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WORKING PAPER

ENHANCING NDCs: OPPORTUNITIES IN THE POWER SECTOR

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EXECUTIVE SUMMARY

Highlights

- Limiting global warming to 2 or 1.5°C requires a virtually decarbonized power sector by 2050.
- The world is not on track to achieve this. In 2018, while renewable energy (RE) generated one-fourth of global power, coal produced 38 percent and remained the largest source of electricity generation, producing 30 percent of global carbon dioxide (CO_2) emissions.
- While most countries mention power in their Nationally Determined Contributions (NDCs), most do not draw on the range of solutions available to move the sector toward smooth integration of higher shares of RE, while enhancing energy efficiency to manage a projected doubling of global power demand by 2050.
- This guidance identifies options to transform the power sector that should be prioritized in the 2020 NDCs. Taking stock of progress in the sector since the first NDCs were developed reveals that while increasing zero-carbon energy is fundamental, increasing ambition in the power sector requires more than merely increasing RE targets. Reflecting power-sector mitigation potential in the NDCs now depends on implementing four foundational strategies for enhanced grid flexibility, addressing existing coal assets, making institutional changes, and tapping synergies between the power and end-use sectors.
- This guidance proposes a structure for policymakers to assess how these foundational elements are addressed in their NDC, and decide how they can fill gaps in the 2020 NDC.

CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues. Working papers may eventually be published in another form and their content may be revised.

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Context

The power sector is the largest source of energy-related CO_2 emissions, accounting for two-thirds of global emissions growth in 2018. As such, this sector is pivotal in tackling climate change. Although coal's share of global electricity generation is shrinking, it remains the largest single source of electricity, accounting for 38 percent of global power generation and 30 percent of global energy-related CO_2 emissions (IEA 2018).

The energy transitions needed to align with climate goals will include the acceleration of the decarbonization of power supply, a strong push for energy efficiency, and electrification of end-use sectors (e.g., transport, buildings). The first two are essential actions to undertake in order to achieve decarbonization of the power sector, while the third is intricately linked.

In 1.5°C consistent scenarios, the power sector will be very different in 2050 than it is today: most 1.5°C consistent pathways share the vision of a completely decarbonized power sector by 2050. Projections see power generation roughly doubling by 2050, in response to rising standards of living and electrification of end-use sectors like transport and industry. Projections see the share of renewable energy in the power sector rising from 25 percent in 2017 to 86 percent by 2050 (IRENA 2019a). This would also entail phasing out 95 percent of operational coal plants and commissioning no new ones in the future (IRENA 2018). Scenarios agree that increased deployment of RE, combined with increased energy efficiency, including to help accommodate deep end-use electrification, are the backbone of the transitions that will get the power sector where it needs to be in 2050.

NDCs are an important lever for decarbonizing the power supply, and national power-sector priorities can help deliver more ambitious climate goals, reflected in strong power-related NDC targets. Because NDCs encompass countries' broad plans for addressing climate change, they can help countries align low-carbon transformation with their national, long-term power sector priorities. NDCs can catalyze holistic planning, help avoid infrastructural lock-ins, and can also facilitate sector-coupling solutions that link energy-consuming sectors with the power-producing sector. In addition, including power in the NDCs sends clear signals to investors and directs financial flows to transitions in the sector.

The current set of NDCs overlooks some important opportunities in the power sector. These NDCs fail to tap the full range of solutions available, feasible, and necessary to enable the fundamental shift required of the power grid. Some of those gaps can be addressed and could cost-effectively enhance power-related targets in NDCs. Analysis shows that RE targets under the NDCs are generally more timid than national energy plans and fall short of countries' cost-effective potential (IRENA 2017b). Few NDCs recognize the synergies among energy efficiency, renewable deployment, energy access, better air quality, and adaptation. And NDCs rarely link power decarbonization to the need to make the grid more flexible, which will be critical to accommodate more renewable energy in the grid.

About This Guidance

This guidance aims to help countries incorporate ambitious, relevant, and tangible power solutions into enhanced NDCs for communication to the United Nations Framework Convention on Climate Change (UNFCCC) by 2020. It reviews the treatment of the power sector in the initial NDCs, taking into account recent technological developments, to identify key opportunities for NDC enhancement. This guidance is part of a series of guides on NDC enhancement developed by World Resources Institute (WRI), the United Nations Development Programme (UNDP), and other partners. The series includes an overarching guide to NDC enhancement, as well as detailed guidance on additional sectors and themes. Its use is voluntary and is intended to complement, but not substitute for, NDC provisions in the Paris Agreement and the Katowice Rulebook.

Opportunities for NDC Enhancement in the Power Sector in 2020

To bring the power-sector NDC targets into greater alignment with the goals of the Paris Agreement, the next round of NDCs needs to carve out targets, policies, and measures that will send transformational signals to global industry and relevant stakeholders aimed to achieve

1. the decarbonization of the supply of electricity; and
2. the significant enhancement of energy efficiency, including to help accommodate increasing electrification of end-use sectors like transport, buildings, and industry.

Taking stock and building on recent developments makes it possible to identify meaningful, novel ways that countries can use to enhance their NDCS. Changes under way across the entire energy system have enabled the integration of larger shares of variable renewable energy. These include the falling costs of RE technology, grid modernization through digitalization and storage, and new business models for scaling the supply of clean energy. These ongoing shifts can mean that countries' capacities and capabilities have evolved as well. This reveals that the needle has moved regarding where ambition in the power sector needs to be today. Five years ago, efforts needed to be channeled toward making RE cost-competitive with coal. With this transition now in full swing, ambition in the power sector needs to support the implementation of four foundational elements to help achieve the two above-mentioned objectives. The following areas represent the biggest opportunities to fill previous gaps and enhance ambition in power-sector NDCs:

- a strategy for enhanced grid flexibility: A reliable power grid requires supply and demand of electricity to balance each other smoothly in real time, and the increasing integration of variable renewable energy (VRE) as a grid power-generation source requires more flexible power systems to enable that. Without this, transitions toward accelerated RE could be slowed or stalled.
- a strategy for addressing existing coal assets: Many economies are still dependent on coal, and policymakers need a plan to address coal in their decarbonization pathways to ensure that the transitions in the power sector can happen with the least disruption.
- institutional changes: In most countries, institutional changes are now arguably more important than technology improvements to achieve full decarbonization of the power sector.
- systemic integration of sector-coupling solutions that link energy-consuming sectors with the power-producing sector: Assuming the power sector is decarbonized by 2050, as is the case in most 1.5°C scenarios, finding synergies with energy efficiency and electrification of end-use sectors is what will close the decarbonization gap.

The 2020 process of enhancing NDCs offers an opportunity for countries to examine the ambition of their initial NDC and identify where gaps in these foundations lie at a country level. These foundational elements can give policymakers the framework they need to track the status of their power sector against the 1.5°C goal, based on which they can identify which targets must be set or revised. This exercise provides an opportunity to strengthen or add commitments in the NDCs that would lay strong grounds for the implementation of these foundational elements. This would be required to ensure that transitions toward a decarbonized power sector by 2050 are not slowed or stalled, in spite of the developments and progress that have already been made.

Foundational strategy 1: A plan for enhanced grid flexibility

As RE costs continue plummeting and are increasingly cost-competitive with coal in most places, grid flexibility has taken the center stage as the main blockage to higher shares of VRE integration in many countries. A realization of power system transitions toward decarbonization can only happen if the cost of VRE plus grid flexibility becomes cheaper than the cost of coal. Grid flexibility can come from a combination of supply-side options, including baseload power from a nonvariable power source (e.g., hydro, nuclear, natural gas) to ensure power when variable renewables like wind or solar are not providing power, and demand-side options like measures to shift demand to match periods during which VRE supply is plentiful. The 2020 NDC enhancement process is an opportunity for policymakers to evaluate their grid's flexibility capacity against the targets and policies contained in their initial NDC and assess whether there is scope to strengthen or add targets that would enable the necessary grid improvement in parallel with the deployment of VRE. The enhanced NDCs can be an opportunity to set clear targets around power storage; for example, taking advantage of recent developments in technical solutions and falling costs in storage.

Foundational strategy 2: A strategy to address existing coal assets

Because many economies are still dependent on fossil fuels, especially coal, ensuring that the energy transitions happen with the least disruption to all sectors means that policymakers need a plan to address coal in their decarbonization pathways. Many, although not all, countries and financial institutions are committed to building no new coal capacity, including, for example, through the Powering Past Coal initiative. But countries also need to manage carefully and in a just manner the rapid shift away from existing coal assets. Looming threats for coal assets are regulatory and economic stranding. The 2020 NDC enhancement process is an opportunity to add targets and measures in the NDC that would enable a holistic and just transition toward coal phase-out and, for those NDCs that already have such targets, to assess and strengthen the economic and social considerations in coal phase-out plans.

Foundational strategy 3: Institutional changes

In most countries, the barriers to transitions in the power sector are no longer the incremental costs, but institutional ones. These will require changing institutions, markets, and infrastructure. This will require better policies, greater coordination, and enhanced institutional capacity to ensure the implementation of policies needed to achieve power-related targets in NDCs. The 2020 NDC enhancement process is an opportunity for policymakers to take stock of the policies they have in place, assess the robustness of their institutions to this challenge, and align markets and infrastructural investments to propel the transitions toward a fully decarbonized power sector. This can include correct electricity policies and pricing regulations, market and regulatory policies to harmonize electricity markets, and ending inefficient fossil fuel subsidies. Carbon pricing for power generation is a strong market signal that can also drive shifts to non-fossil power generation. Embedding carbon pricing as part of a broader mechanism to reflect impacts of air pollution on human health can be an effective and powerful motivator to move countries, especially developing countries, away from coal power generation.

Foundational strategy 4: Integration of sector-coupling solutions

Decarbonization of the power sector by 2050 is, de facto, assumed by most 1.5°C scenarios as a requirement for successful energy-sector transitions. Hence, finding synergies with end-use sectors to enable steep cuts in greenhouse gas (GHG) emissions through energy efficiency and electrification is what will close the decarbonization gap. This needs to be given more attention in the NDCs. Enhanced energy efficiency is critical to allow for successful efforts to increase RE; otherwise, power system transitions become an exercise of trying to cater to inefficient demand. An increasingly electric energy system will transform how the power sector and demand interact. End-use electrification can provide complementary flexibility capacity to the grid, for example, through plugged-in electric vehicles connected to the grid at night to balance limited solar power. This can allow for a greater share of RE to be integrated, in turn raising the renewables' share in end-use sectors. The 2020 NDC enhancement process provides an opportunity for policymakers to determine whether the power and end-use sector elements of their NDCs address those important cross-sectoral interactions and where the scope to maximize synergies and reduce potential conflicts across the sectors lies.

These foundational elements are common requirements for all power systems, and can be tailored for each country based on its circumstances and capabilities. As countries' power systems are at various levels of grid development and efficiency, national power grids are not all ready for the same levels of ambition, and enhancements in the NDC can take different forms of targets, policies, or measures, depending on the national assessments of the status of each country's power sector.

Power-sector GHG mitigation information can be integrated into the economy-wide targets or presented as separate sector targets and/or policies. If the power sector is not covered in the economy-wide target, or the country chooses not to present an economy-wide target, countries can set power-sector GHG mitigation targets and/or policies to make use of the mitigation potential of the sector to raise mitigation ambition. On the other hand, if power-sector emissions are accounted for in the economy-wide target, countries can still consider setting power-sector specific targets and/or policies to bolster action and drive abatement in the sector or presenting an indicative power sectoral breakdown of the economy-wide target to enhance the NDC's clarity and specificity.

Table ES-1 reflects options for NDC enhancement to fill the gaps and tap the opportunities stemming from the four foundational strategies.

Table ES-1 | What Can Be Done in the NDC in 2020

GHG TARGETS
▪ Strengthen or add an economy-wide GHG target to reflect more ambitious abatement options in the power sector ▪ Strengthen or add a power-sector carbon-intensity target ▪ Strengthen or add an ambitious power-specific GHG reduction target, like targets for reduction of emissions from coal plants ▪ Strengthen or add a specific peaking-year target to take advantage of ambitious abatement options in the power sector
NON-GHG TARGETS
Planning for renewables and grid flexibility: ▪ Strengthen or add renewable energy targets as a share of total electricity generation mix ▪ Align RE targets with longer-term national plans and with national cost-effective RE potential ▪ Strengthen or add quantified energy storage targets to massively direct investments in that direction ▪ Strengthen or add energy access targets through the deployment of decentralized energy solutions ▪ Strengthen or add rooftop solar targets ▪ Strengthen or add targets for the deployment of smart meters and forecasting technologies to predict real-time output of variable renewable energy generation
Addressing existing fossil fuel assets: ▪ Strengthen or add a coal phase-out target for the power generation sector, coupled with a clear plan to ensure a just transition for affected workers and communities ▪ Include a commitment to no new added traditional coal-fired capacity after current project pipeline ▪ Strengthen or add target to reduce fossil fuel imports for power generation ▪ Strengthen or add air pollution targets
Integration with end-use sectors: ▪ Add or strengthen energy-efficiency targets in the cooling, buildings, industrial, and transport sectors ▪ Incorporate targets to install electric vehicle (EV) charging infrastructure to kick-start these markets ▪ Targets for clean electrification of end-use sectors, including buildings and industry

Source: Authors.

1. INTRODUCTION

The power sector features in many Nationally Determined Contributions (NDCs) that parties submitted ahead of the 21st Conference of the Parties (COP 21), highlighting that it is a pivotal sector to achieve the ultimate goal of the Paris Agreement. In 2020, countries will have to communicate or update their NDCs according to the Paris ratchet-up mechanism. This guidance report is intended to provide analytical support to policymakers and national planners looking for feasible and effective ways to enhance their country's power-related NDC targets in 2020. The aim is to support them in ensuring that the full potential of their power sector is accurately captured in their NDCs.

The power sector is a crucial one for economic, social, human, and sustainable development. Providing affordable and reliable power has been essential to raising and maintaining decent standards of living. As global population continues to rise, as urban sprawl continues unchecked, and as emerging economies electrify their development to lift their populations out of poverty, global electricity demand is surging. This trend is not reversing anytime soon.

For decades, rising electricity production and consumption has generally coincided with environmental degradation. The power sector today is the largest source of energy-related CO_2 emissions (IEA 2019a), the leading cause of climate change. So achieving the objective of the Paris Agreement—well below 2°C—will hinge on whether a deep transformation of the power sector is achieved at a scale and speed unprecedented before.

In order to become climate friendly, the power sector must aim to do two things: decarbonize the supply of electricity and significantly enhance energy efficiency, including to help accommodate increasing electrification of end-use sectors like transport, buildings, and industry. These end users are poised to generate a spurt in electricity demand and consumption. This is a major reason power production is expected to roughly double by 2050; but this need not be damaging to the environment if the global power sector is able to meet the goal of decarbonizing by that time, too.

To accomplish this, climate action and national power priorities must be reconciled, and this is where the NDCs provide a useful framework to merge and strengthen both of these ambitions. Unpacking the first round of NDCs uncovers gaps in tapping the full range of solutions available to enable the shifts required in the power sector that would increase climate ambition. These gaps stem from the mammoth effort and vastness of the task that is decarbonizing the power system, blending with the broader energy transitions. In addition, when the Intended Nationally Determined Contributions were being developed prior to COP 21, the power-sector landscape was very different from what it is now, with innovations and opportunities today matured in a way that seemed improbable even just five years ago. Filling these gaps in the next round of NDCs could help lay the necessary groundwork for increasing the gigawatt-hours (GWh) of renewable energy (RE) flowing to the grid and enhancing energy efficiency including to help achieve the clean electrification of end-use sectors at levels consistent with the temperature goal of the Paris Agreement.

Following the process outlined in the recent United Nations Development Programme (UNDP) and World Resources Institute (WRI) report *Enhancing NDCs: A Guide to Strengthening National Climate Plans by 2020* (Fransen et al. 2019), this report sets out to take stock of recent developments and trends that have emerged as a result of ongoing energy transitions and offers suggestions on how their potential can be reflected in NDCs. It identifies four foundational policy interventions that policymakers need to consider and plan for upstream so as to design more robust and effective power-related NDCs. These include strategies for enhancing grid flexibility and addressing existing coal assets, necessary institutional and regulatory frameworks, and identifying points of intersection with the efficiency and electrification of other sectors, such as transport, industry, and buildings, as they have a direct impact on the power sector and vice versa.

About NDC Enhancement

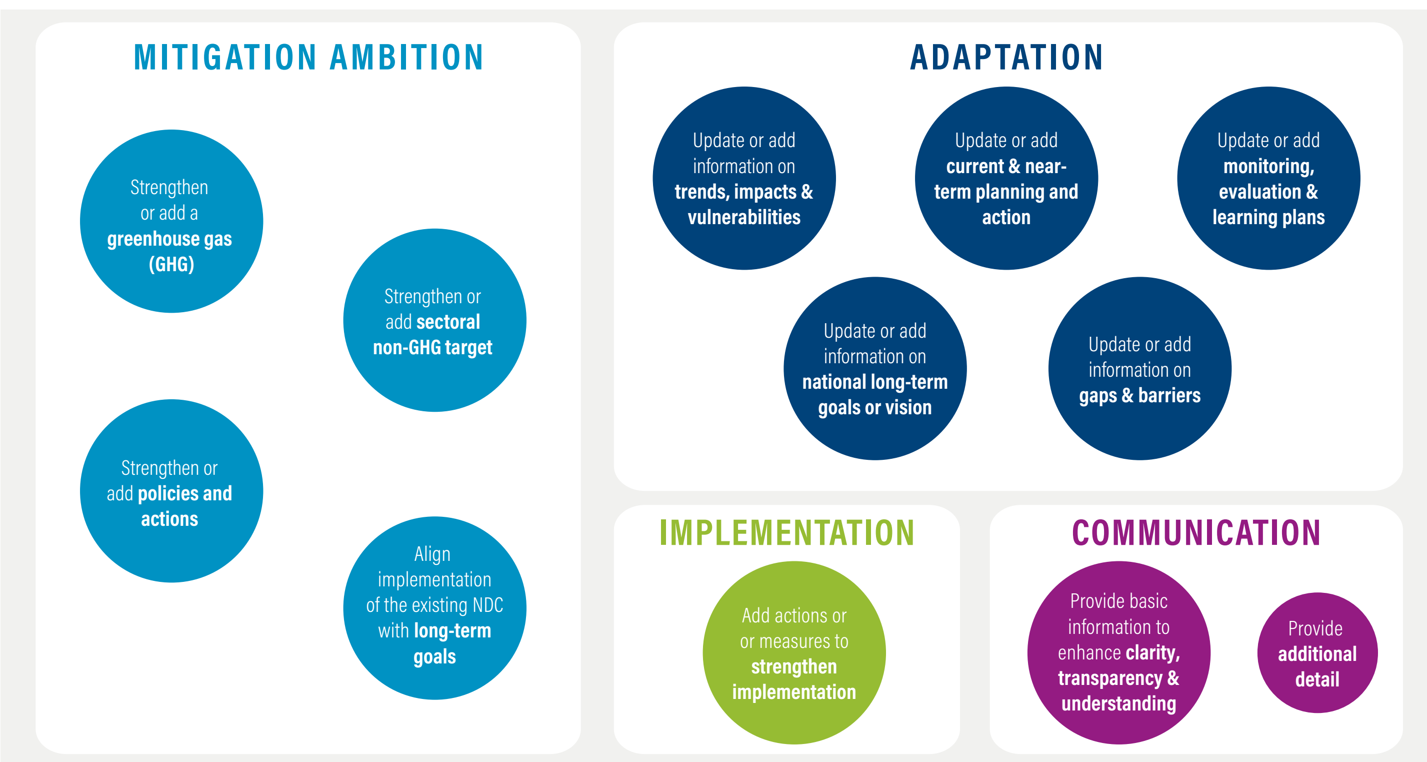
The term *NDC enhancement* captures the idea of NDC progression inherent in the Paris Agreement, starting with the invitation to communicate new or updated NDCs in 2020 (Fransen et al. 2017). NDCs can be enhanced along various dimensions, including mitigation ambition, implementation, adaptation, and transparent communication—recognizing that the objectives and requirements under the Paris Agreement vary across these components (See Figure 1: Types of NDC Enhancement). Ideally, the NDC enhancement process will bring NDCs more closely into alignment with the goals of the Paris Agreement, maximize the benefits of the NDC for development and resilience, incorporate relevant opportunities to strengthen implementation, and improve transparency. These elements of NDC enhancement are not mutually exclusive, and it may be appropriate for a country to enhance its NDC across more than one of these dimensions.

How Can the 2020 NDCs Enhancement Process Help Enhance Climate Ambition in the Power Sector?

Since the initial NDCs were developed, innovation has flourished, and technology costs have fallen. Many countries have made great strides toward implementing and perhaps even overachieving their NDCs, and subnational actors are also significantly contributing to climate action. These developments generate more options for increased ambition than countries were able to consider prior the Paris Agreement (Fransen et al. 2019). This is not to say, however, that enhancing mitigation ambition in the power sector will be easy or straightforward, owing to hard political, financial, and capacity-related on-the-ground realities.

In light of the growing number of options and urgent need for enhanced ambition, the 2020 NDC enhancement process can be used as an opportunity to catalyze political will and support to overcome these challenges. Relative to the power sector, many countries' current NDC targets are, in fact, more conservative than those found in their national energy plans. If those countries were to inscribe their national RE targets as international commitments, it would not only increase transparency but also, in the spirit of the Paris Agreement, level global momentum upward toward more ambition, potentially unlocking global finance and investments for transitions in the sector.

Figure 1 | **Types of NDC Enhancement**



Source: Fransen et al. 2017.

Box 1 | **Terms Related to NDC Enhancement**

New or updated NDC: From the COP decision adopted together with the Paris Agreement (1/CP.21), these terms refer to the request in the COP decision to Parties concerning NDCs in 2020. A new NDC is one subsequent to the initial NDC when a Party's initial NDC contains a time frame up to 2025. An updated NDC is one communicated by a Party whose initial NDC contains a time frame up to 2030.

