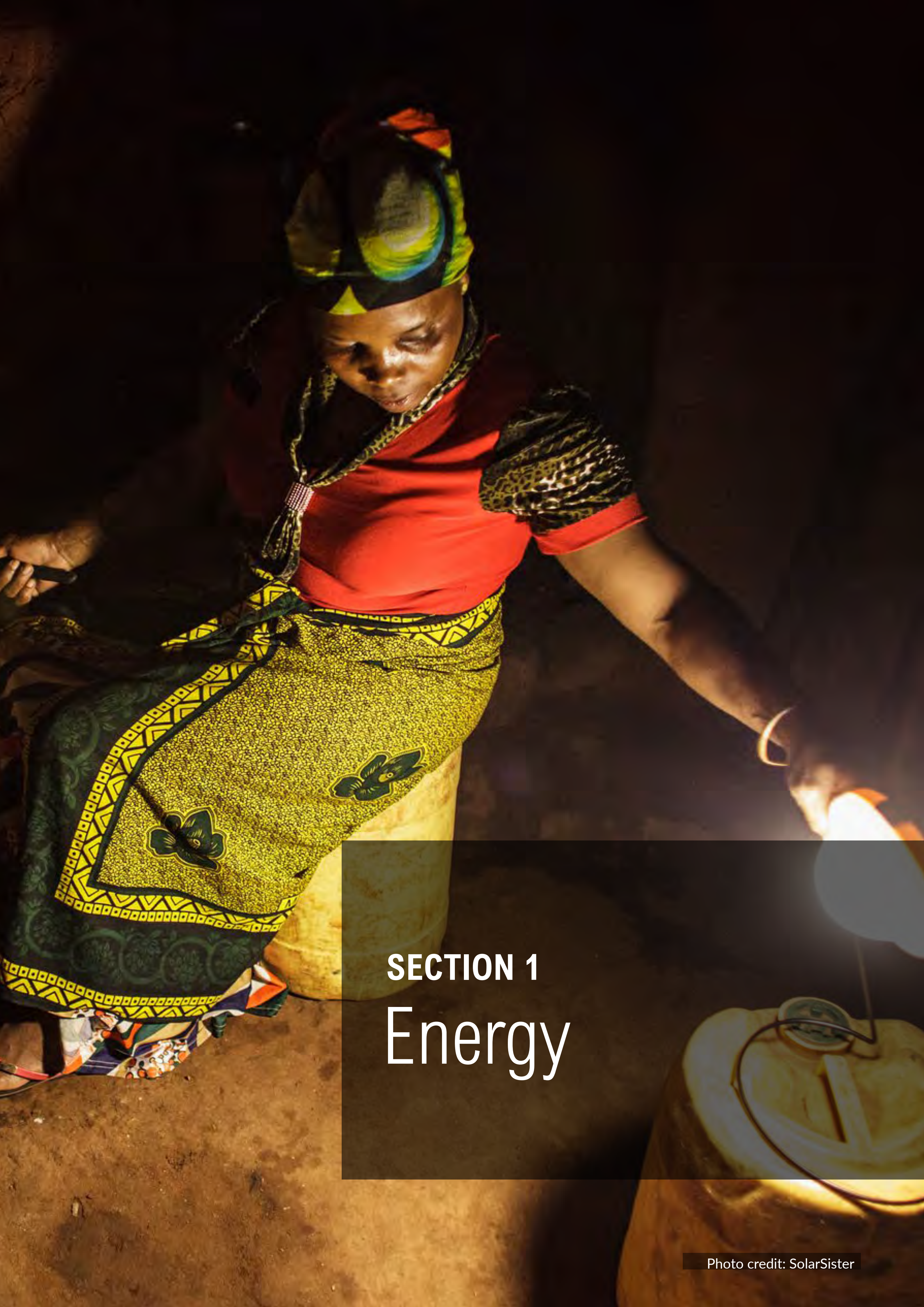


SECTION 1
Energy

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]

