax incentives, regulatory reforms and public support measures such as nurseries, seed banks and extension services—to encourage these and similar green (infrastructure) investments.[761]
- **Financial intermediaries, including DFIs and commercial banks, should use blended finance vehicles to facilitate the scaling up of private investment into restoration.** Financial structures and investments that blend capital can reduce investment risk, making sustainable land use more investable. Such instruments might include first loss capital, partial risk guarantees, insurance, technical assistance facilities, currency hedging, and payment-for-performance schemes. For example, The Tropical Landscape Finance Facility (TLFF) in Indonesia, established by ADM Capital and BNP Paribas, uses long-term loans for rural project investments (Box 35).[762] The blended finance vehicles that have worked so far are one-offs and need to be scaled.
- **Companies, governments, and entrepreneurs should accelerate innovation, R&D, and early phase project development to accelerate new and profitable technological solutions to enable restoration.** There are many entrepreneurs around the world already making forest restoration their business. UK-based company Biocarbon Engineering operates a fleet of drones reforesting areas that are difficult to access. The Dutch firm Land Life Company is the maker of the Cocoon technology, a biodegradable pod designed to increase seedling survival rates by providing water and shelter (see Figure 21). Restoration entrepreneurs need public and investor support, including dedicated incubator funds and innovation prizes, to test their ideas and encourage rapid scale-up of the best models.

Box 35
Tropical Landscapes Finance Facility (TLFF) mobilises private capital to restore degraded land in Indonesia

The Tropical Landscape Finance Facility (TLFF) leverages public funding to unlock private finance in both renewable energy production and sustainable land use, including agriculture and restoration projects. TLFF consists of a lending platform managed by ADM Capital with BNP Paribas as structuring adviser, and a grant fund managed by the UN Office for Project Services.[763] TLFF's first transaction in February 2018 was a US$95 million sustainable land-use bond—a world first. This will help finance a sustainable natural rubber plantation on heavily degraded land in two provinces in Indonesia. The main income underpinning the bond will come from rubber produced from the plantation. Planted areas of project land will serve as a buffer zone to protect the Bukit Tiga Puluh national park from encroachment. Roughly half of the project area is to be set aside for community partnership programmes and well-enforced conservation measures to support forest conservation and protect biodiversity corridors. The production company, PT Royal Lestari Utuma, an Indonesian joint venture between France's Michelin and Indonesia's Barito Pacific Group, will employ and train several thousand employees in its plantations and give them stable incomes.[764]

Figure 21
A Cocoon from LandLife and a BioCarbon Engineering Drone at Work Planting Trees.

Sources: Land Life Company, n.d. The COCOON.[765]

3.C. Farm Smarter: Sustainably Increasing Agricultural Productivity

In 2016, agriculture accounted for less than 5% of global GDP[766] and almost 70% of total employment in low-income countries worldwide.[767] Global demand for food crops is expected to increase by 56% between 2010 and 2050.[768] While the effects of climate change will make it more difficult to meet this demand, commodity agriculture itself poses significant threats to the climate as just four commodities—palm oil, soy, beef, and wood products—account for more than 40% of tropical deforestation.[769] Sustainably raising agricultural productivity on existing agricultural land is a critical solution to the interrelated challenges of feeding the world and addressing climate change[770] (see, for instance, Box 36, on innovative technology solutions to this challenge). Ensuring climate mitigation and adaptation, as well as better soil health and resilience, through the widespread adoption of better agronomic practices is a win-win for the climate and the economy. Achieving greater adaptation and resilience is also an urgent necessity, given the scale of climate change already locked in.

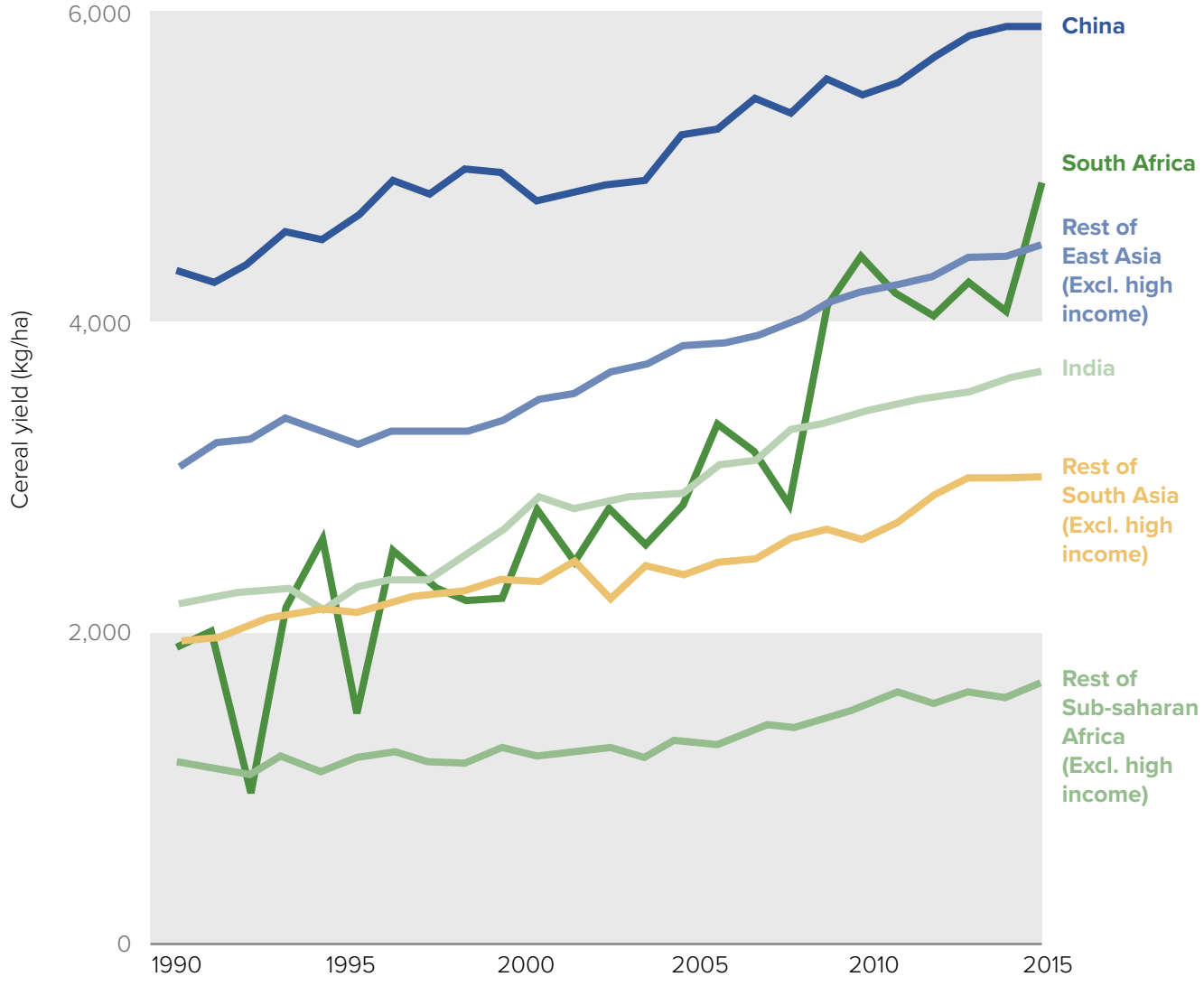
Box 36
Tech Solutions to Improve Agricultural Practices in Sub-Saharan Africa

In Uganda, TechnoServe partnered with the Bill and Melinda Gates Foundation to pilot the use of drones in monitoring and optimizing agricultural interventions to improve practices, yields, and incomes. Through the partnership, TechnoServe helped seed company Equator Seeds Ltd. to monitor the farming practices of their 30,000 contractor smallholder farmers. The pilot delivered significant benefits for both farmers and Equator Seeds in terms of increased yields and decreased input costs. Pesticide use declined by 60%, and there was an average US$2,150 increase in annual profits for the 270 pilot farms. Equator Seeds gained profits of US$6.5 million, delivering a return of US$20 for each US$1 of program investment. A projected 100% increase in yields, coupled with the reduced spending on pesticides, means the 30,000 individual farmers in Equator Seeds' sourcing network can expect returns of over US$3,000 and US$1,500 in their first year of maize and soy seed production, respectively. This would equate to a US$67 million increase in smallholder farmers' income and US$300 million to Equator Seeds' profits in just one year.[771]

Scaling up climate-smart agricultural approaches (CSA) is key to increasing agricultural productivity sustainably.[772] CSA covers a myriad of existing as well as new production systems, including landscape farming approaches and techniques ranging from intercropping and integrated crop-livestock management to improved water, soil, and nutrient management. If done effectively, CSA practices can produce the triple win of higher productivity that creates better jobs and income for farmers, climate mitigation through reduced GHG emissions, and increased resilience and adaptation to climate change in agriculture. If the right approaches are taken, CSA can also deliver important benefits for women farmers.

Agricultural productivity has increased significantly over the past 50 years, due to increasing use of fertilisers, water for irrigation, improved seeds, agricultural machinery, and pesticides (see Figure 22). However, these yield-increasing inputs have also had damaging environmental impacts, such as increased emissions, nitrogen run-off, eutrophication, soil compaction, reduced water reserves and drainage capacity, and biodiversity loss.[773] There is significant scope to achieve further increases in regional yields, especially in developing countries, while at the same time achieving greater adaptation and resilience. Methods such as crop diversification, agroforestry, and soil and water conservation have been shown to increase yields while avoiding the environmental impacts seen elsewhere. For example, an assessment of the impact of the use of fertiliser trees in farms in Malawi, Tanzania, and Zambia found that maize yields doubled, compared to unfertilised, mono-cropped maize plots.[774] Another study found that the addition of woody legumes to maize crops in sub-Saharan Africa increased yields by an average of 1.3 to 1.6 tonnes per hectare.[775] In Colombia, intensive silvo-pastoral systems have driven enhanced livestock productivity while conserving and restoring natural ecosystems.[776]

Figure 22
Cereal Yield Increases for Key Countries and Regions 1990 to 2015.



Source: Alliance for a Green Revolution in Africa (AGRA), 2017.[777]

Evidence of the Benefits

Yield improvements and CSA have generated significant economic growth and jobs for farming communities, including in Southeast Asia and sub-Saharan Africa. Among the benefits of CSA practices are the additional incomes generated by increased productivity, which generates greater economic security in the event of economic shocks, such as falling prices; greater availability of food for farmers and their dependents; and greater resilience to climatic shocks such as drought. In Niger, farmer-managed natural regeneration efforts generate US$280 million per year in ecosystem benefits and yield increases, which provide food for 2.5 million people.[778]

A shift to CSA practices can also protect biodiversity and reduce soil erosion and fertiliser run-off. The relationship with freshwater is particularly significant: More effective allocation of permits for freshwater withdrawals can improve resilience and climate adaptation outcomes (see also Section 4.A). Payments for ecosystem services offer an opportunity for triple wins for investors, farmers and the landscape. For example, the Upper Tana-Nairobi Water Fund in Kenya deploys contributions from public and private donors to provide nearly 15,000 farmers with the training, tools, and resources they need to conserve water, protect the health of the Tana River, and enable higher crop yields and more stable incomes. Investors in the fund, such as the Kenya Electricity Generating Company and Coca Cola, recognise their dependence on the Tana River for their businesses. The fund found that a US$10 million investment in water fund-led conservation interventions could return US$21.5 million in economic benefits over 30 years (see also Section 4.A).[779]

Empowering rural women, who constitute over 40% of the global agriculture labour force, is also critical to feeding the world.[780] Agricultural productivity improves when women have access to land, household welfare, and adequate finance. If women farmers had access to the same financial and technical resources as men, the resulting rise in output could rescue an estimated 150 million people from hunger.[781]

Challenges

By 2050, without a global shift toward smarter practices, agriculture and associated changes in land use could consume 70% of the total GHG budget consistent with limiting global warming to 2°C.[782] Significant investments are needed to increase agricultural productivity, specifically in CSA, enhanced soil health, improved agricultural technology, enhanced access to finance for farmers, and better farm management.[783] Practical obstacles hindering the adoption of CSA on a large scale need to be overcome, in particular the high initial investment it requires in areas where low-cost capital may not be available to farmers, as well as the costs of widespread dissemination thereafter. The political economy challenges of agricultural subsidy reform—with agricultural subsidies worth half a trillion US dollars per year—and better policy alignment also need to be addressed.

More than one-third of palm oil[784] and two-thirds of the world's cocoa[785] are produced by smallholder farmers who often lack access to credit, technology, and training. Providing finance and technical assistance to millions of smallholders, particularly women, would have a big impact on both their livelihoods and agricultural productivity. Innovative ways to reduce the transaction costs involved in reaching so many individual farmers also need to be urgently brought to scale.

Accelerators

- **All governments should reform economically inefficient and environmentally harmful agricultural subsidies.** Across the world, there is an urgent need to reform and redirect agricultural subsidies—which currently amount to an average of US$519 billion annually[786]—in pursuit of stronger economic development, climate, and biodiversity outcomes. This includes a move to 'de-coupled' subsidies, that do not depend on output, and a reduction in those that lower global market prices, making it harder for developing country producers to compete. The recent European Commission's (EC) budget proposal is an attempt to do this: By some calculations, it appears to have cut agricultural support by around 15% over the

past seven years.[787] The EC also aims to introduce greater conditionality to direct payments to farmers, with a significant part of funding to be ring-fenced for actions beneficial to the climate, the environment, and rural development.[788]

- **National governments should align policy and fiscal incentives to promote CSA techniques and remove obstacles to their adoption.** Governments in both the developed and developing world should better align policies to reward CSA and incentivise better soil management. At both the national and sub-national level, targeted policies and incentives—such as those organising and funding farmer training and extension services—are needed to create enabling environments that incentivise, recognise and accelerate the adoption of proven climate smart approaches. In 2014, the Indian government implemented the first national agroforestry policy to improve farmer livelihoods and help deliver their ambitious goal of 33% tree cover (see Box 34).
- **Governments and private donors should increase public funding for national and global agricultural research and development.** This can include support for public-private collaborative agricultural research bodies like the Center for International Forestry Research (CGIAR) to strengthen efforts to improve soil health[789] and to improve global understanding of the scope and limitations of soil carbon sequestration. The CGIAR and other research efforts identify no regrets approaches to improved soil health and contribute to greater scientific consensus on the realistic long-term carbon storage potential of soils. Research efforts can also enable wider take-up of agricultural practices that are associated with improved soil health and resilience (such as reduced fertiliser and pesticide use and precision agriculture).
- **Governments and agricultural companies should invest in programmes that help smallholder farmers increase yields sustainably (coupled with integrated land-use planning to prevent further deforestation).**[790] Increasing smallholder yields could spare millions of hectares from deforestation.[791] In Indonesia, new varieties of oil palm could achieve yields of between 10 and 13 tonnes per hectare, compared to historic yields of 3.6 to 3.8 tonnes per hectare.[792] In Uganda, Technoserve used drones to monitor and improve the agricultural practices of 30,000 smallholder farmers (see Box 36).[793] Projects like these require investment to scale, and should be accompanied by rigorously enforced land-use planning and adequate clearing regulations to ensure that they lead to forest and ecosystem protection and restoration. A particular focus of investment should be on providing innovative, socially inclusive extension services and training.