Enhanced NDC: In this guidance, a new or updated NDC that improves upon the initial NDC with respect to mitigation (ambition and/or implementation), adaptation, and/or communication.

NDC with enhanced mitigation ambition: In this guidance, this refers to an NDC that, if fully implemented, would result in lower cumulative emissions than the fully implemented existing NDC.[1] It is important to note that a new, updated, or enhanced NDC may not necessarily lead to enhanced mitigation ambition. The baseline for determining this is the complete set of mitigation targets and/or actions articulated in the original NDC. In determining the effect on mitigation ambition, it is important to consider the cumulative impact of all changes to the NDC, including the extent to which they overlap with each other as well as the targets, policies, and measures in the existing NDC.[2]

Notes:
[1] The Paris Agreement states that emissions reduction can only be counted toward one country's NDC, meaning that the transfer of mitigation outcomes between countries must result in an appropriate corresponding adjustment to the mitigation accounting of both countries to ensure that the emissions reduction is not double-counted.

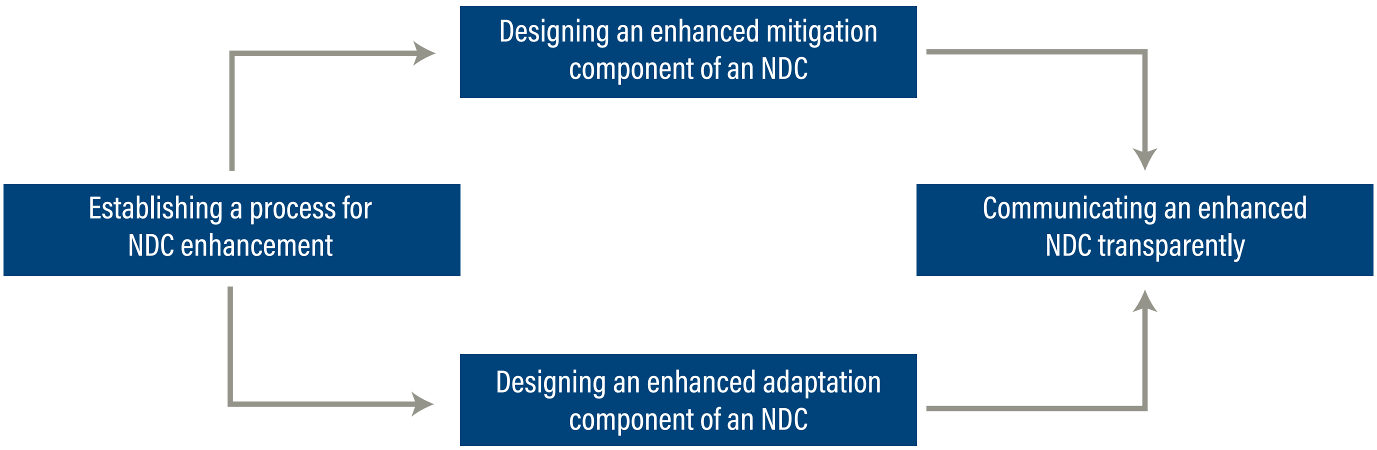
[2] Determining whether a new option will enhance a Party's level of ambition can be technically complex. Consider, for example, an NDC that contains both a GHG intensity target and a renewable energy target. Say the GHG intensity target is close to current projections of GHG intensity, but the renewable energy target vastly exceeds current projections of renewable energy capacity. In this case, the renewable energy target is the key driver of ambition, and raising it will likely enhance overall ambition. Conversely, if the GHG intensity target is more aggressive and the renewable energy target less aggressive relative to current projections, raising the renewable energy target may not raise the overall level of ambition. The GHG Protocol Mitigation Goal Standard (WRI 2014a) and Policy and Action Standard (WRI 2014b) provide guidance on GHG accounting that can inform analysis of ambition.

Source: Fransen et al. 2019.

The process of developing robust NDC targets in 2020 that move the power sector toward being climate friendly has the potential to generate enough buy-in from energy-planners that the national power planning exercises shift to inherently align and contribute to global climate objectives. It is important that the 2020 NDC enhancement process promote inclusive dialogue that secures high-level buy-in as well as stakeholder ownership. If the NDCs includes input and negotiations with power ministries, utility distribution companies, the private and financial sectors, RE producers, fossil fuel electricity generators, regulators, and new disruptive entrants in the power sector, there is an opportunity to rally stakeholders around the implementation of the agreed targets. Such support can, in fact, shift energy planners' priorities and their cost and benefits frameworks to inherently align and contribute to global climate objectives while attracting finance, technology, and capacity building from the international community.

It is now accepted that to align with the 1.5°C goal, decarbonizing the supply of electricity and significantly enhancing energy efficiency, including to help accommodate increasing electrification of end-use sectors like transport, buildings, and industry are required for successful transitions in the power sector. Accelerated renewable energy and greater energy efficiency directly affect decarbonization of the power sector, while end-use electrification is intricately linked. For the next round of NDCs to send a transformational signal to the global industry and stakeholders involved in the power transitions, it must carve out targets, policies, and measures aimed to achieve the decarbonization of the supply of electricity and the significant enhancement of energy efficiency. These targets could include reducing emissions intensity in the power sector, increasing energy efficiency, and promoting clean electrification of the economy against a certain timeline in line with the latest available climate science. This report sets out to outline elements of a strategy that policymakers need to consider and plan for upstream in order to credibly and solidly enhance their NDC targets toward the achievement of power-sector transitions. After applying a diagnostic of where their NDC stands relative to these foundational elements, policymakers can decide how they can fill gaps in their NDC and enhance its existing elements. This report also proposes options for how elements of these foundational strategies can be reflected in NDCs as enhancement.

Figure 2 | **Mapping of Overarching Guidance to Power-Sector Guidance**



Source: Fransen et al. 2019.

About This Guidance

This report is mindful of the different levels of development, contexts, and heterogeneity in the power sector across geographies. It is meant to steer countries through the process of identifying which changes to their national power sector would be required in order to tap the potential to enhance their power-related NDCs. As a navigational tool, it poses questions, raises challenges, and proposes strategies for policymakers and energy planners—ways to understand the complexities that make up power systems that should be considered before revising power-related NDCs. This report identifies options for reflecting enhancements in a nonexhaustive way to give indications while being cognizant of the fact that there is no one-size-fits-all solution to enhancing the NDCs in the power sector. All countries should nonetheless be able to find, in this guidance, elements that are applicable to their national grids.

WRI encourages countries to use this report as a guide for a thorough analysis of their own power sector, to determine the best options for NDC enhancement in light of their national circumstances and capacities.

The remainder of this guidance is organized as follows: Section 2 lays out the rationale for taking climate action in the power sector, briefly touching on key statistics supportive of a 1.5°C consistent power sector. Section 3 reviews the current NDCs and how they address power, identifying gaps in how power is currently treated. Section 4 then presents key costs, technological and business model developments, and progress over the past several years that make possible new opportunities for NDC enhancement in the power sector that seemed improbable just five years ago. Section 5 discusses how the 2020 NDCs can be used to send a transformational signal to the power sector and identifies four foundational strategies and policy interventions in the power sector that need to be under way or planned for in order to ensure the possibility of NDC enhancement. Section 6 proposes a structure for the process of NDC enhancement in the power sector and then applies it, suggesting options to reflect NDC enhancement within the framework of the four foundational strategies. Section 7 presents the authors' conclusions. The appendix outlines benefits that can be reaped from enhancing power-sector ambition in the NDCs.

2. CLIMATE ACTION AND THE POWER SECTOR

Setting the Context

The Intergovernmental Panel on Climate Change (IPCC) *Special Report on Impacts of Global Warming at 1.5°C* (SR1.5) suggests that global mean surface temperature is likely to rise to 1.5°C above pre-industrial levels between 2030 and 2052, if the current trend of anthropogenic emissions continues (IPCC 2018). The aggregated ambition contained in the current set of NDCs falls short of the efforts required to limit global warming to below 2°C or 1.5°C this century and to help mitigate the unavoidable impacts of climate change (Fransen et al. 2017).

The first round of NDCs, if fully implemented, would lead to warming of 2.9°C to 3.4°C over the course of the century (UNEP 2018a). The emissions gap report (UNEP 2018a) showed that the current level of ambition needs to roughly triple for a 2°C scenario to be within reach and rise fivefold if we hope to achieve a 1.5°C scenario. This gap makes enhanced mitigation ambition essential to achieving the Paris Agreement's goal to limit warming to well below 2°C.

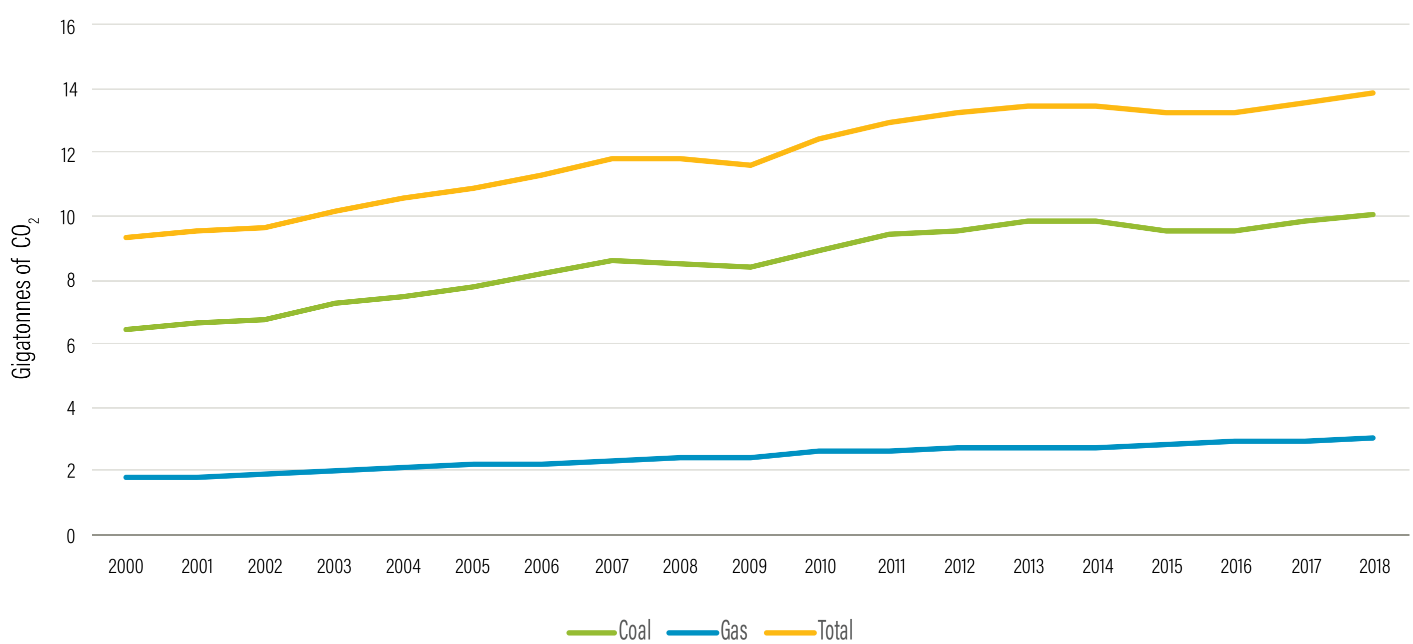
A decarbonized power sector will play a pivotal role in achieving this. To address climate change, policymakers will need to pursue two objectives: decarbonize the supply of electricity and significantly enhance energy efficiency, including to help accommodate increasing electrification of end-use sectors like transport, buildings, and industry, driving up demand and consumption of low-carbon electricity.

Snapshots of Key Statistics

The power sector today, and where it needs to go

Between 2017 and 2018, global electricity demand rose by 4 percent. Non–fossil fuel generation sources catered to most of this growth. Electricity generation from renewables increased by 7 percent from the 6 percent average annual growth in 2010, accounting for a quarter of the power generated globally and meeting 45 percent of the increase in demand between 2017 and 2018. However, coal still generates 38 percent of the world's power and contributes 30 percent of global CO_2 emissions. In 2018, emissions from power generation represented 38 percent of total energy-related CO_2 emissions (IEA 2019a).

Figure 3 | Power-Sector CO_2 Emissions from 2000 to 2018



Source: Re-created from data available in IEA 2019a.

In 1.5ºC consistent scenarios, the power sector will be very different in 2050 than it is today. Projections see power generation roughly doubling by 2050, with the share of renewable energy in the power sector rising from 25 percent in 2017 to 86 percent by 2050, of which 60 percent would come from solar and wind (IRENA 2019a). The IPCC SR1.5 finds that renewables supply 70–85 percent of electricity in 2050 in 1.5ºC consistent scenarios. This would also entail phasing out 95 percent of operational coal plants and commissioning no new ones from this point forward (IRENA 2018).

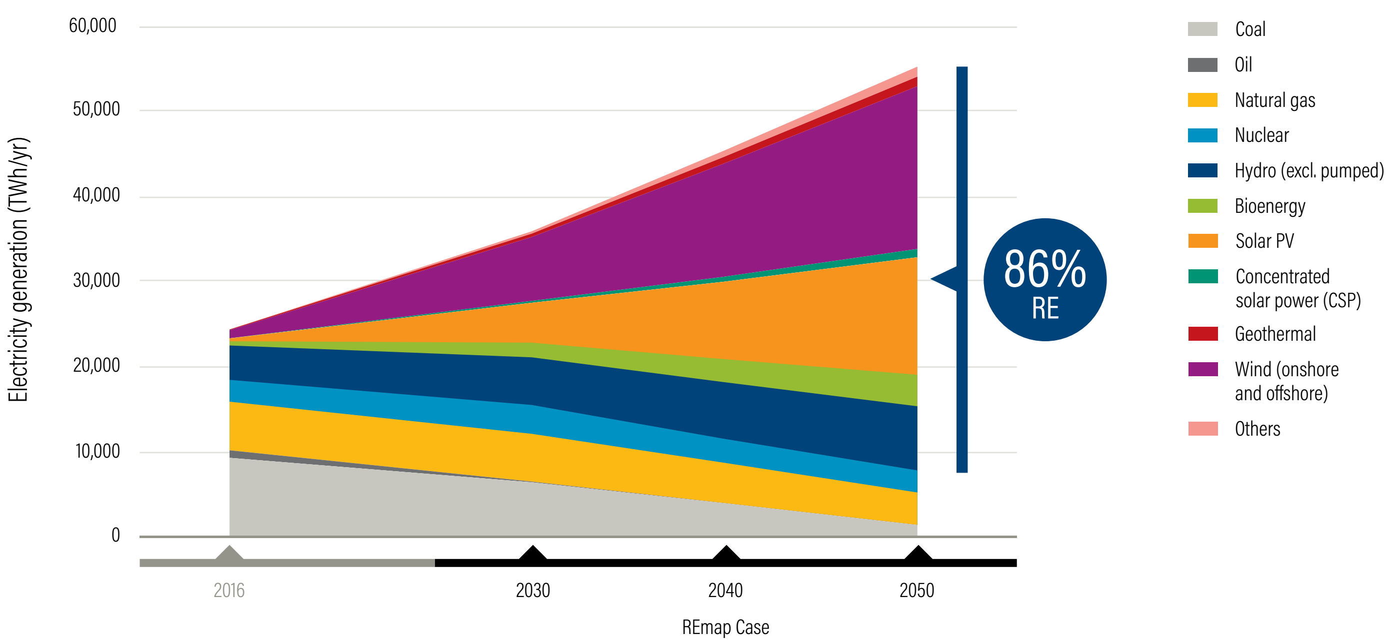
Projections of energy efficiency and electrification in end-use sectors

Beyond a substantial increase in the share of renewables for power generation, 1.5°C consistent scenarios agree that a strong push for energy efficiency, including to accommodate electrification in end-use sectors like transport, buildings, and industry, is an equally important element of a decarbonization strategy for the power sector. Projections find that the share of electricity in final energy use would rise from 19 percent in 2015 to nearly 50 percent in 2050 (IRENA 2019a).

Those same projections find that the share of electricity in final energy use in industry would double by 2050 (IRENA 2019a). In the overshoot 1.5°C pathways assessed in the IPCC SR1.5, the share of electricity used in industry rises to 30 percent by 2050, from 20 percent in 2010. The share of electricity from renewables in industry's final energy consumption should increase from 7 percent in 2015 to 36 percent by 2050 to keep the world on a 2°C track (IRENA 2018).

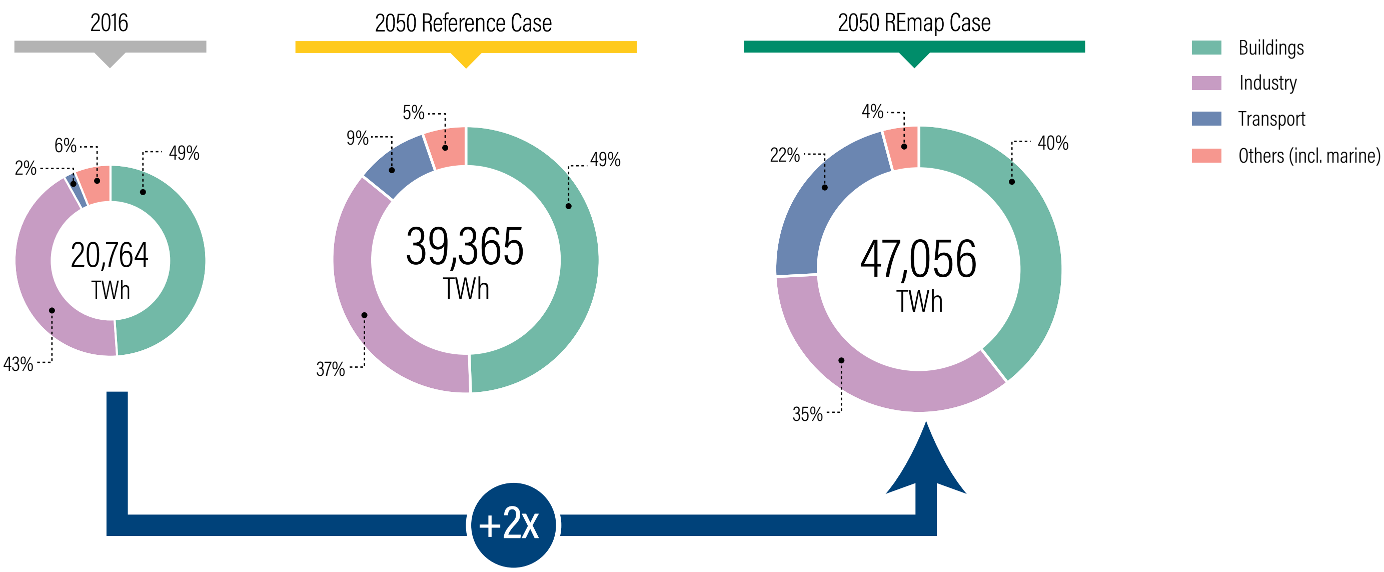
The transport sector has witnessed faster emissions growth than any other end-use sector over the past half century. But recently, transport has been in a state of transition, with a push toward electrification now seen as the best way to decarbonize it. Electricity consumption in transport would jump from 1 percent today to 43 percent in 2050, 86 percent of which would come from renewables (IRENA 2019a). Electric vehicles (EVs) including cars, buses, and two- and three-wheelers, are expected to drive the transition. By 2050, the number of light-duty EVs (including trucks) is projected to be about 70 percent of all vehicles.

Figure 4 | **Breakdown of Electricity Generation by Source Terawatt-Hours per Year (TeraWatt Hour (TWh)/yr)**



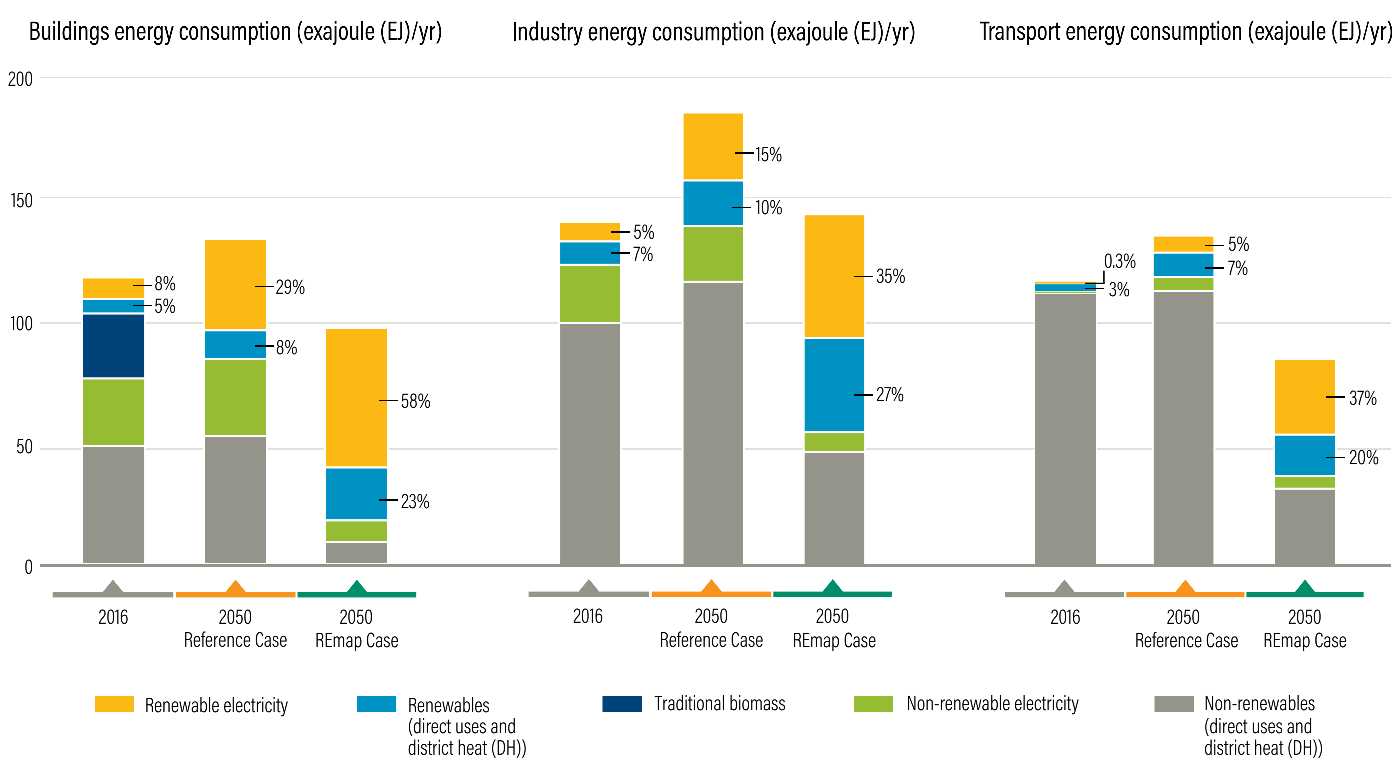
Source: IRENA 2019a.