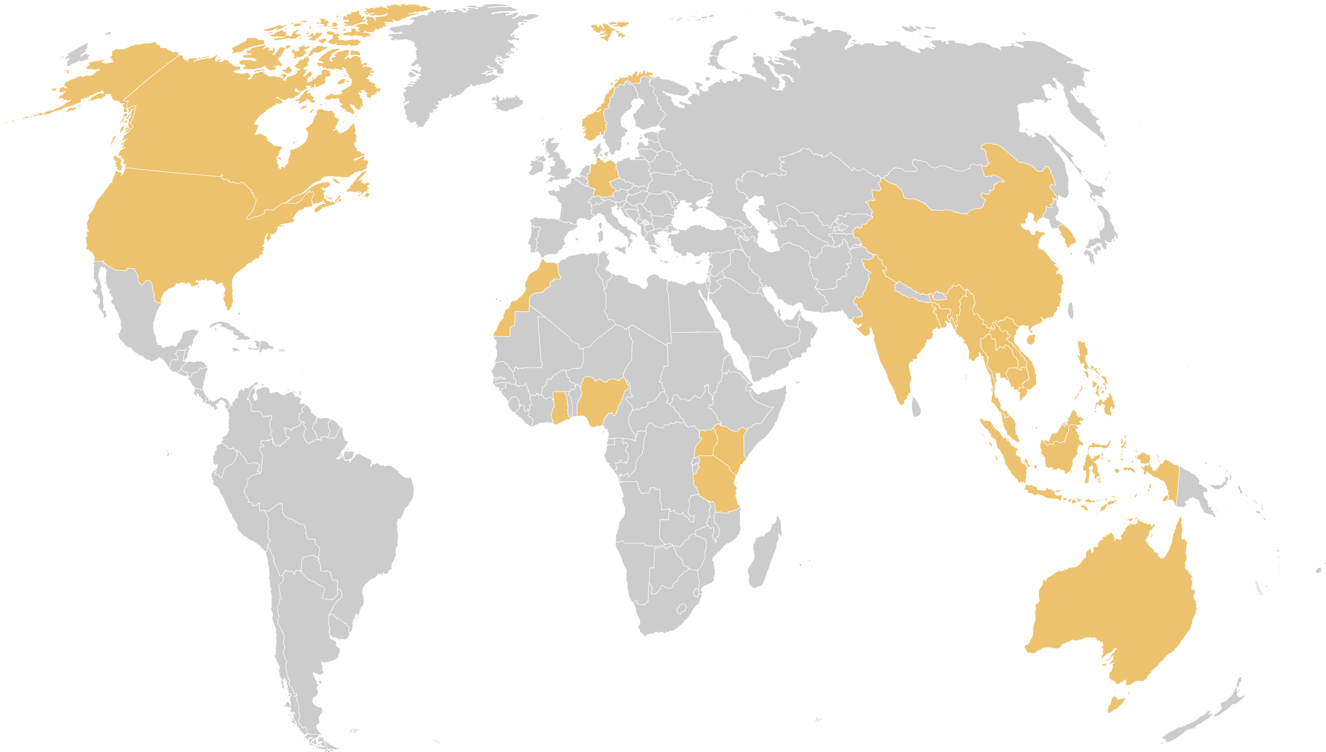
Despite good corporate leadership by some, a recent review of progress on disclosure and SBTs suggests there is much more to do on both fronts. For example, businesses with SBTs are achieving less than one-tenth of their potential for GHG emissions reductions as targets are relatively low in ambition,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