Photo credit: Flickr: Patrick Sheperd/CIFOR

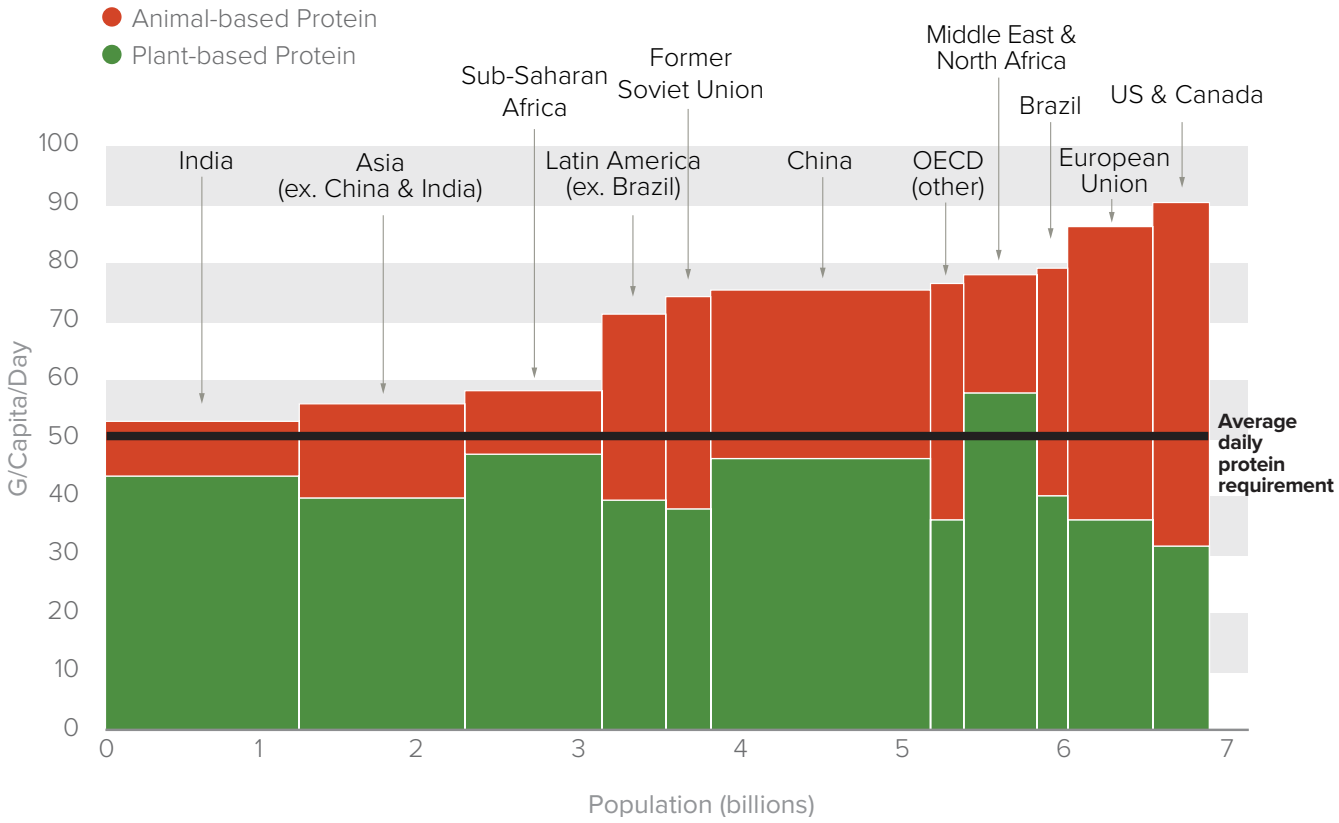
3.D. Setting a Sustainable Table: Advancing Better Food Consumption Patterns

Across the world, almost a billion people suffer from inadequate diets and insecure food supplies.[794] At the same time, current trends towards diets high in processed foods, refined sugars, refined fats, oils, and meats have resulted in over 2.1 billion people becoming overweight or obese.[795] This increase in collective body mass is strongly associated with the increased incidence worldwide of chronic non-communicable diseases, especially type II diabetes, coronary heart disease, and some cancers. If current trends continue, these chronic diseases are predicted to account for two thirds of the global burden of disease.[796] The global economic cost of obesity was estimated to be around US$2 trillion in 2012, roughly equivalent to the global cost of armed conflict or smoking.[797]

Dietary changes are also causing globally significant increases in GHG emissions and contributing to land clearing. These dietary changes drive significant impacts in other sectors given the nature of the energy-food-water nexus. For example, animal-based food production takes up more than three quarters of global agricultural land and produces approximately two thirds of agricultural GHG emissions.[798] The production of animal-based products uses one-third of the total water footprint of agriculture globally, with the average water footprint per calorie of beef 20 times higher than that of cereals and starchy roots.[799] Livestock systems play an important role in many developing countries in nutrition, poverty alleviation and income diversification. Animal-based foods provide a concentrated source of some vitamins and minerals that are particularly valuable to young children in developing countries whose diet is otherwise poor.[800] Furthermore, studies have demonstrated large benefits from modest increases in meat in the diets of the poor in sub-Saharan Africa.[801] However, among populations who consume high amounts of protein and animal-based foods, particularly in developed countries (see Figure 23), shifting to diets with a greater proportion of plants presents a huge opportunity to improve health and wealth and reduce the environmental impacts.

Figure 23

Protein Consumption Exceeds Average Estimated Daily Requirements in all the World's Regions and is Highest in Developed Countries.



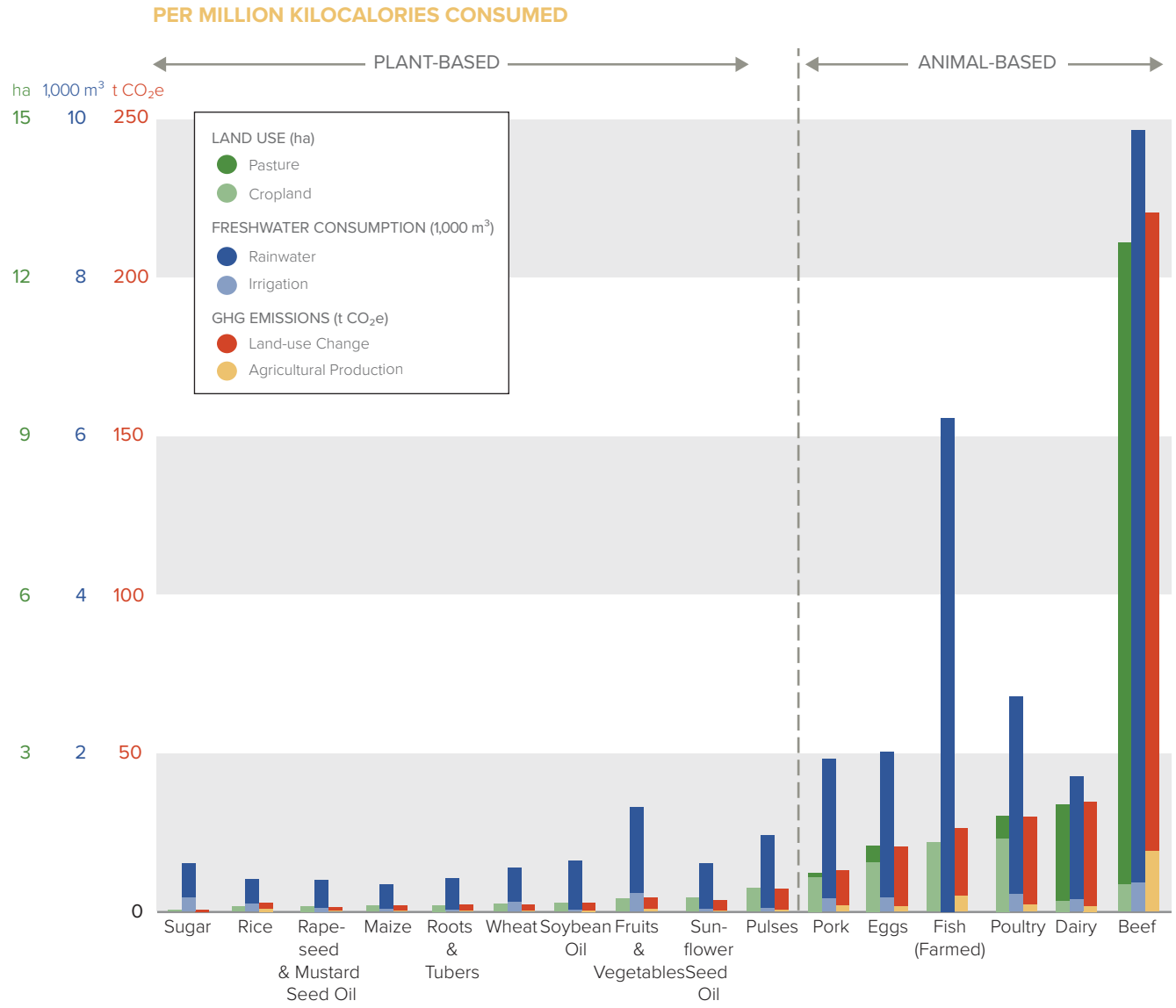
Source: Ranganathan, J., et al., 2016.[802]

Evidence of the Benefits

Shifting the diets of populations who consume high amounts of animal-based foods toward plant-based foods—and especially away from beef—could result in global health-related cost savings of almost US$1 trillion per year by 2050.[803] Consumer shifts towards plant-based protein offer investors and companies significant market opportunities. Alternative protein could constitute a third of the global protein market by 2050,[804] representing a huge new market opportunity.

Shifting diets could also release 150—640 million ha of agricultural land, avoiding future emissions related to changing land use of 37—168 $GtCO_2e$.[805] Even relatively small dietary shifts can have a big impact. Scenarios developed by WRI show that reducing an average American's combined meat/dairy/fish/egg consumption by 50% nearly halves both the land needed to feed each person and agricultural GHG emissions—almost as big a reduction in both as the land and emissions reductions associated with a complete vegetarian scenario.[806] This surprising result is due to two facts: First, production of animal-based foods accounts for more than 80% of the land use and GHG emissions associated with the average American diet; and second, that vegetarians tend to replace a significant amount of their foregone meat consumption with dairy, a relatively high-impact food.[807]

Figure 24
Comparative Resource Intensity of Animal Versus Plant Products.



Source: Ranganathan, J., et al., 2016.[808]

Challenges

As incomes rise between 2010 and 2050, demand for all animal-based food is expected to rise by 68%, and for beef and other ruminant meats by 88%.[809] Typical strategies to shift diets rely on nutrition labelling or public health campaigns about the benefits of different food types or diets. However, evidence suggests that consumers do not regularly check labels when buying food.[810] Actual consumption shifts, for example from caged to free-range eggs and from higher- to lower-alcohol beer in the United Kingdom, or the shift away from shark fin in China, show that collective, collaborative efforts are needed, using tailored marketing approaches informed by behavioural economics. WRI's Better Buying Lab found that simple nudges, like the way vegetarian dishes are presented on a menu, could double sales of these dishes.[811]

Furthermore, government policies often conflict with each other, slowing progress towards better consumption patterns. For example, current agricultural subsidies that benefit beef production in Brazil include concessional loans, insurance for lost income, and tax exemptions. Similarly, US federal agricultural subsidies focus on corn, soybeans, wheat, rice, sorghum, dairy, and livestock, a large proportion of which are converted into high-fat meat and dairy products, refined grains, high-calorie beverages, and processed and packaged foods.[812] Livestock subsidies in OECD countries amounted to US$53 billion in 2013, and pork subsidies in China exceeded US$22 billion in 2012.[813] Powerful lobby groups can at times be behind misaligned government policies. For example, the US government's 2015 Dietary Guidelines for Americans conspicuously lacked recommendations to reduce consumption of red and processed meat, which critics have blamed on powerful meat lobby groups.[814] Manufacturers, distributers, and retailers have powerful vested interests to sell the food that consumers want—including food high in sugar, processed meat, and saturated fats.

The issue of sustainable and healthy diets in the urban context is directly linked to broader concerns about urban poverty, food distribution, affordability, income, and governance (see also Section 2.B). Much of the world's food is sold, distributed and consumed through informal distribution systems. Slum dwellers face particular challenges in finding the time to secure access to and then prepare healthy food.[815] For example, 38% of Kenya's urban populations were found to be chronically food insecure.[816] Ultimately, providing a better and healthier diet to the world's population will also require a concerted focus on the way that food is distributed to and packaged for consumers in cities, in order to ensure that nutritious food is affordable and available to all.

Accelerators

- **National governments' dietary guidance and public health campaigns should highlight health and sustainability and incorporate behavioural economics to encourage consumer choices.** Guidelines that set a clear recommended limit on meat consumption promote sustainability, even when health is the driver. As of 2016, Germany, Brazil, Sweden, and Qatar all included sustainability in their national dietary guidelines.[817] China's dietary guidelines advise individuals to limit meat consumption for their health.[818] More governments can follow suit in their dietary guidelines and support public health campaigns that are informed by marketing and behavioural economics to educate people about their protein requirements and the health benefits of switching, where appropriate, from red meat to other forms of protein or to more plant-based foods.
- **National and sub-national governments should use a combination of policies and collaborate with food chain stakeholders to positively influence population diet and health.** As a first step, policy measures may seek to encourage healthier food choices, for example by providing education on nutrition or subsidising specific food products. Government should also discourage unhealthy food choices and stimulate a food systems response to the problem of unhealthy diets using a wide range of techniques to improve the likelihood of success. This may take the form of voluntary collaboration with the industry regarding food labelling, formulation or portion size or of mandatory measures such as health-related taxes.[819] For example, this year, the US Food and Drug Administration implemented regulations requiring caloric information to be listed in all chain restaurant menus and vending machines.[820]
- **Food manufacturers, retailers, and service companies should increase investment in developing and marketing alternative protein products.** By increasing the number of vegetarian or plant-forward options among

their products, food companies can enter new markets. Pret-a-Manger has launched a "Not Just for Veggies" campaign and seen sales grow (see Box 31). Company menus in the United States at Google, Stanford University, Sodexo, and Sonic now include the blended burger patty: a mix of 70—75% beef and 25—30% mushroom.[821] This practice could be scaled to other countries and companies, as well as to publicly funded canteens (for example, in schools and offices for civil servants).