Figure 5 | Electricity Consumption by Sector Terawatt-Hours (TeraWatt Hour (TWh)/yr)



Source: IRENA 2019a.

Figure 6 | Breakdown of Final Energy Consumption in Buildings, Industry, and Transport Sectors



Source: IRENA 2019a.

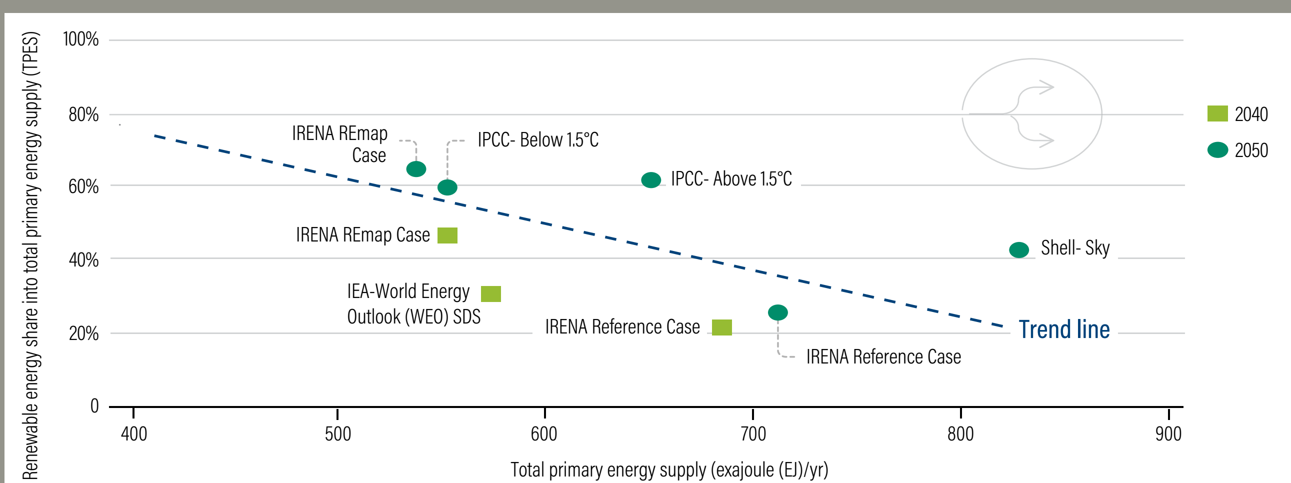
Box 2 | Details of 1.5°C Consistent Scenarios

To achieve the long-term temperature goal, the Paris Agreement aims to have Parties "achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of the century." The IPCC SR1.5 states that global emission levels need to reach net zero by 2050 to limit warming to 1.5°C above pre-industrial levels. There is no single pathway to get there, and models and scenarios rely on different assumptions with varying portfolios of mitigation measures involving different levels of energy and resource reuse, decarbonization, and carbon dioxide removal (CDR) technologies. But what all 1.5°C consistent pathways with no or little overshoot have in common is that they envision the complete decarbonization of the power sector by 2050 (IPCC 2018).

These scenarios see reduced energy use through enhanced energy efficiency, rapid electrification of energy end-use sectors, high shares of non-fossil fuel energy sources, 70-85 percent of electricity supplied by renewables by mid-century, CDR technologies used in all of the pathways and substantially in most, and coal almost entirely phased out (down to 0 to 2 percent of electricity in all pathways) (IPCC 2018).

Regarding assessments of existing deep decarbonization pathways, there is an emerging consensus on the substantial role for expansion of RE, especially wind and photovoltaic (PV), and energy efficiency in achieving the desired decarbonization of power systems in 2050. Most scenarios project 70 percent + for RE in the electricity generation mix by 2050—(86 percent by 2050 in the International Renewable Energy Agency's (IRENA) well below 2°C scenario "REmap case" (IRENA 2019a), and 65 percent by 2040 in the International Energy Agency's (IEA) Sustainable Development Scenario (SDS) that keeps temperature rise at 1.8°C (IEA 2018). Other common features across the scenarios include increased electrification as a crucial element to determine levels of energy consumption. Some differences emerge in the levels of electrification in end-use sectors: The REmap case sees the share of electricity in final energy use at nearly 50 percent in 2050; it exceeds 50 percent by 2070 in the Shell Sky Scenario (Shell International 2018). A clear correlation emerges between energy demand, energy efficiency, and shares of renewables in the energy mix, as the high RE scenarios also show a higher efficiency, resulting from lower overall energy demand (IRENA 2019a). Differences in available deep decarbonization scenarios can mainly be found in the levels of CO_2 reductions and the time frames. If the IEA's SDS trajectory were to be maintained post-2040, net-zero emissions would be achieved in 2070. The REmap case is prepared to support the decarbonization of the global energy system by 2050. Shell's Sky Scenario achieves net-zero emissions by 2070. All the scenarios present a natural bias toward the use of technologies that are currently cost-effective to deploy, and that will become increasingly so.

FIGURE B-1 | BREAKDOWN OF ELECTRICITY GENERATION BY SOURCE (TERAWATT HOUR (TWH)/YR)



Source: Extracted from IRENA 2019a.

Importantly, all scenarios rely on a fair amount of technology to actively remove carbon from the atmosphere and predominantly on bioenergy with carbon capture and storage (BECCS). The longer that these scenarios take to achieve net-zero emissions, the higher are the chances of overshoot, and the heavier is the implied reliance on CDR technologies after 2050—if not for power-sector emissions, then certainly for industry ones—in order to return to a warming of 1.5°C. CDR technologies are still at pilot stages with no certainty on their commercial viability, environmental sustainability, and social acceptability. Hence, the guidance offered in this report will reflect pathways prioritizing RE deployment and energy efficiency as the backbone of transitions in the power sector, with less reliance on CDR technologies for the purpose of NDC enhancement.

In the building sector, growing populations and economies, the democratization of electricity access, and surging demand for electrical appliances and space cooling as living standards improve, especially in developing countries, have led to rising electricity consumption in the sector (IPCC 2018). As these trends continue, electricity consumption in the buildings sector is projected to double and reach 68 percent by 2050, 86 percent of which would come from renewables (IRENA 2019a). In 1.5°C overshoot pathways referenced in the IPCC SR1.5, the share of electricity in the sector's final energy consumption is at 60 percent in 2050. Electric heating and cooling solutions will have a key role here.

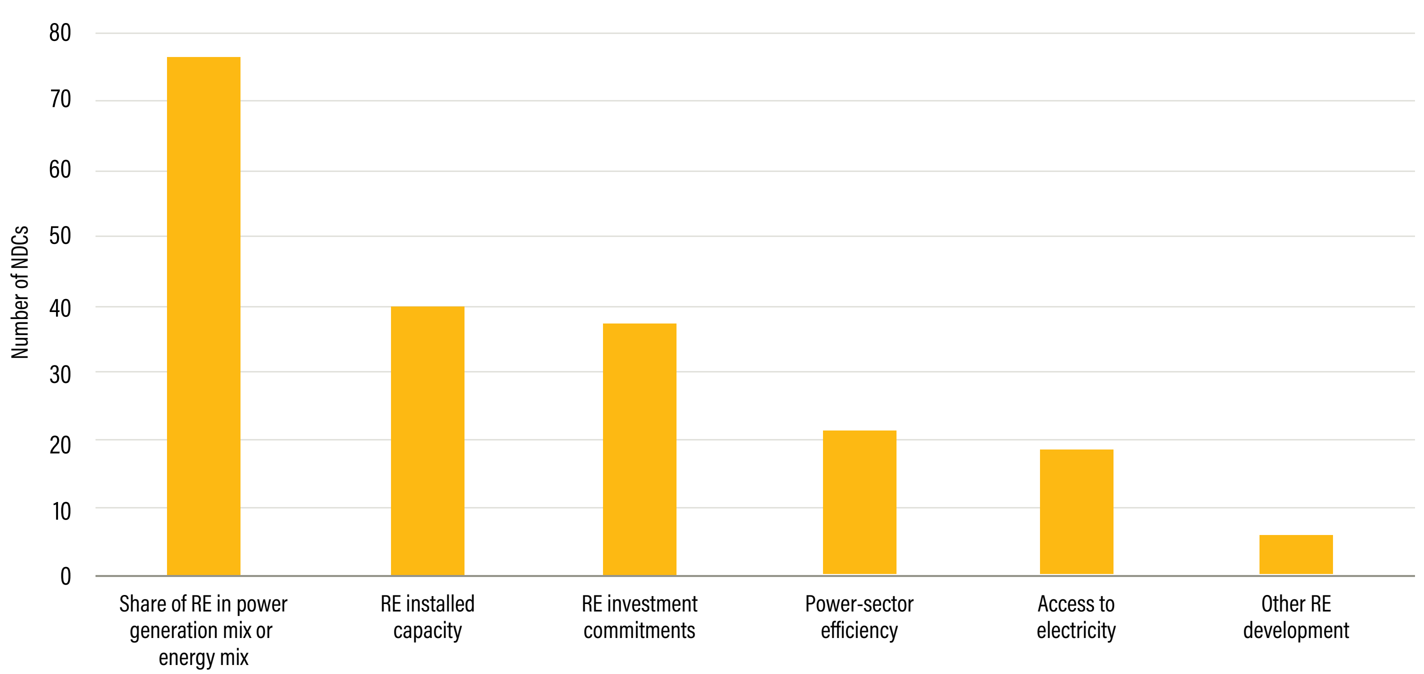
As renewable energy deployment for electricity generation rises and caters to enhanced energy demand from end-use sectors as they electrify, energy efficiency in end-use sectors will be key to achieve major CO_2 emissions reductions; otherwise, power-sector transitions will become an exercise catering to inefficient demand. In scenarios assessed by the IPCC SR1.5, global final energy consumption grows by 10 percent from 2010 to 2050, as opposed to 75 percent in reference scenarios. Taking its data from the International Energy Agency's (IEA) Beyond 2°C Scenario, the IPCC SR1.5 states that energy efficiency will contribute 42 percent to the industry sector's CO_2 emissions reductions and 29 percent to the transport sector's emissions reductions. In IRENA's deep decarbonization scenario, energy-efficient measures add up to almost half of the emissions reductions required as compared to their business-as-usual (BAU) scenario (IRENA 2019a). To get there, efficiency improvements and various demand-reduction measures must be scaled up substantially.

3. POWER IN THE CURRENT NDCS

How Power Is Currently Addressed in NDCs

Today, 184 countries, including 28 from the European Union, have submitted their NDC to the UNFCCC, and one has submitted its second NDC for 2020. Out of 184 NDCs, 103 NDCs included power-sector targets (WRI analysis, based on NDC content). The types of power-sector-specific targets in NDCs include renewable electricity targets, electricity supply side efficiency targets, electricity access targets, and natural gas electricity targets. Renewable electricity targets dominate NDCs, while targets concerning other issues only play a marginal role. (See Figure 7.)

Figure 7 | **Number of NDCs with Quantified Power-Sector Targets**



Source: WRI analysis based on ClimateWatch NDC content.

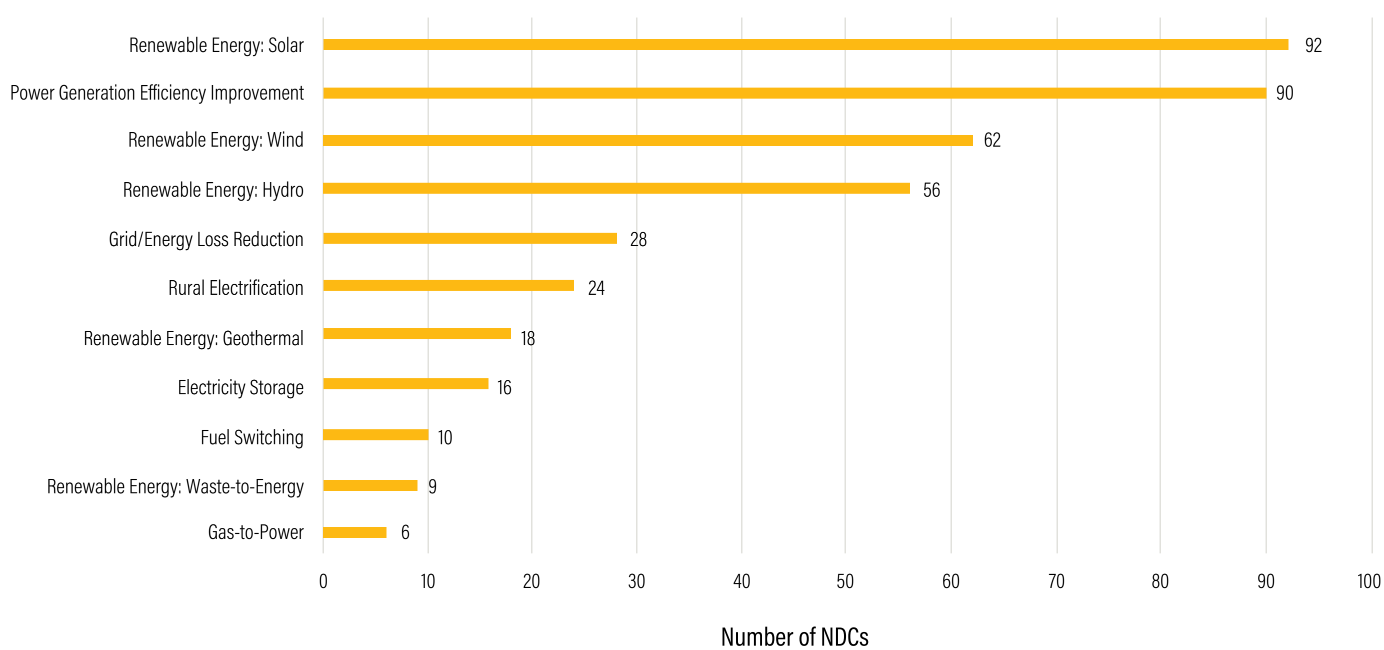
Figure 7 provides a breakdown of NDCs with renewable power targets. Among these NDCs, targets for renewable energy as a share of the power or energy mix are the most prevalent, followed closely by installation capacity targets. A significant number of NDCs also include investment commitments for renewable power. Other targets include GHG emissions reductions attributable to renewable electricity supply, renewable electricity generation, non-fossil fuel as a share of energy mix, number of renewable power systems, and area of land used for renewable electricity installation. Efficiency targets for power generation, transmission, and distribution, and targets focused on electricity access, are included in around 20 NDCs. End-use energy sectors to be powered by renewables like transport, heating, and cooling in buildings are part of only a few countries' NDCs (IRENA 2017b). Some NDCs include multiple target types.

One hundred fifteen NDCs also include policies and measures in the power sector, as shown in Figure 8. The most prevalent include policies and measures related to the expansion of solar energy and improvements in power-generation efficiency. A significant number of policies and measures relate to the expansion of wind and hydro energy. Only 16 NDCs have policies and measures on energy storage.

Key Gaps in the NDCs

There is a need for better aligning of national power priorities with climate objectives. Better addressing the power-sector transition in the NDCs can provide opportunities for countries to ensure that achieving their national power-sector priorities contributes to their climate objectives as well. By taking a visionary look at how the power sector is integral to a country's low-carbon transformation, governments can avoid locking in high-emission pathways, avoid building fossil-fuel power plants, and invest instead in cost-effective, sustainable sources of energy. Governments can also tap economic and development opportunities to create jobs, bolster energy security, and improve air quality. Establishing a process to better align national power strategies with NDCs can involve setting a long-term strategy for mid-century decarbonization within which the NDCs' ambitions fit coherently, that considers both climate and energy-sector priorities, and that is based on sectoral

Figure 8 | **Breakdown of NDCs with Policies and Measures in the Power Sector**



Source: WRI analysis based on ClimateWatch NDC content.

action plans, including the power sector. Such a process can also help policymakers achieve national development objectives, including implementation of sustainable development goals (SDGs).

Implementing the NDCs will lead to much less added RE capacity than is expected in 1.5^{0}C consistent scenarios. Implementing NDCs will add the capacity to generate 1.3 terawatts (TW) of renewable power globally between 2015 and 2030, representing a 76 percent growth in the world's total installed capacity compared to 2014 (IRENA 2017b). This is much lower than what is expected. The IEA's New Policies scenario suggests that by 2030 about 2.7 TW of renewable generation capacity will be added in total, while its sustainable development scenario (SDS) expects the additions to exceed 4 TW (IEA 2018). The NDCs could do much more to accelerate the transition to RE as they have not kept up with the rapid growth of RE. Between 2010 and 2016, RE installed capacity grew globally at an average of 8.5 percent annually, while the aggregation of RE targets in the initial NDCs would lead to a slow increase of 3.6 percent annually from 2015 to 2030 (IRENA 2017b).

Power-sector targets in the NDCs are often not aligned with national energy plans or strategies. Countries' NDC renewable energy targets are often more conservative than the countries' own national energy plans or strategies (IRENA 2017b). For example, if all African countries' NDCs were fully aligned with their existing national energy plans or strategies, the combined renewable energy installed capacity would be 80 gigawatts (GW) greater than it would be under their current unconditional NDC targets—those they have committed to, regardless of international support (IRENA 2017b). For G20 countries, the full implementation of their national energy plans will result in 500 GW more renewable energy capacity than their unconditional NDC targets currently capture (IRENA 2017b). Making national commitments international is encouraged, to spur a positive momentum of ambition in the spirit of the Paris Agreement. If more ambitious power-sector targets are made as international engagements, this would contribute to sending signals to nonstate actors on the direction of the transition, and would catalyze financial flows and investments in that direction. Harmonizing their national and international commitments is a straightforward way for countries to enhance the ambition in their NDCs while making use of the potential that the NDCs have to offer.

Aggregate renewable power targets are lower than the cost-effective potential. The global cost-effective potential of renewables exceeds what is reflected in aggregate NDCs (IRENA 2017b). Among G20 countries, there is a 2.3 TW gap between the cost-effective potential and the unconditional renewable energy targets in their NDCs (IRENA 2017b). This is also true for Africa, where cumulative unconditional NDC targets fall short of the cost-effective potential by 240 GW. (IRENA 2017b). For more ambitious RE targets in NDCs to reflect countries' cost-effective potential, it is important that enabling frameworks are set up and policies adopted to scale up RE as a stable basis for long-term deployment. To self-assess the ambition contained in power-sector NDC targets against cost-effective potential, governments need to consider new opportunities, as relevant in their national circumstances, arising from falling costs of RE; grid modernization, including the availability and likely forthcoming affordability of storage technologies; and innovative business models that have proved cost effective to bring RE power to consumers, as compared to coal.

Most NDCs do not recognize the power sector's potential to contribute to climate adaptation. Diversifying sources for power generation can help countries adapt to climate change. For instance, a country that relies too heavily on one source like hydropower to generate its electricity becomes extremely vulnerable to climate change–induced droughts. Or, a country heavily dependent on fossil fuels for electricity generation is setting itself up for costly lock-ins as climate change objectives start imposing carbon restrictions in a not-so-distant future. More distributed generation from renewables in remote areas improves energy access and can foster economic and social development, which builds communities' resilience. The use of RE can lower water usage and potentially widen the geographical spread, ensuring that climate change–induced drought or floods have less of an impact on power systems. However, only 43 NDCs recognized power, translated as RE, as part of the adaptation component of their NDCs (IRENA 2017b). Countries should be encouraged to develop their power-sector plans and policies such that they contribute not only to mitigation plans but also to climate adaptation and reflect this in their NDCs. By doing this, countries will be treating power more comprehensively as a sector that has socioeconomic development benefits and can enhance resilience to inevitable impacts of climate change beyond obviously mitigating it. Analysis on how to tap the power sector's potential to contribute to climate change adaptation and reflect it as enhancement in the NDCs is out of the scope of this report, which is focused on providing guidance to enhance the mitigation potential of the power sector in NDCs. A discussion of co-benefits of decarbonizing the power sector, including increased resilience, can be found in the appendix.

Most NDCs do not take advantage of the synergy between renewable energy and electricity access. Analyses (IEA 2017a) show that the world is not on track to achieve Sustainable Development Goal 7, which aims to provide access to affordable, reliable, sustainable, and modern energy for all. As discussed in the appendix, renewable energy can make significant contributions to SDG 7. RE can be a low-cost option to provide electricity to the hardest-to-reach populations (IEA 2017b) and financial flows could be directed toward enabling this, if clearly reflected in the NDCs. This is an attractive synergy that countries should exploit; yet, only 18 countries have energy access targets in their NDCs, while only 24 mention rural electrification policies.

Power-system flexibility does not get enough attention in current NDCs. A power system dominated by variable RE requires flexibility to balance electricity supply and demand. This is especially important as flexibility requirements increase merely to respond to growing electricity demand, not to mention as the share of RE in the power mix rises. A variety of measures and technologies can enhance power-system flexibility, including transmission system expansion, smart grids, energy storage, and demand response among others. Addressing flexibility also means having a plan to address existing coal assets. However, very few NDCs include targets for transmission-system expansion or smart grids. While 16 countries reference energy storage policies in their NDCs, none of them have quantified targets. No country mentions demand response measures in its NDC.