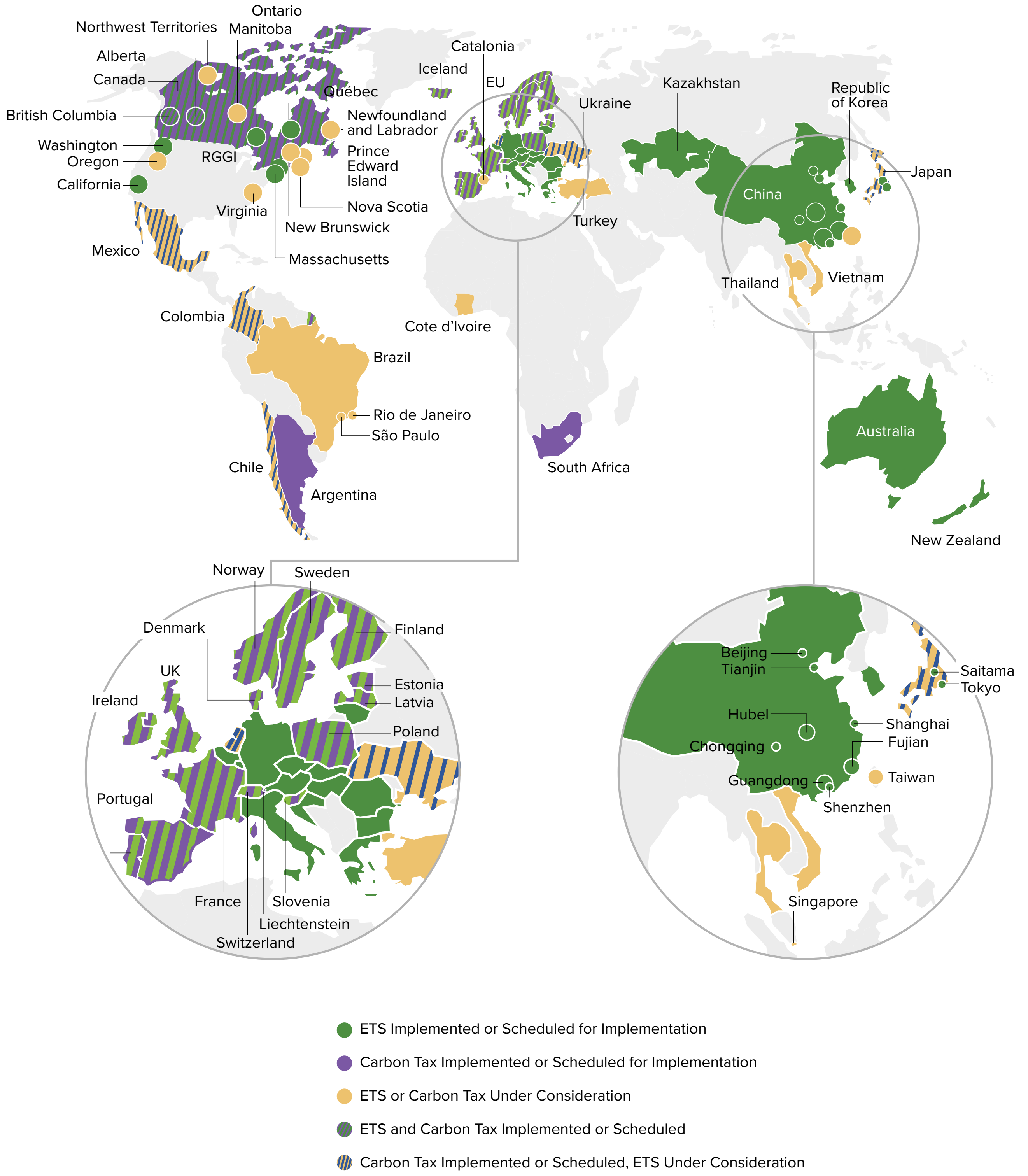
Energy efficiency is also critical to limiting GHG emissions to achieve a below 2°C scenario, and energy efficiency is amongst the most cost-effective of options to provide clean energy (see Section 1.B). More than doubling energy-efficiency investments requires national and local governments to work 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.