- **Shareholders and lobby groups should put pressure on companies to develop and offer more sustainable food products.** Investors and companies should be concerned about the investment opportunities in alternative proteins and financial risks associated with unsustainable food production. Investors are increasingly starting to factor these considerations into their investment decisions (see Box 37). For example, as a shareholder in Tyson Foods, investment manager Green Century Capital Management called for business plans from the company to meet growing demand for plant-based protein in 2016.[822] While many factors may have influenced investing decisions, Tyson subsequently invested in the plant-based protein producer Beyond Meat, which now has products in 19,000 supermarkets across America and plans to triple production.[823] Valuable investment opportunities in disruptive technologies include synthetic leather, alternative protein production, aeroponics, vertical farming systems, and plant nutrient management and delivery.[824]

3.E. Waste Not, Want Not: Reducing Food Loss and Waste

One third of all food produced is lost or wasted along the food chain, costing the global economy an estimated US$940 billion[828] and causing about 8% of global GHG emissions.[829] If food loss and waste were a country, it would rank as the third top emitter after the United States and China.[830] Reducing food loss and waste offers a huge opportunity to generate economic savings for farmers, businesses, and consumers; improve food security; reduce GHG emissions; and improve climate resilience. Economic and social benefits include reducing the likelihood of smallholders becoming net food buyers, increasing the return on investment of time spent farming and the total time needed to work in fields, and raising overall productivity levels. Women are particularly critical to success: In addition to women constituting over 40% of the agricultural workforce,[831] surveys worldwide indicate that women are still responsible for 85-90% of the time spent on household food preparation.[832]

In 2015, the world committed to halve food loss and waste by 2030 (SDG12.3). The group Champions 12.3 is a coalition of executives from governments, businesses, international organisations, research institutions, and civil society dedicated to inspiring ambition, mobilising action, and accelerating progress toward achieving this goal. Their three-step approach—"target, measure, act"—provides a framework for governments and companies around the world to tackle food waste and loss reduction. In 2016, the first global food loss and waste accounting and

Box 37
FAIRR Helps Investors to Assess Risks and Opportunities in Intensive Livestock

Farm Animal Investment Risk and Return (FAIRR) is an investor network including groups such as AEGON Asset Management, AVIVA, and Green Century Funds. It works to put factory farming on the Environmental, Social, and Governance agenda by informing members of the material investment risks connected with intensive livestock farming and helping them to assess these as part of their investment processes. Risks range from potential regulations to price externalities (including deforestation) and shifts in consumer demand towards alternative, plant-based proteins.[825] FAIRR also highlights investment opportunities in meat alternatives. The global plant-based protein market has been forecast to grow from US$8.35 billion in 2016 to US$14.22 billion by 2022.[826] FAIRR's 2018 report, "Plant-based Profits: Investment Risks and Opportunities in Sustainable Food Systems" evaluated 16 multinational companies (including General Mills, Kraft Heinz, Mondelez International, and others) on how well-prepared they were to profit from this hugely promising growth in demand for plant-based proteins.[827] FAIRR contends that by equipping investors with the knowledge they need to better assess companies, they will make more successful—and sustainable—investment decisions.

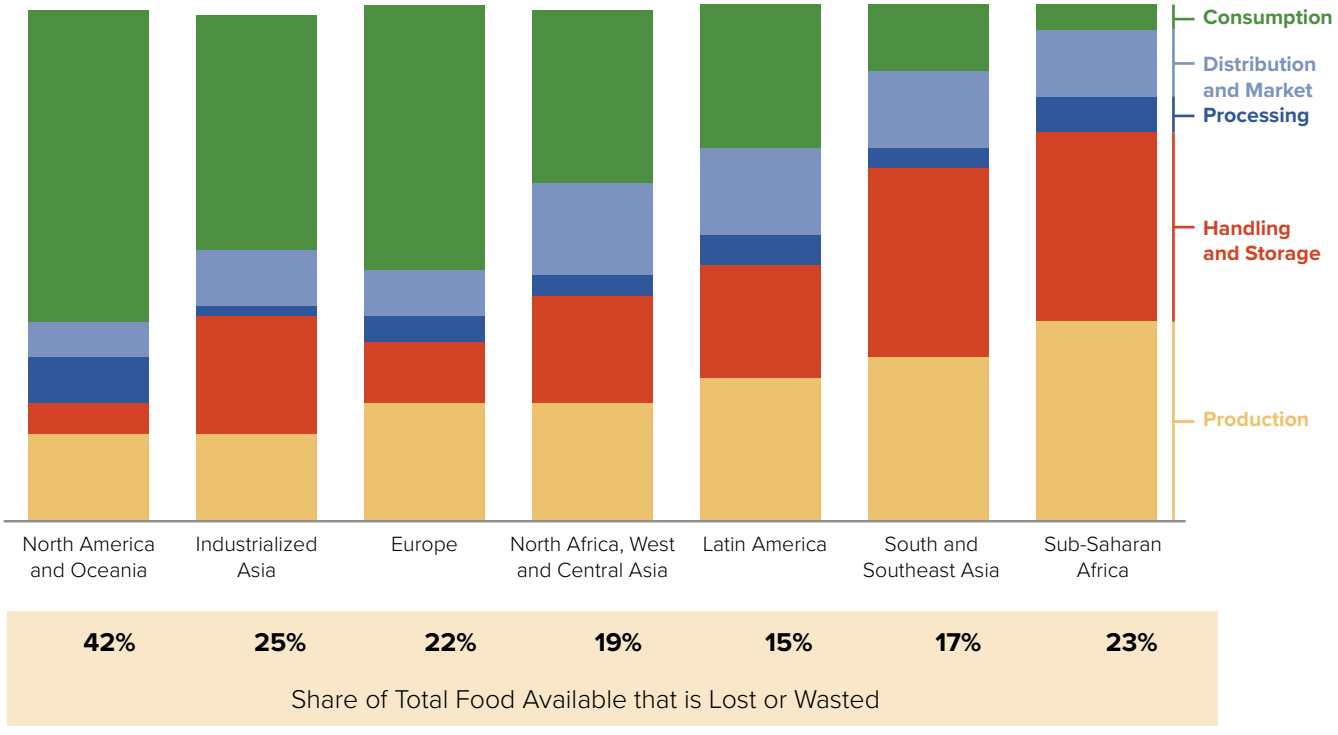
reporting standard was created by the Food Loss and Waste Protocol partnership.[833] Food loss and waste reduction efforts have been launched by the Consumer Goods Forum, the African Union, and Waste and Resources Action Programme (WRAP) in the United Kingdom, and they continue to create considerable momentum. However, rapid urbanisation and the growth of supermarket chains in low- and middle-income countries are fuelling food waste in their urban centres, while at the same time rates of food loss in production, handling, and storage remain high in these countries.[834] Meanwhile, the factors driving household waste in developed countries continue to push it up: UK household food waste increased from 7 million tonnes to 7.3 million tonnes between 2012 and 2015.[835]

Evidence of the Benefits

In 2016, the Business and Sustainable Development Commission found that global opportunities to reduce food waste in the pre-consumer value chain could be worth US$155 billion a year by 2030, and opportunities for reducing consumer food waste could be worth a further US$175 billion.[836] The Champions 12.3 review of nearly 1,200 business sites across 700 companies and 17 countries found that 99% of the sites earned a positive return on investment in activities to reduce food loss and waste, with a median benefit-cost ratio of 14:1. The sectors showing the largest returns were hospitality and workplace canteens.[837]

Saving one quarter of the food currently lost or wasted would be an amount equivalent to enough to feed 870 million people annually— around 65 million more people than currently go hungry.[838] Globally, the amount of crop calories needed to meet rising demand for food, animal feed, and bioenergy is expected to increase by 56% between 2010 and 2050.[839] Halving food loss and waste would reduce the size of the gap between food availability in 2010 and projected need in 2050 by more than 20 percentage points.[840] Losses near production are more prevalent in developing regions while food waste near consumption is more prevalent in developed regions (see Figure 25).
In developing countries, increasing investment in processing, packaging, and distribution technologies would unlock considerable rewards on food security because many of these countries are net food importers rather than exporters.[841] For all countries, but particularly for developed countries, setting targets for national food waste reduction, educating consumers, improving retail forecasting, and standardising food labelling would increase resource efficiency and deliver savings for both consumers and companies.[842]

Figure 25
The Majority of Food Waste Occurs in Developed Countries, Whereas Food Loss is the Biggest Problem in Developing Economies.



Source: Champions 12.3, 2017.[843]

Reducing food waste also has clear benefits for climate change mitigation. WRAP estimated in 2015 that 7.3m tonnes of household food waste was thrown away each year. The avoidable food waste generated 19 million tonnes of GHG emissions over its lifetime—equivalent to taking one in four cars off UK roads.[844] In developing countries, where climate change increasingly threatens the resilience of crops and food security, reducing food loss is an important lever to build resilience by securing the supply of food and thus adapting to climate change.[845]

Challenges

The key challenge to reducing food loss in developing countries is a lack of sufficient handling and storage. Lack of cold-chain storage is a critical cause of food perishing post-harvest: Most degradation processes leading to loss in colour, nutrients, and textural quality double their rate for each increase in 10°C.[846] The lack of handling, packaging, and storage includes insufficient post-harvest storage facilities or basic on-farm storage technologies. This challenge is compounded by limited training and availability of investment to build skills and infrastructure to develop the required infrastructure. Furthermore, unreliable access to markets, in part due to insufficient transport infrastructure, and weak government policy also exacerbate the challenge of reducing food loss and waste in developing countries.

A study of cassava processing in Nigeria, Ghana, and Vietnam suggests that investments in new machinery could reduce post-harvest losses by 44%.[847] Some promising storage technology solutions are emerging but will require investment to go to scale (for example, see Mumbai's sustainable chillers, in Box 38).[848] Introducing new service delivery models, such as centralised farmer managed facilities to better dry grain, weigh, pack, and store are being trialled for maize growers in Kenya. Motorised, movable driers are able to cover at least three to four neighbouring centres where storage sheds hold dried grain before it is sold.[849]

Photo credit: Flickr: Ollivier Girard/CIFOR

Box 38
Rolling Out Sustainable Chillers in India

Companies like Mumbai-based cold chain technology start-up TESSOL have developed solar-powered cold storage units to try to reduce the losses in storage and crop protection. US$19.4 million is wasted in India on a daily basis only due to rejection at the farm and delays in the distribution process.[850] These solutions reduce the running costs of these units by 60% and reduce diesel consumption by 1,000 litres per small vehicle per annum.[851]

Over the last two years, TESSOL has implemented its fuel-free technology across poultry, horticulture, dairy, and frozen food sectors with some of the key players in India, including Godrej, Tyson, Abad Fisheries, Mother Dairy, Chitale, and Fortis hospitals.[852] Yet technologies like these are still nascent in India. Given that Indian farmers face a critical lack of access to suitable on-farm storage facilities and packaging materials, investing in a range of innovative technology companies has the potential to radically reduce post-harvest losses across India and strengthen supply-chain efficiency.[853]

A series of factors contribute to high levels of food waste in developed countries, where 56% of global food waste occurs.[854] Relatively low food prices can mean there is little incentive to prevent waste: WRAP suggests that one cause of increased household waste in the United Kingdom between 2012 and 2015 was a decline in food prices in 2013.[855] Confusing food labelling can also contribute to food waste. Without storage recommendations, consumers can miss opportunities to preserve their foods for longer. Consumers can mistake 'sell by' or 'best before' dates, which are measures of quality, with 'use by' dates, which are measures of safety. In doing so, consumers can waste food that is still safe and nutritious. In some countries, government regulations around health and liability can hinder food donation or other efforts to repurpose food before it is wasted.[856] Another challenge is a culture of large portions, resulting in unnecessary leftovers.

Accelerators

- **National and local governments should set food loss and waste reduction targets and systematic measurement procedures, and then implement policies to reduce waste.** At its core, reducing food loss and waste is about efficiency. In developed countries, governments should also support entities and initiatives that educate consumers, such as WRAP in the United Kingdom. With the support of government funding, WRAP engages with governments, food and drink retailers, manufacturers and trade bodies to improve resource efficiency. Governments can make laws that encourage and enable companies to avoid throwing food away, engage with food industry initiatives to set targets and accelerate action, and work with partners to run consumer education campaigns. Governments can also consider policies like tax incentives (encouraging food donations and reducing recovery costs), liability protections, changing labelling and food safety, organic waste bans, and waste recycling laws.
- **Governments, DFIs, and the private sector should increase on-farm and food supply-chain infrastructures investment in developing countries.** Basic technologies, such as plastic storage bags, small metal silos, and plastic crates, can significantly reduce food losses and waste in storage and transport.[857] Pilot efforts in Benin, Cape Verde, India, and Rwanda have documented reductions of food loss by more than 60% during field trials of a variety of low-cost storage techniques and handling practices.[858] Increasing adoption of post-harvest loss technologies often depends on government-led investments to improve infrastructure (such as access roads), which also improves access to profitable storage technologies. However, private-sector companies are increasingly demonstrating that reducing post-harvest losses represents new market opportunities and viable parts of their business models.

- **Food retailers, manufacturers, and governments should standardise labelling practices by 2020 and inform consumers.**[859] Consumer confusion about the meaning of date labels, or seeing multiple date labels on a product, can result in consumers throwing away food that they could safely eat. Standardising labelling could save consumers up to US$29 billion annually in the United States alone.[860] In 2017, the Board of Directors of the Consumer Goods Forum unanimously adopted a Call to Action to streamline and standardise food date labels worldwide by 2020. By meeting this commitment, companies (and consumers) can realise economic benefits at a global scale. Governments where date label rules are in place can further accelerate action by reforming regulations to support this Call to Action.

- **Governments, companies, and civil society groups should strengthen actions to increase public awareness and shift consumers' and companies' behaviour.** Increasing consumers' awareness and teaching them the skills to store and prepare their food better can help them reduce household waste. Connecting food producers with surplus food to charities and individuals in need is an important and efficient way of rebalancing local and national food systems. Advocacy campaigns are another important way for civil society to bring the issue of food loss and waste into mainstream conversation and encourage governments and businesses to lead in driving change (see Box 39). Supermarket TESCO was the first company to publicly disclose its supply chain waste and has received significant acclaim for its transparency in doing so.[861]

Box 39
Surplus becomes Sustenance in Sydney and Beyond

After noticing the huge volume of food going to waste in the hospitality industry where she worked, Ronni Kahn founded OzHarvest in 2004. Starting with a truck in Sydney, Australia, Ronni delivered surplus food from shops and restaurants to charities supporting people in the area. Four thousand meals were donated in the first month. Today, OzHarvest works nationally, rescuing over 1,000 tonnes of food per week from over 3,000 food donors, including supermarkets, restaurants, catering companies, hotels, airports, farmers shopping centres, delis, cafes, film and TV sets, and board rooms.[862] OzHarvest aims to nourish the country and enable positive change, in particular among vulnerable people.

Since starting in 2004, OzHarvest has delivered 78 million meals, saved 26,000 tonnes of food and built a network of 1,000 charities that it serves.[863] OzHarvest successfully advocated for changes in civil liability and health legislation that prevented food donors from giving away free food without fear of liability: The laws on food donation were changed in four of Australia's states. Training and education programs help to change the broader conversation around food loss and waste, as well as helping vulnerable people to improve their nutrition.