NDCs do not explore the full potential of interactions that exist between the power and end-use sectors. Section 2 discusses the importance of sectors like transport, buildings, and industries, still largely dependent on fossil fuels, to achieve the goals of the Paris Agreement through energy efficiency and RE-powered electrification. As of 2016, RE targets for heating and cooling had been set as national targets by 47 countries and for transport by 41 countries; but only 14 NDCs had targets for deploying RE in end uses (IRENA 2017b). There is scope for more countries to maximize synergies and reduce potential conflicts across power and end-use sectors in the next NDCs through strengthened targets for energy efficiency and RE for end uses.

4. POWER-SECTOR OPPORTUNITIES IN SUPPORT OF NDC ENHANCEMENT

Much has already changed since countries submitted their first round of NDCs ahead of COP 21, and it is safe to say that the global energy transition is now in full swing. These ongoing shifts can mean that countries' capacities and capabilities have evolved as well.

Specific to the power sector, significant changes are under way globally in generation mixes and load, as well as in distribution, storage, and consumption. We are witnessing new ways of operating power systems, different market designs, the deployment of enabling technologies, and innovative business models. These are being driven by new technologies, the integration of climate policies in national planning, new consumer expectations, and awareness of sustainable living. These trends have made the power landscape more complex, and they redefine the way governments and utilities are having to manage energy systems, even as demand for reliable power supply continues to rise.

Changes under way across the entire energy system are enabling the integration of larger shares of variable renewable energy and accelerating their large-scale adoption. These include the falling costs of RE technology, grid modernization through digitalization and storage, and new business models for scaling the supply of clean energy. All of these changes can enable countries to do more in their NDCs, while also providing their people with better access to affordable, reliable, and sustainable electricity.

Indeed, the 2020 process of enhancing NDCs offers an opportunity for countries to examine the ambition of their initial NDCs in light of innovations and declining costs of emissions-mitigation technologies—advances and trends that have emerged since the NDCs were developed with the potential to transform power systems in ways that seemed improbable just five years ago (Fransen et al. 2019). Countries may also wish to reflect shifts that have occurred in the real economy and send accurate signals to the private sector (Fransen et al. 2017).

A Business Case for Renewable Energy Power Generation

Analysis finds that global gross domestic product (GDP) increases more from 2019 to 2050 in deep decarbonization scenarios that in BAU ones (IRENA 2019a). As compared to the Reference Case, IRENA's REmap case boosts the GDP by 2.5 percent in 2050, representing an amount of U.S. $99 trillion over the period 2019 to 2050. Diving further into how much of a role transitions in power systems have to play in this gain, the study looks at macroeconomic drivers behind the GDP boost and finds that a front-loaded investment stimulus in RE generation capacity, energy efficiency, and power-system flexibility to support power-sector transitions is responsible in the short term.

Since 2010, grid power generation from renewable sources has become the center of the global energy transition to low-carbon pathways. In most parts of the world, renewables have become cheaper due to falling costs of generation, especially for solar and wind. With costs continuing to fall, particularly for solar energy, solar PV power generation has started to compete directly with fossil fuel–based power generation in many geographies. Stakeholders are promoting the deployment of RE as they see a business opportunity in the further reduction potential of costs in the decades to come.

In addition to helping decarbonize the electricity sector, the falling cost of renewables also unlocks cost-effective decarbonization opportunities for end-user sectors like transport, industry, and buildings. The world's pathway to a sustainable energy sector foresees an increase in electrification with electricity's share of final energy demand growing from less than a fifth to nearly half in 2050, riding on cost-competitive renewables (IRENA 2019b). Table 1 provides a snapshot of the global-weighted average cost of electricity ($/kWh) in 2010 and 2018.

The global-weighted average cost of electricity generation from all commercially available renewable power generation technologies fell in 2018, with solar PV, concentrated solar power (CSP), and onshore wind experiencing the largest declines. The global-weighted average levelized cost of electricity (LCOE) of hydropower stood at $.047/kWh in 2018, 11 percent lower than in 2017, but 29 percent higher than in 2010.

As an element of reference, the fossil fuel–fired power generation cost range by country and fuel is estimated to be between $0.049 and $0.174/kWh in 2016–2018 (IRENA 2019b).

Table 1 | **Global Electricity Generation Costs in 2010 and 2018**

GENERATION SOURCES	SOLAR PV	CONCENTRATED SOLAR POWER	ONSHORE WIND	OFFSHORE WIND	HYDRO	BIOENERGY
Cost of Electricity ($/KiloWatt hour (kWh)) in 2010	0.371	0.341	0.085	0.159	0.037	0.075
Cost of Electricity ($/kWh) in 2018	0.085	0.185	0.056	0.127	0.047	0.062
Change in the Cost of Electricity 2010–18	-77%	-46%	-35%	-20%	+ 27%	-17%

Note: The levelized cost of electricity (LCOE) looks only at costs of producing a unit of electricity during a plant's lifetime without taking into consideration revenue, value, and other costs associated with transmission, for example. LCOE does not show a full picture for comparing generation technologies but is nonetheless useful to track generation costs of a specific technology over time and for technologies that are used to provide similar services to the grid (Malaguzzi 2019).

Source: IRENA 2019b.

Figure 9 provides the weighted average LCOE of utility-scale renewable energy power-generation technologies from 2010 to 2018.

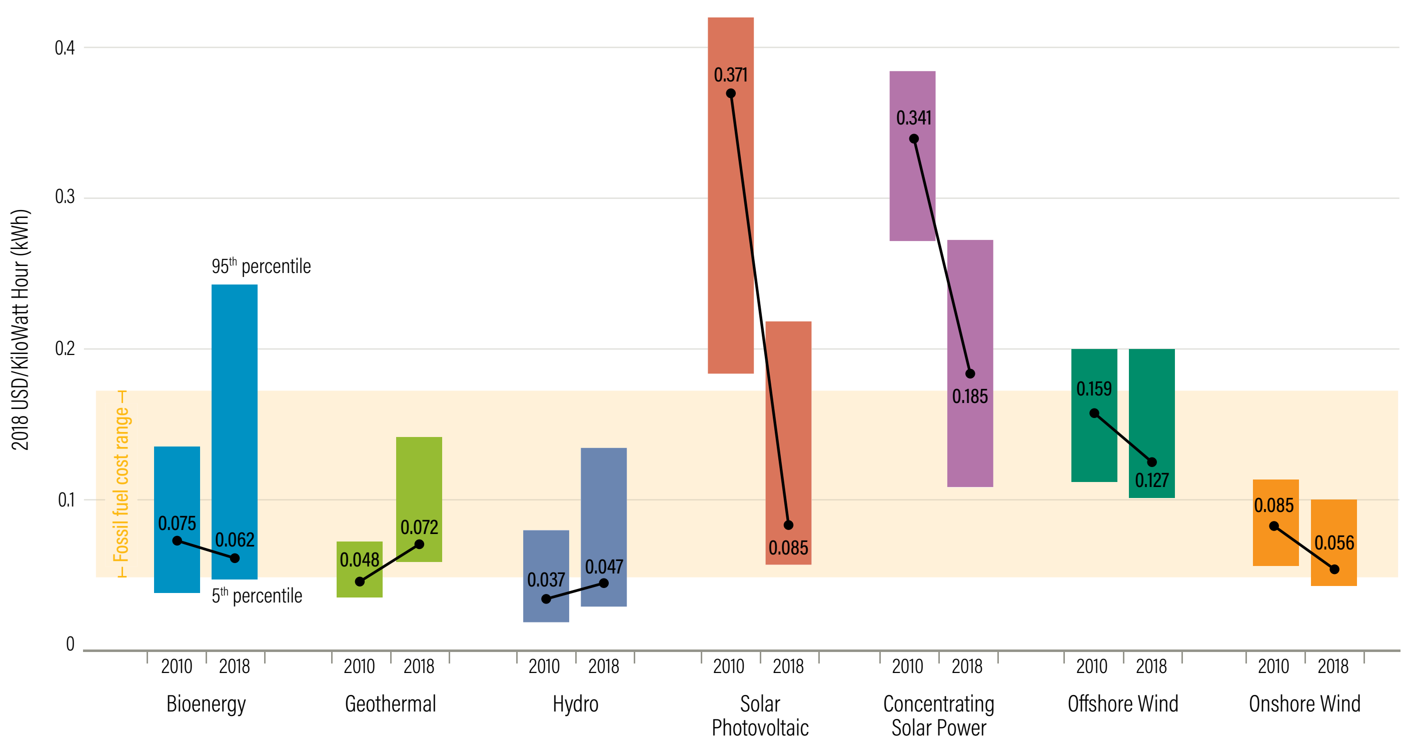
With RE costs coming down, their cost-competitiveness with coal, and scope for further cost reductions, renewables today represent a significant opportunity for policymakers to enhance their NDCs. More ambitious RE targets will encourage and intensify national power-sector transitions toward the global energy transition required to keep the 1.5°C goal in reach. As RE costs continue to decline, it will become easier for countries to reflect their ongoing energy transitions in their NDCs by strengthening the RE targets that they already have and adding new ones if they do not yet have them. Adding or strengthening an RE component to the NDC is fundamental to unleashing the potential of RE to decarbonize the power sector, as well as to mobilize stakeholders and financing that will further drive RE deployment (IRENA 2017b).

Grid Modernization, Digitalization, and Energy Storage

Grid modernization

Grid modernization is needed to respond to sweeping changes that the power system has undergone in recent years. These changes include higher shares of variable renewables, decentralized solar power generation, and aging power infrastructure. Countries are making progress in ramping up their grids' ability to adapt to evolving electricity supply and demand. Managing increasingly complex systems requires integrated and visionary approaches, including large-scale deployment of energy storage technologies and smart grid digitalization that implant the intelligence and flexibility required to adapt to rapid technological changes in power generation, transmission, and distribution. This is called grid modernization.

Figure 9 | **Global LCOE of Utility-Scale Renewable Power Generation Technologies, 2010–18**



Source: IRENA 2019b.

Of course, underlying reasons for grid modernization, as well as grid modernization levels and efforts, vary widely across nations. Some countries are looking at building new infrastructure as their load growth is projected to rise, while others are focused on retrofitting or replacing old infrastructure. Some are working toward connecting clean electricity from distributed generation, and others are using smart data to improve electricity supply and demand forecasting in order to improve the grid's reliability.

Over and above those variations are opportunities that come with grid modernization that can be tapped and captured in countries' NDCs through targets, enabling policies, incentives, and research and development (R&D) expenditure. Grid modernization is closely linked with the grid's ability to become cleaner and take in greater shares of RE (Graham et al. 2017) because it helps structure a grid in ways that support the integration of RE and distributed clean energy. As the role of RE gains more recognition and prominence as a key to meaningful energy access, it must be holistically included in national electrification plans so that all stakeholders, including the public and private sector; local, state, and federal agencies; energy regulators; financial institutions; communities; and nongovernmental organizations (NGOs), can work together toward modernizing power services with higher shares of clean energy (IRENA 2018).

A modern grid improves the system's reliability, efficiency, and resiliency, which, in turn, boosts residential and commercial consumers' trust in a strong and healthy energy delivery system (IRENA 2018). Grid modernization, through digitalization and energy storage, represents new opportunities for policymakers that were not as mature prior to the Paris Agreement to accelerate their national transitions to a clean grid. Policymakers should assess the new potential arising from grid modernization to strengthen or add power-related NDC targets and to tap synergies that exist with SDG 7.

Energy storage

As noted earlier, developing energy storage technologies to commercial viability and plugging them into the grid is part of grid modernization. Energy storage is needed to respond to the transitions shaking up the power distribution grid, and deploying energy storage technologies will further disrupt the grid in the near future. However, the large-scale use of such technologies is an undeniable requirement if the world is to realize an energy transition with higher shares of integrated RE. The cost of RE has fallen over the course of the last decade, making it cost-competitive and sometimes even cheaper than coal. But solar energy is only available during the day, and wind energy only when the wind blows. This variable nature of RE renders serious backup capacity essential for grid reliability in a network with high shares of RE and as the reliance on renewable power sources increases.

In addition, many developing countries poised to grow their electricity demand and consumption will soon face the added cooling challenge whereby, as living standards go up, households will acquire an air conditioner and generate a peak in demand for electricity at night when they turn it on. This phenomenon is already occurring in India, even though less than 10 percent of households own an air conditioner, and will likely grow more acute as more people buy them (Mangotra et al. 2018). Because solar energy is not available at night, solar coupled with storage technologies will most likely provide the solution.

The energy transition will become irrevocable only if the cost of RE plus grid flexibility (including storage) becomes cheaper than the cost of coal. Although developing-country grid requirements are not fully considered by the current energy storage market, it is however encouraging that a majority of storage technologies required to transform the power system already exist and their deployment can be accelerated immediately (IRENA 2018). For a discussion on storage technology options and costs, see section 5. There is a real requirement to catalyze a new market for storage technologies that are suitable for a variety of grid and off-grid solutions. This is exactly what the Energy Storage Partnership convened by the World Bank in May 2019 sets out to do: foster international cooperation to adopt and develop energy storage solutions for developing countries. This should lead to positive development on the horizon in technology improvement and cost reductions.

The power sector is increasingly interested in reaping the benefits of deploying energy storage at large scale, and governments should recognize the opportunity that this offers to achieve and strengthen their power-related NDCs. Advanced battery systems could add required flexibility to the grid by reducing peak power challenges and becoming stabilizers of the distribution grid. Two-way energy flows, by which energy stored in batteries can be released into the grid when required, can cut system costs, particularly during peak demand (Graham et al. 2017); increase grid efficiency; and integrate more RE, thereby reducing carbon emissions.

By leveling rapid shifts from variable renewable electricity that could otherwise lead to fluctuations in customer service voltage (Graham et al. 2017), energy storage is contributing to grid reliability, an important component of achieving meaningful energy access and meeting the SDGs. In addition, as energy storage technologies help to reduce load in peak-demand periods (peak shaving) and provide assurance of balancing generation and load at certain times (firming) (Graham et al. 2017), they guarantee a certain level of grid reliability that is a prerequisite for the delivery and strengthening of other sectoral NDC targets aiming to decarbonize the transport, buildings, and industry sectors. For instance, grid reliability and stability are critical to integrating electric transportation and the associated infrastructure sustainably into the grid, as they build trust in electricity as a dependable transportation fuel.

When policymakers reflect on how to update power-related targets from the initial NDC, it is important that they consider up-to-date assumptions regarding the availability and costs of energy storage technologies, as well as the scope of coming improvements in their commercial viability. The cost-benefit balance of energy storage technologies has shifted since 2015, opening up new mitigation opportunities and potential that are not currently reflected in the NDCs. With costs falling and battery technology improving, policymakers must consider how much more and how much faster RE can be plugged into the grid. Likewise, with improved and cheaper charging infrastructure, countries can look at how much faster than anticipated the transport sector can electrify and factor this into updated NDCs.

Digitalization

Decentralized power generation, increased shares of variable renewable energy, new and emerging technologies like battery storage, new business models, and pressure to decarbonize make power systems increasingly complex. Consequently, it is becoming harder to operate and monitor power systems manually and more essential to leverage advanced information plugged in at all levels of the grid. As stated in the Bloomberg *New Energy Finance—BNEF Report* (Bloomberg 2017), "As electrical grids evolve to meet the needs of the 21st century, one thing is clear: Digitalization will be everywhere." Digitalization is a key amplifier of power system transformations.

Digitalization allows the grid to be smart and self-balancing, leveraging smart data to open up possibilities, such as dynamic balancing of electricity supply and demand in real time, as well as remote monitoring and operations (Mathur et al. 2019). Digitalization is already facilitating more efficient and effective operation of the power grid and helping to stabilize transmission grids by balancing variable renewable resources (Bloomberg 2017) but requires increased capital investments, better data management and stakeholder coordination (Graham et al. 2017). Grid digitalization presents opportunities that feed directly into helping countries enhance their NDC power-related targets. Digitalization can improve grid efficiency and reliability, manage energy usage data for more accurate load prediction, enhance grid designing and planning, create new revenue streams, heighten consumer satisfaction, unleash new untapped potential to accelerate the shift to RE, and set more ambitious NDC targets.

Energy usage data management: To allow for greater integration of RE in the electricity grid, power markets need to be faster in their grid balancing, meaning that they must be able to adjust in real time to fluctuations in supply and demand, rather than hours or days ahead of electricity distribution (Mathur et al. 2019). This is because the prediction of renewable sources of energy is more accurate in real time, given their variability.

Digitalization improves data collection and management, making it possible to use these data in real time to forecast both power supply and demand through the deployment of smart meters, digital networks, and interconnected appliances. This enables operators to make better decisions and could lead to automated balancing operations of the grid (Bloomberg 2017), such as shifting electricity demand to times when electricity is in larger supply. Indeed, real-time forecasting of renewable sources of energy can enable greater RE integration and optimize power generation. Availability of real-time data can also ensure that fossil fuel assets are used more precisely as peaking plants (Bloomberg 2017). Similarly, smart data collection and management at the customer level can help utilities deal with challenges like grid balancing and integrating power produced by consumers through rooftop solar systems. Today, we are only scratching the surface of harnessing and using these data adequately (Bloomberg 2017), but digitalization holds great potential for designing reliable and stable decarbonized power systems and enabling countries to reduce GHG emissions more quickly than envisioned under their first NDCs.

Because digitalization of grid operations can connect different areas at any time, it can help to create the bigger markets needed to integrate higher shares of RE in the grid. The more vast the geographical area covered by the power market is, the more likely it is that variable renewable sources will be available (the sun is always shining somewhere) (Mathur et al. 2019). Digitalization can enable operations over larger geographical areas and enable those markets to manage the variability of renewables. This is conducive to supporting enhanced NDC power-related targets.

New income streams and cost efficiency: Digitalization and smart grid technologies, paired with storage technologies, demand response, and decentralized renewable generation, can create new opportunities that can generate new income streams, especially for technology providers. There are several economic benefits attached to the deployment of digital technology on the grid. Bloomberg (2017) estimates that by 2025 the annual revenue from energy digitalization will be $64 billion, up from $54 billion today, thanks to increases in sales of smart meters and home management solutions.

Digitalization improves the efficiency, not only of the grid, but also of homes and buildings, saving energy and costs to consumers, along with GHG emissions. Additionally, smart meters empower consumers to become 'prosumers' (producers and consumers of power) through the installation of rooftop solar systems, while feeding the excess power they produce back into the grid. With the right policies and incentives in place, digitalization can enable enhanced NDC targets that further incentivize energy conservation and renewable energy.

New intersections among the power, transport, and buildings sectors: Deploying digital technology for the power grid creates new intersections among the transport, buildings, and power sectors (Graham et al. 2017). Information technology, along with demand-side management, can be used to reduce peak electricity demand and grid operational costs. Reduced costs, in turn, can accelerate the electrification of the transport and buildings sectors (IRENA 2018). In terms of the deployment of electric transportation and associated infrastructure, digitalization provides the ability to manage charging stations smartly on a real-time basis. This makes digitalization of the power grid indirectly important for countries wishing to achieve and enhance their sectoral NDCs.

Essentially, digitalization enables a much smoother running of grid operations with more efficiency and effectiveness as it can help ensure an adequate supply of power by keeping track of fluctuations in supply and demand, tapping electricity generated in various places from different sources, accessing backup generators as needed and channeling electricity where it needs to go. This is conducive to the integration of higher shares of RE in the grid. Hence, digitalization permits faster transitions to power grids with greater shares of RE than seemed feasible when countries submitted their first round of NDCs. Policymakers should assess the new opportunities arising from digitalization and ensure that the up-to-date potential for more RE in their power grid is reflected in their next NDCs.

New Business Models for Scaling the Supply of Clean Energy

The expanding scale of grid modernization, energy storage technologies, and digitalization has set the stage for fundamentally altering business models. Innovative business models enabled by digital technologies that improve the system's flexibility and incentivize RE have a big role to play in creating the enabling environment necessary to accelerate integration of RE in the grid. Those new business models include virtual power plants; novel power purchase agreements; platform business models, such as peer-to-peer trading; and business models that maximize demand-side response (IRENA 2018).

Today, thanks to lower costs and technological advances, decentralized renewable energy generation has become a mainstream business model (IRENA 2018). The maturation of distributed renewable generation solutions takes the form of rooftop solar PV installations, mini and micro grids, and community scale technologies and others. The business models can involve smart micro grids for accelerating energy access in remote parts of the world with internal power flows; or owners of rooftop solar panels that are connected to the grid and generate excess solar electricity during the day, which is fed back into the grid. By decentralizing energy supply, these models allow consumers to become net energy producers, meaning that the location of energy generation is shifting. One-way flows are developing into multi-directional power flows. If well managed, these models can go hand in hand with better grid operations and management.

These options are not new. The transformation of the decentralized renewable energy sector in the last decade stems not from technological novelty, but from a shift in perspective. These are no longer one-off pilot projects, unable to sustain themselves. They are being scaled up with the private sector increasingly engaged and with business innovations that are lowering costs and making these options accessible to rural communities (IRENA 2018). The spread of these models is exemplified by how solar, once a custom installation, is now packaged into unit sales. As distributed solar and associated business models continue to mature and become well established, policymakers may start considering them in their national energy-sector planning and as a strong foundation on which to base the enhancement of their NDCs. By recognizing the opportunities that these business models present, aggregating them into national planning, and using them as tools to achieve NDC targets of RE deployment, planners and policymakers would set a framework and send signals to direct investments toward RE and accelerate the transition to clean energy.

Governments have no more reason to see these business models as isolated projects that cannot be aggregated. The benefits of providing affordable, reliable, and clean electricity for all are undeniable. These models promote RE deployment, energy efficiency, energy access, and local revenue generation. In addition, digitalization will simultaneously give more control to consumers by providing them with behind-the-meter assets to generate power at home and by enabling them to join local micro grids and blockchain schemes, or trade with their neighbors (Bloomberg 2017). At the same time, those digital systems will provide closer and more transparent monitoring of those activities and data integration (Bloomberg 2017).