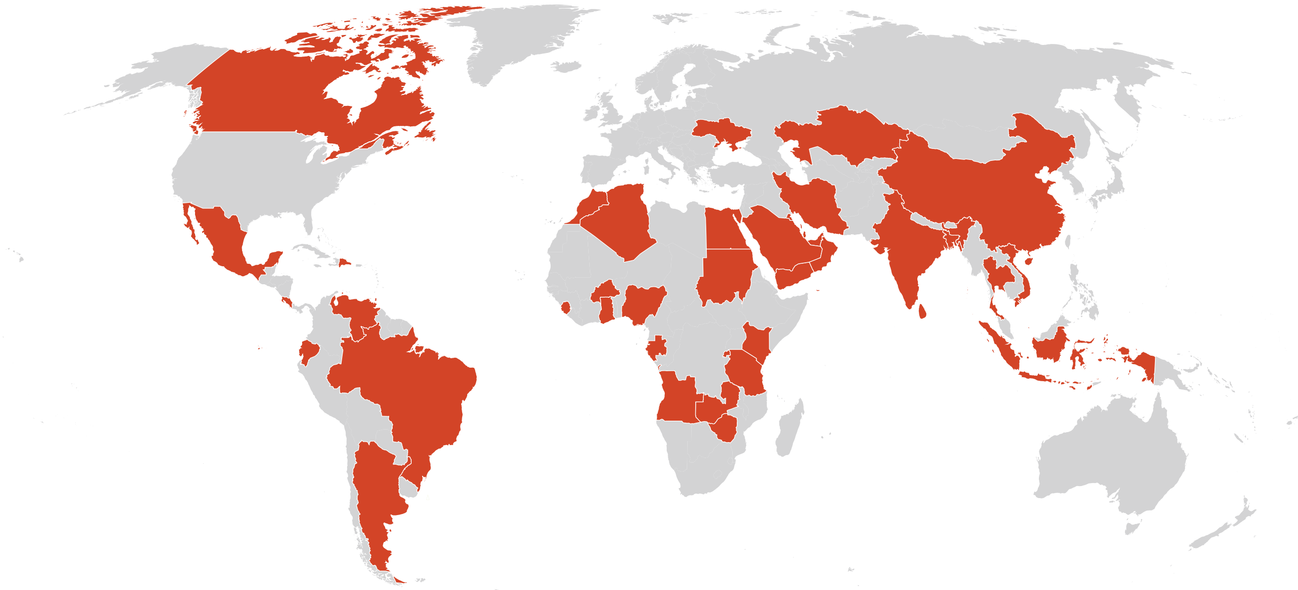


Note: This graph represents data as of August 2018.

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

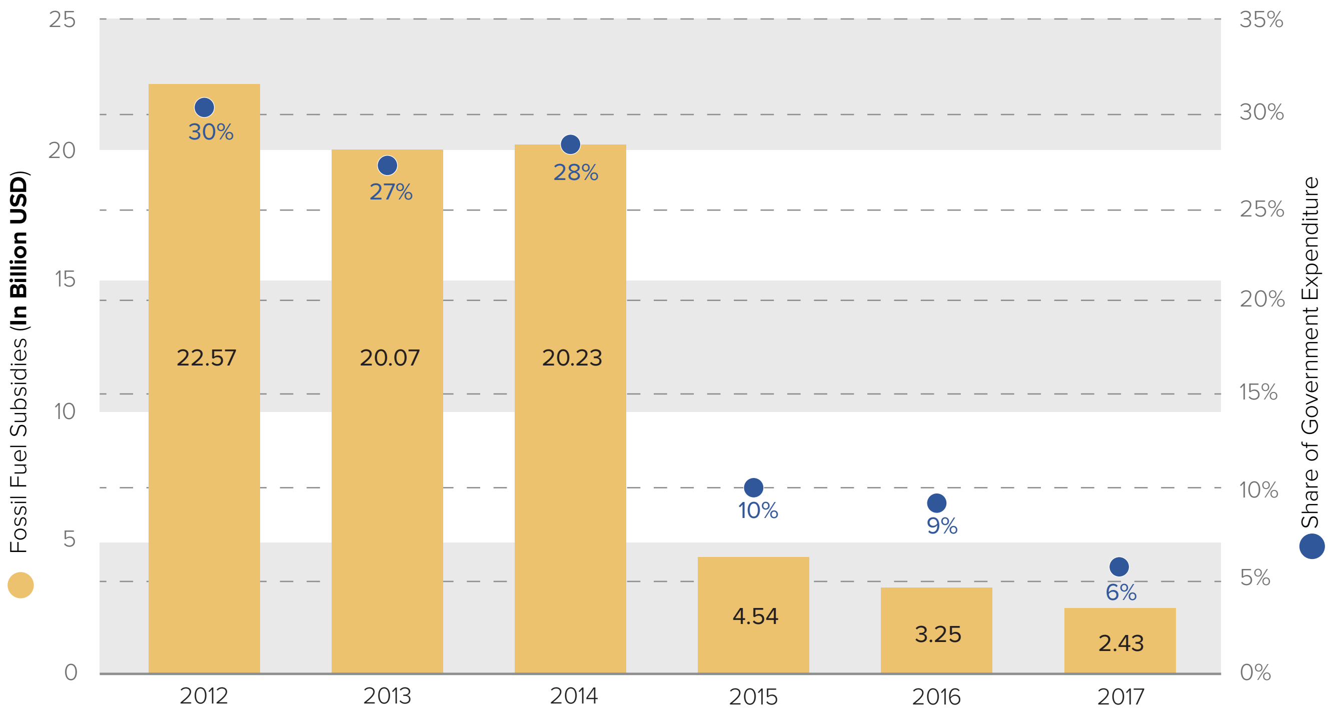
Carbon Pricing in British Columbia

In 2008, British Columbia introduced a carbon tax covering three-quarters of its emissions. With a starting price of US\$8/tCO_2e it gradually increased to US\$24/tCO_2e 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/tCO_2e 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