SECTION 4

Water

Photo credit: Flickr: Arne Hoel / World Bank

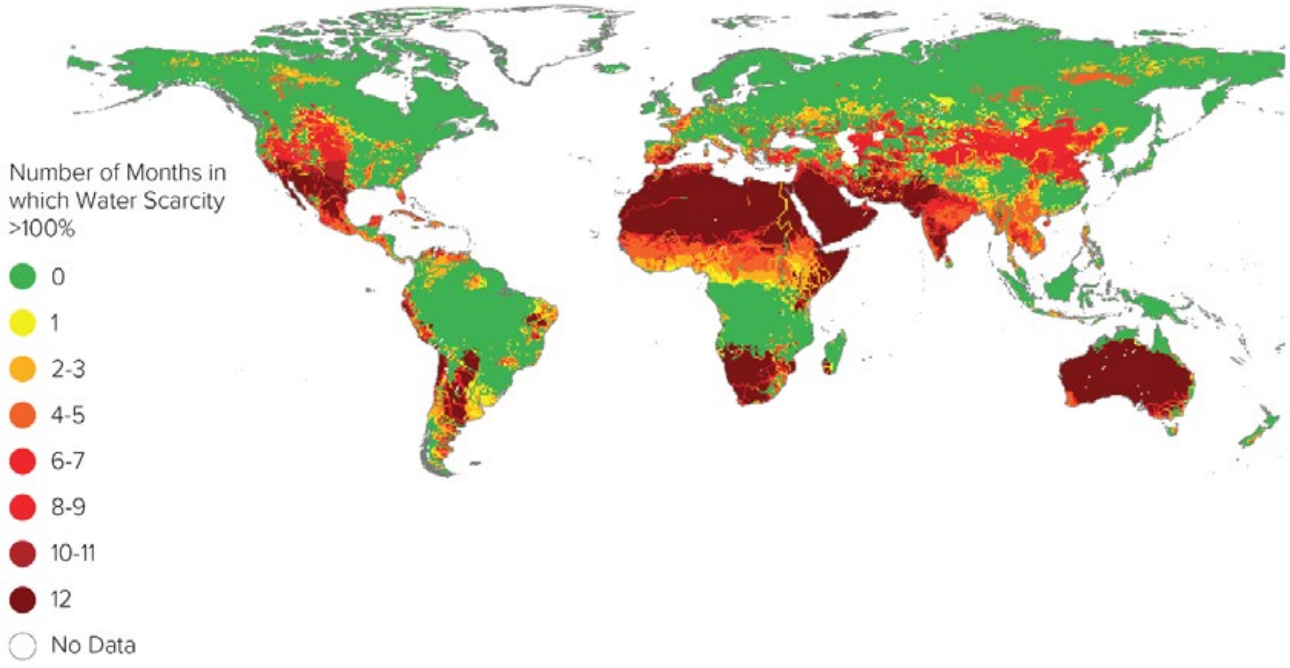
Flowing through every part of our economy, water is a fundamental necessity for lives and livelihoods. Access to safe, sufficient water and sanitation and sound management of freshwater ecosystems are essential to economic prosperity, health and development outcomes, and to environmental sustainability.[864] Yet the world is not managing water well or making the most of it, due above all to failures of policies, governance, leadership and markets. The existing challenges include inadequate access, poorly managed risks and increasing competition for water resources. Climate change will amplify all of these challenges (Box 40).

Already, 4.5 billion people, about two-thirds of the world's population, rely on sanitation that puts their own or their neighbours' health at risk from waterborne diseases, and 2.1 billion people live without readily available, safe water supplies at home.[865] Where piped water is absent, women and girls spend hours every week, or even every day, collecting water at the cost of their education and earnings. Fewer than a quarter of women and girls in Niger are literate,[866] and on average every one of them loses 13 days a year travelling to and from a water source.[867] What's more, the effects of poor management of water risks can play out over an entire lifetime. For instance, a girl in rural Africa born during a severe drought is more likely to grow up physically shorter, receive less education, become less wealthy and, indeed, pass on aftereffects to her own children, who are also more likely to suffer from malnutrition.[868]

Today, more than half the world's population, roughly 4.3 billion people, live in areas where demand for water resources outstrips sustainable supplies for at least part of the year (Figure 26).[869] Societies can move and store water, for example in reservoirs, to manage the impacts of this kind of water deficit on their economies and people. Freshwater ecosystems however, do not have this option, and require water of specific quantity (and quality), at specific times, to thrive and build resilience to local and global change.[870]

Figure 26

The Number of Months per Year in Which More Water Is Withdrawn Than Is Sustainably Available (Annual Average 1996—2005).



Source: Mekonnen, M., and Hoekstra, A., 2016.[871]

Irrigated agriculture already uses around 70% of available freshwater,[872] and the world will need to produce 55-70% more food to feed its people by 2050.[873] With demand in other sectors set to rise by 55% globally over the same period—mainly for electricity generation, manufacturing, and domestic use—competition is set to increase.[874] It is vital to improve the productivity of water use, getting more value from each drop, but it is also vital to protect poor and marginalised users who are most likely to lose out from increasing competition. Better governance is needed to balance supply and demand, securing sustainable, productive, and equitable shares of water for all in a changing climate. We also need investment to improve access to water where and when it is needed, and to protect people from hazards that are already increasing in frequency and intensity (Box 40).

Box 40
How Climate Change Affects the Water Cycle

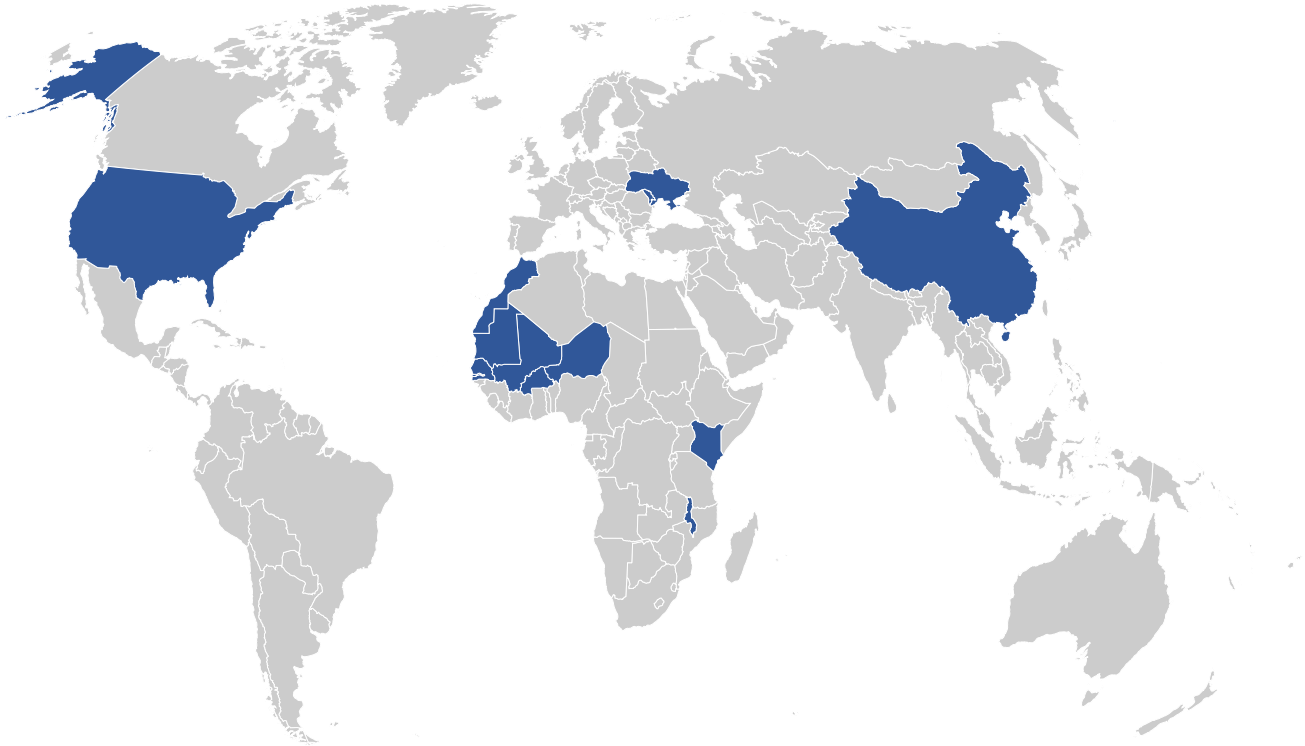
Water is the front-line for climate change and the sector most often mentioned for adaptation actions in developing countries' NDCs.[875] Climate-change impacts affect the water cycle primarily on four fronts, amplifying existing challenges. First, climate change affects availability: less water for some and more for others. Recent estimates suggest that climate change will expose more people to water scarcity,[876] which, combined with other factors, could lead to greater demand for already-depleted groundwater.[877] Second, climate change affects unpredictability, including increased levels of rainfall variability, as well as glacier loss and rain rather than snow at altitude, that reshape the flows of rivers and stores of groundwater.[878] Third, quality is affected. For example, rising sea levels and storm surges drive saltwater into unconfined coastal aquifers and deltas.[879]

Finally, extremes: Water-related natural disasters are increasing in frequency and intensity, with mounting evidence from China[880] to California[881] attributing these crises to a changing climate. Climate change tripled the likelihood of the drought that pushed Cape Town to the brink of 'Day Zero'.[882] Moreover, the economic costs of these disasters are also projected to rise. California's drought cost US$2.2 billion and over 17,000 jobs in the agricultural sector in 2014 alone.[883] Germany, France, Italy, and Poland can all expect average annual flood damage costs to rise to more than €1 billion each by 2020. The proliferation of infrastructure in flood-risk areas could nearly double these costs for Poland and Germany to around €2 billion each.[884]

There is sufficient freshwater on the planet to secure clean and accessible water for all, according the UN.[885] Locally, physical water volume is already a serious concern in some areas, whether in terms of scarcity or floods, and climate change could worsen this. But the biggest existing water and sanitation challenges have more to do with economics and politics than physical availability. Market failures and weak policies occur not only within the water system, but also in the other systems discussed in this Report. Energy sector planning ignores water risks. Subsidised fertiliser, energy, and crops drive unsustainable levels of water usage and pollution in agriculture. Politicians and service providers ignore the vulnerability of sprawling city slums to waterborne disease and floods. The political economy challenges are also exacerbated by the transnational nature of water, given that 151 countries and roughly 2.8 billion people share transboundary river basins. Managing water resources will require strong international collaboration, for example through adaptation planning initiatives such as in the Dniester Basin (see Box 41).[886]

Market and policy failures are already undermining our ability to balance supply and demand, and to improve access and resilience.[887] There is a heavy economic and social cost of doing nothing, but climate change provides new impetus and ways to turn those costs into benefits. This chapter identifies two key opportunities: first, to improve water governance through policies and collective action that balance supply and demand, as well as the benefits and risks from water; second, to make smarter investments in resilient, low-carbon infrastructure to improve access. In both of these areas, this chapter highlights promising examples of water management around the world.

Figure 27
Locations of Transformative Examples in Water Highlighted in This Report.



Note: The map reflects the regional example on the African Risk Capacity (ARC) insurance pool (see Box 43). It shows the ARC signatory countries that have participated in the insurance pool.

Box 41
Climate Adaptation Planning as an Entry Point to Cooperation in the Transboundary Dniester Basin

The Dniester River is one of the largest basins in Ukraine and the largest in Moldova, covering more than 10 million people over an area of more than 72,000 km2 and supporting a wide range of industries including mining, extractives, chemicals, food and forestry, and hydropower production.

In 2015, high-level government representatives from the two countries signed a Strategic Framework for Adaptation to Climate Change that identified joint cooperative actions at the basin level, including improving the monitoring and forecasting of flows and information-sharing, updating rules for the system of reservoirs in the basin, and providing public and local authorities with timely information on flood risk. [888] Critically, careful facilitation ensured that the framework was developed without political dispute. For example, at national workshops, a basin-wide map without national borders was used by stakeholders to discuss the location of vulnerable areas within the basin and potential climate adaptation measures. [889] The strategic framework was developed by expert representatives from both countries but was supported by the United Nations Economic Commission for Europe (UNECE) Water Convention secretariat and the Organization for Security and Co-operation in Europe with financial support from the Austrian Development Cooperation and the European Union's Instrument for Stability.

Some measures—ecosystem restoration, monitoring stations, and awareness-raising activities—have already been implemented. Outcomes have included increased adaptive capacity in the basin as well as the improvement of transboundary water cooperation more broadly, particularly through the entry into force of the transboundary Dniester treaty in 2017.[890]

Lessons from here are being shared and replicated elsewhere in the framework of the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention).[891] There are opportunities to learn from them in river basins from the Danube to the Mekong, where several transboundary climate adaptation strategies are agreed to or in development.[892]

Box 42
Finance for Water

By 2030, investment in water and sanitation infrastructure will need to be around US$0.9—1.5 trillion per year, roughly 20% of the total infrastructure investment requirement.[893] About 70% of this total infrastructure investment will be in the global South with a large share in rapidly growing urban areas.[894]

In developed countries, large investments will be required for renovation and upgrade, while in developing countries many people lack even minimal sanitation and water supply services. For example, in sub-Saharan Africa, 72% of the people lack even a 'basic' standard of sanitation, and 42% lack a basic water supply.[895] (See also Figure 13 in Section 2.B). Roughly US$114 billion per year, mainly in developing and emerging economies, could secure access to safely managed drinking water and sanitation for all. While the financing required for infrastructure to meet SDG 6 water supply and sanitation targets is modest compared to total water and sanitation investment needs, it is still more than three times historic investment trends.[896]

Making sure water and sanitation infrastructure is sustainable need not cost more than non-sustainable infrastructure. In fact, it may even be cheaper, but it requires shifting the way we invest and prioritise finance, including prioritising public finance for the most vulnerable. To that end, all public and private water and sanitation investments should take into account climate risks, which in turn requires the embedding of climate risk-screening and design into public procurement policies.[897]

Maximising returns on investment requires recognising the potential for natural or green infrastructure to complement or replace built infrastructure. For example, watershed protection can reduce the need for investment in water purification and storm water management (see Box 45). [898] Downstream users can pay upstream users for land and water conservation activities that improve water availability and quality and reduce flood risk (see Box 32 on Finance for Food and Land Use).[899]

To mobilise private finance and investment at scale, it will be vital to put an appropriate value on water and sanitation services, without pricing out poor consumers, to generate reliable revenue streams. Greater concern over water risks with climate change provides even greater impetus to do this. For example, in water-scarce South Africa, the secure revenue offered by mining companies purchasing treated wastewater helped secure a US$37 million commercial loan for upgrading Rustenburg's wastewater and water infrastructure.[900] In Jordan, where large volumes of treated wastewater are already reused for irrigation, freeing up freshwater for higher value uses in cities. Here, a public private partnership (PPP), was used to finance, upgrade, and operate the As-Samra Wastewater Treatment Plant.[901] Disaster risk financing offers another set of tools to improve people's ability to cope with unavoidable water risks and shocks, but action will need beyond to extend beyond the water sector to expand financial and social inclusion (including for women and girls), to promote social protection, the use of insurance, and the availability of contingent finance.[902] (See Box 43). These examples show how use of scarce public funds can leverage private-sector engagement to raise capital and help close the water and sanitation infrastructure financing gap.[903]

Use of green bonds is gaining some traction as a way to finance water and sanitation infrastructure investment. Notable are the water sector criteria established in the new Climate Bonds Initiative (CBI) standard, which are being extended to cover upstream natural or green infrastructure.[904] The recent issuance of green bonds by San Francisco and Cape Town, both of which were certified by CBI and received a positive market response,[905] shows the potential for scaling up green bond debt financing in this sector.[906]

Finally, financial disclosure of climate-related and other water risks is another key way to shift investment. Institutional investors and their asset managers should explicitly integrate sustainability considerations into their decision-making processes and report on how they are doing this, per the recommendations of the TCFD. While an increasing number of companies are voluntarily disclosing water risk information, with more than 2,000 companies reporting annually to CDP,[907] the lack of standardisation in disclosure slows change. To truly shift financial markets, regulators need to move towards mandatory and standardised approaches to enhanced disclosure.