5. HOW CAN THE NDCS ENABLE ENHANCED CLIMATE AMBITION IN THE POWER SECTOR?

Decarbonizing Electricity Generation by 2050

Achieving the 1.5ºC or 2ºC goals will require the power sector to be virtually decarbonized by 2050 (IPCC 2018). To get there, transitions need to substantially accelerate. Reliable scenarios agree that faster and greater deployment of RE, combined with increased energy efficiency and deep end-use electrification, are the backbone of the energy transitions needed to align with climate goals. The first two are essential to decarbonize the power sector by 2050 while the third is intricately linked. End-use electrification met with increased RE generation can deliver 60 percent of the required energy-related CO_2 emissions reduction. This increases to 75 percent if combined with the direct use of renewables (IRENA 2019a). Adding energy-efficiency, this jumps to 90 percent in high mitigation scenarios (IRENA 2019a).

Further, RE-generated power, end-use electrification, and energy efficiency do not operate in parallel to each other; rather, there are synergies to be harnessed among them, leading to reduced energy-related CO_2 emissions, which highlights the importance of a systemic approach. Energy efficiency technologies or measures result in less power demand, enabling a smoother and larger integration of renewables in the grid—in turn, allowing for the electrification of those sectors to be powered by RE but also meaning that the same capacity of renewables can cover a higher share of total demand. Additionally, increased electrification reduces growth in overall primary energy use if supplied with renewable power, which allows a given amount of RE to yield a higher percentage share in the energy system at the same time and can help integrate higher shares of variable RE as demand can better be synchronized with power supply (IRENA 2019a). These synergies help address the mandates of increased RE and energy efficiency simultaneously (IRENA 2019a).

While the energy transition is solidly under way, achieving it will entail major changes in the way we conceptualize and operate power systems, enhance flexibility to cost-effectively accommodate greater shares of RE in the grid, make holistic policies, take novel approaches to grid planning, redesign regulations, and institute innovative market mechanisms. Failing to meet requirements for grid flexibility could slow or stall the power sector's transition to renewables.

How Can the NDC Help Achieve These Objectives?

In light of the requirements to decarbonize the power sector by 2050 outlined earlier, for the next round of NDCs to send a transformational signal to the global industry and stakeholders involved in these transitions, it must carve out targets, policies, and measures aimed to achieve the decarbonization of the supply of electricity and the significant enhancement of energy efficiency, including to accommodate increasing electrification of end-use sectors like transport, buildings, and industry. These could be targets for reducing the emissions intensity of the power sector, energy-efficiency targets, and targets for clean electrification of the economy, against a certain timeline in line with the latest available climate science. But enhancing the mitigation component of the power sector in the NDC is no longer merely enhancing RE targets. Certain foundational strategies and policy interventions need to be under way or planned for in order to ensure successful transitions toward a decarbonized power sector by 2050. This report identifies four of them in the next section. How moving toward the implementation of these foundational strategies can be reflected in enhanced NDCs is further outlined in Section 6.

Four Foundational Policy Interventions and Strategies for NDC Enhancement in the Power Sector

Building on falling emission-mitigation technology costs, improvements in grid modernization, and business models, certain foundational strategies and policy interventions need to be under way or planned for in order to ensure that transitions toward a decarbonized power sector by 2050 are not slowed or stalled, in spite of all the progress that has already been made. These foundational elements can give policymakers indications of what data, information and considerations they need in order to track the status of their power sector against the 1.5°C goal, based on which they can identify which targets need to be set or revised.

These foundational issues for a decarbonized power sector exist within and beyond the NDCs. The 2020 NDC enhancement process can help identify where gaps in these foundations lie at a country level and provides an opportunity to strengthen the grounds for their implementation.

Foundational Strategy 1: plan for enhanced grid flexibility

With projections such as power generation roughly doubling in 2050 in mitigation scenarios, enhanced flexibility is required and urgent regardless of the amount of RE plugged into the grid. Adding the projection that the share of RE in the power sector will rise from 25 percent in 2017 to 86 percent by 2050 (IRENA 2019a) raises an unquestionably substantial technical challenge, and not investing today in the resources required to substantially improve flexibility capacity will slow down power systems' transitions to clean grids. Matching supply and demand with such high shares of variable RE will require increasingly smart, digitalized, and flexible grids. Now that RE costs have plummeted and are cost-competitive with coal in most places, flexibility has taken the center stage as the main blockage to higher shares of VRE integration in many countries. A realization of power system transitions toward decarbonization can only happen if the cost of VRE plus grid flexibility becomes cheaper than the cost of coal.

Greater grid flexibility to accommodate daily and seasonal variability of RE can be planned for with a number of short-term priority improvements as well as long-term planning. Some measures would be on the supply side, such as super-grid deployment for grid interconnection, new market and operation rules, and the deployment of storage technologies. Fortunately, just like solar PV did 10 years back, storage technologies show huge deployment and cost reduction potential and should be economically viable in the mid-2020s (Mathur et al. 2019) as longer lifetimes and improved performance lead to cost reductions. Pumped-hydro systems still dominate the storage markets, but larger deployment of new battery systems and stationary applications, especially for lithium ion batteries has been driving costs down by 73 percent between 2010 and 2016. Total installed lithium ion battery costs could fall by another 50 to 60 percent by 2030, potentially to below $200 per kilowatt-hour by 2030 for installed systems (IRENA 2017a).

Other flexibility options are on the demand side, such as shifting demand to match periods during which VRE supply is plentiful thanks to the deployment of smart meters that enable real-time pricing. An integrated flexibility portfolio is required to avoid over-dependence on one option only and to boost grid resilience. This also enables a smoother operation on the grid, lowering systems costs (Udetanshu et al. 2019).

Estimates find that $13 trillion would be invested in the required grid infrastructure and system flexibility to accommodate the amount of VRE required in 2050 decarbonized power systems, which is about $4 trillion more than in BAU scenarios (IRENA 2019a).

Foundational Strategy 2: a strategy for addressing existing coal assets

Transitioning to decarbonized power systems by 2050 is attractive for multiple reasons that have already been discussed in this report and are further outlined in the appendix. But policymakers are faced with economic, financial, structural, and infrastructural realities that can stand in the way of the transition. One of these realities is that many economies are still dependent on fossil fuels, especially coal. Global coal demand increased in 2018 by 0.7 percent, or 40 million tonnes of CO_2 equivalent ($MtCO_2e$), growing for a second year as higher demand in Asia outpaced declines everywhere else (IEA 2019a). Coal is therefore an integral part of the transition, economically and socially, and cannot be labeled as an issue to deal with on the sidelines, if we want the transition to be successful.

Ensuring that the energy transition happens with the least disruption to all sectors means that policymakers need a plan to address coal in their decarbonization pathways. Many countries and finance institutions, though not all, are committed to building no new coal capacity, including, for example, through the Powering Past Coal initiative. But countries also need to manage carefully and in a just manner the rapid shift away from existing coal assets. The primary looming threats for coal assets are regulatory stranding that could occur due to changes in policy legislation to achieve climate objectives and economic stranding due to a change in relative costs and prices as the cost of renewable technologies keeps falling. There is also a social stake, as coal is a high employment sector all along its supply chain; hence a coal phase-out would mean millions of job losses in the sector.

The risks associated with coal-stranded assets involve financial distress in the coal fleet, which does not benefit the transition toward low-carbon power systems, as significant financial losses impinge on the capacity of financial and corporate sectors to invest in the coming years, including in the deployment of RE. In addition, the social effects and job losses may have a feedback effect on the willingness of populations to accept the implementation of progressive climate policies. Scenarios that are 1.5^{0}C consistent may foresee a phasing out of 95 percent of operational coal plants and the commissioning of no new ones, but planners need to integrate potential coal-stranded assets in overall risk assessments in order to get there.

Strategies to mitigate negative impacts of phasing out coal will involve retirement of old and inefficient plants and repurposing power plants to use the existing coal capacity as a reasonably cost-flexible option that can play an important role in daily balancing, ramping, and seasonal balancing. There is scope for thermal power plants to provide more flexibility than they do today. Within limits, power plants can be turned on or off and up and down, enabling them to provide services such as ramping or daily balancing (Udetanshu et al. 2019). There are limitations, as power plants cannot operate stably below certain levels of peak capacity, require time to raise temperatures to provide steam and increase their output (ramp speed), and require time to get the plant up and operating (start-up time) (Udetanshu et al. 2019). To circumvent these, operators would need to be notified well in advance of when the plant would be needed. Importantly, no new coal capacity should be built to cater to flexibility needs, as it is questionable whether new coal is the most cost-effective resource for peaking power or daily balancing.

Foundational Strategy 3: institutional changes

In most parts of the world today, conditions are right for more ambition from the power sector than is currently reflected in the NDCs. The first necessary transition—for RE to become cheaper than coal—has to a large extent already occurred. But cost-competitiveness of RE and technological progress, while they can open doors to deployment, are not enough to ensure a successful transition. The challenges in the power sector are not always the incremental costs but can be institutional ones that include changing institutions, markets, and infrastructure. This means better policies, greater coordination, and enhanced institutional capacity to ensure implementation of policies needed to achieve the power-related targets in the NDCs. The institutional changes required at this point are arguably more important than more technological progress.

MARKET REGULATIONS

Many grids have been built on the paradigm of centralized baseload generation and are therefore tied up in long-term, inflexible mechanisms like power purchase agreements. To drive commercial efforts for the deployment of renewable power generation, electricity markets for grid balancing and ancillary services will be necessary.

The benefits of RE are not always adequately reflected in market prices, even though analysis projects that the benefits of RE can outweigh the costs by 2030. There can be complicated regulatory reasons for why relative costs of RE remain high and hard to roll out. But today, there can be gaps between market signals and policy objectives, which policymakers need to correct. Correct electricity pricing is crucial in that regard. It should ensure that the actual costs of conventional fuels are reflected, accounting for hidden costs and avoiding inefficient fossil fuel subsidies. In 2016, subsidies and other support to fossil fuel production and consumption amounted to around $340 billion (OECD and IEA 2019). Despite recent reform efforts—40 countries started or accelerated fossil fuel subsidy reforms between 2015 and 2017 (Zinecker et al. 2018)—much more is still needed as fossil fuel subsidies continue to discourage investments in RE-generated power and encourage the lock-in of high-carbon assets for power generation. Relative to the IEA's current policies scenario, a global phase-out of fossil fuel production subsidies reduces emissions by up to 37 Gt of CO_2 by 2050 (Gerasimchuk et al. 2017).

Electricity pricing can provide flexibility for variations like tariffs that vary depending on the time of use. Grid codes and electricity pricing mechanisms can also be changed to incentivize energy consumers to produce and consume their own energy, and to promote digitalization technologies that can help manage loads (IRENA 2019a).

Similarly, storage technologies will not penetrate the market on their own. A number of market and policy barriers need to be overcome to unlock the flexibility that storage technologies can offer. The value of energy storage can be very location- and time-specific, but the way electricity is priced usually does not reflect this. Policymakers could intervene for markets to allow for electricity price arbitrage (charging during lower-price hours and discharging during higher-price hours) and for tariffs that reflect locational value.

Policies also need to be in place to create enabling frameworks and conditions for investments in low-carbon, long-term solutions that promote electrification and decentralization. These would be geared toward renewable power generation but also to key enabling infrastructure like smart power grids, charging stations for EVs, storage, smart meters, etc.

CARBON PRICING

1.5°C consistent pathways require stringent and integrated policy interventions, including assumed policies reflecting a price on carbon, higher than the ones seen in real markets, and about three to four times higher than in 2°C scenarios (IPCC 2018). Carbon pricing for power generation is a strong market signal that can drive shifts to non-fossil power generation and has long been considered a way to cost-effectively reduce emissions. Beyond the power sector, carbon pricing can provide incentives to use energy more efficiently, can generate substantial government revenue, and can provide important local environmental benefits like reduced air pollution (IMF 2019). Introducing a minimum price on carbon is also a way to tackle emissions from sectors, including transport and buildings, that are not always covered by emissions trading schemes even though they are substantial power end-users. Carbon pricing initiatives are now in place in 76 jurisdictions worldwide, and cover one-fifth (20 percent) of global GHG emissions (World Bank Group 2019). This is a remarkable increase from the less than 1 percent coverage in 2004. As a result, carbon pricing programs generated around $44 billion in government revenues in 2018 (Partnership for Market Readiness 2019). By creating such sources of public finance, carbon pricing can enable government investments in critical public priorities like healthcare, education, or infrastructure. A reliable price on carbon can also reduce volatility and uncertainty for investors, reducing the cost of financing and increasing financing capacity in RE projects.

The price of carbon is central to propel transitions in the power sector but needs to be complemented with other policies. For the decarbonization of power generation, the diversity and interaction of various policy mixes, including regulatory policies in the power sector, subsidies, performance standards, technology policies like feed-in-tariffs, and moderate carbon pricing, is critical, especially in the short term. Studies find that combining stringent energy-efficient policies with a carbon tax is more cost effective than carbon pricing alone to put power sectors on 1.5°C pathways (IPCC 2018).

The political difficulty of carbon pricing for power generation—and generally —comes from its direct impact on electricity prices and potential public opposition.

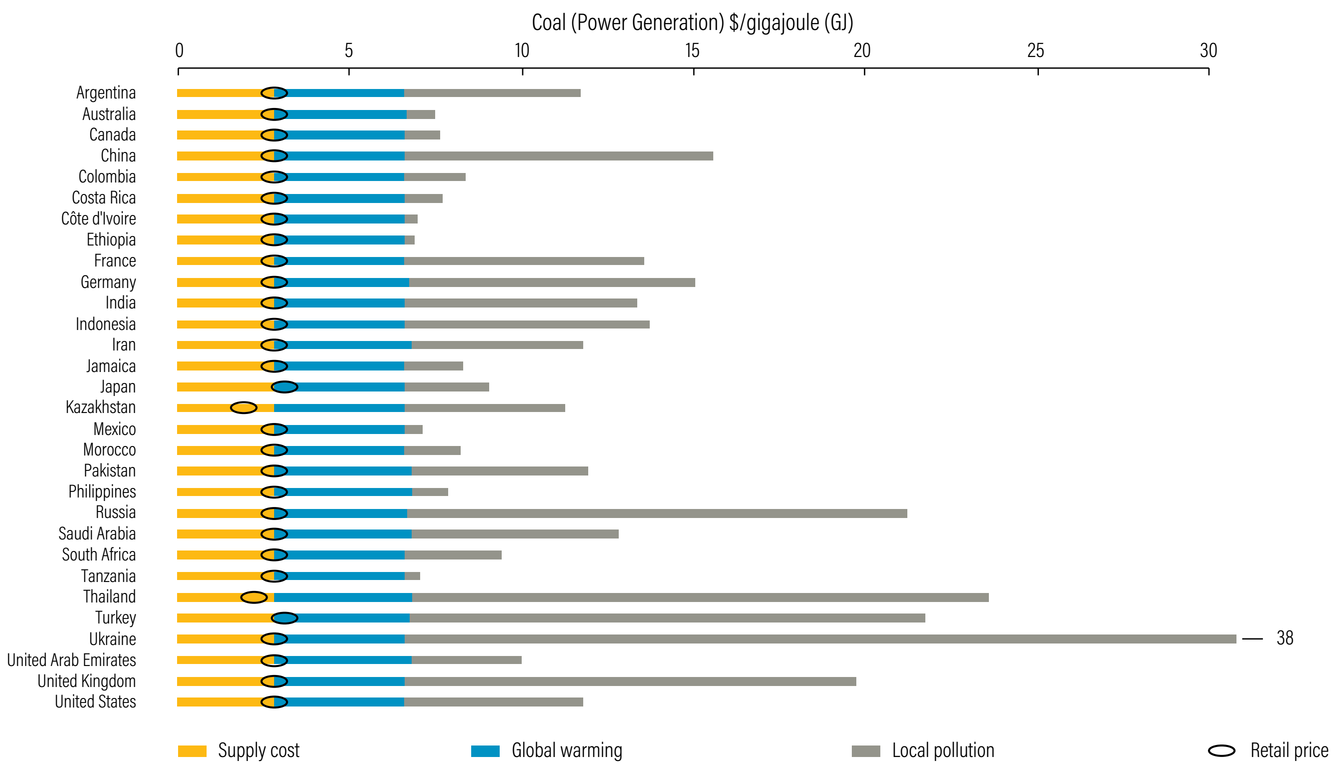
To overcome this, policymakers must integrate carbon pricing in a broader strategy with accompanying details on how the generated revenue will be fairly used and redistributed for assistance to vulnerable households. Studies have estimated that by using a small portion of carbon pricing revenue (about 10 percent) to specifically target low-income households, policy designers can ensure that these groups are no worse off under a carbon price than alternative policy pathways (Mathur and Morris 2012). Alternatively, carbon prices for power generation can be imposed implicitly, although less effectively, by regulatory policies like emission standards for power generation or fiscal instruments that tax or subsidize power generation activities with above or below average emissions intensity (IMF 2019).

AIR POLLUTION PRICING

To be economically efficient, power generation prices in principle should reflect not only supply costs but other costs from negative impacts of coal combustion on health and climate. Air pollution has several impacts, including morbidity, impaired visibility, building corrosion, crop damage, lake acidification, etc., but the highest costs are those associated with mortality (IMF 2019). (For a discussion of air pollution co-benefits of a decarbonized power sector, see the appendix).

Figure 10 shows that for coal, global warming costs (assumed to be at $40 per ton) are higher than supply costs and that air pollution costs can be higher than global warming costs. Variations are due to differences

Figure 10 | **Country-Level Estimates of Fully Efficient Prices for Coal Used in Power Generation in 2015, Compared with Actual Prices**



Source: IMF 2019.

in emissions rates, population sizes exposed to air pollution, age and health of populations, and people's willingness to pay for lower health risks. Supply costs are covered by the prices of coal-generated power, but not environmental costs (IMF 2019).

Although there is uncertainty about how to estimate environmental costs, underpricing for an honest estimate of them signals classic market failures, just as with underpricing for supply costs (IMF 2019). Instead, embedding carbon pricing for power generation as part of a broader mechanism to comprehensively reflect the full range of other impacts, including air pollution, would match market signals with policy objectives. Accurate pricing redirects investments toward technologies with lower externality costs, in this case, RE generated power. Adding the price of air pollution to the cost of power generation would be one of the greatest motivating factors for major emerging economies that suffer from alarming air pollution levels to shift away from coal power generation. This potential should be given greater attention in the NDCs.

DISTRIBUTION UTILITY REFORMS

Decarbonizing the electricity grid has different implications around the world. Specifically, developing countries where basic services are in the course of being provided or not being provided at all, are still grappling with high losses and inefficiencies of power systems and with chronic and potentially increasing situations of financial distress of their distribution utilities. Where the conventional, central utility model of operating the grid is being challenged owing to increasing trends of distributed generation and the technical requirements that come with higher shares of VRE, distribution utility reform is at the root of further transitions in the power system.

As cheaper RE becomes increasingly attractive to distribution utility customers, including industry and commercial sectors, utilities can find their revenue streams cut off. This is why in some parts of the world, the utilities have been reluctant to incentivize decentralized generation through rooftop solar PV where electricity consumers become "prosumers"—a term of art indicating individuals who are both producers and consumers—and bilateral contracting between large industrial and commercial consumers and RE. Simultaneously, distribution utilities often lack the technical expertise required to integrate VRE in their operations. Finding new business models for distribution utilities to become self-sustaining during these transitions will be crucial. Such business models should prioritize the convergence of the economic interests of the distribution utilities and of the small- and large-scale prosumers. Tariffs can once again ensure that the excess RE that prosumers feed back to the grid is priced lower than the cost of coal, enabling distribution utilities to buy wind and solar at preferential tariffs, as compared to electricity bought through inflexible market mechanisms. Plugging the use of storage technologies into these models will also be a game changer to ensure that prosumers are not exacerbating the problems faced by distribution utilities by all providing electricity at the same time.

Foundational Strategy 4: Integrate sector-coupling solutions

Limiting global mean surface temperature rise to 1.5°C is a formidable task, and the solution will not emanate from a single policy option. Decarbonization of the power sector by 2050 is de facto assumed by most 1.5°C scenarios as a requirement for successful energy transitions; hence, finding synergies with end-use sectors to enable steep cuts in GHG emissions is what will close the decarbonization gap and needs to be given more attention in the NDCs. The global transition to a 1.5°C pathway will require accelerated changes, such as greater energy efficiency that is essential for the power sector, and faster electrification, which has intricate repercussions for power suppliers. Indeed, an increasingly electric energy system will transform how the power sector and demand interact, and the choices in one sector will affect the efforts required in others.

As seen in Section 5, RE-generated power, end-use energy efficiency, and electrification do not operate in parallel; rather, there are synergies to be harnessed among them, leading to reduced energy-related CO_2 emissions, which highlights the importance of a systemic approach. There are correlations between energy efficiency and renewables which are revealed as scenarios with high shares of renewable energy are also the ones with higher efficiency resulting from lower overall energy demand (IRENA 2019a). The electrification of end-use sectors with renewable power also leverages synergies with energy-efficiency measures and generates energy-intensity improvements as it contributes to reducing energy losses, promotes fewer energy-consumptive behaviors, and helps the penetration of RE. In some end uses, electrification will still require some research and scalability of technology before electrification is able to happen cost-effectively.

ENERGY EFFICIENCY IN END-USE SECTORS

Interventions to enhance energy efficiency are critical to allow for successful efforts to increase RE in the power sector; otherwise, power systems' transitions become an exercise catering to inefficient demand. If some transport, industry, or buildings energy needs are met though energy efficiency, then the overall need for thermal-generated electricity is reduced, resulting in lower requirements in capacity addition, and this is critical to achieving the Paris goals. In addition, demand-side efficiency can significantly reduce the reliance on technologies like BECCS, thus reducing the probability of potential trade-offs between achieving the 1.5ºC goal and other sustainable development dimensions.

Energy efficiency in the buildings sector holds particular promise. The buildings sector will have a major impact on the power sector because heating and cooling will play a big role in driving up demand for electricity, especially in emerging economies. In many developing countries as standards of living increase and more people gain access to heating and cooling equipment, they will consume more power and do it at times that exacerbate peak-demand challenges, which the power grid will have to balance with enhanced grid flexibility. Cooling and heating equipment and buildings (new and renovated) will generally become more efficient, but achieving the 1.5ºC and 2ºC goals would depend on shifting to renewable energy supply to cater to the remaining electricity demand; hence, the importance of decarbonizing electricity supply.