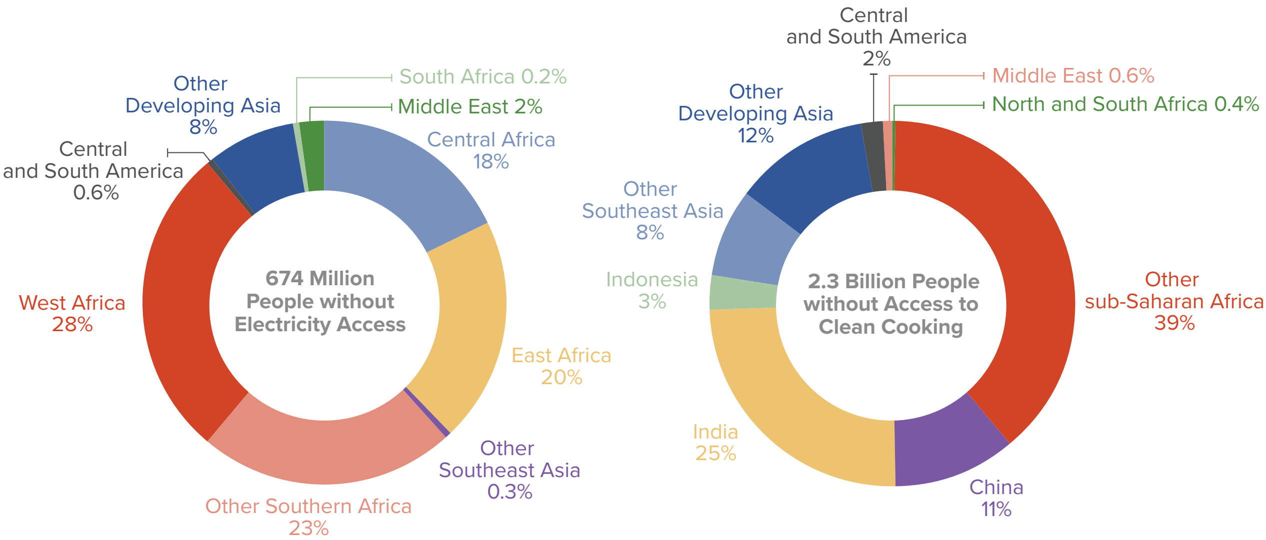
In the 1990s, a nongovernmental organisation (NGO) called Grameen Shakti piloted a successful SHS programme in Bangladesh. Drawing on Grameen Shakti's experience, the Government of Bangladesh established Infrastructure Development Company Limited, a public-private institution to support market development 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]

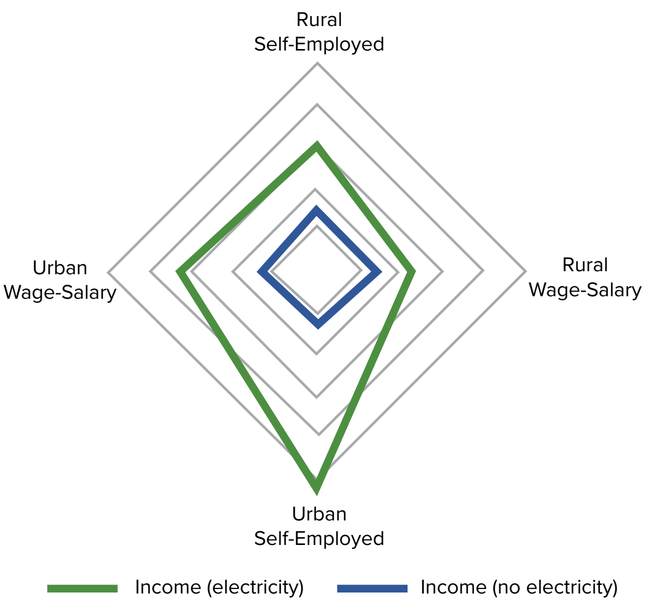
Figure 7
2030 Gaps in Access to Electricity and Clean Cooking—Planned and Current Policies



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]