4.A. Fair Flows: Balancing Benefits and Risks from Water between Different Users

Climate change has the potential to amplify extremes and further disrupt the delicate balance between water demand and supply. Better governance, policy, and planning is urgently needed to allocate water resources and the risks and benefits arising from water more equitably, efficiently, and sustainably.[908] This section points the way, highlighting successful examples of governments balancing demand and supply with clear plans and the right information; of companies taking action to understand and reduce their water risks and working with others to address shared water challenges through collective action; and of international collaboration to manage water-related disaster risks through packages of policies that balance ex-ante risk reduction with investments that can enable faster post-disaster recovery.

Evidence of the Benefits

Robust policies for sustainable and equitable water allocation safeguard the availability of water for people and for a huge range of valuable goods and services. While poor water allocation policy can hamper economic growth, the World Bank estimates that sound policies could increase GDP in some regions by as much as 6% by 2050, despite climate change and population growth.[909] Governments bear overall responsibility for water allocation policy, especially at the national and river basin scales. However, at smaller scales, such as the watersheds that make up a larger river basin, a wide range of stakeholders can also contribute to wiser water management and share the benefits.

Businesses can reduce costs by using less water in their own operations. Beverage company Diageo estimated that it saved US$3.2 million in 2014 in this way.[910] But businesses can also secure broader benefits by working with others beyond the factory fence. An increasing number of companies see sufficient business value to invest in water stewardship, a stakeholder-inclusive approach to secure benefits from water use through on-site and watershed-based actions.[911]

Payment for watershed protection services is an increasingly prominent instrument to incentivise collective responses to balance and mitigate shared water risks, both in water stewardship initiatives and more widely (for example, as part of smart agricultural subsidies, see also Section 3.C). These allow downstream users to pay upstream users for land and water conservation activities that improve water availability and quality or reduce flood risk.[912] In Nairobi, business and industry partners contribute to a scheme helping farmers upstream on the Tana River to reduce deforestation, which in turn prevents sediment from running into waterways and clogging dams and other water supply systems. The initiative, managed by The Nature Conservancy, has reduced water delivery interruptions caused by sediment spikes by 30% since 2013.[913]

At a range of scales from countries to individuals, improved water policy and planning also carries economic and resilience benefits where it mitigates water-related disasters. At the level of a single national economy, historical analysis suggests that mitigating half the effects of major droughts between 1980 and 2012 could have added 7% to per capita GDP in Brazil and as much as 20% for Malawi.[914] At the individual level, during large and protracted reductions in rainfall in the period 1990—2013, formal sector workers across Latin America lost around 7% of labour income, while those outside the formal sector lost as much as 11%.[915] To avoid costs and unlock additional benefits of resilience to disasters, countries need a wide range of complementary policies and an assessment of water governance conditions in place to establish priorities for the future.[916] Water-related disasters account for 70% of all deaths related to natural disasters,[917] and efforts to improve water governance and management are an important but often a neglected strategy to reduce exposure and vulnerability to climate variability and change. However, to improve people's ability to cope with unavoidable shocks, action is needed far beyond the water sector: to expand financial and social inclusion (including for women and girls), to promote social protection, the use of insurance, and the availability of contingent finance.[918] Approved in 2017, the ADB's US$15 million Pacific Disaster Resilience Program for Samoa, Tonga, and Tuvalu supports policy actions for disaster risk management (DRM) and provides the three countries with a source of contingent financing for timely disaster relief, early recovery, and reconstruction activities.[919] Box 43 on African Risk Capacity Insurance Company Limited (ARC Ltd.), a sovereign insurance pool, highlights one possible part of this resilience package, operating at an international scale, as well as the need to integrate it with other parts, such as national social protection systems.

Box 43
Africa's Sovereign Disaster Risk Insurance

Agriculture is the main source of income for 90% of Africa's rural population, and over 95% of farmed land in the continent is rain-fed, making many African farmers vulnerable to drought.[920] Drought risk can be managed in part with better policies and investments in adaptation in the water and agriculture sectors. However, when severe drought strikes, poor rural communities need rapid and dependable support to stave off hunger and avoid having to sell off their assets.

In response, African governments through the African Union have established a specialised agency, African Risk Capacity (ARC). One of ARC's innovations is a sovereign risk pooling facility, African Risk Capacity Insurance Company Ltd (ARC Ltd). ARC Ltd. is designed to provide predictable and rapid financial assistance to meet part of member governments' response costs as extreme weather hits. The drought insurance is parametric, meaning it is paid according to a country specific pre-determined index and can therefore can arrive in countries' treasury accounts well before either international humanitarian appeal funds or conventional insurance, which involves an assessment of actual loss.

After an extensive 12- to 18-month capacity building exercise, which involves learning the proprietary early warning system of ARC and the completion and subsequent approval by peer member states of a contingency plan, the sovereign is entitled to purchase the insurance. The insurance drought model employs an index based on satellite rainfall estimates, which are used to model the impact of rainfall on crop yields and pastures at different times of the season and overlaid with in-country vulnerability data to ensure it serves the most vulnerable in society. Development partners have supported this with funding for capitalisation of ARC Ltd., as well as grant funding for technical support and capacity-building in ARC member states.

Because risks are pooled across countries in very different climatic zones, the fund is unlikely to have to make payouts to all countries at once.[921] In three years of operation, ARC Ltd. made two payouts to four countries: US$26.3 million to Mauritania, Senegal, and Niger in 2015, against a combined premium of US$8 million; and US$8.1 million to Malawi against a US$4.7 million premium. Together the payouts supported an estimated 2 million drought-affected people.922 There are challenges. For instance, Malawi's payout in 2017 was not triggered until the software model translating rainfall data into a response cost was recalibrated, slowing disbursement of funds.[923] Investing in risk insurance also clearly carries opportunity costs, potentially shifting scarce funds from other priority objectives.

As occasional extreme weather events become more frequent,[924] a grim new normal especially in Southern Africa, the longer-term implications for ARC Ltd. will need to be carefully considered. In the meantime, this innovative model is also being used in the Caribbean and Pacific region and supported by the InsuResilience Global Partnership. The InsuResilience Global Partnership seeks to facilitate faster and more reliable post-disaster responses. In further developing these regional risk pools, it aims to better prepare for climate and disaster risk by using financial solutions, reducing humanitarian impacts, and assisting the poor and vulnerable in order to strengthen adaptive capacity and local resilience.[925] The partnership has raised US$715 million in less than three years.[926]

Empirical evidence is still limited on how effective insurance is in supporting poor people in the face of disasters, however. Investment in climate and disaster-risk financing, including through insurance at the sovereign level or below, is one piece in a much larger adaptation puzzle. To be effective for the poorest people, risk financing requires strong social safety nets in-country[927] and should be complemented by ex-ante risk reduction.[928]

Challenges

Water allocation and management regimes in many countries are not fit for purpose under current climate conditions, let alone under a changing climate.[929] Policy reform efforts are often blocked or captured by powerful interest groups. India's groundwater levels, for example, are already over-exploited, and 54% of the country faces high or extremely high water stress.[930] Here and elsewhere, groundwater will be increasingly important, as climate change increases variability in precipitation, soil moisture, and surface water availability[931] (see Box 40). Subsidies for electricity, however, continue to drive unsustainable groundwater withdrawals. Solar powered groundwater pumps open up new opportunities for irrigation around the world, including in India where they, too, are being heavily subsidised.[932] To keep withdrawals to sustainable levels, policy-makers need to work around vested interests or develop compensatory measures. For example, quantitative regulation of water use in the manner developed in China's Turpan Prefecture has reduced groundwater overdraft, while still boosting farmer income by around 4% with higher value crops.[933] (see Box 44).

Water's physical characteristics also pose challenges. Establishing real water savings at the scale of a river basin is much harder than saving water at the level of a single field, factory, or home. There may be real energy savings from saving water—moving and treating water globally used nearly as much as Australia's total energy demand in 2014[934]—but unlike energy, water that is seemingly wasted through inefficiencies will often be used productively by someone else within a basin.[935] Policy and planning to manage demand and ensure that risks are properly allocated must therefore be based on solid water accounting at the level of the river basin.[936] Ultimately, the key strategic objective must be to establish and enforce sustainable limits on total withdrawals for the entire river basin—including ensuring enough water, seasonally, to ensure resilient freshwater ecosystems. Only then can the overall productivity of water use be improved, through a range of policies and technologies, including permitting and pricing, precision irrigation, making industrial processes more water-efficient, and wastewater reuse. Circular economy approaches that consider the productivity of water across multiple users can offer greater value overall. Jordan, for example, successfully used treated wastewater for nearly a quarter of its irrigated agriculture in 2014.[937] In Belgium, Heidelberg Cement has ensured that 95% of water pumped out of its limestone quarry in Antoing is used for drinking water supplies, helping groundwater levels to stabilise and increase.[938]

Much better data are needed to support water accounting, with the number of hydro-meteorological monitoring stations declining since the 1980s.[939] Business and civil society can contribute to plugging the water data gap. For example, WRI's Aqueduct is seeking to expand its public data platform with a global geodatabase of public water management indicators crowdsourced from companies.[940] New technologies, such as remote sensing to measure evapotranspiration (Box 44), can increase transparency on how much water is actually being used by agriculture at least at larger scales. Strides are also being made in measuring the benefits and risks associated with water—from water utilities in the United Kingdom that are mainstreaming natural capital accounting into their infrastructure planning decisions[941] to metrics that reveal the much greater impact of disasters on poor people, by focusing on well-being in addition to infrastructure and production.[942]

Box 44
Getting More Value from Less Water in Turpan, China

Agriculture accounts for around 70% of employment in China's Turpan Prefecture, and the expansion of irrigated land has increased pressure on groundwater reserves. Traditionally managed and distributed through a network of tunnels and access shafts, called the Karez, in many areas these traditional approaches have been overwhelmed by the intensification of farming and other industries. Despite initial government efforts to use modern irrigation technologies with the aim of expanding production while saving water, groundwater levels continued to decline by 1.5 to 2 metres each year because water savings from more efficient technologies were used to expand the area under production (by a third from 2000 to 2008), ultimately driving increases in overall water consumption at a basin-scale.

In 2008, the government tried a new approach, in collaboration with the World Bank. A thorough assessment of the water balance at basin level helped build the case for the politically challenging decision to reduce the area under irrigation and impose strict water consumption caps. The prefecture's water managers turned to satellite remote-sensing to assess evapotranspiration, allowing them to monitor water use and productivity and reform the allocation system on the basis of actual consumption. The programme focused on getting more value from less land and water through a shift from commodity crops like cotton and maize to higher value melons and grapes. As a consequence, farmer incomes increased at around 4% above inflation, and groundwater decline reduced by almost 170 million m3. [943]

Accelerators

- **Governments should put in place robust water allocation policies and plans that establish the full value of water, protect the poor as well as ecosystems, and factor in population growth and a changing climate.** Incentives like water pricing and permits and technologies to enhance water productivity can contribute to balancing supply and demand. Yet as the Turpan experience shows, strong public regulation is essential, using accurate water accounting to establish agreed and enforceable limits on overall and individual usage. Taking account of climate change and other drivers like population growth, water accounting must also underpin planning, and water can be better embedded in national development and climate plans, including both mitigation and adaptation components of NDCs. Government can also establish cross-subsidies for poor users in water pricing regimes and make dedicated allowance for environmental needs within allocation policies. Women can play a key role in improving water management outcomes: Countries can follow the example of Uganda, which has a dedicated five-year gender strategy for water and sanitation.[944] The World Bank estimates that improved policies for water allocation could increase GDP in 2050 by 6% in some regions.[945]
- **Businesses should identify water risks, develop water-smart business models, and monitor progress in their operations and supply chains against context-relevant targets.** Companies around the world are waking up to water risks and opportunities. Those companies disclosing on water issues to CDP reported US$23 billion in investment commitments in 2017 to tackle water risks in their operations and beyond.[946] Radical transparency requires all businesses to work to understand and disclose water risks to their stakeholders, including investors and customers, and mitigate these through actions in their own premises, factories, and farms. Companies can also do more to improve water management in their supply chains[947] and engage with government and other stakeholders, transparently, to improve water policy at river basin scale.[948] Targets to drive ambition and innovation should be set contextually, according to the capacity of surrounding river basins to provide water and absorb pollution.[949]
- **Water users, including businesses, utilities, public agencies, and households, should collaborate via watershed protection schemes.** Improving water management requires finding innovative ways to incentivise collective action, for example, by better allocating benefits and costs. In 2015, 197 watershed protection payment schemes around the world—covering an area greater than Mexico's total arable land—channelled US$657 million from upstream users to downstream users for land and water conservation activities in order to secure improved water availability and quality and reduce flood risk for downstream users. A much larger sum, US$23.7 billion, was spent by governments in the form of incentives for landowners to undertake watershed protection.[950] These kinds of payments could also support a just transition for vulnerable communities away from conventional agricultural subsidies that encourage unsustainable use of water, energy, and land.
- **Governments and regional organisations should promote tailored policy packages to reduce exposure, minimise losses from natural disasters, and increase resilience, at least cost.** A wide range of policies and investments from improving water management to slum-upgrading, land zoning, and titling and investments in early warning, can reduce exposure and vulnerability of people and infrastructure before disaster strikes (see also Section 2 on Cities). Additional policies to improve financial inclusion and establish social safety nets, contingency funds, and insurance (such as ARC, Box 43) can increase resilience by accelerating recovery and smoothing the impacts of shocks. Implemented globally, a comprehensive package of policies for disaster risk reduction and improved resilience could avoid losses of around US$100 billion per year, once the outsize impacts of disasters on poor people are properly accounted for.[951]

4.B. Priming the Pump: Targeting Investment to Resilient Infrastructure for People and Economies