ELECTRIFICATION OF END-USE SECTORS

Electrification of end-use sectors is understood to be a practical option for decarbonizing end-use sectors. Electrification is also an enabler that provides complementary flexibility capacity to the grid, allowing for a greater share of RE to be integrated, in turn raising the renewables' share in end-use sectors. This sector coupling can provide significant support to the power sector for integrating higher shares of VRE. Electrification strategies must be planned carefully with considerations of wider impacts on the power sector, notably paying attention to getting the sequencing right between expanding end-use electrification and decarbonization of power generation. In the transport sector, for instance, should the sequencing be badly planned, it could end up creating new demand for transportation for which new coal capacity may have to be added. This prospect reinforces the importance of systemic planning across sectors for the smooth roll-out of electrification powered by RE plans.

Increasing electric transportation could potentially trigger a virtuous cycle of grid decarbonization, as it can be used to stabilize the grid by helping to manage supply and demand of electricity. Incentives can encourage the charging of vehicles at times when there is surplus power generation or availability of VRE, thereby shifting demand. At the same time, EV batteries that are plugged into the grid could be used as storage and employed at times of peak-demand, provided that specific investments and measures are built into EV deployment from the outset. This improves flexibility in power systems, a critical component for optimal integration of VRE, and avoids network congestion.

Electrification of heat process in industry also holds potential for the next stage of the transition in the power sector. The dynamic interaction between industry and power systems will present new opportunities and challenges for both sectors as the share of variable renewables climbs. The increased electrification of the industry sector is likely to be closely aligned with a more flexible use of electricity (Brolin et al. 2017) and to generate new roles for industrial players in the power system. For instance, in the case of hydrogen produced from electrolysis, the energy carrier, hydrogen, is storable. This could provide enhanced flexibility and supply options. New approaches to planning and process design, including direct electrification of industrial processes, present opportunities for industry to release capacity reserves as needed, adding flexibility and efficiency to the grid, which is conducive to higher penetration of renewables.

This report has so far identified requirements to decarbonize the power sector by 2050 and discussed which transformational signals the next round of NDCs must send for the world to meet those requirements. The report has identified four foundational strategies that need to be in place to provide strong bases for credible NDC enhancement. With this framework in place, Section 6 provides a structure for policymakers to help them think through the process of enhancing the mitigation ambition contained in their power-sector NDCs, drawing from UNDP and WRI's overarching guidance *Enhancing NDCs: A Guide to Strengthening National Climate Plans by 2020* (Fransen et al. 2019).

6. A PROCESS FOR ENHANCING THE NDC IN THE POWER SECTOR

Before determining how to reflect enhancement of ambition in the power sector in the NDCs—whether in the form of a GHG target, a sector-specific non-GHG target, policies and actions, or a combination of these—a practical framework is required for policymakers to review their initial NDCs with the aim of identifying the potential for enhancements that can actually be achieved.

An Inclusive Process

Establishing a clear and inclusive process to enhance the NDC is a vital first step (Figure 11). The process of developing robust NDC targets in 2020 that move the power sector toward being climate friendly is a moment for gaining support from affected constituencies and from those who will implement the NDC, define institutional arrangements to ensure leadership and coordination, engage stakeholders, and develop a work plan with defined roles and responsibilities to undertake the enhancement (Fransen et al. 2019).

Authorities that are responsible for climate policies should take charge to facilitate discussions and cooperation among various stakeholders and encourage energy planners to lead the planning process, mindful of the synergies and trade-offs with climate objectives. Including input and negotiations with power ministries, utility distribution companies, the private and financial sectors, RE producers, fossil fuel electricity generators, regulators, and new disruptive entrants in the power sector is crucial for integrating power-sector targets and actions in NDCs. This inclusiveness has the potential to generate enough buy-in from energy planners that the national power planning exercises shift to inherently align and contribute to global climate objectives. It is important that the 2020 NDC enhancement process for the power sector promote inclusive dialogue that secures high-level buy-in and stakeholder ownership to rally support around the implementation of the agreed targets. This can, in fact, shift energy planners' priorities and their cost and benefits frameworks to inherently align and contribute to global climate objectives while attracting finance, technology, and capacity building from the international community.

Figure 11 | **Steps to Establish an NDC Enhancement Process**

1 SECURE HIGH-LEVEL BUY-IN

- Prime minister's or president's office
- Key ministries

2 ESTABLISH INSTITUTIONAL ARRANGEMENTS

- Lead institution
- Intra-governmental coordination
- Alignment with development objectives

3 PLAN FOR STAKEHOLDER ENGAGEMENT

- Civil society
- Academia
- Private sector
- Subnational actors
- Trade unions
- Vulnerable populations

4 DEFINE DOMESTIC OBJECTIVES

- Driving action
- Directing finance
- Generating political support
- Mainstreaming climate change
- Reflecting mitigation and adaptation in key sectors

5 DESIGN A WORK PLAN

- Roles and responsibilities
- Timeline and milestones
- Monitoring mechanisms

Source: Fransen et al. 2019.

Securing support from nontraditional allies like health, finance, transport, industry, and urban planning ministries throughout the 2020 NDC enhancement process can also help articulate the economic, social, and environmental benefits of a decarbonized power sector and share strategic visions among relevant ministries, agencies, and stakeholders. This can encourage more holistic planning across sectors (e.g., transport, industry, and power) that may have historically operated in silos. Such systemic transitions that are required to decarbonize the power sector will require leadership and political buy-in and a significant scale-up of investments on a wide spectrum of mitigation options across sectors for which the NDC 2020 enhancement process can provide opportunities.

Countries should also expand beyond the usual stakeholders and try to reach subnational and nonstate actors. States or provinces, for example, are usually responsible for the implementation of at least some power policies, and clean, accessible, and reliable power systems are critical to subnational governments' pursuit of sustainable and thriving economies. Civil society representatives like consumer groups, resident welfare associations, industries, or workers' unions also have a direct interest in electricity services, and their support would be critical to the success of a shared strategic vision for the power sector.

Lastly, the NDC process should build in opportunities for feedback and learning from affected stakeholders and from those responsible for implementing power-sector policies on the ground. In doing so, countries will be able to monitor their progress in decarbonizing the power sector, helping to make corrections when needed and raise ambition when opportunities arise.

Take Stock of Recent Developments

Achieving enhanced mitigation ambition in the power sector NDC is defined to mean that the enhanced power sector NDC, if fully implemented, results in lower cumulative emissions than the fully implemented initial power sector NDC (Fransen et al. 2019). The steps outlined below will help policymakers identify options for mitigation enhancement in the power sector and reflect them in their NDCs in the form of GHG or sectoral non-GHG targets, measures, or policies or alignment with long-term goals.

Since countries developed their first round of NDCs ahead of COP 21, power systems have undergone significant shifts globally in generation mixes and load, as well as in distribution, storage, and consumption. We are witnessing new ways of operating power systems, different market designs, the deployment of new technologies, significant cost reductions, and innovative business models. This means that countries' capacities and capabilities have evolved as well (see Section 4).

The 2020 process of enhancing NDCs offers an opportunity for countries to examine the ambition of the initial NDCs in light of innovations in grid modernization, digitalization, increasing potential of storage technologies, and declining costs of renewables—advances and trends that have emerged since the NDCs were developed with the potential to transform power systems in ways that seemed improbable just five years ago (Fransen et al. 2019).

Countries may also wish to reflect shifts that have occurred in the real economy and send accurate signals to the private sector (Fransen et al. 2017). Those developments have moved the needle in terms of where the focus for ambition in the power sector needs to be today. Five years ago, it was crucial to channel all efforts toward bringing down costs of RE and improving the technology. Hence, announcing high RE targets in the initial NDCs was a good vector to send transformational signals to global industry, to the corporate and finance sectors, and to all stakeholders involved in power-sector transitions in order to catalyze efforts toward making RE cost-competitive with coal. Today, with this phase of the transition successfully achieved and with the new developments discussed in Section 4, the focus for raising ambition in the power sector has moved to enabling the implementation of the four foundational strategies outlined earlier. For most countries, merely increasing RE targets in the NDCs would no longer reflect the real and achievable level of ambition required to successfully transition to a decarbonized power sector. Enhanced grid flexibility, strategies for addressing exiting coal assets, increased institutional capacity, and tapping the synergies with energy efficiency and electrification in end-use sectors have arguably become the areas where resources need to be directed to enable the second phase of the power-sector transition to lay the grounds for ultimately accommodating higher shares of renewable power generation. Targets and policies in the next round of NDCs can be geared toward achieving this.

Take Stock of Long-Term Objectives and Benchmarks to Inform NDC Enhancement

Since countries developed their first NDCs ahead of COP 21, the international community's understanding of global benchmarks for safe temperature increases has evolved. The Paris Agreement states a goal of "achieving well-below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." But in October 2018, the IPCC came out with a special report on impacts of global warming at 1.5°C, where it emerged clearly that temperatures are already up to more than 1°C globally and are rising at a rate of 0.2°C per decade. Thus, a 1.5°C increase will be reached in a couple of decades. The report also found that what the international community thought to be a safe limit to global warming—2°C above preindustrial levels—was, in fact, riskier than previously thought. The report highlighted the synergies and trade-offs of making 1.5°C the new global benchmark for climate mitigation, while making the case that the benefits were more numerous in 1.5°C than in 2°C scenarios. Finally, it found that the 1.5°C goal is still technically and financially within reach (IPCC 2018). These indicators can help contextualize power-sector mitigation ambition in the NDC enhancement process. Consensus is emerging in 1.5°C consistent scenarios that the route to decarbonization by 2050 goes through a combination of faster and greater deployment of RE, increased energy efficiency, and deep end-use electrification, as the backbones of the energy transition. The first two are essential actions for the decarbonization of the power sector, and the third is intricately linked.

Since the Paris Agreement, the international community has largely assimilated these messages. The requirement for mid-century net-zero national strategies within the NDCs has also emerged strongly as a framework to ensure adequate levels of short-term ambition to reach long-term goals. Countries can assess the progress of their power sectors in light of these new global benchmarks for mitigation to achieve the temperature goals, as well as SDGs (see Table 2). Countries can review their power sector's emissions against available and refined 1.5°C consistent scenarios and consider the relevance to their particular country (see see Section 2).

Apply Diagnostic Questions at the Power-Sector Level with a View to Identifying and Filling the Gaps and Enhancing the NDC

In this step, countries will identify power-sector-related NDC enhancement options stemming from opportunities to fill gaps and to strengthen power-sector elements of their initial NDCs. The output of this step will be a list of NDC enhancement options for the power sector (see the following section, "Applying the Process"). In compiling the list of enhancement options, countries should strive to bring the power-sector NDC targets more closely into alignment with the benchmarks associated with the Paris Agreement temperature goals; take full advantage of recent developments, innovation, and best practices; maximize the benefits of the power sector NDCs for development and resilience; fill gaps in sectors and gases not yet addressed; and incorporate relevant opportunities

Table 2 | **Power-Sector Shifts and Benchmarks Associated with Limiting Warming to 1.5°C**

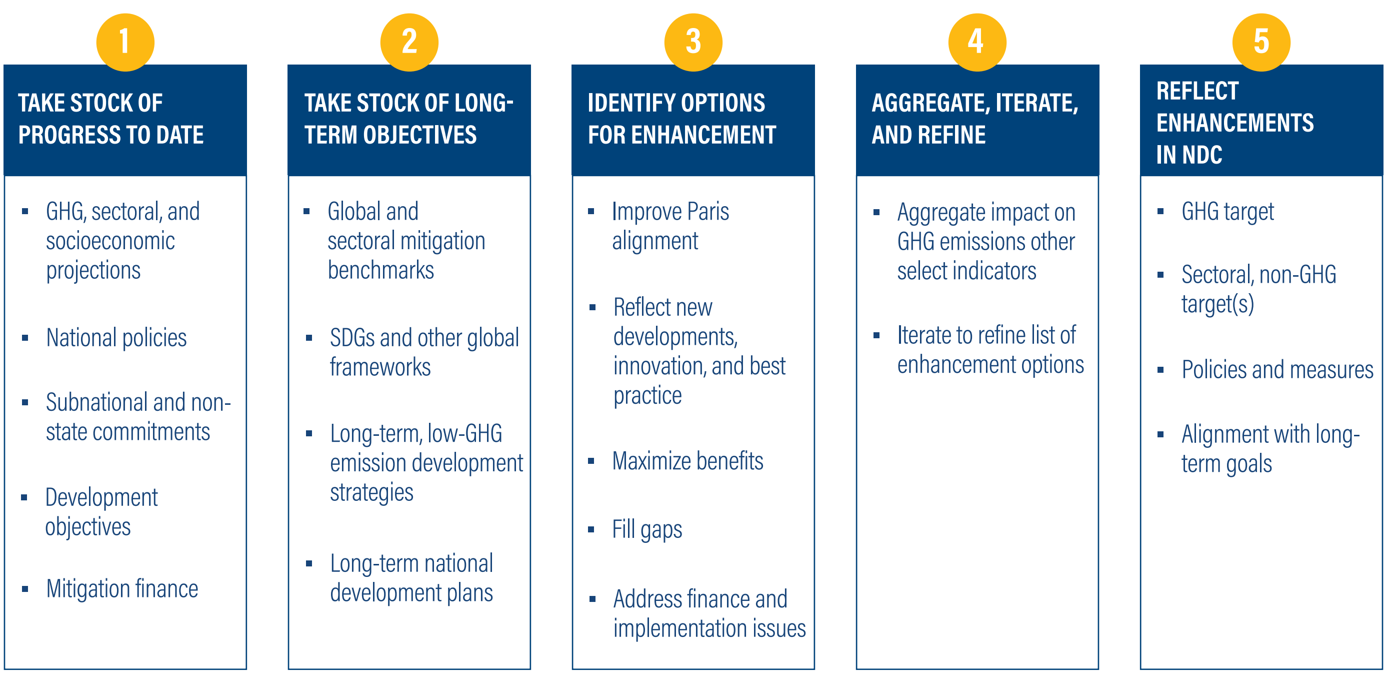
SECTOR	BENCHMARK (FOR 2030 UNLESS OTHERWISE NOTED)
Power generation	▪ Achieve 60–80% zero-carbon electricity generation (this implies growing the share of renewables and other zero- and low-carbon sources by approximately 2.5 percentage points per year) ▪ Reduce electricity generation from coal by 65% from current levels; phase out coal plants in the EU and OECD countries

Source: Extracted from Fransen et al. 2019.

to strengthen implementation and finance (Fransen et al. 2019). UNDP and WRI's overarching guidance for NDC enhancement proposes diagnostic questions to aid in the systematic evaluation of the NDC to identify opportunities for enhancement. These can be applied to how the initial NDCs address the four foundational strategies that underpin national power sectors:

- Are power-sector targets in the NDC consistent with a trajectory that aligns with key benchmarks? Does the treatment of the power sector in the initial NDC reflect up-to-date assumptions regarding available technologies and their costs?
- Do the power-sector-related NDC targets reflect the relevant plans, policies, and measures that are being implemented or considered in the country or that ought to be considered, based on available best practices?
- Do the power-sector NDC targets reflect the relevant climate action commitments being made by nonstate and subnational actors in the country? Do these open up opportunities to enhance the NDC in the power sector?
- Do the power-sector NDC targets maximize synergies and reduce potential trade-offs with development objectives, including climate resilience?
- Do the power-sector NDC targets address all relevant sectors, subsectors, and gases?
- Do the power-sector NDC targets reflect the potential associated with finance?
- Do the power-sector NDC targets address important cross-sectoral interactions?
- Can the power-sector NDC targets otherwise facilitate strengthened implementation?

Figure 12 | **Designing an Enhanced Mitigation NDC**



Source: Fransen et al. 2019.

To run a diagnostic of their power sector, policymakers can make use of tools such as IEA's *Tracking Clean Energy Progress* (IEA 2019c) to help them track progress against a sustainable development pathway and identify options for enhancement for their NDCs in the power sector according to their national circumstances and capabilities. The tool proposes a set of possible metrics to track the status of critical technologies and sectors to assess whether they are on track with the IEA's SDSs.

Those metrics relevant to sustainable power systems include measuring the carbon intensity of power generation, the share of low-carbon energy (RE, nuclear, and carbon capture and storage) being used in the power generation, power-sector investments, share of network investments in digital infrastructure, and energy storage and demand response capacity.

While the IEA's tool tracks this progress globally, policymakers looking for opportunities to enhance ambition in their power sector in 2020 would be encouraged to take stock of their national power sector against the proposed metrics and subsequently apply the recommendations proposed by the tool to their diagnostic to help them get on track.

After thinking through steps 1 to 3 in Figure 12 as they relate to the power sector, this report has identified the business case for the deployment of renewable energy technology, developments in grid modernization, and the mainstreaming of novel business models for scaling the supply of clean power as recent innovations that have unleashed new opportunities in the power sector that seemed improbable even just five years ago. The 2020 NDC enhancement process is a moment to reflect on these opportunities, based on refined global benchmarks for temperature increase, and the updated understanding of the power-sector elements required to keep the 1.5°C goal in reach. To bring the power-sector NDC targets into greater alignment with the goals of the Paris Agreement, countries now need to carve out targets, policies, and measures that will send transformational signals to global industry and stakeholders involved in the transitions. The report has identified four elements of a strategy for the power sector that policymakers need to consider and plan for upstream if they are looking to credibly and solidly enhance their power-sector NDC targets toward successfully achieving power-sector transitions:

1. planning for enhanced flexibility
2. developing a strategy for addressing existing coal assets
3. making institutional changes
4. integrating sector-coupling solutions

These elements of strategy are common to all power systems, although each country, based on its circumstances and capabilities, will engage differently with the various elements. All of the elements, however, would need to be fully implemented for countries to be able to respond "yes" to the diagnostic questions outlined in the section on applying diagnostic questions, p. 32 . After assessing where their NDC stands relative to these foundational elements, policymakers can decide how they can fill gaps in their NDC and enhance its existing elements. The next section will propose (non-exhaustive) options for how these can be reflected in NDCs as enhancement.

Applying the Process: Reflecting NDC Enhancement to Fill the Gaps and Tap the Opportunities Stemming from the Four Foundational Strategies

UNDP and WRI's overarching guidance for enhancing NDCs in 2020 identifies that enhancement can be reflected in NDCs as GHG targets, sectoral non-GHG targets, policies and measures, and alignment with long-term decarbonization (Fransen et al. 2019). Policymakers can decide how they can best fill gaps in their NDC and enhance its existing elements after taking stock of the potential that recent developments have unleashed in a country's power sector; then taking stock of long-term objectives and how they can be reflected in national policies and plans, considering their relevance for a certain country; and, finally, once options for enhancement have been identified, applying diagnostic questions to initial NDCs, mindful of the four foundational strategies identified in Section 5.

For some options reflecting NDC enhancement in the power sector, progress on the four foundational strategies would have to be under way at once for such an NDC

Table 3 | **Reflecting NDC Enhancement to Fill the Gaps and Tap the Opportunities Stemming from the Four Foundational Strategies**

GHG TARGETS
▪ Strengthen or add an economy-wide GHG target reflective of more ambitious abatement options in the power sector
SECTORAL NON-GHG TARGETS
▪ Strengthen or add a power-sector carbon-intensity target
ALIGNMENT WITH LONG-TERM DECARBONIZATION
▪ Align NDC power-sector targets with the long-term mid-century decarbonization goal ▪ Complement near-term solutions (RE, decentralized generation) with long-term measures integrating new business models in national planning, coal phase-out policies, R&D policies, etc.

Source: Authors.

target to mean real ambition in the power sector. If this was not the case, such targets would be hollow shells. Taking, for instance, the options to strengthen or add an economy-wide GHG target reflective of more ambitious abatement options in the power sector, showing results toward the achievement of this would only be possible should national grids unlock adequate amounts of grid flexibility, existing coal fleets justly and economically be phased out, institutional capacity be adequate to support the changes, and the potential from synergies with sector-coupling solutions be tapped. This economy-wide target would require further disaggregation into subtargets, policies, and measures in order to ensure its achievement and unleashing of ambition in the power sector.

Reflecting plans for enhanced grid flexibility as NDC enhancement

As discussed in the section on Foundational Strategy 1 (p.24), grid flexibility has taken center stage as the main blockage to higher shares of VRE integration in many countries. If this blockage is not systematically addressed, there is a risk that the transitions currently under way toward higher shares of RE grid integration could be slowed or stalled.

The 2020 NDC enhancement process is an opportunity for policymakers to evaluate their grid's flexibility capacity against the targets and policies contained in their initial NDCs and assess whether there is scope to strengthen or add targets that would enable the necessary grid improvement in parallel with the deployment of VRE. Because countries are at various levels of grid development and efficiency, national power grids are not all ready for the same levels of ambition. Consequently, addressing the flexibility question will take the form of different NDC targets or policies and measures in different countries. Countries that do not yet have high shares of RE penetration in their grid, and have some inbuilt grid flexibility, could think of strengthening or adding RE targets as shares of total electricity generation mix in the short to medium term, with relative assurance that they would be able to achieve them. National assessments would have to be undertaken to estimate when the flexibility needs would exceed current flexibility capacity of the grid in order to determine a feasible time frame for such targets.