The world will need to invest around US$90 trillion by 2030 to close the global infrastructure gap.[952] Around 20% of this is the infrastructure needed for water resources management and water and sanitation services, for which investment needs by 2030 are estimated at US$0.9—1.5 trillion per year.[953] While infrastructure renovation and upgrade are needed in developed countries, roughly two-thirds of the global infrastructure investment that is required will be in the global South.[954] Here, especially, investments can help to bridge the adaptation gap and reduce poverty.[955] For example, a small share of total global water infrastructure spending—an estimated US$0.1 trillion per year, mainly in developing and emerging economies—could secure access to safely managed drinking water and sanitation for all (SDG targets 6.1 and 6.2). These volumes of finance, while relatively modest, are still more than three times historic investment trends.[956] Currently, billions lack these essential services, exposing them to diseases like diarrhoea (still a leading cause of death globally);[957] imposing huge burdens on well-being, dignity, and productivity; and undermining their ability to cope with climate change. Similar deficits are found in infrastructure for water storage, irrigation, and flood defence, which are needed to manage rainfall variability and climate extremes.[958]

Infrastructure in other sectors also needs to contribute to water security and withstand water-related climate risks such as floods, droughts, and rainfall variability.[959] Not only are 40% of India's power plants located in highly water-stressed areas, but the country's largest power utilities lost more than US$1.4 billion in potential revenue due to water shortage-related disruptions between 2013 and 2016.[960] The transition to a low-carbon economy is not immune to water risk. Hydropower dams being built on Africa's Zambezi and Nile rivers, for example, are clustered in areas with high rainfall variability, increasing the risk of a single dry period interrupting electricity generation and critical energy services.[961] Under one clean energy scenario, water withdrawals could be reduced by 12% by 2040, but in other scenarios with more biofuels, concentrating solar, carbon capture and storage, and nuclear in the mix, the amount consumed (not available to other users downstream) could still increase by 2%. Impacts are dependent on the exact mix of technologies and how they are distributed in relation to available water.[962]

Excitingly, innovations are opening up new possibilities for water system design and management, for example, in ICT, circular economy approaches, and nature-based solutions. China's Spong City project, for example, aims for 70% of rainwater to be absorbed and reused across 80% of its urban areas by 2030, through a mix of green and grey infrastructure.[963] Initial results include reduced urban waterlogging and improvement of water-related ecosystems, as well as improved public satisfaction.[964] While interest rates may be low, financing challenges must also be overcome, not only to find the money but to make spending more climate-smart.[965] That means embedding climate resilience as well as mitigation into infrastructure investments. This can be done by ensuring that international grant finance goes towards increasing access to basic infrastructure, including drinking water and sanitation services in the poorest countries, and incentivising resilience and reduced emissions. In emerging and developed economies, domestic and concessional international finance, including through MDBs, can crowd in private investment in infrastructure. Much more can be done to direct this private investment to infrastructure that offers resilience as well as mitigation co-benefits. And private finance can also incentivise improved and mainstreamed assessment, disclosure, and action on water-related and other climate risks across infrastructure projects and portfolios.

Evidence of the Benefits

The return on investment from conventional water and sanitation infrastructure and services is high. At the global level, every dollar invested in sanitation returns on average US$5.5 in benefits, and every dollar invested in drinking water supply returns US$2 (Figure 28).[966] Adequate water supply, sanitation, and hygiene for all could avert the deaths of 361,000 children under the age of five every year.[967] In urban slums particularly, closely packed living conditions, inadequate infrastructure, and poverty combine to increase disease risk.[968] Investments in water storage and conveyance infrastructure also carry significant benefits. In 2010, securing water for existing irrigators could have generated global welfare gains of US$94 billion.[969]

Well-constructed and managed water supply networks, sanitation systems, storage, flood defences, and early warning systems are also a foundation of resilience to climate change and water-related extremes.

Nonetheless, water and sanitation infrastructure, and indeed all infrastructure, needs to be made more resilient through better choice of technology, siting, and, above all, improved policies, governance, and management. There will be costs to this. Adaptation costs for water supply and riverine flood protection, for instance, have been estimated at US$27—34 billion per year from 2010 to 2050.[970] A related challenge is that it is not always easy to quantify the benefits especially if they accrue over time.

There are clear advantages to acting now. First, including a more comprehensive assessment of risk and design in adaptability from the outset may not be more expensive than conventional approaches and could even be cheaper. Here, there is an increasingly recognised role for nature-based solutions to help build resilience to climate change and disasters, as an alternative to fixed concrete infrastructure. Nature-based solutions are frequently emphasised in National Adaptation Programmes of Action,[971] and there are many opportunities to use them in water management. In the United States, the DC Water utility has, for example, invested in natural or green infrastructure to manage stormwater and prevent pollution of rivers, allowing it to adaptively increase capacity in ways that large concrete infrastructure often prohibits, as well as spread costs more smoothly for its ratepayers over time. The utility also raised US$350 million in 2014 for its wider Clean Rivers project through a municipal century bond with a 100-year tenure—the first of its kind in the United States. Attracting over US$1 billion in market interest, there are signs that smart investors are increasingly looking for this kind of long-term, green opportunity.[972] DC Water has issued a further US$200 million in green bonds[973] and in 2016 pioneered an innovative US$25 million environmental impact bond, again the first of its kind in the United States (see Box 45).[974]

Box 45
Greening Washington DC's Water Infrastructure

Combined sewer overflows (CSOs), where drains mixing sewage and rainwater overflow into rivers during storms, are a major problem for DC Water, in the historic heart of the US capital city. Nitrogen and other pollutants flow into the Potomac river when CSOs occur, ultimately starving aquatic life of oxygen in the Chesapeake Bay, the largest estuary in the US.[975] In response, DC Water initially planned a US$2.6 billion Clean Rivers Project involving three large holding tunnels for sewage and stormwater, and the utility funded it through a green 'century bond'. The bond, worth US$350 million and attracting more than US$1 billion in market interest, was the first bond from a municipal water and wastewater utility with a 100-year tenure and the first green bond in the United States to receive an independent review.[976]

Subsequent to the bond issuance, DC Water negotiated with federal authorities to substitute one of the tunnels with green infrastructure. Green infrastructure, including grassed swales, permeable pavements, and increased tree cover, can absorb stormwater and reduce the amount running into drains in the first place. Although mandated by a federal decree, the whole project depends ultimately on revenue from customers. A levy is placed on customer bills, based on the impervious area of properties.[977] This links the fee closely to the proximate cause of CSOs and and includes an offset mechanism in which customers can get a small discount for specified stormwater management actions on their own property. Some regard the charge as unfair, as it penalises customers such as cemeteries and churches with minor wastewater treatment needs but large impervious areas. Nonetheless, the project is set to meet the objectives of a 96% reduction in system-wide CSO volume and prevent 500 tonnes of nitrogen from flowing into the Chesapeake, while offering additional benefits. These include increased property values through improved aesthetics and more opportunities for local job creation.[978] Made up of many small interventions, green infrastructure initiatives of this kind are also more adaptable in the face of climatic and other future changes, compared to a large single tunnel project.

DC Water has subsequently issued a further US$200 million in green bonds,[979] and in late 2016 it issued the first US Environmental Impact Bond, at US$25 million, privately placed with Goldman Sachs and the Calvert Foundation. A portion of risk associated with green infrastructure construction is transferred to investors, for whom a higher return is triggered if reduction in storm water runoff per acre exceeds an estimated 41.3%, while investors owe a risk-share payment to DC Water if runoff reduction is below an estimated 18.6% (generating funds for further remedial work to reduce sewer overflows, if required).[980]

Second, any increase in up-front costs—a potential 'resilience premium'—must be set against the cost of adaptation in the case of action. Without up-front action, of which infrastructure is a key part, the climate-change adaptation costs in developing countries alone are expected to soar to as much as US$300 billion per year by 2030 (6–13 times current levels of international public finance for adaptation) and US$500 billion by 2050.[981] Already, inadequate drinking water supply and sanitation entails an estimated US$260 billion per year in economic losses globally, more than twice the investment required for safely managed services for all. These economic losses represent 4.3% of GDP in sub-Saharan Africa and 2.9% in South Asia.[982]

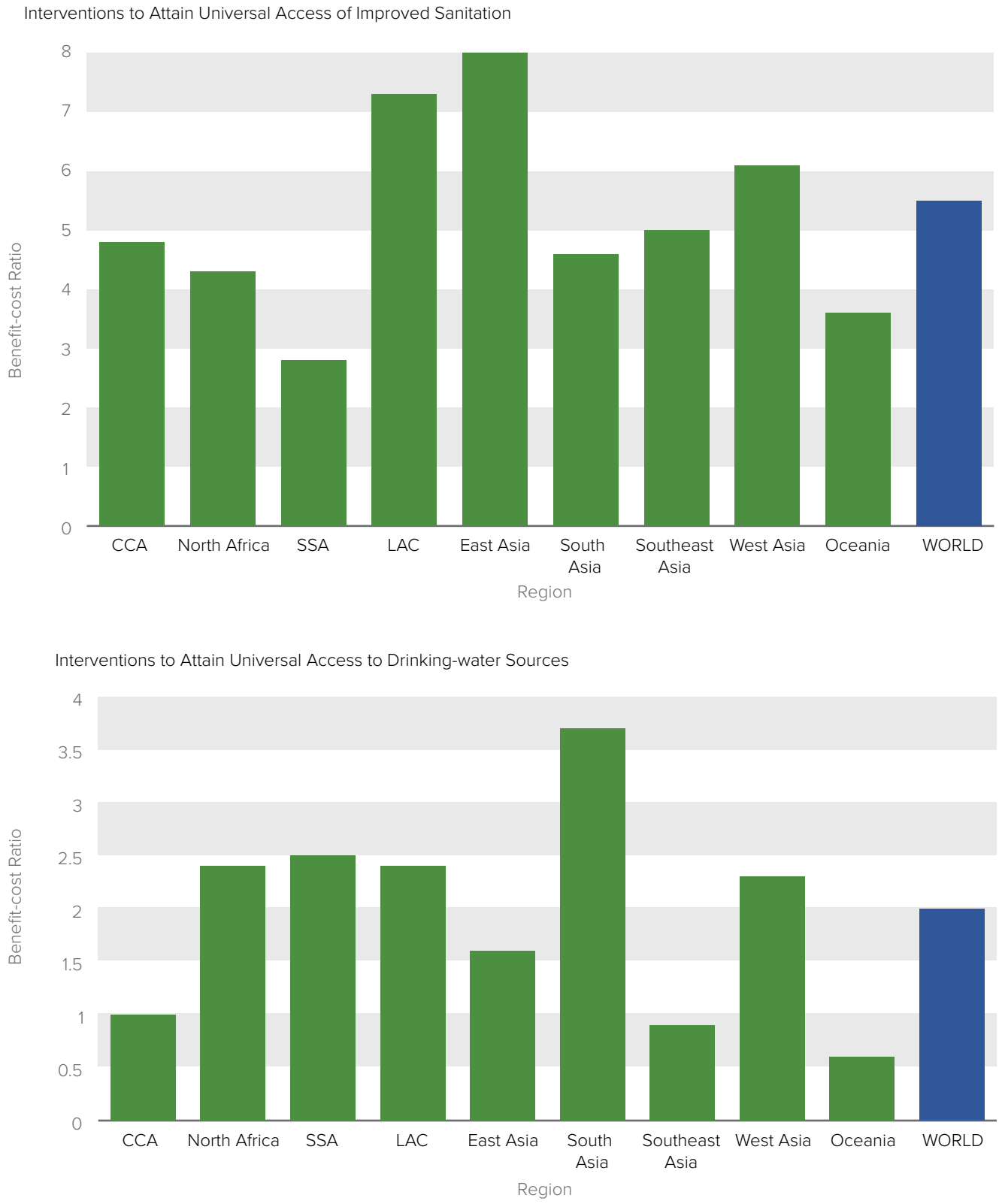
Third, there are significant benefits to optimising current and future infrastructure investments, which could see a modest extra investment in planning generate large financial and non-financial returns. The Nature Conservancy, for example, estimates that a system-scale approach to planning and managing hydropower could keep 100,000 km of river free-flowing, providing biodiversity and ecosystem service benefits without sacrificing energy development. This would cost an estimated US$3 billion per year globally, over business as usual.[983] Yet in basins where hydropower has a significant role, even a 5% improvement in other water services like irrigation, drinking water supply, and flood protection could generate an additional US$38 billion per year in additional benefits.[984]

Fourth, there is uncaptured value in the form of climate-related opportunities to reduce costs by improving efficiency and recovering value in the water and sanitation space. In water supply, a programme of leakage identification and control in Lisbon by the utility Empresa Portuguesa das Águas Livres generated approximately US$84 million (€64 million) in accumulated savings from 2005 to 2015, increasing drought resilience while also reducing emissions for treatment and pumping.[985] In wastewater, a pilot waste-to-energy project in Xiangyang, China, is set to reduce emissions 95–98% compared to traditional sewage sludge treatment. The sale of biogas and digestate obtained from sewage sludge generates more than US$1.5 million for the Chinese plant annually.[986] Circular economy approaches that can recover energy, agricultural products, water, and other vital resources from human waste are being expanded worldwide, including in many developing countries.[987] In India, which has a huge sanitation shortfall, it has been estimated that adopting technologies that can recover biogas compared to conventional pit latrines could avert a 7% increase in national emissions.[988] Meanwhile in Ghana, the company Safi Sana is pioneering a design-build-operate model for waste-to-energy factories, which receive faecal and organic waste from slums and sell biogas, fertiliser, and recycled water as end-products.[989]

Photo credit: Flickr: Arne Hoel / World Bank

Figure 28

Benefit-cost Ratios of Interventions to Attain Universal Access to Improved Sanitation (Top) and Drinking-water Sources (Bottom), by Region (2010).



Source: The World Health Organization, 2012.[990]

Challenges

The key challenge is not the infrastructure price tag itself but making the money that is available (most of which is public) deliver stronger services that secure revenue streams, while delivering to all segments of society, including poor people. No matter the source of finance, people need to receive reliable, quality services if they are to pay the fees or taxes that will ultimately repay infrastructure costs. Again, underlying policy and market failures must be overcome, requiring strong institutions and regulation.

Water supply and sanitation have proved stubborn in this regard, particularly in developing countries. High capital costs for infrastructure stretch public budgets, while limited demand for sanitation, low economies of scale in rural areas, and weak policy and regulation make private investors wary. In urban piped water systems, monopolies are hard to avoid and require strong regulation to ensure poor consumers are not exploited by high connection fees and tariff hikes, whether they are publicly or privately operated. Politicians may neglect whole sections of society—from remote rural communities to urban slum settlements—in favour of large, visible infrastructure and services for more powerful constituents like wealthy users and businesses.[991] The challenges are significant but not insurmountable. With political commitment and patience, Senegal has reformed its water sector, regulating its private operator and public asset holder through performance contracts.[992] Eighty-seven percent of its urban citizens have access to piped water, against a regional average in sub-Saharan Africa of 57%.[993] Donors can provide public financial management support to poorer countries to improve generally low utilisation rates of budgets for water and sanitation.[994] They can also help more utilities secure finance from domestic capital markets by providing viability gap funding and facilities to aggregate projects, as is being done in Kenya.[995] More developed cities, like Casablanca in Morocco, can explore alternative finance sources like levies and taxes on land value (seeBox 46). Public-private partnerships could develop supplementary revenue streams—the Toilet Board Coalition estimates that sanitation could be a US$62 billion market in India, once circular economy and health data collection possibilities are exploited.[996]

Box 46
Capturing the Value of Land to Finance Urban Services in Casablanca, Morocco

Morocco has made greater progress on urban water and sanitation than many of its regional neighbours, but half a million people in the greater Casablanca area still lack access to adequate services.[997] By 2030, the population of the city is set to grow from around 3.5 million to 5 million. The city has developed an innovative financing mechanism to internalise the value of service provision for property developers. Developers' contributions finance the costs of land acquisition, network extension, and social connections via a dedicated fund. Contributions range from 1.3% of the selling cost of luxury apartments, to 0.7% for social housing and may be waived altogether when a development occurs in slum areas, while they are increased for developments that are not part of the city's master plan. In 2014, the fund financed 54% of the investment programme for water supply and sanitation services and flood risk mitigation, versus 7% in 2004. The remaining costs, mainly operations and maintenance and asset renewal, are funded by user fees. The mechanism is one example of land-value capture—charging developers fees to connect developments or using taxes to capture increased real estate value arising from infrastructure provision (see also Box 24 in Section 3). It is easier to internalise the additional value of infrastructure where there is a new development on undeveloped, unserved land. This might imply that the mechanism would incentivise sprawl, but it is possible in principle to tailor the different contribution rates paid by property developers to avoid this, such as by reducing contributions on infill developments.[998] (See also Box 16 on Morocco's solar deployment).

Ultimately, however, it is likely that public finance, whether from international transfers or domestic sources, together with strong sector leadership from national governments, will continue to be key to close the water supply and sanitation access gap. Governments and their development partners will therefore need to strive to improve the effectiveness of direct public spending on infrastructure—improving policy coherence as well as prospects for climate resilience, for example, by mainstreaming climate-risk screening and low-emissions technology preferences into public procurement.

The story is different where revenue streams are more secure, as is increasingly the case for several infrastructure sectors, including for water and sanitation in some emerging as well as developed economies. Here private finance will be possible. Across all infrastructure sectors this could contribute an additional US$1—1.5 trillion per year if barriers are tackled—as much as half the current shortfall in total investment requirements.[999] The barriers, however, are significant, and include undeveloped and unclear investment pathways and project pipelines from governments;[1000] insufficient project scale; political economy challenges like corruption; and financial regulations that discourage long-term, cross-border investments.[1001] Public policy, as well as smarter financing from MDBs, is therefore essential to improve the attractiveness of infrastructure investments for private partnerships and investors. The public sector also needs to carefully consider what risks it takes on, for example, by stepping in when large infrastructure projects fail, as well as protecting vulnerable groups through effective regulation.

Climate-related risks from water and other factors introduce additional uncertainties, which must be priced and allocated to the best placed party. Depending on the overall risk-return profile, governments may choose to absorb climate-change risks (for example, through partial guarantees) or not. PPP frameworks in the United Kingdom, Belgium, and Australia, for example, pass risks of certain weather events like floods and storms to contractors, separating them out from force majeure events.[1002] Financial regulations also have a key role to play, for example in encouraging greater disclosure on water-related climate risks. Central banks, financial regulators, and finance ministers have the most powerful levers at their disposal in this regard. They have a key role to make mandatory the recommendations of the TCFD, which call for disclosure on climate-related governance, strategy, risk management, and metrics and targets in public annual company filings.[1003] For developing countries, however, better disclosure of physical climate impact risks will often highlight greater existing climate vulnerability, increasing the cost of capital they face when borrowing to finance resilient infrastructure. This makes public international and domestic finance to improve resilience, and innovative risk financing initiatives such as insurance (see also Box 43) even more essential.[1004]

Accelerators

- **Together with their development partners, governments of countries with inadequate drinking water, sanitation, and bulk water systems should invest scarce public finance in resilient infrastructure for the most vulnerable.** Since 2000, China has brought drinking water to the homes of nearly half a billion people and provided safely managed sanitation for a similar number.[1005] Both existing and new water and sanitation infrastructure must be made more resilient. By using climate resilience and low-carbon criteria in public procurement[1006] and promoting risk-management tools such as climate-resilient water safety plans,[1007] governments can safeguard the significant benefits from water and sanitation for their citizens and economies in the face of extreme events.
- **Governments worldwide should encourage private capital to flow to infrastructure that is resilient to water-related and other disaster risks that are driven by climate change.** Better regulation, credible long-term strategies, project preparation and pipeline development, and selective guarantees are needed to attract private investment in water and sanitation infrastructure, especially given additional climate risks on top of existing political risks to revenue streams.[1008] The public sector must also be ready to appropriately allocate these risks through PPP frameworks and regulation to secure value for money for taxpayers and to protect poor users. In some cases, climate-change risks could provide

additional impetus for innovative private finance. In water-scarce South Africa, the secure revenue offered by mining companies willing to purchase treated wastewater secured a US$37 million loan for upgrading Rustenburg's wastewater and water infrastructure.[1009] Since May 2016, the San Francisco Public Utilities Commission has issued more than US$1 billion in green bonds,[1010] and the City of Cape Town has issued a US$76 million green bond, both mainly for water.[1011] Both were certified under the water sector criteria of the CBI standard, which includes mitigation and adaptation elements, and are being extended to cover upstream natural or green infrastructure.[1012] The San Francisco and Cape Town bonds received strong ratings from credit agencies and a positive response from the market,[1013] showing the potential for scaling up green bonds for infrastructure.[1014]

- **Government, private institutional investors, and international financial institutions should set out standards requiring that projects and portfolios are transparently assessed for exposure to water-related and other disaster risks driven by climate change and that these risks are disclosed and managed.** There has been significant progress with voluntary disclosure, for example the water risk disclosures secured by CDP from over 2,100 companies annually.[1015] However, agreement on disclosure standards for assessing the resilience of infrastructure investments would also steer much needed capital to the right endpoints.[1016] Investors can insist on such disclosure by investment managers in mainstream annual filings, and financial regulators can make it mandatory or provide incentives for disclosure, building on the TCFD recommendations.[1017] MDBs and DFIs should also be using state of the art climate-risk screening tools to identify and manage climate-risk across their infrastructure portfolios. With improved disclosure, poor countries will need international public finance and policy support to ensure they do not pay a premium for their existing vulnerability, when financing infrastructure on the international debt capital markets.[1018]

Photo credit: Heather Arney / WaterPartners International

SECTION 5

Industry, Innovation, and Transport

Photo credit: Chuttersnap/Unsplash

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,

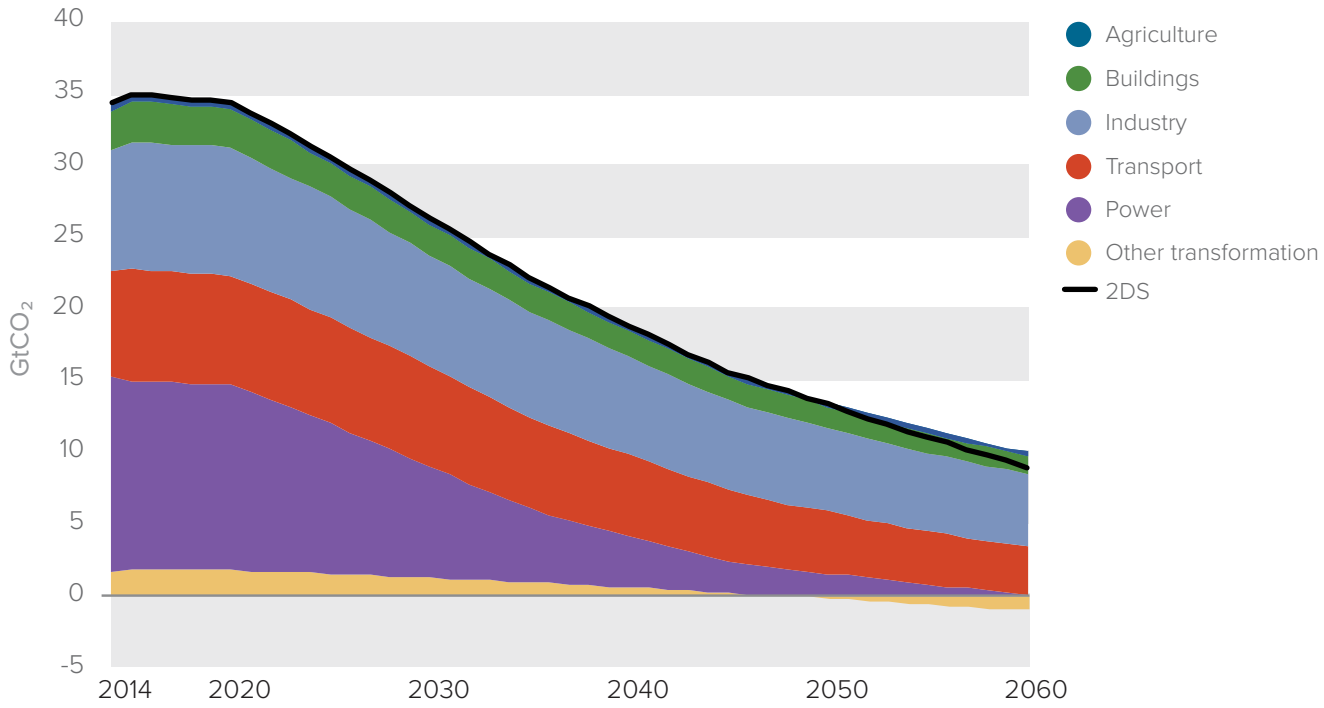
putting the electrification of heavy road transport or shipping within reach with potentially large benefits for human health due to reduced air pollution (see also Section 1.A).[1027] There are also fruitful business opportunities to applying the circular economy approach to these sectors, for instance, 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.



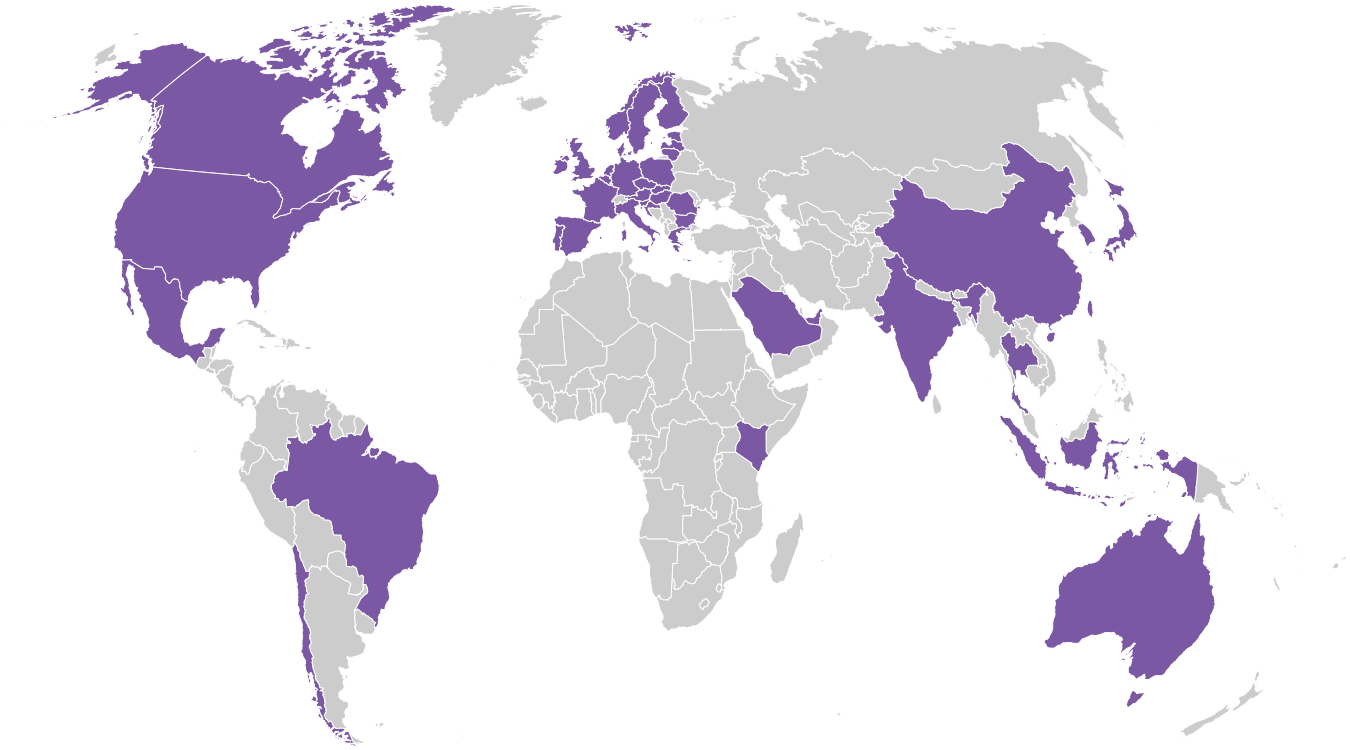
Source: IEA, 2017. Energy Technology Perspectives.[1029]

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.