Countries that already have RE targets as shares of the generation mix in their initial NDCs and are on track to achieve or overachieve them need to assess the technical feasibility of merely enhancing the target. In many cases, they will find that enhanced flexibility is a prerequisite for enhanced RE targets to translate into achievable ambition. Such countries should turn to the potential of NDC targets and policies to unleash flexibility capacity in the grid. These could include quantified storage targets to massively direct investments in that direction, market and regulatory policies to strengthen interconnection capacity, targets for the deployment of smart meters, and forecasting technologies to predict

Table 4 | **Reflecting Plans for Enhanced Grid Flexibility as NDC Enhancement**

SECTORAL NON-GHG TARGETS
▪ Strengthen or add renewable energy targets as shares of total electricity generation mix ▪ Align RE targets (not as share but in GWs) with longer-term national plans and with national cost-effective RE potential ▪ Strengthen or add energy access targets through the deployment of decentralized energy solutions ▪ Strengthen or add rooftop solar targets ▪ Strengthen or add quantified storage targets to massively direct investments in that direction ▪ Strengthen or add targets for the deployment of smart meters and forecasting technologies to predict real-time output of VRE generation ▪ Commitments on investments in network digitalization
POLICIES AND MEASURES
▪ Commitments to provide subsidies for the installation of decentralized solar power solutions ▪ Policies to deploy large-scale battery storage technologies commercially ▪ National flexibility missions to enhance the grid's capacity to balance supply and demand in real time through options including storage, demand reduction measures, and use of existing thermal capacity ▪ National strategies for energy access for all, mindful of local development agendas and integrating new business models based on decentralized energy generation ▪ Tax exemptions on RE equipment for manufacturers and consumers ▪ Policies to create enabling frameworks to attract new investments in the RE sector and to de-risk financing in the sector

Source: Authors.

real-time output of VRE generation, and commitments on investments in network digitalization. Such measures reflected in the NDCs would send transformational signals to global industry, which is where the potential of the NDCs lies to move the needle. Depending on how power systems are designed and operationalized, some countries might find greater potential to unlock flexibility through the proliferation of decentralized solutions and business models. In such cases, enhanced targets and commitments could include energy access targets through the deployment of decentralized energy solutions, rooftop solar targets, or subsidies for the installation of grid-connected decentralized solar solutions.

Reflecting strategies for addressing existing coal assets as NDC enhancement

The section on Foundational Strategy 2 (p.25) discussed the importance of including a strategy to address existing coal assets as part of decarbonization strategies, in order to ensure that transitions happen with the least disruption to all sectors. The 2020 NDC enhancement process is an opportunity for policymakers to assess how comprehensive of economic and social consideration their coal phase-out plans are, if they have any, or to add targets and measures to the NDC that would enable a holistic and just transition toward a coal phase-out.

National assessments would need to be undertaken to project electricity demand growth in order to estimate when it would absorb current grid capacity or overcapacity. This would be the moment when new investment decisions would have to be made to cater to demand growth, and getting them right would require informed planning now (TERI 2019). Policymakers are encouraged to compare BAU scenarios with 1.5ºC sustainable development pathways against which they can track energy mixes in their power sectors and determine how the mix needs to evolve. Strategies to address existing coal assets could include a coal phase-out target against a timeline in line with 1.5ºC consistent pathways and considerate of national electricity demand and supply options, commitment to no new coal capacity additions beyond the current project pipeline, and commitments or targets for divestments from new coal energy.

Table 5 | **Reflecting Strategies for Addressing Existing Coal Assets as NDC Enhancement**

GREENHOUSE GAS TARGETS
▪ Strengthen or add ambitious power-specific GHG reduction targets, such as targets for reduction of emissions from coal plants ▪ Strengthen or add a specific peaking year target to consider ambitious abatement options in the power sector
SECTORAL NON-GHG TARGETS
▪ Strengthen or add a fossil fuel phase-out target for the power generation sector, coupled with a clear plan to ensure a just transition for affected workers and communities ▪ Commitment to no new added traditional coal-fired capacity after current project pipeline ▪ Add or strengthen targets to close down and retire traditional coal-fired fleet, coupled with a just transition plan ▪ Strengthen or add commitments or targets for divestments from new coal energy ▪ Strengthen or add a reduction of tonnes of CO_2 in the power-generation sector target ▪ Strengthen or add a target to reduce fossil fuel imports for power generation ▪ Strengthen or add air pollution targets
POLICIES AND MEASURES
▪ Strict national emissions standards for thermal power plants ▪ National strategies to plan the transition in the coal sector, mindful of making the transition just. Such national strategies can outline schemes for retraining coal workers and include policies setting aside resources to facilitate just transitions in the sector. ▪ Policies to manage potential competitiveness impacts on energy-intensive industries for costs arising from the price of a CO_2 pollution allowance

Source: Authors.

In developing countries, especially, where bad levels of air pollution can drive the shift away from coal-based electricity generation, enhanced NDC targets that would contribute to addressing existing coal assets would include strengthened air pollution targets, targets for emissions reductions from coal power plants, or strict national emissions standards for thermal power plants.

In countries where coal assets are already or could soon be at risk of becoming stranded assets, enhanced NDCs could include targets to close down or retire old and inefficient power plants. Where the coal sector is currently a prominent employment sector across its supply chain, NDCs could include policies setting aside resources to facilitate just transitions in the sector. Ahead of setting the new or enhanced NDC target reflecting a strategy for addressing existing coal assets leading ultimately to a phase-out, it is important that multi-stakeholder consultations be conducted. Perhaps a commission may be formed, consisting of national, regional, and local governments; employers and trade unions; NGOs; and experts to chalk out a plan in accordance with the country's climate policy targets (Galgóczi 2019).

Reflecting institutional changes as NDC enhancement

The section on Foundational Strategy 3 (p.25) discussed why institutional changes are now arguably more important than technological progress for transitions in the power sector to succeed. While envisaging how enhanced institutional capacity, better policy, and greater capacity can be reflected in the NDCs is not straightforward, there is potential in the form of policies and measures, rather than GHG and sectoral non-GHG targets.

The 2020 NDC enhancement process is an opportunity for policymakers to take stock of the implementation policies they have in place, reflective of how ripe their institutions, markets, and regulatory regimes are to propel the transitions toward a decarbonized power sector. Adding or strengthening measures and policies in the NDC for greater institutional capacity and stronger market signals would enhance a country's ability to achieve enhanced targets for the power sector. New business models and smart regulatory regimes, including carbon pricing, will be the drivers of change.

Likely, countries that have already begun adding RE to their grids are already building up options to enhance their grid flexibility and would be those looking to make required institutional changes, as those requirements become all the more evident as the transitions progress. Overcoming institutional challenges that transitioning power systems face is what will further drive commercial efforts to mainstream the penetration of RE.

In countries where electricity markets account for a small share of generation, policymakers may wish to use the 2020 NDC enhancement process to submit enhanced market and regulatory policies that would bridge gaps between market signals and policy objectives. These could include electricity pricing schemes that incentivize off-peak usage (like time-of-use tariffs) or ending fossil-fuel production subsidies to ensure that prices are not distorted. In countries where distribution utility reform is at the root of further transitions in the power sector, enhanced NDCs could include incentives for innovative business models and smart regulatory regimes that prioritize the convergence of distribution utilities' economic interests with decentralized renewable generation, in order to mainstream them into national energy planning. The implementation of such measures would certainly enable more real ambition in the power sector.

The 2020 NDC enhancement process can also be a moment for national policymakers to evaluate the environmental, fiscal, and economic impacts of 1.5°C consistent carbon pricing for their power sector against other alternative policy options. For that to happen, it is helpful for governments to have transparent and consistent cross-country procedures for evaluating implicit prices of power-related NDC pledges, which will inform NDC revisions (IMF 2019). Power sector NDCs and carbon price trajectories can also be aligned, requiring national assessments of fuel use and emissions projections from the power sector, with and without carbon pricing. If the power sector's emission targets are systematically not met, prices can be periodically updated (IMF 2019). Other approaches consist of matching cost-effective carbon price trajectories for power generation with the 1.5°C and 2°C goals, or with environmental damages, and estimating power-sector emission prices as relevant to national circumstances (IMF 2019).

It is crucial that power supply capacity decisions better reflect air pollution impacts on health. The 2020 NDC enhancement process is an opportunity for governments to assess that as part of a full cost-benefit analysis on infrastructure and investment choices and then address the gaps through air pollution pricing. This could take the form of clean air regulations and policies requiring coal plants to control their harmful emissions with the installation of air pollution control devices. The acquisition, installation, and maintenance of such devices isn't cheap and increases the final cost of coal-generated power. Such legislation implicitly puts a price on the human health impacts of coal combustion, making RE alternatives more cost-competitive with coal.

Table 6 | **Reflecting Institutional Changes as NDC Enhancement**

POLICIES AND MEASURES
▪ Electricity policies and electricity pricing regulations that reflect correct pricing and incentivize off-peak usage (like time-of-use tariffs) ▪ Market and regulatory policies to strengthen interconnection capacity and harmonize power markets to make them bigger by incentivizing cooperation and grid planning and operation involving subnational entities ▪ Carbon pricing for power generation with accompanying measures for political and social acceptability ▪ Pricing air pollution from fossil-fuel use ▪ Clean air regulations and policies, including emissions regulations for thermal power plants ▪ Commitments to end subsidies and tax breaks to fossil fuel exploration, production, and use ▪ Taxes or subsidies on power-generation activities with above or below average emissions intensity ▪ National plans and strategies for utility distribution reform, including incentivizing business models that prioritize the convergence of distribution utilities' economic interests with decentralized renewable generation

Source: Authors.

Reflecting the integration of sector-coupling solutions as NDC enhancement

This report has discussed how decarbonization of the power sector by 2050 is de facto assumed by most 1.5°C scenarios as a prerequisite for successful energy transitions. Finding synergies with end-use sectors to enable steep cuts in GHG emissions through energy efficiency and electrification is what will close the decarbonization gap and needs to be given more attention in the NDCs. Reforms that integrate power policies and targets with sector policies and targets need to be implemented early on to drive the power-sector transition (p.28).

The 2020 NDC enhancement process provides an opportunity for policymakers to determine whether their power and end-use sector NDCs address those important cross-sectoral interactions, and where the scope lies to maximize synergies and reduce potential conflicts across the sectors. National assessments will have to be carried out to evaluate this potential. Different levels of maturity of national power sectors means that not all will be ready to tap the synergies to the same extent. Countries that are still in early stages of developing reliable power systems could include policies or targets to install EV charging infrastructure and targets for shares of EV penetration to kick-start these markets. More-developed economies with power grids that are already operational and efficient could look at targets for flexibility coming from end-use sectors. Generally, countries could include clean electrification of end-use sector targets and, where electricity demand growth is projected to be high from end-use sectors, power consumption reduction targets going beyond just shifting to renewable sources of power generation.

R&D funding for alternative heating technologies to electrify industry processes would be crucial to tap synergies with the industry sector. In the buildings sector, targets for the deployment of energy-efficient electric heating and cooling equipment could have a real impact on decarbonizing the power sector, especially in areas where demand for such equipment is expected to grow substantially due to rising living standards, and/or due to climate change–induced rising or reducing temperatures.

Table 7 | **Reflecting the Integration of Sector-Coupling Solutions as NDC Enhancement**

SECTORAL NON-GHG TARGET
▪ Add or strengthen energy-efficiency targets in the cooling, buildings, industrial, and transport sectors ▪ Targets to install EV charging infrastructure to kick-start these markets ▪ Targets for share of EV penetration in the market against a timeline, in line with 1.5°C consistent scenarios ▪ Targets for clean electrification of end-use sectors ▪ Power consumption reduction targets in end-use sectors going beyond just shifting to renewable sources of power generation ▪ Targets for flexibility provided by end-use sectors ▪ Targets for the deployment of energy-efficient electric heating and cooling equipment
POLICIES AND MEASURES
▪ Policies that incentivize energy efficiency in homes, offices, and commercial buildings ▪ Policies promoting public awareness of energy efficiency and conservation ▪ R&D funding for alternative technologies that would electrify heat processes in industry

Note: For more-exhaustive suggestions of options for NDC enhancement in the end-use sector, see WRI and UNDP sector guidance reports for NDC enhancement in transport, agriculture, and forestry; UNEP 2018b; and K-CEP 2018.

Source: Authors.

7. CONCLUSIONS

This report has shown the strong potential for enhanced climate ambition through transitions in the power sector and how this potential can be better captured in the next round of NDCs. As the international climate community looks to 2020 with the anticipation that Parties to the UNFCCC will enhance their climate ambition, this report should shed some light on the steps policymakers can follow in order to identify options available to them to add or enhance power-related NDC targets, mindful of their circumstances and capabilities.

Those options can be more nuanced than simply increasing targets for RE shares in the electricity generation mix. Instead, they can include enhanced grid flexibility targets, such as energy storage targets or demand-response measures, as the literature shows that the power sector's transition to higher shares of variable RE will only be possible with more grid flexibility. Policy options can support the economically and socially acceptable phase-out of coal. They can bring about the fundamental institutional changes required to enable power system transitions. They can take advantage of the synergies between renewable power generation, enhanced energy efficiency, and increasing end-use electrification. They can exploit the close alignment of RE with adaptation efforts through the diversification of power-generation sources. Policymakers can leverage the new opportunities provided by technologies, business models, and grid modernization and integrate them in their national planning as mainstream tools to enable transitions in their power sectors.

Ultimately, the NDC is useful to structure ambition in the power sector, as it provides a guiding thread for countries to align their national power-sector priorities with climate objectives. NDC-related power targets send signals to investors, redirecting financial flows toward power-sector transitions, and they encourage cooperation among various ministries, such as those in charge of transport, urban planning, industry, and power that otherwise would operate in separate silos, toward co-creating shared strategic visions that mainstream climate action.

APPENDIX. MAXIMIZING BENEFITS FROM ENHANCED NDCS IN THE POWER SECTOR: THE POWER SECTOR AND SUSTAINABLE DEVELOPMENT

There is a wealth of evidence to support the alignment of climate action, economic growth, and development benefits. The IPCC SR1.5 finds many synergies between the decarbonization of power supply with the SDGs, including eradication of poverty, zero hunger, good health and well-being, clean water and sanitation, affordable and clean energy, sustainable cities, and responsible production and consumption.

In addition to global GHG-emission-reductions benefits over a longer time scale, climate action in the power sector can have immediate co-benefits, including reduced air pollution and associated harmful health impacts and acceleration of energy access for all.

Co-benefits of Climate Action in the Power Sector

Air pollution and health

Air pollution and climate change are intrinsically linked, the main driver of climate change being the combustion of fossil fuels, which generates toxic emissions and is also a major cause of air pollution. Globally, air pollution is ranked as the fifth-worst threat to human health and is responsible for more deaths than infectious diseases (Health Effects Institute 2019). Eight out of ten people living in urban areas are exposed to air pollution that exceeds World Health Organization (WHO) air quality guidelines. Each year, 6.5 million deaths can be attributed to air pollution, equivalent to around 18,000 deaths per day (IEA 2016a).

Coal power generation is a primary cause of GHG emissions and pollutants like fine particles (PM2.5). The health risks posed by thermal power plants vary by region and are most acute in India, eastern China, and other parts of Asia (Oberschelp 2019).

In many developing cities, concentrations of PM2.5 are commonly around 35µg/m^3. WHO estimates that reducing annual average fine particle levels down to the recommended WHO air quality guideline level of 10µg/m^3 could reduce air pollution–related deaths by around 15 percent (WHO 2018). Studies find that the health co-benefits associated with GHG abatement substantially outweigh the policy costs of climate action required to meet the 1.5°C goal, with the number of premature deaths in the 1.5°C scenario decreasing by 28 to 32 percent (Markandya et al. 2018). In many developing countries, the air pollution crisis is bad enough to justify moving away from coal-based generation, beyond climate change considerations.

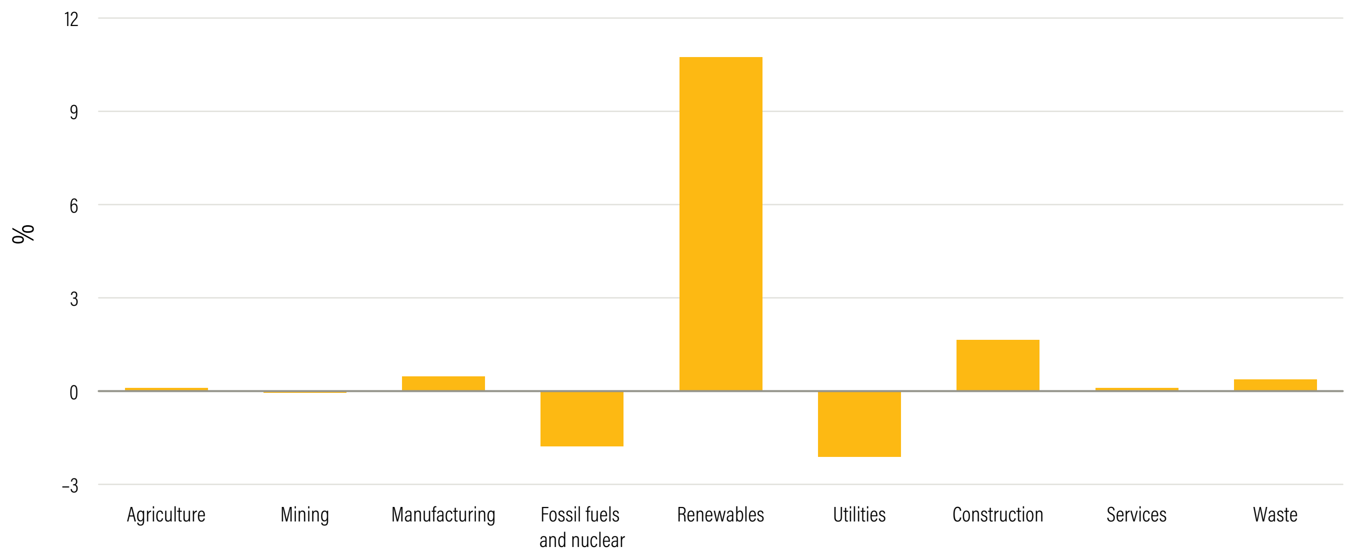
Huge reductions in the combustion of fossil fuels for electricity generation through the deployment of renewables and energy efficiency measures, the co-generation of heat and power, and distributed energy generation via mini grids and solar rooftop solar power generation hold the potential to drastically cut air pollution while improving health and lowering health care costs. Studies find that BAU scenarios can result in additional costs of $96 trillion by 2050 related to impacts of air pollution and other negative impacts of climate change, as compared to deep decarbonization pathways that prioritize RE scale-up and energy efficiency and give a big role to electrification (IRENA 2019a), making inaction in the face of climate change costlier. Other economic benefits of mitigating harmful gases and pollutants are lower investments in air pollution control technologies, by 35 percent globally in 1.5°C consistent scenarios, representing billions of dollars annually to 2030 (IPCC 2018).

Employment opportunities

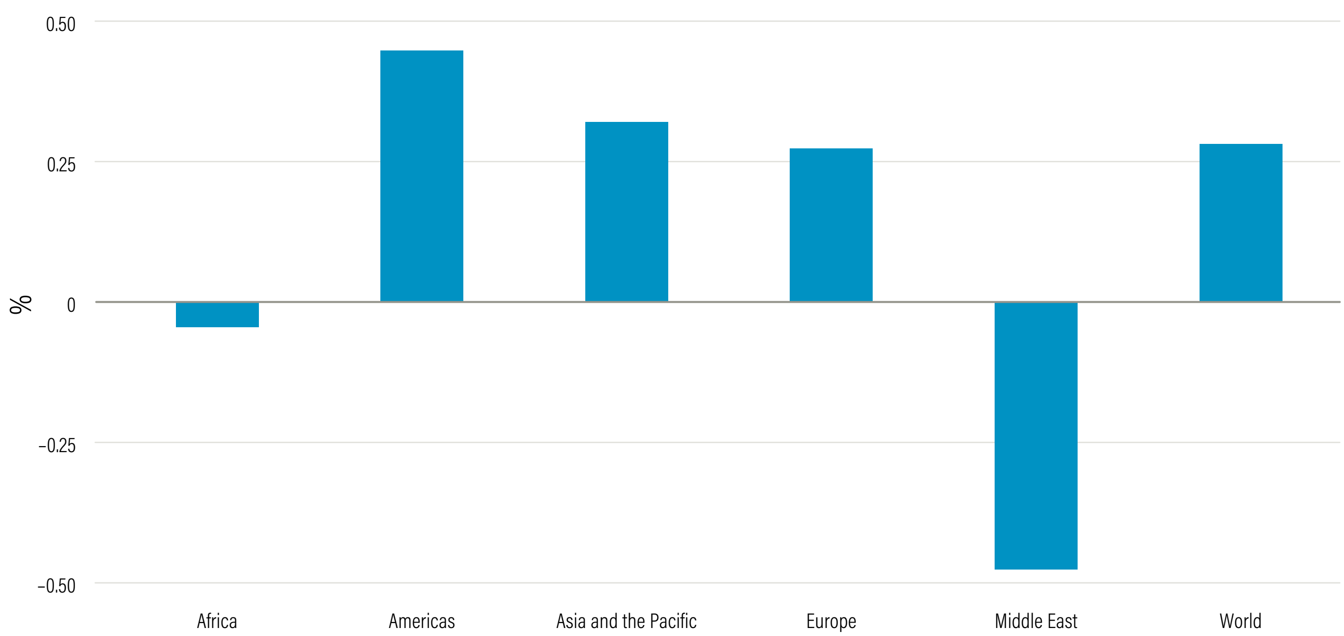
Studies comparing BAU with 1.5°C consistent scenarios find that employment increases globally in both cases between now and mid-century; but the more mitigation-stringent scenarios produce more jobs (IRENA 2019a). The effects on employment in the overall economy are not significant; however, they are very positive in the energy sector, with many new jobs created to enable power-sector transitions in the fields of RE generation, energy efficiency, and energy flexibility. These gains outweigh job losses in the fossil fuel sector. Compared to BAU scenarios, changes in the production of electricity sector in 2°C consistent scenarios lead to a net creation of 2.5 million jobs in renewable-based electricity generation, offsetting employment losses of about 400,000 jobs in fossil fuel-based electricity generation (Montt et al. 2018). Adding changes that include greater energy efficiency, projected deployment of EVs, and construction work to achieve more energy-efficient buildings, the

Figure A-1 | **Energy Sustainability and Employment by 2030**

Employment by Sector (percentage difference)



Employment by Region (percentage difference)



Note: Percentage difference in employment between the sustainable energy scenario and the IEA 6°C (business-as-usual) scenario by 2030. Vertical scales differ by panel.
Source: Montt et al. 2018.

net employment gains soar to 18 million jobs globally, resulting from the creation of 24 million new jobs and the loss of approximately 6 million in 2030 (Montt et al. 2018). These overall positive gains, however, hide sectoral and regional differences, as seen in Figure A-1.