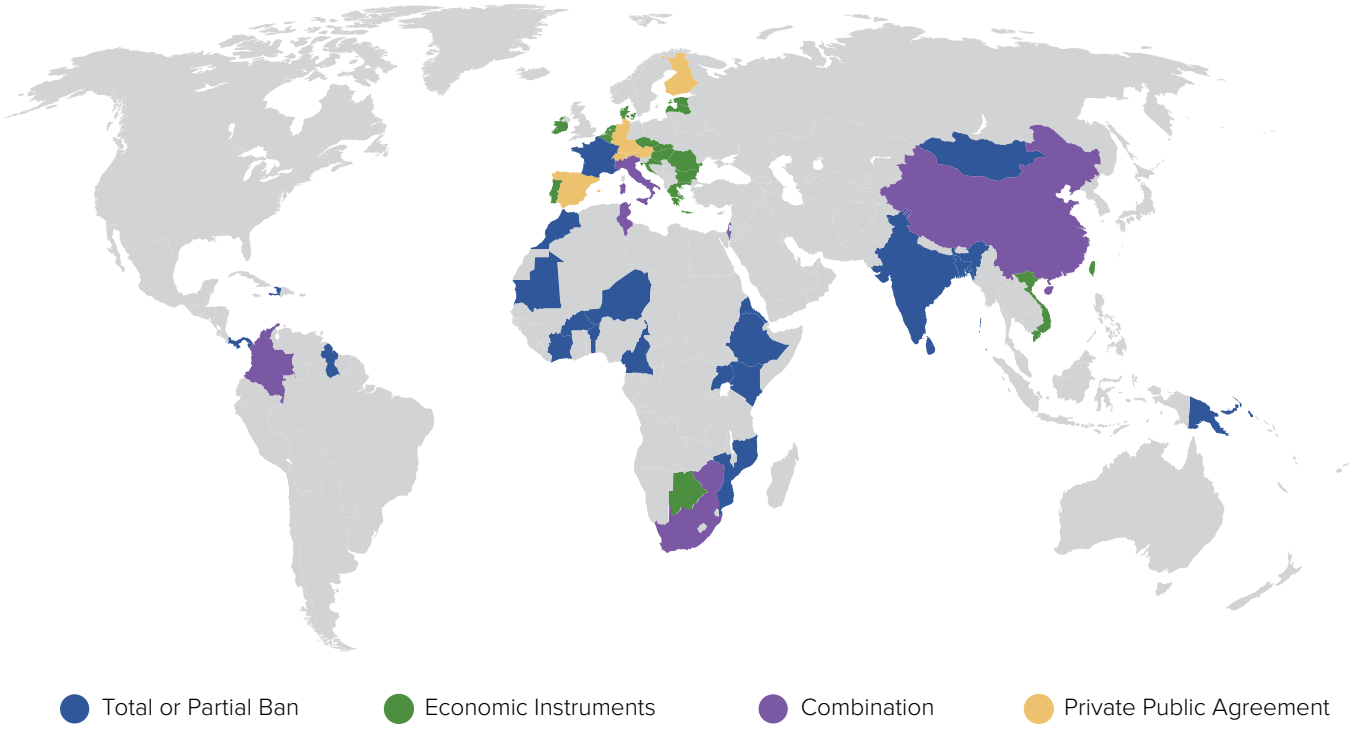
Beyond carbon emissions, plastics are also a huge source of environmental damage, with some plastic items taking 400 years to break down[1093] and with particular issues regarding their overflowing into waterways, most notably in Southeast Asia. Each year, at least eight million tonnes of plastics leak 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.

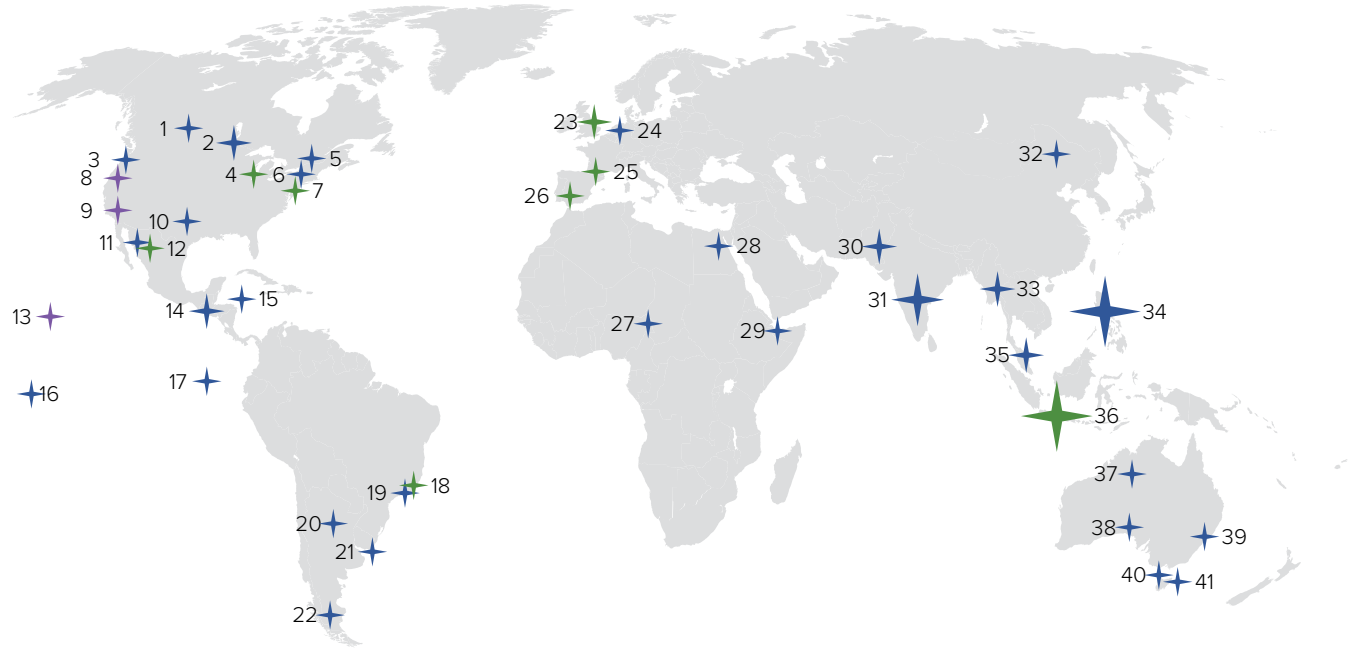
Despite the challenges, recent commitments by several governments of both developed and developing countries indicate an increasing willingness to improve the plastic value chain. For example, several national and subnational governments—including Taiwan,[1103] Malibu, California,[1104] Vanuatu,[1105] 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 CO_2 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.

Photo credit: Flickr: IICD

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]

Photo credit: Visty Banaji

ENDNOTES

Report Summary

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Acknowledgements

The Commission is grateful to the many organisations and individuals that have made comments or substantial contributions to this Report, as listed below. They are, however, not responsible for the accuracy, content, findings, or recommendations. The findings do not necessarily reflect their views, or those of the organisations they represent.

Special thanks for their expert comments, inputs, and guidance to:

Faig Abbasov (Transport and Environment), Nate Aden (WRI), Rudiger Ahrend (OECD), Solstad Gry Asp (Norwegian International Climate and Forest Initiative (NICFI)), Jen Austin (WMB), Anupam Badola (Dalmia Cement), Charles Batchelor, Manish Bapna (WRI), Chris Barrett (ECF), Veronika Bertram-Hümmer (KfW), Maxime Beaugrand (Institute for Governance & Sustainable Development), Preety Bhandari (ADB), Nathan Borgford-Parnell (IGSD), Milan Brahmbhatt (NCE), Barbara Buchner (CPI), Angela Churie Kallhauge (Carbon Pricing Leadership Coalition), Helen Clarkson (The Climate Group), David Cooper (CBD), Anthony Cox (OECD), Annette Detken (KfW), Helen Ding (WRI), Kathleen Dominique (OECD), Deborah Drew (WRI), Jane Ebinger (World Bank), Todd Edwards (Mission 2020), Meredydd Evans (Pacific Northwest National Laboratory), Emily Farnworth (WEF), Sofia Faruqi (WRI), James Foster (UK BEIS), Jean-Francois Mercure (Radboud University), Vibjuti Garg (Global Subsidies Initiative), Ivetta Gerasimchuk (Global Subsidies Initiative), Lucy Gilliam (Transport and Environment), Jessica Glicker (International Energy Agency), Thomas Hale (Oxford), Stephane Hallegatte (World Bank), Craig Hanson (WRI), Bill Hemmings (Transport and Environment), Norbert Henninger (NCE), Dario Hidalgo (WRI), Guy Howard (DFID), Krsitin Igusky (WRI), Joel Jaeger (NCE), Guy Jobbins (ODI), Thomas Kerr (World Bank), Robin King (WRI), Kip Koskei (African Risk Capacity), Jennifer Kurz (Water Funders Initiative), Long Lam (Ecofys), Cate Lamb (CDP), Berenice Lasfargues (OECD), Hannah Leckie (OECD), Xavier Leflaive (OECD), Thomas Lingard (Unilever), Tianyi Luo (WRI), Bertrand Magne (Sustainable Energy for All), Anjali Mahendra (WRI), Laura Malaguzzi (WRI), Sumedha Malavia (WRI India), Michelle Manion (WRI), Pantsar Mari (Sitra), Ajay Mathur (The Energy and Resources Institute), John Mattews (AGWA Alliance), Colin McCormick, Fiona Messent (Sustainable Energy for All), Astrid Michels (German Corporation for International Cooperation), Diana Mitlin (University of Manchester), Gareth Morgan (City of Capetown, South Africa), Adele Morris (Brookings), Bessma Mourad (Water Funders Initiative), Andrew Murphy (Transport and Environment), Virginia Newton-Lewis (WaterAid), Michael Oko (WRI), Kjell Øren (Confederation of Norwegian Enterprise), Betsy Otto (WRI), Ian Parry (IMF), Kelsey Perlman (Carbon Market Watch), Edward Perry (OECD), Per Pharo (NICFI), Melissa Pinfield (FOLU), Céline Ramstein (World Bank), Beatriz Martinez Romera (Copenhagen University), Claudia Sadoff (IWMI), Jeff Seabright (Unilever), Frances Seymour (WRI), Andrew Scott (ODI), Tristan Smith (University College London), Ronald Steenblik (OECD), Andrew Steer (WRI), Katherine Stodulka (SYSTEMIQ/BSDC), Josué Tanaka (EBRD), Alison Tate (ITUC/JTC), Daniel Vennard (WRI), Bella Tokonogy (CPI), Nigel Topping (WMB), Anders Turesson (Sweden), Kurt van Dender (OECD), Richard Waite (WRI), Frank Walter (P4G), Bob Ward (Grantham Institute), Caroline Watson (C40), Lena Weingartner (ODI), Shelagh Whitley (ODI), Louise Whiting (Food and Agriculture Organization of the United Nations), Davida Wood (WRI), John Woolard (WRI), Durwood Zaelke (IGSD).

Special thanks also for guidance, inputs, and support during discussions, including at the 2018 Global Commission Summit:

Gebrehiwot Ageba (Ethiopian Development Research Institute), Mahua Acharya (GGGI), Marco Albani (TFA 2020), Amal-Lee Amin (IDB),Claus Astrup (GEF), Aimee Barnes (California Governor's Office), Michael Bloomberg (UN Special Envoy for Climate Action), Joke Brandt (Netherlands), Barbara Buchner (Climate Policy Initiative), Arne Cartridge (Yara International), Robin Chase (Zipcar), Sherard Cowper-Coles (HSBC), Tomas Anker Cristensen (UN/Denmark), Patrick Curran (London School of Economics), Minister Gemedo Dalle (Ethiopia), Ashwin Dasgupta (NCE), Ian de Cruz (P4G), Anne Caroline Duplat (SYSTEMIQ/BSDC), Ebadullah Ebadi (NCE), Patricia Espinosa (UNFCCC), Ingrid Gabriela-Hoven (BMZ), Madhavi Ganeshan (NCE), Melinda George (SYSTEMIQ/BSDC), Nick Godfrey (CUT), Elliot Harris (UN), Martin Bille Hermann (Denmark), Andrew Higham (Mission 2020), Caroline Holtum (WMB), Neo Gim

Huay (Temasek), Naoko Ishii (Global Environment Facility), Stewart James (HSBC), Rajat Kathuria (Indian Council for Research on International Economic Relations), Noah Kaufman (Columbia University), Sebastian Keneally (NCE), Lise Kingo (UN Global Compact), Martin Kipping (BMZ), Jason Klein (Shell), Till Kötter (BMUB), Rachel Kyte (Sustainable Energy for All), Christine Lagarde (IMF), Andrew Light (WRI), Deputy Minister Stephen Lucas (Canada), Xinyue Ma (NCE), Marina Mansilla (Mission 2020), Mathilde Mansoz (Mission 2020), Virginie Marchal (OECD), Minister Kasaija Matia (Uganda), Irving Mintzer (Potomac Energy Fund), Deputy Secretary-General Amina Mohammed (UN), Priyanka Mohanty (NCE), Minister Bill Morneau (Canada), Luis Alberto Moreno (IDB), Suahasil Nazara (Indonesia), Cherie Nursalim (GITI Group), Michael Obersteiner (International Institute for Applied Systems Analysis), Minister Petteri Orpo (Finland), Cristiana Paşca Palmer (CBD), Stina Reksten (Norway), Karsten Sach (Germany), Cristián Samper (Wildlife Conservation Society), Feike Sijbesma (DSM), Mahendra Singhi (Dalmia Cement), Alex Thier (ODI), Pablo Vieira (NDC Partnership), Joachim von Amsberg (Asian Infrastructure Investment Bank), José Viñals (Standard Chartered),David Watson (ODI), Dominic Waughray (WEF), Bill Winters (Standard Chartered), Farhana Yamin (Track 0/Chatham House), Zhuo (Joy) Zhang (NCE).

Thanks to the following organisations for their inputs:

African Development Bank (AfDB)

Asian Development Bank (ADB)

Business & Sustainable Development Commission (BSDC)

Cambridge Econometrics (CE)

The Climate Group

Climate Policy Initiative (CPI)

Coalition for Urban Transitions

Confederation of Norwegian Enterprises

Convention on Biological Diversity (CBD)

Energy Transitions Commission (ETC)

European Bank for Reconstruction and Development (EBRD)

European Climate Foundation (ECF)

Food and Land Use (FOLU) Coalition

Government of the City of Cape Town

Grantham Research Institute on Climate Change and the Environment

Hongkong and Shanghai Banking Corporation (HSBC)

International Monetary Fund (IMF)

International Trade Union Confederation (ITUC)

Just Transition Centre (JTC)

Mission 2020

NDC Partnership

Organisation for Economic Co-operation and Development (OECD)

Overseas Development Institute (ODI)

Partnerships for Growth (P4G)

SYSTEMIQ

Unilever

The United Nations (UN)

The World Bank

World Business Council for Sustainable Development (WBCSD)

We Mean Business (WMB)

World Economic Forum (WEF)

World Resources Institute (WRI)

This Report has been prepared by:

Helen Mountford (NCE), Jan Corfee-Morlot (NCE), Molly McGregor (NCE), Ferzina Banaji (NCE), Amar Bhattacharya (Brookings), Jessica Brand (NCE), Sarah Colenbrander (Coalition for Urban Transitions/ IIED), Ed Davey (WRI/FOLU), Laëtitia de Villepin (SYSTEMIQ/ETC), Faustine Delasalle (SYSTEMIQ/ ETC), Annabel Farr (FOLU/SYSTEMIQ), Leonardo Garrido (NCE), Ipek Gençsü (ODI), Saira George (SYSTEMIQ/ETC), Catlyne Haddaoui (Coalition for Urban Transitions), Leah Lazer (Coalition for Urban Transitions /Siemens), Nathaniel Mason (ODI), Jeremy Oppenheim (SYSTEMIQ/ETC), Rachel Spiegel (NCE), Lord Nicholas Stern (Grantham Institute), and Michael Westphal (Coalition for Urban Transitions/WRI).

The dedicated modelling work using the E3ME model was undertaken by a team from Cambridge Econometrics:

Dora Fazekas, Hector Pollitt, Alistair Smith, and Malin Berg von Linde

WRI Design Team: Bill Dugan, Billie Kanfer, Carni Klirs, Julie Moretti, Romain Warnault

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