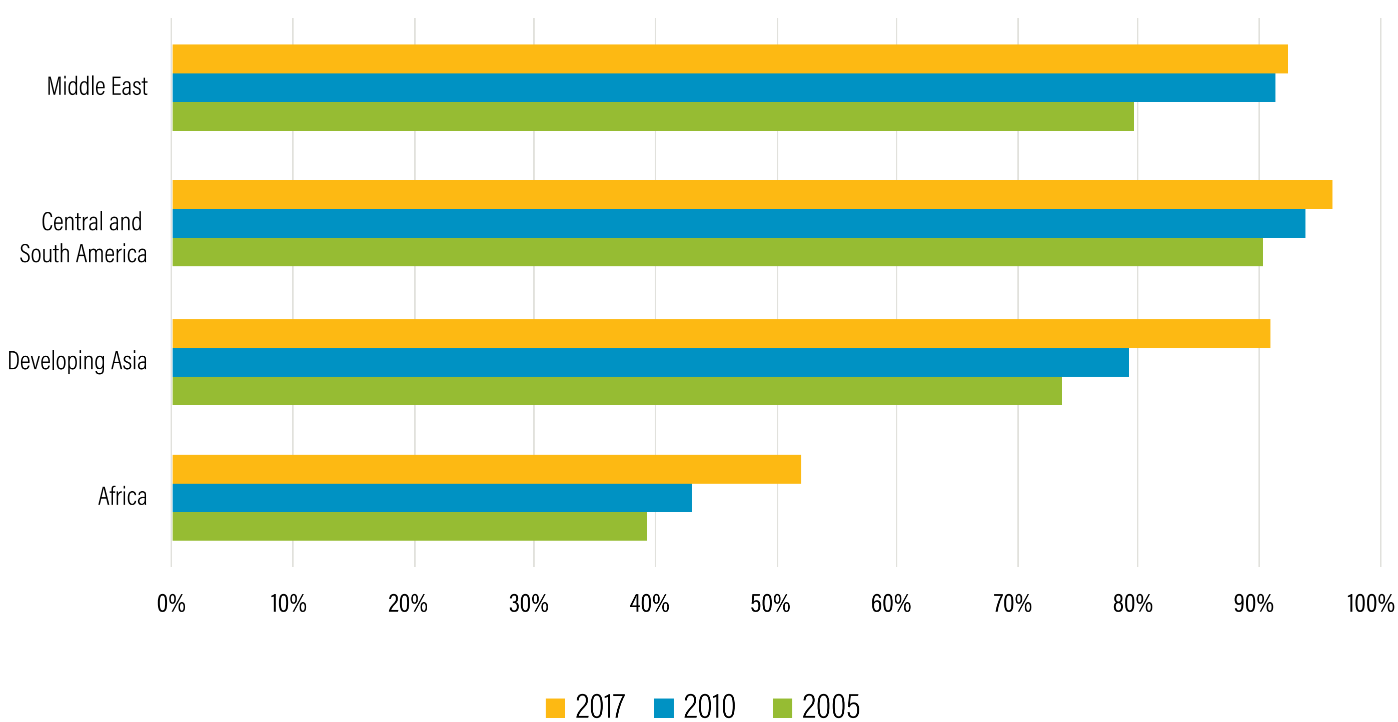
Considering the large-scale employment that the fossil-fuel sector provides (IPCC 2018), accompanying policies and measures like social protection schemes and skills development policies will be required to ensure that those sectors and regions that will face disruption are not left behind. Research on historical transitions shows that managing the negative impacts on those workers is crucial to aligning the phase-down with climate objectives (IPCC 2018). This will be particularly relevant in developing countries where the coal workforce is mostly semi-skilled or unskilled.

Achievement of SDG 7: Access to affordable, reliable, and clean energy for all

Globally, access to electricity is recognized as a basic need, as affordable and reliable electricity has been essential for economic and social human development. The Sustainable Energy for All initiative, launched in 2013, has focused more attention on expanding energy services into even the poorest and remotest areas (Odarno 2016).

Progress on this front has been uneven. Policies in some developing countries have been driving access to electricity, bringing the total number of people without access to below 1 billion in 2017. India completed the electrification of all villages in early 2018 and plans to achieve universal access to electricity by the early 2020s. But despite significant steps forward in Kenya, Ethiopia, Tanzania, and Nigeria, about 600 million people in sub-Saharan Africa still lack access to electricity. The IEA's New Policy Scenario expects that 650 million people will remain without electricity, even in 2030 (IEA 2019b).

Figure A-2 | **Electrification Rate by Region**

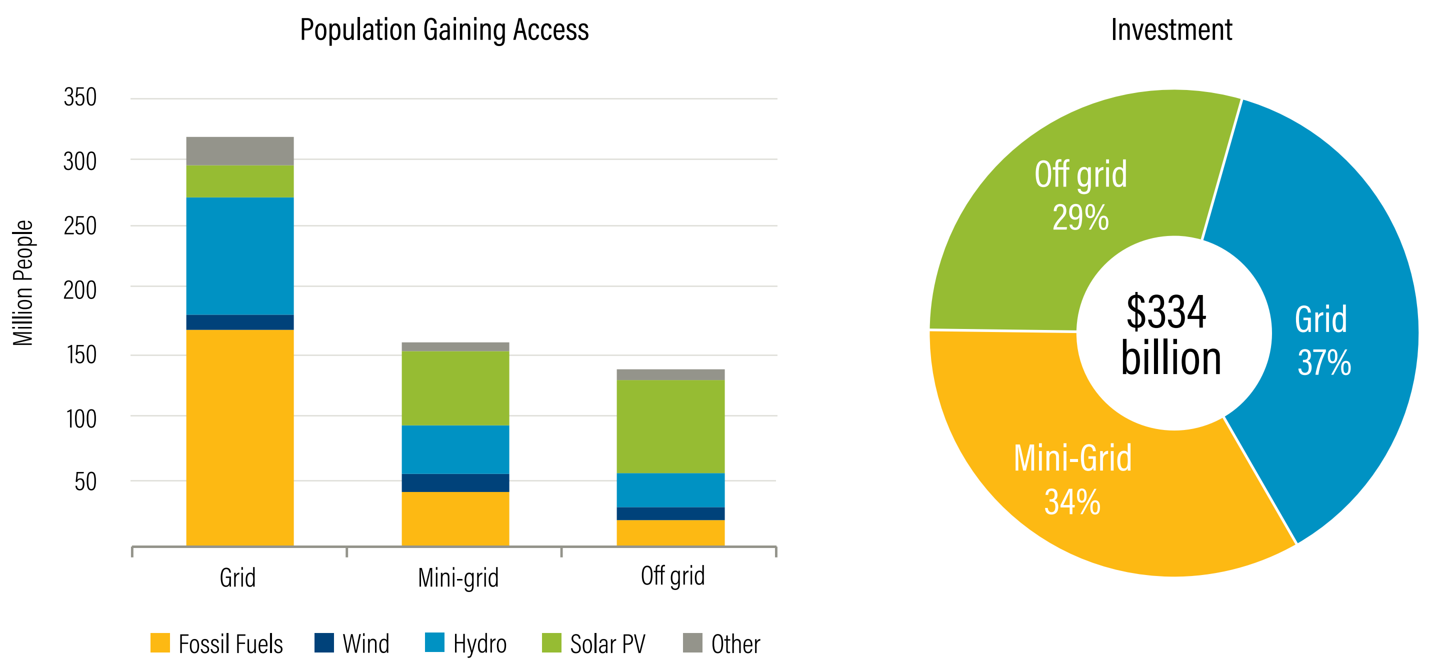


Source: Re-created from IEA 2018.

Populations with no access to electricity are often so poor that making electricity accessible is insufficient to drive up demand. Electricity must also be affordable and reliable. Globally, the cost of renewable energy has been tumbling in the course of the last decade. By using more renewable energy sources, countries can capture this in savings, thanks to reduced fossil-fuel import bills. However, translating this into lower energy bills for consumers is not linear. Studies find that aggressive mitigation scenarios could affect energy prices significantly and slow the transition to clean energy access (IPCC 2018). Ensuring the reliability and affordability of electricity can bear associated costs, which can be higher if it is to be powered by RE. Compensatory measures like subsidies on cleaner fuels would be required to compensate for the negative effects of mitigation in 1.5°C scenarios on energy access (IPCC 2018). Given the climate benefits associated with SDG 7, global climate finance could legitimately be thought of as a resource to be deployed for this purpose. Catalyzing international climate finance in this direction would require adding or enhancing renewable energy targets for improved energy access in the NDCs.

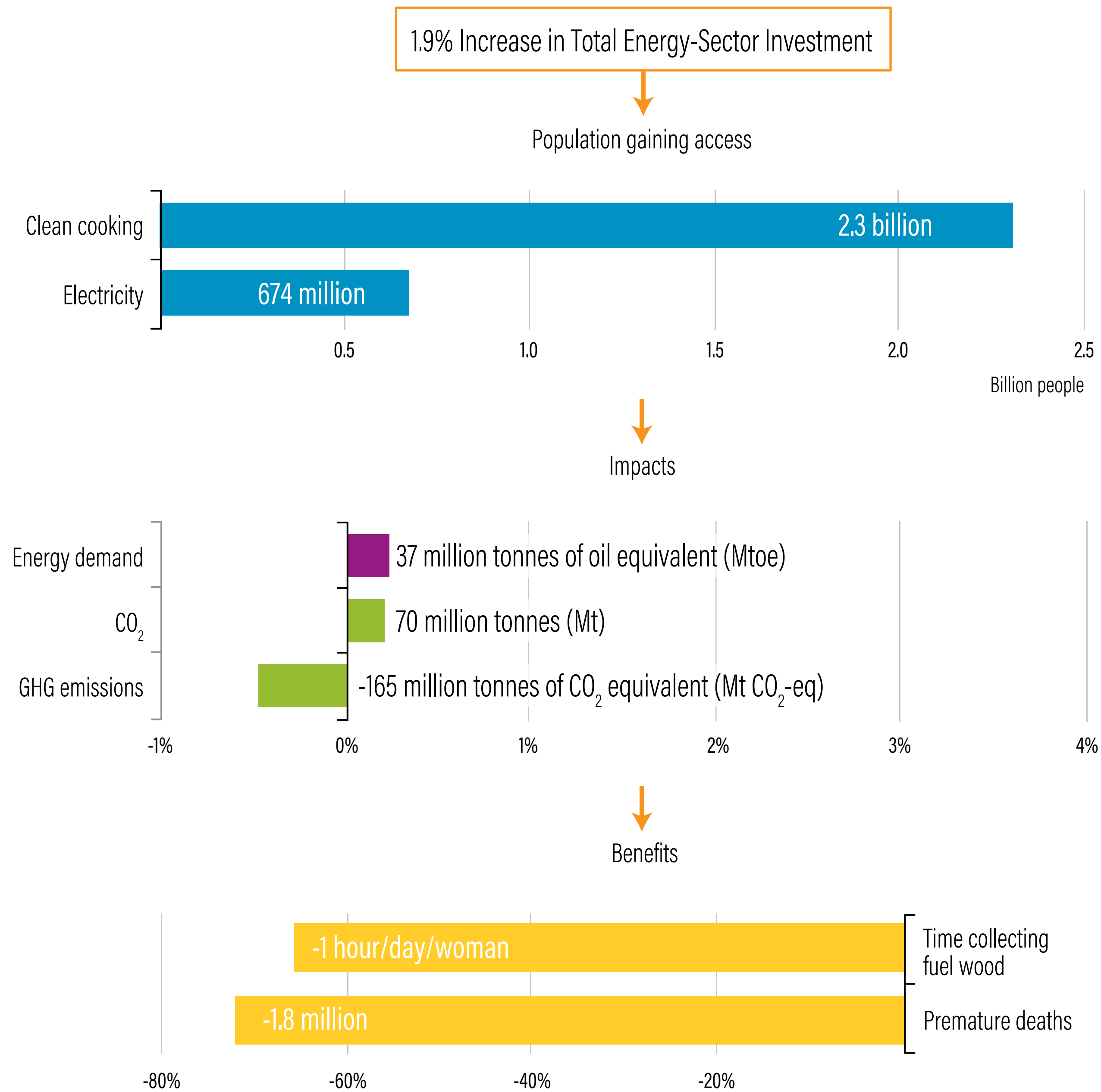
Decentralized renewable energy systems hold enormous promise for expanding access to affordable and reliable electricity for millions of poor people, while making power generation cleaner. The IEA's World Energy Outlook 2017 projects that these systems could provide more than 485 million people with electricity by 2030. Roughly 195 million would gain access through off-grid solutions (predominantly solar PV), while mini grids would provide access to 290 million, and grid expansion would deliver energy access to 185 million (IEA 2017). Challenges remain around the deployment of decentralized energy solutions, including a lack of financing, capacity building, and operations and management issues. However, these solutions can also support job creation, poverty reduction, and health improvements and feed clean energy back into the grid, acting as storage systems if excess solar energy is produced during the day, and if they are interconnected to a distribution network.

Figure A-3 | **Additional Population Gaining Access and Additional Investment in the Energy for All Case, Relative to the New Policy Scenario, 2017–2030**



Source: IEA 2017.

Figure A-4 | **Additional Impact of the Energy for All Case, Relative to New Policies Scenario, in 2030**



Source: IEA 2017.

If RE can play a pivotal role in fostering energy for all, global energy-related CO_2 emissions would increase by just 70 million tonnes relative to the IEA's baseline climate action scenario (the New Policies Scenario) in 2030 (IEA 2017). As those without access to clean energy make the switch from traditional biomass combustion to clean lighting and cooking solutions, an equivalent of around 165 million tonnes of CO_2 could be saved by 2030. Solar home installations, solar lanterns, and mini grid extensions can go a long way in achieving this and have sometimes been added as an adaptation component of the NDCs, highlighting the significance of modern energy for increased resilience (IEA 2017). There is scope for such solutions to feature more prominently in the NDCs.

Opportunity to improve resilience

Done right, adopting more ambitious power-sector targets in updated NDCs that incentivize RE and energy efficiency can improve the climate resilience of the power sector and communities.

Climate change will continue to affect the electricity sector globally. Temperature rise is a climate risk that will fundamentally affect the power sector. It will naturally have an impact on seasonal energy demand and increase the vulnerability of power generation and transmission infrastructure.

Building power systems that are resilient is crucial in order to provide reliable and safe electricity when extreme events and longer-term climate changes like droughts occur. Such systems rely on integrated planning processes and a variety of technical solutions so that their operations are not reliant on one source of energy and so that they can anticipate, adapt, and react to climate disruptions (Cox et al. 2017).

Renewable energy and energy-efficiency solutions can help build resilient power systems, support climate resilience, mitigate GHG emissions, and foster cost-effective access to electricity. Scaling energy efficiency through integrated energy-efficient planning, demand-side management, and energy-efficient building codes can help with shifting demand that is potentially expected to have greater peaks as temperatures rise or as heatwaves strike. Diversifying the generation portfolio to include various RE sources ensures that electricity production is dependent on generation assets with varying levels of vulnerability to heat and water stress or flooding. Distributed generation increases resilience in the event of blackouts and extreme weather events. Deploying storage solutions provides backup capability to the grid in the event of power outages. Smart grids can enable a better grid management in cases of disruption, by isolating parts of the system remotely and as needed, rather than populations having to wait for technicians and engineers to get to them. Smart grids also help with running the grid more efficiently, even as demand conditions change with the climate. All these measures also support GHG emissions reductions in a virtuous cycle of further mitigating climate change (Cox et al. 2017).

It is important to note certain nuances, as RE can also be vulnerable to climate change; hence the important notion of diversifying the generation portfolio of power systems to include a variety of energy sources. In the state of Rajasthan in India where temperatures can rise as high as 50°C, solar panels have been found to overheat, which reduces their efficiency, and instances of melting cables and conductors have been reported. In other parts of India that are prone to flooding, additional costs must be factored in to project costs of elevating distributed RE infrastructure on platforms, allowing them to operate during floods. Policymakers are responsible for evaluating the potential that RE and energy-efficient solutions hold to add resilience to their national grids.

Reduced stress on the energy-water nexus

Water plays a critical role in power generation. Globally, the energy sector is responsible for 10 percent of global water withdrawal (excluding hydropower), mainly from the operation of thermal power plants that require large quantities of water, which will increase as energy demand rises.

Table A-1 shows that renewables, including bioenergy, geothermal, concentrated solar power, solar PV, and wind, represented only 2 percent of total energy-related water withdrawal and 1 percent of total energy-related water consumption.

Table A-1 | **Power Generation-Related Water Withdrawals and Consumption, 2014**

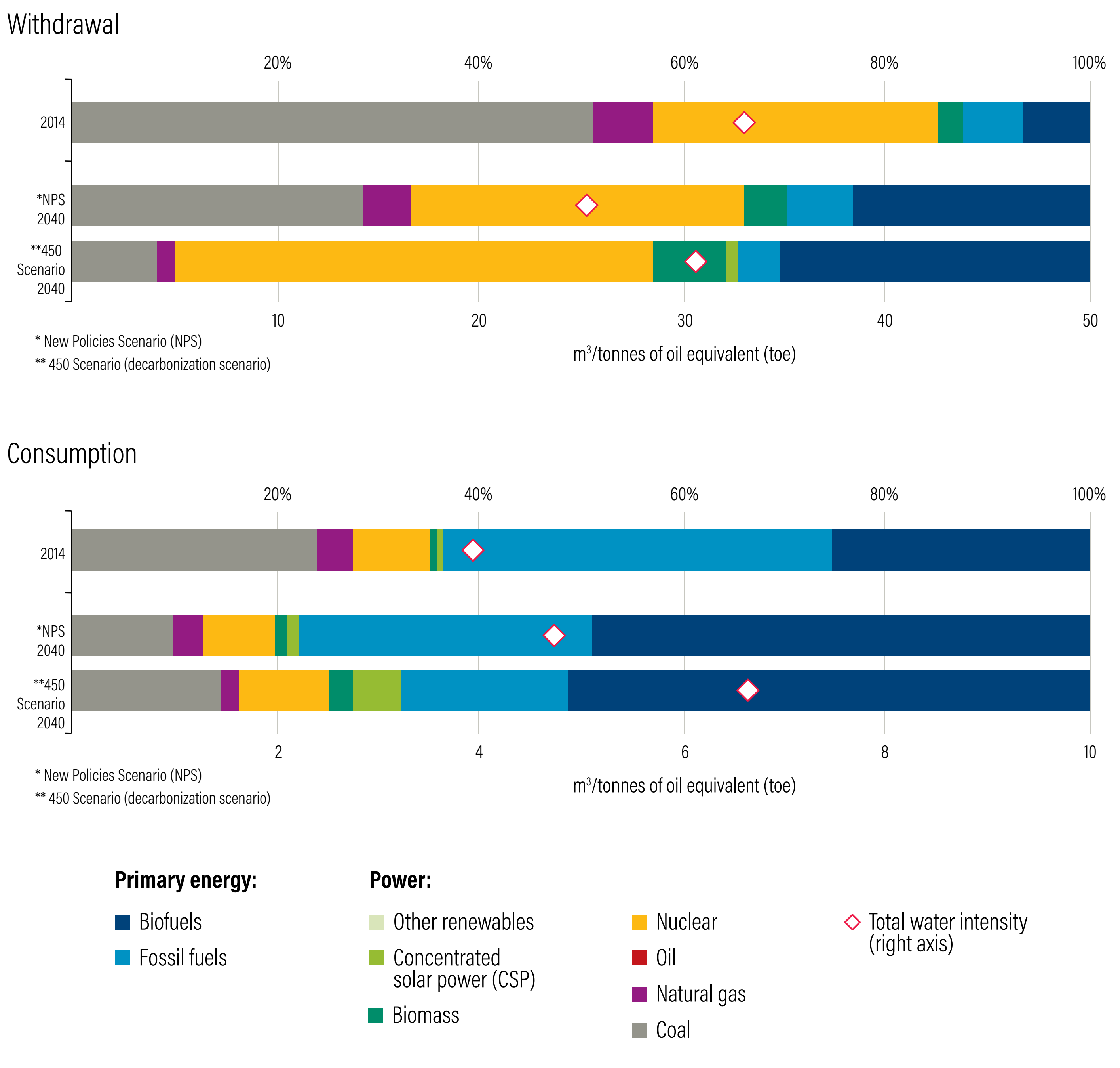
SECTOR	WITHDRAWAL (BILLION M^3)	SHARE OF TOTAL ENERGY WATER WITHDRAWAL	CONSUMPTION (BILLION M^3)	SHARE OF TOTAL ENERGY WATER CONSUMPTION
Fossil Fuel	230	58%	13	28%
Nuclear	112	28%	4	8%
Renewables	9	2%	1	1%

Source: Extracted from IEA 2016b.

The power sector's transition must be carefully managed in order to ensure that it reduces water demand. In most scenarios that prioritize renewable and energy-efficient solutions for power supply transformations, water demand is consequently reduced, as wind and solar have low water requirements and water-intensive thermal generation declines (IPCC 2018). But other low-carbon pathways reliant on bioenergy, concentrated solar power, carbon capture and storage (CCS), nuclear, and hydropower consume more water (IEA 2016b) and can compound existing water stresses. Additionally, bioenergy can have adverse effects on food security as well.

Water is necessary to generate power, but power is also needed to manage water supplies. Electricity is required to extract, treat, and distribute water. In the IEA's scenario based on existing and announced policies (including NDCs), electricity used for water increases 2.3 percent and reaches 1470 TWh in 2040, from 820 TWh in 2014 (IEA 2016b). There is, however, great scope for saving energy in the water sector by implementing the holistic and integrated energy, water, and infrastructure policy measures needed. Energy efficiency can provide an additional 225 TWh in the water sector relative to BAU, while energy recovery provides another 70 TWh of electricity generated from sewage sludge in the IEA's Sustainable Development Scenario.

Figure A-5 | **Share of Withdrawal and Consumption by Fuel or Technology and Total Water Intensity by Scenario, 2014 and 2040**



Source: IEA 2016b.

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Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of governments, businesses, and communities combine to eliminate poverty and sustain the natural environment for all people.

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